**ENVIRONMENTAL SERVICES ASSOCIATION RESEARCH TRUST**

# A PRACTITIONER'S GUIDE TO TESTING WASTE FOR ONWARD REUSE, TREATMENT OR DISPOSAL ACCEPTANCE

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# A PRACTITIONER'S GUIDE TO TESTING WASTE FOR ONWARD REUSE, TREATMENT OR DISPOSAL ACCEPTANCE

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Authors: Kathy Lewin, Jane Turrell and Julian Ellis

Contract Manager: Adele Graham

Contract No.: 12139-1



Any enquiries relating to this report should be referred to the authors at the following address:

WRc Swindon, Frankland Road, Blagrove, Swindon, Wiltshire, SN5 8YF.
Telephone: + 44 (0)1793 865000 Fax: + 44 (0) 1793 865001

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## SUMMARY

A draft European sampling standard, prEN 14899 'Framework for the preparation and application of a Sampling Plan' and five supporting technical reports, have been prepared by CEN TC 292/ WG1[1]. The documents provide a wealth of information on the design and implementation of Sampling Plans for waste sampling and testing programmes.

This Practitioner's Guide identifies where relevant information within the CEN documentation can be found and explains some of the fundamental principles that the draft framework standard and supporting reports outline. Example Sampling Plans show how such testing programmes might be conducted and co-ordinated to deliver maximum benefit and value for money for the main stakeholders - the waste producers and waste management industry. The ultimate aim of the Practitioner's Guide is to provide practical information and guidance on the sampling and testing of wastes, whether the objectives of the testing programme are concerned with reuse, treatment or disposal.

Following an outline of the structure and objectives of the prEN 14899 framework standard and technical reports, the main drivers for waste sampling and testing are explored. Aspects of the two key steps of a sampling programme (as identified by CEN TC 292/WG1), 'design of a Sampling Plan' and 'taking a sample in line with the Sampling Plan' are then covered. The appendices provide practical examples of Sampling Plans for scenarios that could be encountered by a primary waste producer, waste treatment plant operator and a landfill operator.

The conclusions and recommendations focus on the benefits of the Sampling Plan, how it complements the Quality Assurance plan for a process or waste management facility and can be universal in its application. Specifically, a phased approach is recommended to sampling and testing, including initial brainstorms with appropriate personnel. In addition there is a need to acknowledge the time and budget that may be required to continue a characterisation exercise to completion, including implementation of any corrective steps that may required.

Where a characterisation programme is driven by the need to ensure compliance with end-use specifications or acceptance criteria, we recommend that the waste producer should undertake routine compliance monitoring of his own to provide early warning of any trend in waste quality towards non-compliance. Operational improvements (e.g. segregation of problematic component streams) can then be considered, Alternatively it might then be appropriate to improve knowledge of waste characteristics (e.g. by using leaching behaviour tests) which may inform the decision making process for developing treatment options for the waste.

[1] CEN Technical Committee TC 292 (Waste Characterisation) Working Group 1 (Waste Sampling)

## ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of the three companies who agreed to be ‘guinea pigs’ for the production of the sampling plans.

In addition we recognise the contribution of Nick Blakey (now head of Waste Research Team, Waste Strategy Division, Defra), who, as Research Coordinator for ESART, identified the need to tailor the CEN sampling outputs into guidance that would be of greater practical use for the UK waste industry.

# 1. INTRODUCTION

## 1.1 Background

A reliable dataset on the composition and leachability of secondary materials and residual wastes is needed for any BPEO assessment – whether for reuse, treatment or disposal. Recently, the publication of waste acceptance criteria for landfill, has focused the attention of waste producers on the need to produce characterisation information to secure continued landfill disposal for most wastes[2]. By 2005 most wastes will be required to meet the waste acceptance criteria under Annex II of the Landfill Directive. However, this is just one aspect of waste testing. With increased focus on sustainable consumption and production issues, characterisation of materials across the resource use cycle will be applied for fitness for purpose assessments for a whole range of applications.

In addition to BPEO assessments and landfill acceptability, waste characterisation is also required to determine whether or not a waste is hazardous, to provide data under Duty of Care, and to undertake environmental and health and safety risk assessments. Waste producers and landfill operators therefore face the challenge of maximising the value of an appropriate, but potentially small, amount of sampling and testing effort against a restricted budget.

A draft framework sampling standard and detailed supporting technical reports for waste sampling and testing have been prepared by the European standards organisation, CEN. Although they provide the basic information needed to start developing a specific waste testing programme, they do not provide practical advice or guidance.

## 1.2 Scope

This project aims to provide practical information and guidance for UK practitioners on how waste sampling and testing programmes might be conducted and co-ordinated to deliver maximum benefit and value for money for the main stakeholders - the waste producers and waste management industry.

The scope of the project is to provide guidance on waste testing for onward reuse, treatment or disposal. Guidance is not provided for those scenarios where testing is not required.

## 1.3 Objectives

In this project we have set up a programme of work to:

- prepare experimental designs and testing specifications for a range of scenarios where waste characterisation may be required, using representative UK industrial waste streams to illustrate the required approaches; and

[2] Some inert wastes will be exempt from testing, such as the listed single-stream, single-source inert wastes.

- provide practical information and guidance for UK practitioners on the sampling and testing of wastes.

## 1.4 Approach

The project team, in conjunction with ESART, identified three generic testing scenarios to cover some of the key inter-relationships in the management of residue streams:

- ***Primary waste producer/landfill operator*** - industrial waste production and in-house landfill.
- ***Secondary waste producer/merchant treatment plant operator/landfill operator*** - treatment of solid and aqueous wastes prior to landfilling at own sites as non-hazardous waste;
- ***Landfill operator*** - waste producer and owner of inert waste landfill.

Candidate companies were met at least once. The first priority was to establish whether or not any relevant historic data existed that could be evaluated in the scoping phase of the project. In addition, relevant technical and operational information was obtained as required for the production of a testing programme.

Waste producers and landfill operators now face a number of new challenges with respect to waste characterisation, particularly the need to identify a waste as hazardous or non-hazardous and in determining whether the wastes are 'fit for landfill' under the new regulatory regime[3]. Previously many waste producers declared wastes as special waste without recourse to testing, as marginal uplift on disposal charges as special waste were frequently outweighed by the testing costs. Consequently relatively little information on hazard status or leachability of the wastes exists.

Our three candidate companies were typical of the general situation. They had data but it was not necessarily relevant data. It was not possible to commence development of the example sampling plans with an evaluation of a detailed dataset. Therefore the following approach was taken to make the output from this project relevant to the majority of UK practitioners.

- A brainstorm exercise was conducted to identify potential objectives for sampling and testing the wastes.
- A testing programme to deliver against those objectives was designed. Often this involved a series of small steps, screening exercises to identify the sources of variability in waste quality or characteristics with time, input streams and/or operational factors. Only then could a more comprehensive investigation be proposed, based upon

[3] Landfill (England and Wales) Regulations 2002; Landfill (England and Wales) (Amendment) Regulations 2004.

leaching behaviour and the desired ability of the waste to meet waste acceptance criteria.

In the case of the landfill operator of an inert waste landfill, the basic approach was very different. Not all inert wastes require testing by the landfill operator. For those wastes that do require testing, they are often highly variable in nature and attract only a low profit margin. A spreadsheet tool was therefore developed to indicate the level of risk of missing non-compliant loads for a given compliance testing scheme i.e. against numbers of samples tested and the impact of notional testing costs against potential profit margin.

## 1.5 Structure

Section 2 of this Practitioner's Guide outlines the content of the draft European standard documentation for development of a Sampling Plan. The technical reports supporting the sampling standard do not advocate a prescriptive approach. Instead a range of potential approaches and tools are outlined so that the project manager can tailor his sampling plant to the specific scenario (i.e. a 'shop shelf' approach to sampling plan development for waste testing).

Section 3 examines the fundamental issues which underlie why wastes need to be tested under the new regulatory regime, as there is still considerable confusion, particularly amongst waste producers about what testing is needed and when.

In Sections 4 and 5 we take apart the steps in a Sampling Plan and detail the factors that need to be considered when 'defining the Sampling Plan' (Section 4) and 'taking a sample in accordance with the Sampling Plan' (Section 5). This section of the guidance is generic and a basic plan is outlined to illustrate the approach that could be taken in a very simple single waste stream scenario.

Three examples of waste sampling plans are appended. They all address the issues posed by residue reuse, treatment or continued landfill disposal in 2004 and beyond. The plans cover a variety of processes where residues are being landfilled and some of the processes are complex. Most operational detail has been excluded to protect the identities of the companies involved. In particular, although based on real-life scenarios, some poetic license has been used in developing each plan, to ensure that at least one stream represents a situation which will be faced by many other waste producers. While the quantity of technical material for the two waste producer scenarios may appear overwhelming on first reading, the underlying principles are relatively simple to grasp. Our recommendations to the UK practitioner are to take a step-wise approach to sampling and testing, resolving one issue at a time, and to allow sufficient time for this testing programme to benefit from its findings well ahead of regulatory or operational deadlines.

This is the third of a series of ESART projects under the research theme 'Characterising Granular Waste Materials: Leaching Test Validation & Dissemination'. Previous work included:

- Validation of prEN 12457 (now BS EN 12457, the compliance leaching test for granular wastes);

- Characterising waste for disposal option assessment (jointly funded by ESART and the Environment Agency) which included technical input to drafts of the CEN TC292/WG1 European sampling standard and supporting technical reports.

# 2. CEN SAMPLING STANDARD PREN 14899

## 2.1 Background

In order to evaluate re-use, treatment and disposal options for waste materials, testing, and therefore sampling of the waste is required. The potential scope of such a testing programme can be complex and the European Standardisation Committee (CEN), Technical Committee 292 have been working for a number of years to produce a range of standards to support waste characterisation testing. Members of Working Group One (WG1) have been addressing the complex issue of waste sampling.

The key premise to the approach taken by TC 292/WG1, is a requirement to define a Sampling Plan. The key purpose of the Sampling Plan is to ensure that sampling and testing procedures are carried out in a standardised (and documented) way to help ensure that the expectations of all involved parties are recognised and satisfied. A Sampling Plan will help ensure that clear and appropriate objectives are defined for any given testing programme and that the subsequent sampling exercise is well executed so that it provides relevant data to meet those objectives. Importantly it provides an audit trail of the sampling exercise and sampling should only be carried out when an agreed plan is available.

TC292/WG1 was originally convened to develop a single European Standard for waste sampling, but due to the prescriptive nature required of a standard and the complexity and range of materials of concern it was clear that one single prescriptive standard could not hope to address all the issues of concern. As a result, the concept of the ‘shop shelf’ approach was developed. Whilst the ‘framework for sampling plan preparation’ is to be published as a European standard (pr EN 14899), it is supported by a series of Technical Reports (TRs). The basic rules outlined in pr EN 14899 can be used to develop a sampling plan to meet the requirements of any testing programme, and effectively standardises the design process. The standard provides the route map to the supporting TRs which ‘display’ the shop-shelf of options that are currently available for the various aspects that must be considered to adequately define the sampling exercise. This approach allows flexibility in the selection of the sampling approach, sampling point, method of sampling and equipment used. Specifically guidance is available on the selection of an appropriate sampling strategy (TR5), a relevant statistical approach to sampling (TR1), sampling techniques (TR2), sample size reduction in the field (TR3) and sample storage, preservation and transport (TR4). The appropriate approach, tools, methods etc can be selected on a scenario-specific basis, but do not present a barrier to technical innovation. Hence, while alternative choices for sampling equipment are provided in TR 2, depending on the sample medium to be sampled, there is no reason why other suitable methods cannot be substituted .

The Landfill Directive and more recently UK Landfill Regulations[4] require that Sampling Plans must be prepared in accordance with the CEN Framework Standard.

[4] Environmental Protection Act 1990; Landfill (England and Wales) (Amendment) Regulations 2004.

## 2.2 Key steps in the testing programme

CEN TC 292 have developed and agreed a process flow chart that defines the essential elements of a testing programme and how those elements are linked. This flow chart is presented in Figure 2.1.

Seven key steps are identified, that should each be considered in the development of a testing programme.

The first three of these key steps (The dark shaded area of Figure 2.1) encompass those activities that relate specifically to sampling and are covered by the development of the Sampling Plan as advocated in the Framework Standard prEN 14899. Steps 4 to 7 are covered by a series of complementary standards produced within TC 292. Generic guidance for following Key Step 1 ‘defining the Sampling Plan’ and key Step 2 ‘taking a sample in accordance with the Sampling Plan’ is provided in Section 4 and 5 of this Practitioner’s Guide.

The procedural steps that must be considered to complete Key Step 1 “The preparation and application of a Sampling Plan” are detailed in Figure 2.2. It is this process map that provides the basic framework for the practitioner developing a Sampling Plan. This framework can be used:

- for the production of standardised sampling plans for use in routine/regular circumstances;
- in the design and development of a Sampling Plan for use on a case by case basis, and if required;
- to meet the specific requirements of national legislation.
- More than one Sampling Plan may be required to satisfy all the objectives of a testing programme. Ultimately the Sampling Plan provides the Sampler with detailed practical instructions on how sampling should be carried out by defining the boundaries and logistics of the sampling element of the testing programme in an unambiguous way.

The Framework Standard and toolbox of supporting technical reports provide instruction and guidance on how to complete and document each of the procedural steps identified in Figure 2.2. The selection of the most appropriate approach will be entirely governed by the overall objective of the Testing Programme. Figure 2.2. indicates which technical report the reader can use to access appropriate guidance.

This thought/ decision process will initially result in a detailed and somewhat lengthy Sampling Plan, along the lines of the examples presented in Annex A and B of this Guide. However, the final step in the development of the Sampling Plan would be to summarise this information to provide a practical instruction to the Sampler and document of the activities to be undertaken as per the short form example provided in Section 5.

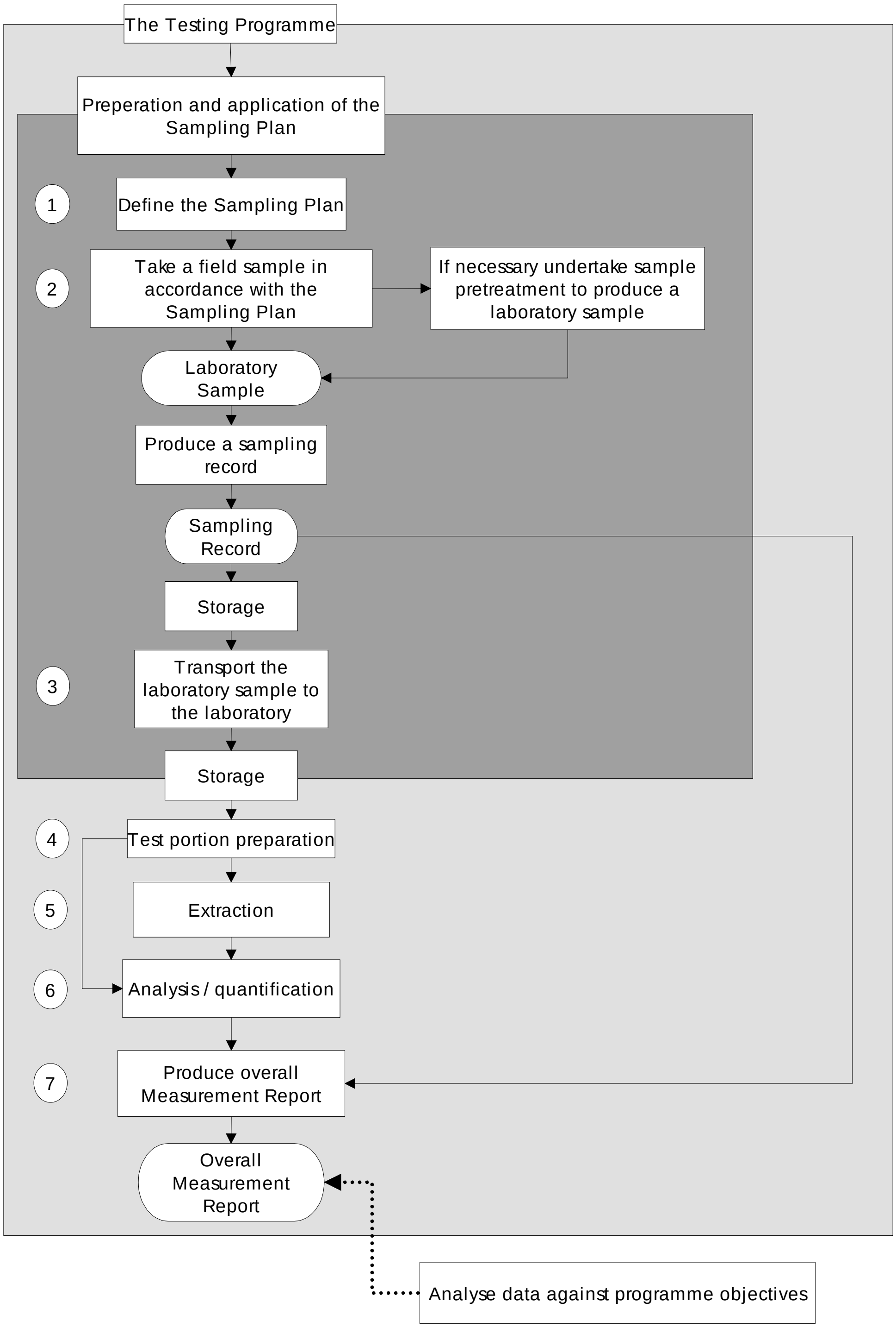


**Figure 2.1 Links between the essential elements of a testing programme (prEN 14899)**

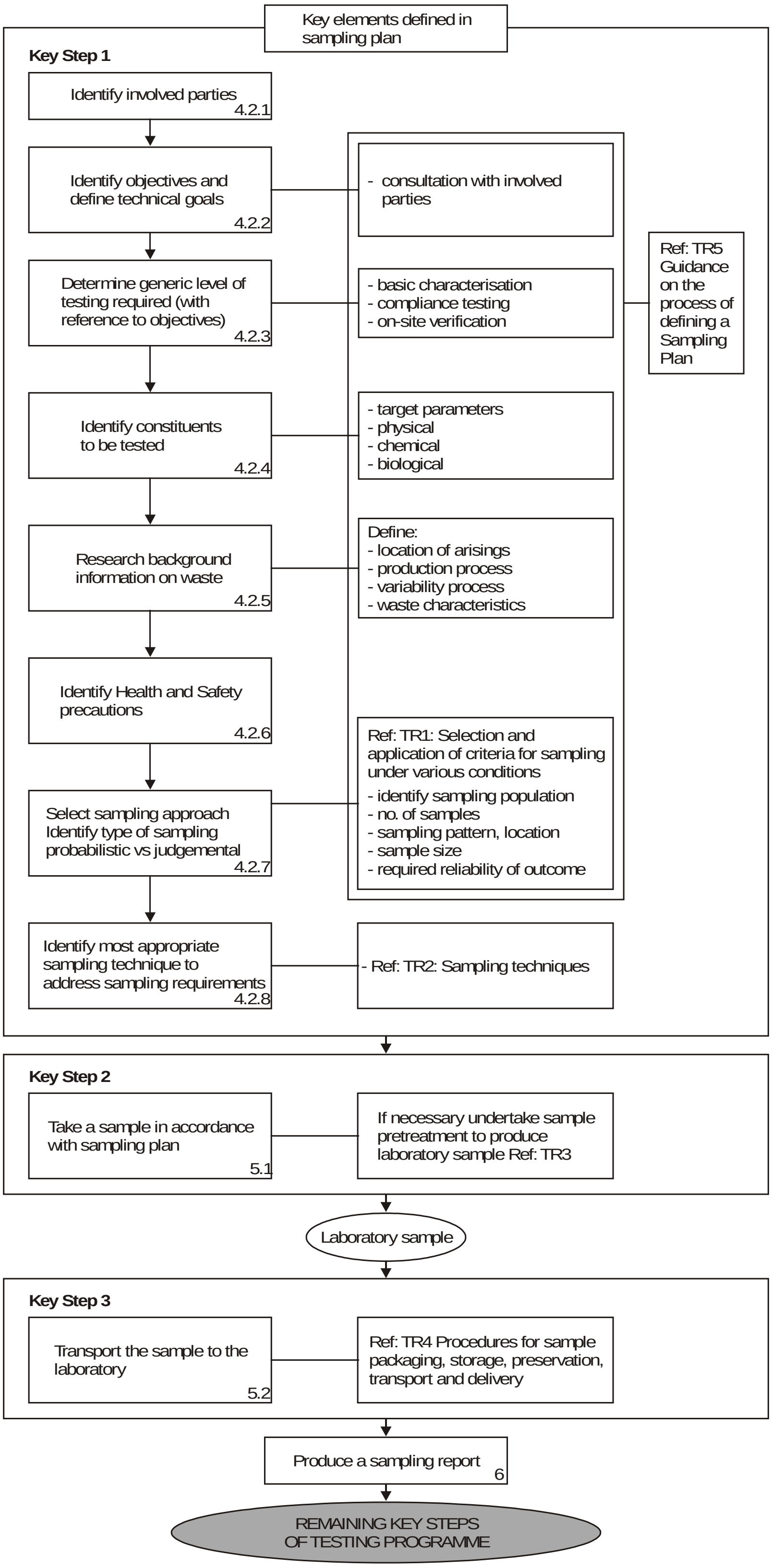


**Figure 2.2 Key elements of a Sampling Plan (prEN 14899)**

## 2.3 Supporting technical reports

References to the CEN Framework Standard and supporting TRs are as follows:

| | |
|---|---|
| prEN 14899 | Characterisation of Waste - Sampling of waste materials: Framework for the preparation and application of a Sampling Plan. |
| TR 1 xxxx (WI 292002) | Waste – Technical Report on Sampling – Part 1: Information on the selection and application of a basic statistical approach to sampling under various conditions. |
| TR 2 xxxx (WI 292017) | Waste – Technical Report on Sampling – Part 2: Information on sampling techniques. |
| TR 3 xxxx (WI 292018) | Waste – Technical Report on Sampling – Part 3: Information on procedures for sub-sampling in the field. |
| TR 4 xxxx (WI 292019) | Waste – Technical Report on Sampling – Part 4: Information on procedures for sample packaging, storage, preservation, transport and delivery. |
| TR 5 xxxx (WI 292041) | Waste – Technical Report on Sampling – Part 5: Information on the process of defining the Sampling Plan. |

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The Technical Reports contain procedural options (as detailed in Figure 2.2) that can be selected to match the sampling requirements of any testing programme.

# 3. REASONS FOR SAMPLING AND TESTING WASTES

## 3.1 Outline

The main steps to be taken in preparing a Sampling Plan are discussed in Section 4. Although the specific objectives of the sampling and testing programme are included in the sampling plan, the strategic objectives are not. When preparing the detailed sampling instructions, the sampling personnel need to know the reasons for the sampling that affect the way the samples are taken, how many are taken, what they are to be tested for and precautions needed to preserve their integrity during transport to the laboratory. The fact that the testing data will be used to assess whether the waste stream should be composted, incinerated or landfilled is not of direct relevance. This should not preclude the project manager engaging the sampling personnel in these issues but they are outside the scope of the Sampling Plan.

In this section we examine the main reasons for taking the waste samples in the first place - why is the dataset from the sampling programme needed? This fundamentally affects how and why the Sampling Plan is prepared. Further information on the strategic aspects that might control or direct the design of a testing programme can be found in TR5 (TR 5 xxxx WI 292041, Waste – Technical Report on Sampling – Part 5: Information on the process of defining the Sampling Plan).

## 3.2 Waste sampling drivers for the waste producer

The principal reason for collecting waste samples for testing is to be able to answer one or more of the following questions:

- Is the waste hazardous or non-hazardous?
- Is the waste 'fit for landfill'?
- Can landfill disposal charges be reduced?
- What are the non-landfill options for the management of the wastes?
- Does the waste meet the limit values for end-use applications?

These aspects frequently overlap and are covered in the following four sections.

### 3.2.1 Classification as hazardous or non-hazardous waste

The European Waste Catalogue (2002) lists wastes by industry sector and defines them as hazardous (absolute or mirror-entry hazardous/non-hazardous) or non-hazardous wastes, according to their known hazard characteristics. The Hazardous Waste Directive[5] lists the 14

[5] Council Directive 91/689/EC

hazardous properties H1-H14, which include oxidising, flammable, irritant, harmful, toxic, carcinogenic, corrosive, infectious, mutagenic, and ecotoxic hazardous properties.

Producers of absolute hazardous waste are required to declare the relevant hazard properties (either from prior knowledge or testing) before treatment or disposal at a site that is licensed or permitted to handle hazardous wastes.

Producers of mirror-entry hazardous/non-hazardous wastes (on the basis of the presence/absence of dangerous substances) have two options. These depend on whether the hazard assessment and subsequent testing confirms the presence or absence of dangerous substances or hazardous properties:

- Mirror-entry wastes that are shown by testing to be hazardous must be treated as for absolute hazardous waste above.

- Where absence of dangerous substances/hazard properties can be demonstrated the wastes can be handled and disposed as non-hazardous wastes.

Detailed guidance on the hazard assessment of wastes is provided by the Environment Agency (WM2, 2003a).[6]

From July 2004 co-disposal of hazardous and non-hazardous waste destined for landfill disposal must cease and therefore hazard assessment of absolute and mirror entry wastes on the EWC will become mandatory to secure landfill disposal. For absolute hazardous wastes there may be a sufficient knowledge of hazard properties to base the hazard assessment on available information. However, in most instances for absolute and mirror-entry wastes this will require sampling and testing to:

- declare the relevant hazard for hazardous wastes for Duty of Care purposes prior to transport and disposal;

- demonstrate the absence of dangerous substances/hazards for handling or disposal as a non-hazardous waste.

*Classification as hazardous or non-hazardous waste must be undertaken before a review of waste management options can be undertaken or before compliance with landfill waste acceptance criteria can be ascertained.*

### 3.2.2 Determining whether the waste is acceptable for landfill disposal

The UK waste acceptance procedures and criteria for landfilling have been laid down in the Landfill Regulations 2002 and 2004[7]. Supporting technical guidance has been provided by the Environment Agency[89].

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[6] Hazardous waste. Interpretation of the definition and classification of hazardous waste. Technical Guidance WM2, Environment Agency 2003.

[7] Landfill (England and Wales) Regulations 2002; Landfill (England and Wales) (Amendment) Regulations 2004.

[8] National Interim Waste Acceptance Procedures, Environment Agency Consultation Draft, August 2002.

Quantitative waste acceptance criteria (WAC) have been set as maximum limit values for the disposal of granular wastes at landfill sites for hazardous wastes and for inert wastes. Granular WAC have also been set for stable non-reactive hazardous wastes to be accepted in mono-cells at non-hazardous waste landfills and for any non-hazardous waste disposed with them. The WAC for these three classes of WAC are abbreviated as haz WAC, SNR-haz WAC and inert WAC throughout this section. The limit values are presented in Table 3.1 and summarised below.

- Leachability limit values have been set for eluate concentrations generated at liquid-to-solid ratio 10 litres/kilogram dry waste (L/S10) for the following parameters for all three classes of site: As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Sb, Se, Zn (hereafter referred to as 'WAC metals'), Cl, F, $SO_4$, TDS (total dissolved solids), and DOC (dissolved organic carbon)[10];

- Levels of total organic carbon are limited to 3%, 5% and 6% for inert, stable, non-reactive hazardous (SNR-haz) and hazardous waste landfills respectively. Alternatively a loss-on-ignition (volatile matter loss at 550°C) limit of 10% can apply to hazardous wastes instead of the TOC limit.

- Additional determinands must be tested for acceptance to inert waste landfills, trace organic components BTEX, PCBs, PAHs and leachability of phenol index limit at L/S10.

Once the WAC have been introduced the implications are as follows:

- Wastes that have been identified as **hazardous** (Section 3.2.1):
  Either,
  - must be treated to comply with the WAC for hazardous waste landfills, i.e. all samples must return testing results which are *below* the limit values for all haz WAC parameters;

  or

  - must be treated to render them 'stable and non-reactive' wastes *and* comply with the WAC for stable, non-reactive hazardous wastes, i.e. all samples must return testing results which are *below* the limit values for all SNR-haz WAC parameters.

- The following options are available for wastes that have been identified as **non-hazardous** (Section 3.2.1):

  - any non-hazardous wastes which are destined for mono-cells with stable, non-reactive hazardous wastes must comply with the SNR-haz WAC;

**Table 3.1 UK landfill waste acceptance criteria for granular wastes**

[9] Draft guidance on the Sampling and Testing of Wastes for Waste Acceptance Procedures. Consultation draft. Environment Agency, 2003.

[10] The UK is regulating against L/S10 data from the two stage compliance leaching test for granular wastes (BS EN 12457-3) which generates eluates at L/S2 and L/S2-10 (cumulative L/S10) rather than the single step LS10 test BS EN 12457-2. Test samples must be crushed to <4mm particle size before testing.

| Parameter | Inert waste landfill | Stable non-reactive hazardous waste in non-hazardous landfill¶ | Hazardous waste landfill |
|---|---|---|---|
| **Parameters determined on the waste** | | | |
| Total organic carbon (w/w %) | 3% | 5% | 6%* |
| Loss on ignition | | | 10%* |
| BTEX (mg $kg^{-1}$) | 6 | | |
| PCBs (7 congeners) (mg $kg^{-1}$) | 1 | | |
| Mineral oil $C_{10}$-$C_{40}$ (mg $kg^{-1}$) | 500 | | |
| PAHs | To be set | | |
| pH | | >6 | |
| Acid neutralisation capacity | | To be evaluated | To be evaluated |
| **Limit values (mg $kg^{-1}$) for compliance leaching test using BS EN 12457- 3 at L/S 10 l $kg^{-1}$** | | | |
| As (arsenic) | 0.5 | 2 | 25 |
| Ba (barium) | 20 | 100 | 300 |
| Cd (cadmium) | 0.04 | 1 ( 0.1)§ | 5 (1)§ |
| Cr (chromium (total)) | 0.5 | 10 | 70 |
| Cu (copper | 2 | 50 | 100 |
| Hg (mercury) | 0.01 | 0.2 (0.02) § | 2 (0.4)§ |
| Mo (molybdenum) | 0.5 | 10 | 30 |
| Ni (nickel) | 0.4 | 10 | 40 |
| Pb (lead) | 0.5 | 10 | 50 |
| Sb (antimony) | 0.06 | 0.7 | 5 |
| Se (selenium) | 0.1 | 0.5 | 7 |
| Zn (zinc) | 4 | 50 | 200 |
| Cl (chloride) | 800 | 15,000 | 25,000 |
| F (fluoride) | 10 | 150 | 500 |
| $SO_4$ (sulphate) | 1,000# | 20,000 | 50,000 |
| Total dissolved solids (TDS)+ | 4,000 | 60,000 | 100,000 |
| Phenol index | 1 | | |
| Dissolved organic carbon@ | 500 | 800 | 1,000 |

¶ And non-hazardous wastes deposited in the same cell

* Either TOC or LOI must be used for hazardous wastes

** UK PAH limit values are under development

§ Following the recent consultation exercise the UK Govt may review the limit values in two years time (2006)

# If an inert waste does not meet the $SO_4$ L/S10 limit, alternative limit values of 1500 mg $l^{-1}$ $SO_4$ at $C_0$ (initial eluate from the percolation test (prEN 14405)) and 6000 mg $kg^{-1}$ $SO_4$ at L/S10 (either from the percolation test or batch test BS EN 12457-3), can be used to demonstrate compliance with the acceptance criteria for inert wastes.

+ The values for TDS can be used instead of the values for Cl and $SO_4$.

@ Or DOC at pH 7.5-8.0 and L/S10 can be determined on prEN 14429 (pH dependence test) eluates

From: EC Decision 2003/33/EC OJEC L11 16.01.03 and Landfill (England and Wales) (Amendment) Regulations (2004)

- o any non-hazardous wastes which are destined for inert waste landfills must comply with the inert WAC;
- o other non-hazardous wastes can be accepted at non-hazardous waste landfill without testing against WAC for the foreseeable future. Waste producers would be advised to pre-empt the introduction of WAC for non-hazardous wastes by comparing the quality of their wastes with the WAC for other classes of site (especially the SNR-haz WAC) and taking appropriate action.

Waste acceptance criteria for monolithic wastes are also being published for consultation imminently. The monolithic WAC apply to two classes of landfill: hazardous and stable, non-reactive hazardous wastes. Limit values will apply to organic content (6% TOC and 10% loss on ignition at 550ºC). Leachability limit values will be set for eluates derived from the 64-day, 7-step diffusion (‘tank’) test NEN 7345[11]. The leachability parameters will be the same as for granular wastes. The proposed limit values are presented in Table 3.2 for both characterisation (cumulative leaching over 64 days) and compliance (cumulative leaching over 4 days).

Knowledge of the consistency of the waste quality is essential before determining whether the waste is ‘fit for landfill’. This can be obtained over a long-period of compliance monitoring using the WAC testing results. However, this carries the risk of WAC failure for one or more determinands and potential loss of landfill disposal route. Alternatively a focused screening exercise as part of a characterisation programme can be carried out over a shorter period of time to demonstrate whether the waste is consistently compliant or whether the waste quality is erratic. If compliance against WAC is tested under worst-case as well as average operational conditions, technical modifications to the operational process (including the feedstock) can be introduced to generate a less variable waste stream which is always WAC-compliant. This is discussed further in Section 4.5.2.

Where waste is not being landfilled directly but is being treated prior to landfilling, it will be the responsibility of the treatment plant operator (the secondary waste producer) to ensure that the treated residues are WAC-compliant before they are accepted for disposal at the landfill.

### 3.2.3 Reducing landfill disposal charges

Testing wastes against the landfill WAC is beginning to expose the cost-benefits of managing plant residue streams differently. For example, where combined wastes are landfilled, detailed examination of the quality and variability of component waste streams may highlight two options. The data may indicate that some components could be accepted at a different class of landfill with more attractive disposal charges, or, diverted from landfill altogether

[11] NEN 7345 (1995) Leaching characteristics of soil and stony building and waste materials. Leaching tests. Determination of leaching of inorganic components from building and monolithic waste materials with the diffusion test. Netherlands Normalisation Institute (NEN).

**Table 3.2 Proposed UK landfill waste acceptance criteria for leachability of monolithic wastes[(1)]**

| | Stable non-reactive hazardous waste in non-hazardous landfill and non-hazardous waste in same cell | | Hazardous waste landfill | |
|---|---|---|---|---|
| **Parameter** | **Limit values using cumulative leaching data (mg $m^{-2}$) from NEN 7345:1995** | | | |
| | **For compliance (cumulative 4 day leaching)** | **For characterisation (cumulative 64 day leaching)** | **For compliance (cumulative 4 day leaching)** | **For characterisation (64 day leaching)** |
| As (arsenic) | 0.325 | 1.3 | 5 | 20 |
| Ba (barium) | 11.25 | 45 | 37.5 | 150 |
| Cd (cadmium) | 0.05 (0.0075) | 0.2 (0.03) | 0.25 (0.01) | 1.0 (0.04) |
| Cr (chromium total) | 1.25 | 5 | 6.25 | 25 |
| Cu (copper) | 11.25 | 45 | 15 | 60 |
| Hg (mercury) | 0.025 (0.0025) | 0.1 (0.01) | 0.1 (0.0025) | 0.4 (0.01) |
| Mo (molybdenum) | 1.75 | 7 | 5 | 20 |
| Ni (nickel) | 1.5 | 6 | 3.75 | 15 |
| Pb (lead) | 1.5 | 6 | 5 | 20 |
| Sb (antimony) | 0.075 | 0.3 | 0.625 | 2.5 |
| Se (selenium) | 0.1 | 0.4 | 1.25 | 5 |
| Zn (zinc) | 7.5 | 30 | 25 | 100 |
| $Cl^-$ (chloride) | 2500 | 10,000 | 5000 | 20,000 |
| $F^-$ (fluoride) | 15 | 60 | 50 | 200 |
| $SO_4^{2-}$ (sulphate) | 2500 | 10,000 | 5000 | 20,000 |
| DOC (Dissolved Organic Carbon) | must be determined | must be determined | must be determined | must be determined |
| pH | must be determined | must be determined | must be determined | must be determined |
| Electrical Conductivity (µS.$cm^{-1}$.$m^{-2}$) | must be determined | must be determined | must be determined | must be determined |

(1) Dr J. Gronow, Environment Agency, *pers. comm*. June 2004

§ as with granular wastes, the UK Govt are consulting on the two sets of values for List 1 substances (Cd and Hg).

particularly when on-site reuse is possible. This may require separation of non-contaminated residue streams at an early stage of the industrial process, or ensuring that contaminated hot-spots can be identified and removed, or controlling the variability of input wastes or feedstocks to the plant. A sampling and testing programme will be needed to demonstrate whether any of these options is feasible.

Where a significant body of information is available, and it shows that the waste stream is consistently compliant with the inert WAC, it may be possible to apply for inclusion on a site-specific list for exemption with respect to testing. Furthermore, some industrial wastes demonstrate relatively consistent characteristics from plant to plant. In specific cases it may be feasible to conduct a coordinated industry-wide sampling and testing programme. If this demonstrates that a generic industrial waste consistently met the inert WAC, it may enable inclusion on a national list of inert wastes (e.g. Table 1, the Landfill (England and Wales) (Amendment) Regulations (2004) that are exempt from testing, under certain conditions.

### 3.2.4 Identification of non-landfill options for the management of the wastes

In addition to the cost-benefits mentioned above, increased legislative, corporate responsibility and sustainability drivers for limiting the use of landfill, are encouraging waste producers to review alternative management options for their wastes.

Some waste management options may require waste acceptance testing (see Section 3.3 below) or compliance testing against limit values. For example, where the waste can be reused as a construction material (e.g. secondary aggregates) there may be rigorous technical and performance specifications to meet. These may require testing against limit values for specific contaminants in the waste such as limits on levels of $SO_4$ and Cl.

Where other waste management options are being reviewed the chemical specification may be more relaxed and blending of different waste streams by the plant operator may be feasible to ensure that the operational tolerances of the facility are met (e.g. calorific value and moisture content for thermal treatment plant). For these BPEO assessments, knowledge of average waste quality is generally needed.

As with landfill acceptance, the need to demonstrate that the waste or product meets the limit values is a significant driver for undertaking testing. In most cases it is important to support the compliance programme with characterisation data that, at the very least, gives both parties the confidence that the material is always compliant. Information is therefore needed on variability obtained from testing a reasonable number of samples over a reasonable period of time and/or over different conditions. Once such a database has been obtained it may indicate that only a small number of parameters are close to the limit value. The compliance monitoring programme can then be focused more specifically on assessing compliance against these key variables, with potential cost savings.

## 3.3 Waste sampling drivers for operators of waste management facilities

### 3.3.1 Testing of input and output streams to ensure compliance with product standards or acceptance criteria

Some sectors of the waste management industry have checked waste quality under current waste acceptance procedures for incoming wastes for many years (see Section 3.3.2).

However, in general, there has not been a need to examine in any great detail the link between the quality of input wastes to a plant, the operational variables and the quality of output streams. Compliance testing schemes are changing this.

For example, for organic wastes, the PAS 100 compost standard, SEPA's draft guidelines for landfill restoration material (SEPA 2002)[12] and ultimately biodegradability indices, require compliance monitoring of the products. Such product standards are also focusing attention on the quality and variability of input streams in order to improve product performance against the standards.

The landfill waste acceptance criteria for both granular and monolithic wastes require compliance monitoring of landfilled wastes including the residues from treatment plant (e.g. chemical and thermal). Previously the plant operator has needed basic information on the quality of input wastes to ensure that operational conditions are maintained within the tolerances for the plant, but now he will want to be sure that contaminated input wastes will not compromise acceptability of the output residue at the landfill gate. In many cases this will simply become an extension of the quality assurance plan for the waste management facility: protocols and procedures that provide instructions and contingencies for incidents on site, such as reports of non-compliance.

Therefore, in addition to sampling products or output residues as part of a compliance monitoring scheme, the waste management facility operator will also need to characterise input waste streams in much the same way as a primary waste producer. He will need to establish the factors that may compromise acceptability at the chosen disposal or treatment route. For example he will want to identify and remove sources of unacceptable variability and contamination hot-spots, and to reject materials that cannot be blended to prevent non-compliance with limit values. In these types of instances the treatment plant operator is referred to as a secondary waste producer. His obligations will, in most instances, be identical to that of the primary waste producer.

Specifically the landfill operator has a key role to play in demonstrating that wastes meet the waste acceptance criteria for landfill. Not all wastes require sampling and testing by the landfill operator (e.g. non-hazardous wastes and single-stream, single-source listed inert wastes, or non-regular inert wastes which have already been characterised). However, acceptance to landfill of most wastes will require the landfill operator to take waste samples to determine whether or not they comply with the WAC. Where the wastes are non-compliant he must obtain reassurances from the waste producer that further loads of the same waste will be compliant, or he must refuse to accept future loads. Regular reporting to the Environment Agency will be required. As the WAC are maximum limit values he needs to be sure that the average quality of loads generated under both worst-case and optimum conditions are compliant for all parameters.

The landfill operator will have other data requirements for operational purposes such as total concentration data for the calculation of loading criteria. In addition he will need acid/base neutralisation capacity (ANC/BNC) data to ensure that the landfilling of wastes with differing buffering capacities and pH values is properly managed.

[12] Draft Interim Guidance on the Use of Composted Material at Licensed/Permitted Landfill Sites. Version 5. 30 August 2002, SEPA 2002.

### 3.3.2 Risk assessments

Sampling and testing of wastes will be required to obtain source term characterisation data for a range of risk assessments, including total concentrations and leachability data on solid wastes to:

- assess risks from dust inhalation by exposed workforce/residents;
- Regulation 15 risk assessments;
- environmental risk assessment (ERA) to obtain IPPC permit.

### 3.3.3 Verification

Some sectors of the waste management industry have adhered to strict waste acceptance procedures for incoming wastes for many years such as visual inspection and pH measurement of drummed waste prior to high temperature incineration. In addition to the visual inspection the testing is limited to key variables. In the example of a chemical treatment plant the pH of aqueous wastes and free lime content of solid wastes may be undertaken on a sample from every load to ensure safe and appropriate blending prior to treatment.

The operator of a waste management facility has to include contingency for *ad hoc* sampling for example on a delivery of suspect waste with undeclared hazardous properties or following accidental spillage.

# 4. DEVELOPING A SAMPLING PLAN

## 4.1 <u>Outline</u>

The principal reasons or objectives for the sampling and testing of wastes have been considered in Section 3, and have a fundamental influence on the decision making process that ultimately leads to the development of the Sampling Plan.

Figure 4.1 shows the relationship between the first two key steps identified in Figure 2.1 and the procedural steps that are described in greater detail in Sections 4 and 5. Thus Section 4 addresses the eight procedural steps within key step 1 ‘define the sampling plan’ while section 5 outlines the information needed for the six procedural steps within key step 2 ‘taking a sample in accordance with the Sampling Plan’.

The relationship of each procedural step is highlighted schematically in each sub-section.

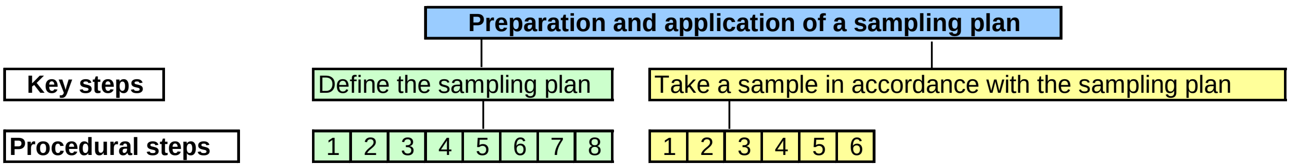



**Figure 4.1 Routemap for Sections 4 and 5 of the Practitioner’s Guide**

The guidance on sampling and testing wastes is based upon key elements in the following two documents:

- Sampling of waste material: framework for the preparation and application of a sampling plan (prEN 14899, CEN 2004) and associated technical reports, TR1-5).

- Sampling and testing wastes for waste acceptance procedures v4.3a. Environment Agency 2003. Draft for consultation.

The main steps to be taken in preparing a sampling plan as outlined in Section 2 are posed as a series of questions.

## 4.2 Who needs to be involved in the production of the sampling plan?

Define the sampling plan

| 1 : Identify involved parties | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|

### 4.2.1 Waste producer's sampling and testing programme

- *Waste producer:* including legislation compliance managers, technical managers and operatives. A project manager should be designated who will have overall responsibility for drawing up the Sampling Plan, they should also be responsible for ensuring that all relevant parties are involved in the planning process. Other essential personnel would include those who understand the implications of modifying operational practices or feedstock on the quality of the wastes. Initially this aspect is important to deciding when and where the most appropriate samples could be collected but ultimately they will be responsible for operating the process to deliver residues that are compliant with the requirements for the appropriate end-use or disposal route.

- *Testing laboratory*: It may often be useful to discuss the objectives of the testing programme with the designated analytical laboratory, who would be able to supply or recommend appropriate sample containers and preservation methods to ensure the integrity of the samples is maintained prior to analysis and fitness for the intended analytical tests.

- *Sampler*: The project manager must ensure that personnel designated to undertake sampling are adequately briefed. It is important that the sampler recognises that all deviations from the Sampling Plan may have important quality implications for the testing programme and must only be undertaken with prior agreement from the project manger and adequately recorded for audit purposes.

- *Landfill operator:* Once the waste producer is satisfied that the correct class of landfill has been identified and that the waste is compliant, it may benefit both parties to rationalise compliance monitoring on-site and at the landfill gate. At the very least the 'scale of sampling' should be agreed to ensure that the landfill operator is testing for non-compliance within the same quantity of waste as tested by the waste producer.

- *Technical consultant:* In addition to providing guidance on the most cost-effective phased testing programme, and interpretation of the technical data generated by the sampling programme, it can be helpful to have an objective view of the thought processes involved in preparing a sampling plan. In particular an independent party can challenge the issues which the waste producer considers to be 'sacred cows'.

- *Regulator:* The UK Environment Agency may require consultation on the sampling protocols to be used in any compliance monitoring carried out under an IPPC permit.

### 4.2.2 Landfill operator's compliance monitoring programme

In the case of compliance failure the landfill operator has a duty to inform both the waste producer and regulator. Where continued acceptance of the waste has been agreed on the basis of improvements in waste quality to achieve compliance, the Environment Agency may wish to be consulted on the Sampling Plan for demonstrating compliance (in particular the number and frequency of sampling events).

As in Section 4.2.1 above, agreement should be reached with the waste producer on scale of sampling and it may be cost-effective for both parties to rationalise compliance sampling.

The landfill operator may wish to take independent advice regarding the design of a sampling programme, in particular determining the number of samples required to limit both the risk of missing non-compliant loads and the costs of sampling and testing.

## 4.3 What are the objectives and technical goals for the testing programme?


The main drivers for sampling and testing wastes have been presented in Section 3. Most testing programmes have a very general overall objective, an example for a waste producer might be:

> “To establish the appropriate class of landfill for ‘x’ waste stream after July 2005”.

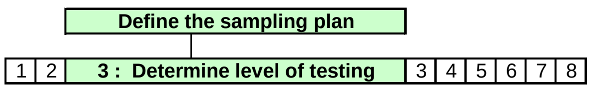
This objective represents the most important driver for defining the type and quality of information that is to be gained through sampling and importantly is usually key to defining the population of waste, e.g. a year’s production, that must be sampled. Further examples of some of the main objectives for sampling and testing wastes have been presented in Section 3.

In the majority of cases the overall objective is too general to be useful as an unambiguous instruction to the sampler and it is useful to have a brain-storming exercise to translate this objective into a number of practical technical goals, which provide a more detailed specification for the sampling activity, which can then be further developed and linked to specific sampling and analytical requirements. One technical goal might be:

> “To improve knowledge of quality and consistency of input wastes and their impact on the quality and consistency of output wastes to provide confidence in achieving 100% compliance with the appropriate WAC”.

Identification of one or commonly more technical goals will allow further development of the sampling plan in terms of determining the type, size, scale and number of samples to be taken, this is further elaborated in Section 4.8. Commonly a phased approach will be needed to meet each technical goal, each with its own specific sampling plan.

## 4.4 What level of testing is required?




The three principal levels of testing have been laid down in the Landfill Directive as follows, but the general principles stand for all types of testing:

- ***Level 1: Comprehensive ('basic') characterisation****. A thorough determination, according to standardised analysis and behaviour-testing methods, of the short and long term leaching behaviour and/or characteristic properties of the waste.*

- ***Level 2: Compliance testing****. Periodical testing by similar standardised analysis and behaviour testing methods to determine whether a waste complies with permit conditions and/or other specific reference criteria*. The tests focus on key variables identified by basic characterisation.

- ***Level 3: On-site verification****. Rapid check methods to confirm that a waste is the same as that which has been subjected to compliance testing and that which is described in the accompanying documents.*

Level 1 testing (comprehensive/basic characterisation) is the key to the waste acceptance system. Its purpose is to determine the intrinsic properties of the waste, in order to decide on the appropriate methods and site for the treatment, disposal or reuse of the waste. *It may include a significant desk-based element*. In general, it is undertaken by the waste producer at the producer's premises. Once the comprehensive characterisation of the waste material is documented, provided the waste is of a consistent nature, only infrequent confirmation of this characterisation by the waste producer is necessary (Figure 4.1). Periodic monitoring at level 2 and 3 is based on the bank of characterisation data provided by level 1. However, should the composition of the material change either through a change in operations at the waste production plant or through treatment prior to reuse or disposal, level 1 testing will have to be repeated (Figure 4.1).

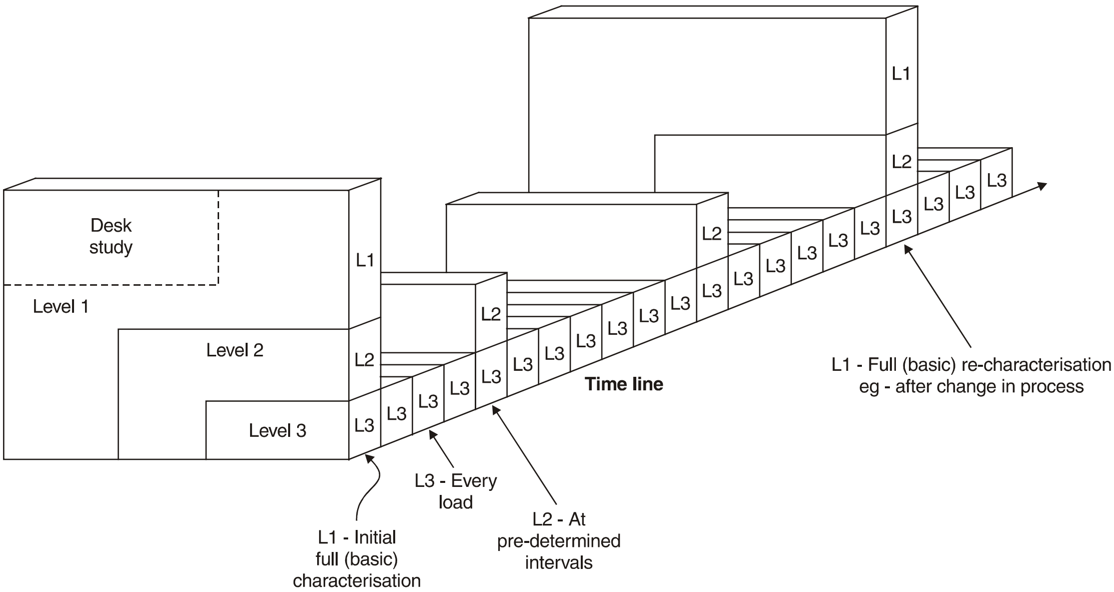



**Figure 4.2 The timeline for different levels of sampling and testing**

### 4.4.1 Level 1 – comprehensive characterisation

In many cases there is neither a significant historic database of relevant information on the characteristics of a particular waste stream or good knowledge of what operational factors influence the quality of the waste. In these situations it is often more cost-effective to take a step-wise approach to characterisation.

The decisions about the levels of testing that are required can often only be made after the background information on the process which generates the waste has been undertaken (Section 4.6).

Ultimately the need to demonstrate compliance with limit values for end-use or disposal is the principal driver for the characterisation programme.

The aims of the characterisation exercise and background research may well be to identify gaps in knowledge and the carry out small, potentially intensive screening exercises to plug those gaps. As the understanding of the waste quality and consistency and links between inputs and outputs to the waste grows, it is possible to design a programme to deliver data for the strategic objectives.

Examples of screening exercises include assessments of variability[13] in total concentrations and leachability with:

- time (day-to-day, week-to-week or seasonal variations when changes in other factors are either known or believed to be minor, or can be linked to time);
- feedstock (or other input streams);
- other changes in operational conditions such as shift patterns;
- plant at the same site (e.g. output from different production lines or incineration boilers) or between plant at different locations.

Having ascertained the variability of each parameter of interest, the principal factors controlling that variability and parameters which may compromise compliance with end-use or landfill criteria, it may be appropriate to modify operations to deliver a more consistent residue which is more likely to comply with the appropriate limit values.

Further screening steps might be needed to more rigorously examine which parameters are potential challenges to compliance with appropriate acceptance criteria and to highlight further operational changes that could be effected to deliver compliant residues. Alternatively a more detailed assessment of leaching behaviour under a range of conditions could provide data to inform the choice of physical or chemical treatments that could be used to bring about favourable modifications to the waste characteristics.

As part of this final phase of characterisation testing, the testing tool which is to be used for the level 2 compliance monitoring programme should also be carried out to provide a benchmark for the compliance database.

Thus the aims of the characterisation programme should be to understand the characteristics of the waste and to resolve the following questions:

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[13] Technical report TR1 describes in detail the different components in variability that may need to be addressed in the design of the sampling programme: spatial variability (scale of sampling, within-batch and between-batch variability ) and temporal variability (cyclic, driven and random variability), see Section 4.3.

- Is the waste consistent or erratic in quality?
- What are the ranges of concentration of parameters of interest as well as their average concentrations?
- What are the operational or time-related factors that have the greatest impact on residue quality?
- Does the residue meet the compliance limit values on all occasions or do operational changes need to be carried out or the residues treated to enable compliance?

### 4.4.2 Level 2 - compliance testing

The waste producer should periodically monitor waste quality to demonstrate that its characteristics have not changed significantly since the comprehensive characterisation. If it has changed, then re-characterisation may be required (see second level 1 characterisation step in Figure 4.1).

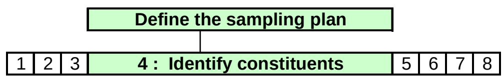
By including the compliance checks which a third party may be using to assess acceptability against end-use or other acceptance criteria, the waste producer receives early warning that he may be generating non-compliant residues with the potential for rejection. This should spur investigation into the causes of non-compliance and possibly operational or other changes, quality improvement through treatment or use of another management option.

The landfill operator has particular obligations in operating the landfill WAC compliance scheme. The benefits of co-ordinating sampling and testing and/or exchanging information with the waste producer have already been highlighted (Section 4.2.2).

### 4.4.3 Level 3 – verification

In many cases level 3 will not involve any testing. As a minimum, the accompanying documents must be checked to confirm that the waste is as described. Prior to landfill acceptance, a visual inspection of a load of waste before and after unloading at the landfill site may suffice to confirm that is appears to be the same waste for which characterisation and/or compliance information has been provided. Waste acceptance procedures at some facilities may require testing of key variables (e.g. pH) on every load for operational or safety reasons. Level 3 checks can also be used to trigger level 2 compliance testing (or rejection) if a load is suspect.

## 4.5 <u>What are the constituents and properties to be tested?</u>




### 4.5.1 Hazard assessment

Where the status of the waste as a non-hazardous or hazardous waste is unknown (for example there is ambiguity over the appropriate EWC code, or the waste has a mirror-entry code) an assessment of hazardous properties assessment will be required. This will be necessary for landfilled wastes after July 2004 when co-disposal of hazardous and non-hazardous wastes ceases (see Section 3.2.1) and for the first time lack of hazard will need to be demonstrated for mirror-entry wastes which are to be handled and disposed as non-hazardous wastes.

In many cases the hazard assessment can be done though a desk study approach using MSDS (Material Safety Data Sheet) information for relatively simple wastes that contain a small number of products with good hazard information. The Environment Agency's guidance WM2 (2003) highlights the likely hazardous properties that need to be investigated for many of the waste streams which are potentially (mirror-entry) or actually (absolute entry) hazardous.

Where the waste is more complex and potentially hazardous on the basis of dangerous substances, the first approach is to identify which compounds are most likely to be present in the waste. In the absence of concentrations of the specific compounds of interest these can be calculated from existing chemical data (e.g. total metal concentrations, PAHs, PCBs, mineral oils etc) or a new dataset may need to be obtained as part of the characterisation programme. The risk phrases associated with each of the compounds then need to be totalled and compared with the appropriate threshold level for assigning the waste as hazardous. However, presence of a single compound above the appropriate threshold will trigger hazard classification for some H categories. For example, if a single compound with risk phrase R45 (may cause cancer) or R49 (may cause cancer by inhalation) exceeded 0.1% w/w, the waste would be classified as hazardous on the basis of carcinogenicity (property H7). This is a particular issue for wastes containing traces of oil. Comparison of chemical data against threshold values can be carried out for many of the hazard properties (e.g. H4/8 irritant/corrosive, H5/H6 (harmful/toxic), H7 (carcinogenic), H10 (toxic for reproduction), H11 (mutagenic) and H14 (ecotoxic).

Where there is any doubt, or the results are marginal, a range of screening tests are available, for example:

- bacterial luminescence assay test and/or enhanced chemiluminescent assay test (H5/6 harmful/toxic);
- EC test method C2 (acute toxicity test for daphnia) and EC test method C3 (algal inhibition test) (H14 ecotoxic).

Detailed guidance is provided on the whole process of hazard assessment and testing in Technical Guidance WM2 (EA 2003).

### 4.5.2 Compliance-driven characterisation

The need to demonstrate compliance with limit values for end-use or disposal is the principal driver for the characterisation programme, along with parameters that are key for operational control by the end-user or treatment plant operator. Therefore all parameters for which relevant limit values exist should be tested, examples of which are presented in Table 4.1.

Sufficient time should be allowed in the characterisation programme for the testing, particularly when decisions about further phases of testing are dependent on the results of earlier testing. For example, the standard turnaround time for sample preparation, analysis and reporting for most of the tests described in Table 4.1 is usually of the order of 3-4 weeks. However the 64-day 'tank' test NEN 7345 for monolithic wastes or construction products and the 28-day seed growth trials for PAS 100 extend this to 6-9 weeks.

During the characterisation phase the same constituents will need to be tested, but the aim would be to provide information on links between levels of those constituents in the waste with operational activities and inputs upstream in order to identify whether operational changes are needed to maintain compliance. If this is not possible then enough samples should be tested for ranges of concentrations of each constituent to be established along with the average concentration.

Once the variability of the constituents has been assessed along with the implications of that variability against the limit values, the wider toolbox of available characterisation tests can be used. For example, where leachability limit values are exceeded (as for the landfill waste acceptance criteria) a better understanding of the leaching behaviour of the waste may allow more informed decisions to be made on pre-treatment of the wastes.

Examples of leaching behaviour tests:

- ***Maximum availability for leaching (NEN 7431).*** This is an aggressive leaching test that indicates the potential availability of a contaminant for leaching under worst-case environmental conditions. While total concentrations provide information on the quantity that can be released by a boiling acid digest, the maximum availability test indicates the total quantity that could be released through long-term flushing (liquid to solid ratio 50 and 100) by milder liquids (e.g. rainwater) albeit under more challenging pH conditions (pH 7 and 4). Comparing leachability at increasing liquid to solid ratios with the maximum availability for leaching provides an indication of the timescales for depletion and ultimately exhaustion of the contaminant source term, assuming no change in pH conditions. (Plots showing relationship of maximum availability for leaching with other leaching behaviour tests are shown in Figures 4.2 and 4.3).

- ***Cumulative leaching at 0.1-10 l kg$^{-1}$ using the upflow percolation test (prEN 14409).*** This provides cumulative leaching values from L/S 0.1 l kg$^{-1}$ (e.g. when natural moisture content is at 10%), through 0.5, 1, 2, 5 and 10 l kg$^{-1}$ (equivalent to flushing the dry waste with ten times its volume with water). Comparison of the cumulative L/S 0.1-10 l kg$^{-1}$ profile with the maximum availability for leaching and the limit value itself may demonstrate whether controlled washing of a water-soluble phase could enable compliance with a leachability limit value. The comparison will give a good indication of how much flushing is likely to be required to either exhaust the source or to meet the limit value (Figure 4.2). The test is conducted at natural pH, (as is the compliance

**Table 4.1 Example constituents for compliance testing programmes or characterisation programmes driven by the need to ensure compliance**

| Compliance test | Constituents to be tested |
|---|---|
| **Acceptance of granular wastes to landfill**<br>(Specific WAC for hazardous, stable, non-reactive hazardous and inert waste landfills) | • TOC and/or LOI<br>• Total concentrations of organic contaminants – BTEX, mineral oils, PCBs and PAHs.<br>• BS EN 12457-3 L/S2 and L/S2-10 eluate determinations for As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Sb, Se, Zn, Cl, F, $SO_4$, TDS, DOC and phenol index.<br>• Acid/base neutralisation capacities over a range of pH values |
| **Acceptance of monolithic wastes to landfill**<br>(WAC for hazardous and non-reactive hazardous waste landfills). 64-day characterisation and 4-day compliance limit values in mg/m3. | • NEN 7345:1995 and 7 eluate determinations for As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Sb, Se, Zn, Cl, F, $SO_4$, TDS, DOC |
| **BS PAS 100 specification for compost** | • aqua regia total metals Cd, Cr, Cu, Hg, Ni, Pb, Zn;<br>• physical contaminants (glass, metals, plastics, stones etc);<br>• phytotoxins;<br>• weed propagules, and<br>• microbiological contaminants *Salmonella s.p.p.* and *E Coli.* |
| **SEPA draft guidelines for landfill restoration (2002)** | • Total (aqua regia) concentrations of Cd, Cr, Cu, Hg, Ni, Pb, Zn<br>• Impurities >2mm (excluding gravel and stones)<br>• Faecal coliforms |
| **Thermal treatment (e.g. co-incineration with MSW)** | • moisture content, calorific value, TOC or LOI, |
| **Draft sludge directive** | • Total (aqua regia) concentrations of Cd, Cr, Cu, Hg, Ni, Pb and Zn |
| **Secondary aggregates/cement bound material in construction products (various)** | • Particle size distribution<br>• Specific contaminants e.g. Cl, $SO_4$, Fe, Mn, Al, otherwise major elements as oxides |

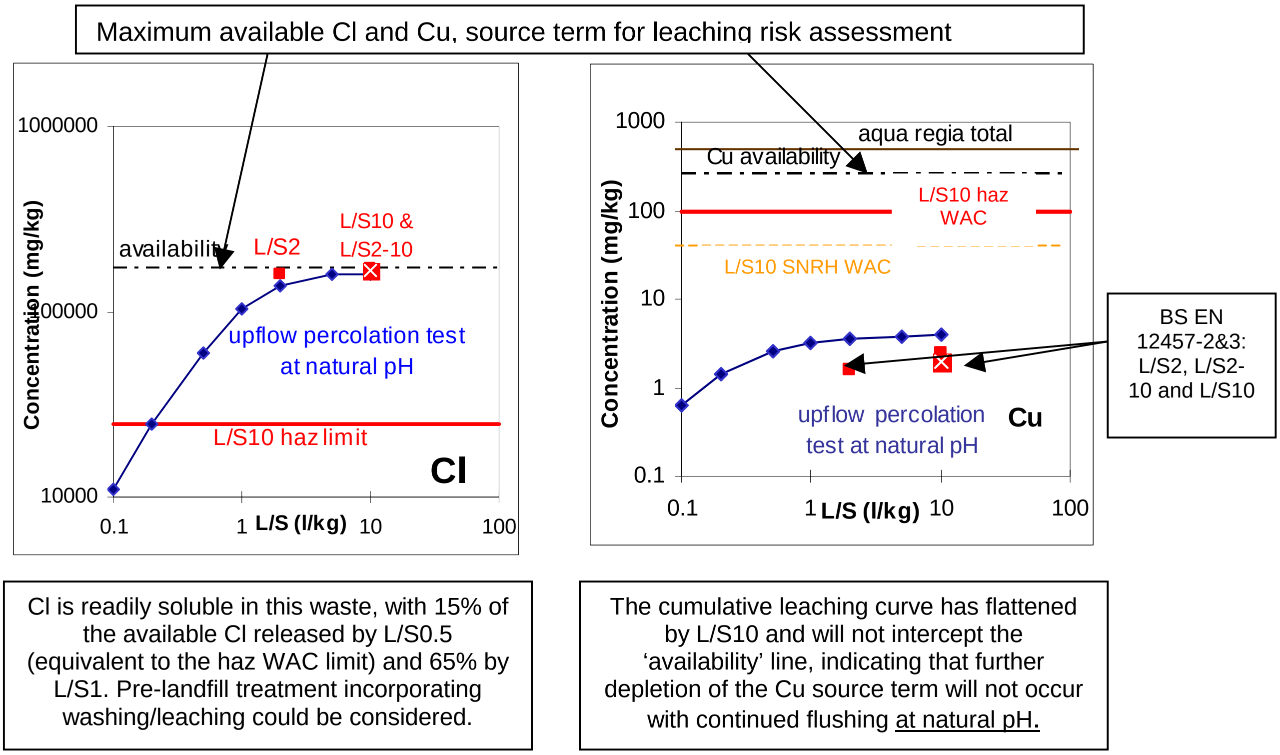
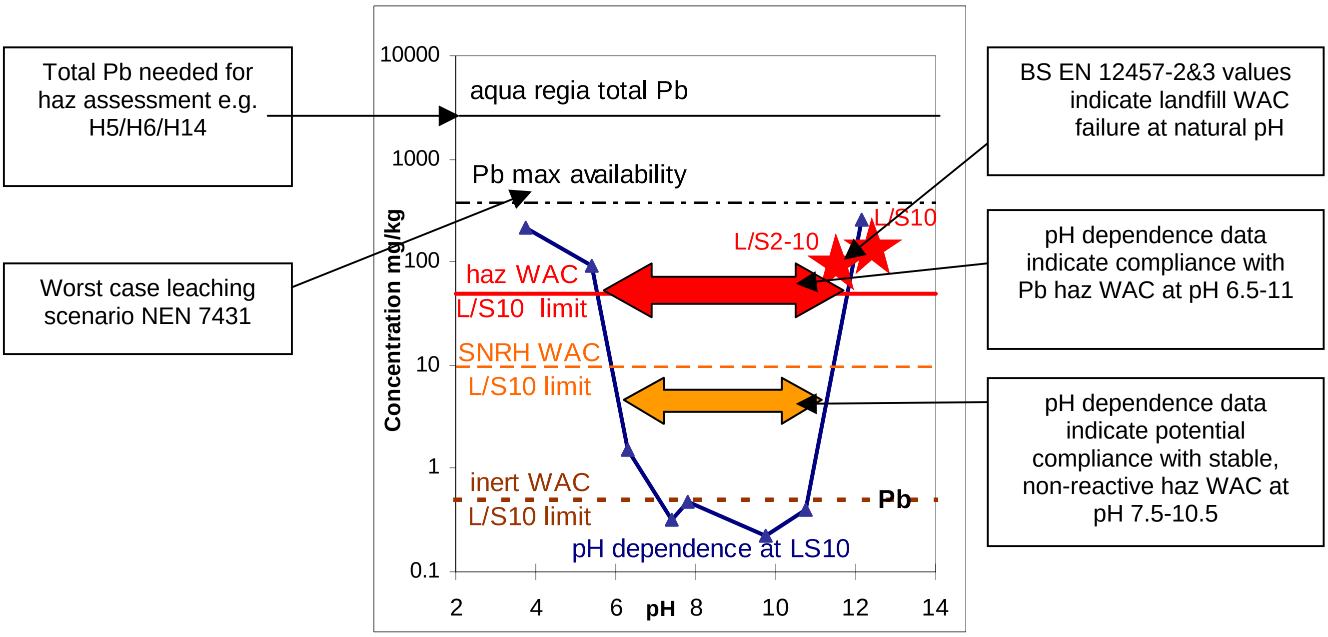



**Figure 4.3 Example plot of cumulative Cl leaching (0.1-10l/kg) using prEN 14405**



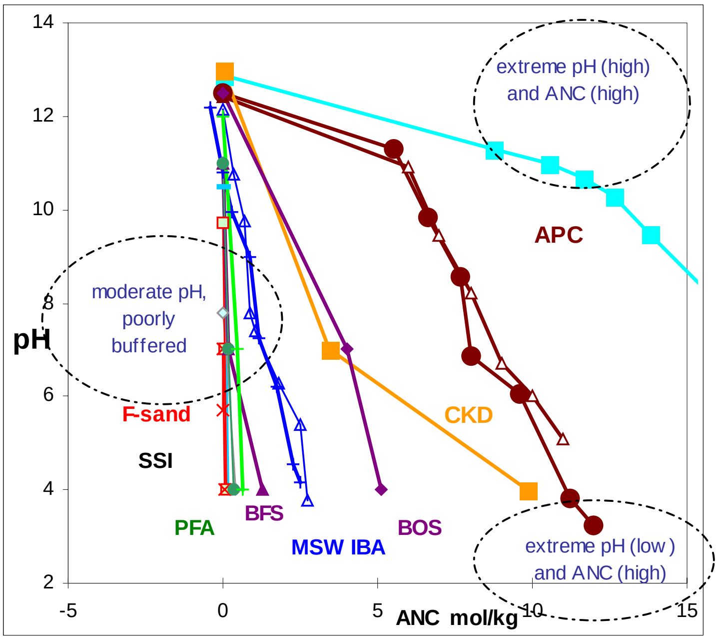

The plot shows the development of a potential pH treatment window. The exercise must be repeated for all WAC parameters as pH adjustment may increase the solubility of some phases enough to make previously compliant parameters fail the relevant WAC. Pre-landfill treatment to the target pH could ensure compliance with the appropriate landfill WAC. However, single stage treatment may not be feasible.

**Figure 4.4 Example plot of pH dependent leaching of Pb (using prEN 14429)**

leaching test BS EN 12457) and hence no information is provided on changes in leachability that are controlled by pH.

- ***Leaching at L/S2 and L/S10 at natural pH (BS EN 12457-3).*** As well as being the preferred test for assessing compliance with the WAC at L/S10 for granular wastes, the two-step test also provides additional leaching behaviour information with leaching under different liquid-to-solid ratios. The release profile at L/S2 (flushing dry waste with twice its volume of water) and cumulative L/S10 can be compared with the availability for leaching. It can provide a useful insight to the ease with which the supply of the contaminant can be mobilised by water and flag up the need to undertake the full upflow percolation test (see Figures 4.2 and 4.3).

- ***pH dependent leaching of metals (pH dependence test - prEN 14429).*** Replicate samples are leached for 48 hours at a specific pH value between pH 4 and pH 12 as well as at natural pH. The resulting leaching curves demonstrate the impact of adjusting the pH of the material outside its normal pH domain and therefore assist predictions of leachability under varying *in situ* pH conditions or to provide additional information when considering waste treatment options (for example pre-landfill treatment to meet WAC - Figure 4.3). This test also provides information on acid/base neutralisation capacity over the pH 4 –14 range (Figure 4.4).




Mixing a high ANC/BNC waste of extreme pH with a less well-buffered waste of different pH should be avoided. If the leachability of the lower ANC/BNC waste is predicted using an 'own' pH leaching test (e.g. BS EN 12457) the swamping effect of the extreme pH/high ANC/BNC waste will compromise those leachability predictions.

Residues plotted include: foundry sand, sewage sludge incineration ash, blast furnace and basic oxygen slags, MSW incineration bottom ash and air pollution control residues and cement kiln dust.

**Figure 4.5 Plot of acid neutralisation capacity versus pH for a range of residues**

Guidance has been published for selecting the most appropriate leaching tests and verifying that the results of the testing do support the objectives of the testing programme[14]

[14] BS DD ENV 12920, 1998) *Characterisation of Waste - Methodology for the Determination of Leaching Behaviour of Waste under Specified Conditions.* British Standards Institution (CEN/TC292/WG6).

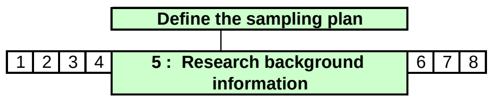
### 4.5.3 Review of management options

As part of the characterisation phase, suitability of other options can be considered that are relevant to the waste matrix. One of the basic characterisation requirements of the Landfill (England and Wales) (Amendment) Regulations 2004 requires this, ("check if the waste can be recycled or recovered"). Thus although the characterisation programme may be driven by the need to attain compliance with a specific end-use or disposal route, or upon demonstrating that the waste is non-hazardous, it is worth considering at an early stage what other information is required to assess feasibility of alternative options for a BPEO assessment. This may include investigating compliance with other standards listed in Table 2.1. If this is allowed for when the Sampling Plan is prepared, the additional costs of testing the samples for a range of purposes may be marginal in comparison with the costs of time and travel needed to collect and transport the samples.

### 4.5.4 Compliance programme

The analytical results from the compliance testing programme will gradually develop as a historic routine monitoring dataset on waste quality. As the tests will have been included in the characterisation programme there will be a benchmark for data comparison. Significant deviation from this set could trigger re-characterisation. All the constituents considered under Section 4.5.1 (compliance-driven characterisation) will therefore apply. However, with time, it may be possible to limit the compliance testing programme to a smaller number of key variables which are closest to any limit values or which exhibit the greatest variability.

## 4.6 What background information exists for this waste?




Although testing data may be at a minimum, it is often surprising how much information can be gleaned by talking with site personnel involved in the production process and waste handling operations. This information will help to target the sampling exercise. A round the table discussion should be one of the first actions in the Sampling Plan development process. The type of information to be collated includes:

- ***Site details:*** Number of sites, are they similar processes at all sites, potential access issues which might control the approach (for practical or safety purposes) or the physical method of obtaining the sample.
- ***Process generating the waste or nature of arising,*** how is the waste generated? are component streams combined at any stage?, key factors likely to influence the quality. Either inspect the process or obtain info from on-site operational experts.
- ***Evaluation of existing compositional data,*** e.g. examine the plant input streams. What are their relative proportions? Is there any information on variability in quality? Could this contribute to waste quality? Are there any obvious links between quality of inputs and outputs? If checking for WAC compliance, consider carrying out a 'traffic light' analysis of WAC data that highlights potentially problematic parameters. Do the same for input streams if there is direct link (e.g. chemical treatment plant).

- ***Material type and dimensions of the batch to be sampled:***
    - Are the wastes generated as a stream or batch?
    - Solids: if static and stored and/or transported in a container, is this a drum, silo, tanker or other container (record). Or is the waste in a heap/stockpile? What is the quantity of the batch that is to be sampled (e.g. volume or weight of waste in a heap, number and size of containers).
    - Liquids: if static, how is it contained? (bottle, drum, tank, lagoon etc). What is the size of the batch, i.e. litres or cubic metres;
- ***Physical and chemical characteristics, hazardous properties.*** Is the waste a solid, sludge or liquid? Is it granular (in which case, what it the approximate particle size range?) or a monolithic waste? Is the waste stream composed of large shaped or irregular pieces? If it is a liquid, does it separate into layered aqueous solution and/or sludges? (Where information is incomplete an initial screening exercise may be required).

## 4.7 What health and safety precautions need to be identified?

| | | | | | Define the sampling plan | | |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | **6 : Health & safety** | 7 | 8 |

The European Framework Standard prEN 14899 states the following:

"The Sampling Plan shall identify all safety precautions that must be adhered to by the sampler. For further information on general health and safety aspects on sampling see ISO 10381-3 (Clause 7).

All sampling activities are potentially hazardous. A risk assessment shall be carried out prior to undertaking the work and safety precautions identified to protect the sampler and minimise risks. (Inter)national legislation and site specific systems for controlling the exposure of workers to substances hazardous to health should be complied with.

Any organisation involved in sampling should have a safety policy that sets out the requirements for safe working. Adherence to the policy should be a part of the conditions of employment of all personnel.

The policy should be supported by standard procedures setting out the requirements for safe working in general, and in specific locations, such as confined spaces. These standard procedures should include the provision and use of protective clothing and equipment and the minimum number of personnel that may be involved in site work. The standard procedures should also identify the requirements for advising local emergency services and the methods of communications and methods of washing and decontamination.

> NOTE Compliance with this European Standard does not in itself confer immunity from (inter)national heath and safety regulations and site specific regulations".

## 4.8 What is the selected sampling approach?



### 4.8.1 General

One of the key activities in the development of a Sampling Plan is the consideration and selection of what can collectively be regarded as the 'statistical criteria'. The importance of this step is identified in Clause 4.2.7 of prEN 14899. Due consideration of these criteria ensures that appropriate boundaries are set for the sampling exercise, and in particular that the type and number of samples taken will ensure that the data collected is fit for purpose. A technical report is dedicated to providing additional guidance/clarification on this aspect of the sampling plan development: (TR 1 (WI 292002): Waste – Technical Report on Sampling – Part 1: Information on the selection and application of a basic statistical approach to sampling under various conditions). In addition it provides a number of worked examples which follow a prescribed decision making process, as detailed in Table 4.2. As a minimum, the process identified in Table 4.2 should be followed in the development of any sampling plan.

**Specify the objective of the testing programme**
Specify the objective of the testing programme

↓

**Develop the technical goals from the objective**
Define the population to be sampled
Assess variability
Select the sampling approach
Identify the scale
Choose the required statistical approach
Choose the desired reliability

↓

**Determine the practical instructions**
Choose the sampling pattern
Determine the increment/ sample size
Determine the use of composite or individual samples
Determine required number of samples

↓

**Define the Sampling Plan**

**Figure 4.6 The main statistical steps addressed in TR1 that must be considered in developing the sampling plan**

The following sections will address each of the items listed in Finger 4.5 and provide an overview of the main issues of consideration, identifying potential impacts on the sampling operation. Further explanatory text and worked examples can be found in TR1.

### 4.8.2 Develop the technical goals from the objective

#### 4.8.2.1 Objectives

The definition of the testing programme objectives and subsequent identification of technical goals will be one of the first activities to be completed in developing the sampling plan, and this aspect has been previously dealt with in Section 4.3. It is now necessary to 'put the technical meat' on those goals in order to develop the Sampling Plan into something that can be used by the sampler.

#### 4.8.2.2 Population and sub-population

The term 'overall population' represents the total volume of waste about which information is required through sampling, such as the total volume of waste generated by a factory in a given year. In practice it is usually impractical to sample from the overall population and it is customary to define the population for sampling as a convenient sub-set of that overall population which importantly is believed to be typical of the overall population. For example, process logistics might indicate that one month's waste production is typical of any other. Process knowledge is key to the definition of the sub-population, as it relies on experienced judgement. The definition of one or more further sub-populations may be necessary in some cases if targeting of known changes in the production process or expected concentration levels is required, or where access restrictions are difficult for the population.

#### 4.8.2.3 Variability

The sources of variability in the population of waste to be sampled must be understood and then exploited to ensure sampling is appropriately targeted. The different components in variability that may need to be addressed in the design of the sampling programme include:

- **spatial variability** (within-stratum and between-stratum variability). This is commonly due to the mixing of a waste stream generated at differing locations or processes or simply from temporal variation within an individual process. Spatial variability may be reduced by mixing, or through segregation of individual streams.

- **temporal variability** (cyclic and random variability and variability which is driven by other factors). The majority of processes show variation through time – due, for example, to changes in the nature of the input materials, changes in the process or operational efficiency in the plant or a combination or all three. Knowledge of the causes of temporal variation is important as it has important bearing on the sampling programme. For example, a preliminary sampling exercise may show that the day-to-day variation in stockpiles from a production process is much greater than the variation within a stockpile in any given day. More information would be gained in a subsequent sampling activity if samples are taken on as many different days as is possible as opposed to focusing sampling effort on a single day.

#### 4.2.8.4 Type of sampling

Two primary types of sampling are distinguished in prEN 14899, termed ‘probabilistic’ and ‘judgemental’ sampling. Probabilistic sampling is a statistically based approach whereby any part of the population has an equal chance of being sampled, and this allows limits of uncertainty to be calculated for any resulting data. This is in direct contrast to basic judgemental sampling (often referred to as ‘ad-hoc’ sampling), where samples are commonly taken from a restricted sub-population (e.g. the top of a truck or side of a stockpile) that is usually not representative of the population and sample numbers and sample locations have no statistical basis. It should be noted that there may be a perfectly good reason to target a specific part of the population: for example, the objective may be to take a hot-spot sample.

As the ideal of any sampling exercise is be able to extrapolate any data from a limited number of samples to a much larger population, it is clearly important that any sampling exercise follows the probabilistic route whenever possible. Even when judgemental sampling seems the only option, a well chosen sub-population and subsequent adherence to statistical criteria in terms of sample number, size and sampling pattern will give a wealth of additional information over a ‘spadeful of waste taken from not sure where’.

#### 4.2.8.5 Scale

The ‘scale’ is crucially important to defining a sampling programme. It defines the minimum quantity (mass or volume) of material below which variations are judged to be unimportant. For example, if the scale is defined to be ‘a skip of waste’, then variations in any characteristic of the waste within the volume of a skip are declared to be of no concern. This means that during characterisation of the waste, concentration and leaching data must be representative of average concentrations within a skip. Samples collected at a smaller scale would be expected to exhibit greater variability, and so would need to be composited and thoroughly mixed before analysis. The definition of scale has obvious implications for compliance testing where it is important that any compliance samples are evaluated at the same scale as the characterisation data to avoid possible rejection of what is a compliant load at the agreed scale. In this example this would mean either that samples would need to be collected through the full depth of the waste at a number of points in the skip, or that the skip should be emptied and samples taken throughout the waste.

It is important, therefore, that all involved parties agree the appropriate scale at the outset of any sampling and testing programme. For landfill acceptance compliance testing, it is the waste producer (or treatment plant operator) and the landfill operator that must agree the appropriate scale for the sampling programme. Any enforcement samples taken by the regulator must also be collected at the same scale.

#### 4.2.8.6 Statistical parameter

This is any numerical characteristic of a population - for example, its mean or its 90-percentile. The chosen parameter will have a critical bearing on both the type of sampling and the number of samples needed. For a number of commonly used parameters, TR1 provides methods for estimating the parameter and calculating the associated uncertainty. The second of these is a critical piece of information, because it provides the quantitative link between the number of samples and the achievable reliability (see below).

The choice of parameter will often depend on the level of testing. For basic characterisation, for example, measures of variability (e.g. relative standard deviation) and extreme behaviour (e.g. 95-percentile) are likely to be required. For compliance, it is likely that the required statistical parameter has been defined by the regulator.

#### 4.8.2.6 Choose the required level of reliability

The reliability of a testing programme is a general term embracing three statistical concepts: ‘bias’, ‘precision’, and ‘confidence’. The objective of the programme will influence the degree of reliability that is regarded as acceptable, but the final selection of reliability criteria will nearly always need to be a compromise between cost and expectation. Given the important decisions that are likely to rest on the findings of a basic characterisation exercise, it is suggested that the reliability should be as high as possible. Conversely, given the ‘quick check’ format envisaged for on-site verification, the achievable reliability for any one assessment will in many cases be low. However, this could be offset to some extent where a large number of similar checks are available.

All types of sampling introduce a degree of random uncertainty (known as ‘sampling error’). Because of this, the result from a sampling programme - mean concentration, say - will never be exactly equal to the true value in the population. This uncertainty can be quantified by putting what is termed a ‘confidence interval’ around the result - with the semi-width of the confidence interval being known as the ‘precision’ of the estimate. Associated with any confidence interval is a specified level of confidence, such as 90%. With 90% confidence intervals, for example, the guarantee is that, in the long run, about 9 in 10 such intervals will truly contain the true population parameter. It might seem sensible to improve this ‘success rate’ by using a higher level of confidence, like 95% or 99%. However, this can only be done at the cost of making the precision poorer. For example, a 99% confidence interval will be more than half again as wide as a 90% confidence interval: that is, the attainable precision at this higher level of confidence will be more than 50% poorer than before.

For a given level of confidence, two main factors influence the width of the confidence interval. The first is the *number of samples* - clearly, the more samples that can be afforded, the better the precision will be. The second is the *variability of the underlying population* - the more variable this is, the poorer the precision will be (for a given number of samples). The statistical methods set out in Annex A, TR1, enable these common sense notions to be quantified. This is of vital importance, as the key benefit of being able to estimate the achievable confidence and precision associated with any proposed Testing Programme is that it provides a quantitative link between the sampling resources used and the reliability of the resulting answers.

### 4.8.3 Determine the practical instructions

#### 4.8.3.1 General

The technical goals must now be translated into practical instructions that are given to the sampler prior to sampling. A number of additional practical issues must be considered in identifying these instructions as follows:

#### 4.8.3.2 Identify the sampling pattern

This defines where, when and how the required samples will be selected from the population. Figure 4.4 illustrates 3 potential approaches that could be used in probabilistic sampling, and two options for judgemental sampling.

- Example of simple random sampling – although every part of the population has an equal chance of being sampled, the resulting samples may not be very evenly spread across the population, and other more structured patterns of sampling may therefore be preferred.
- Example of stratified random sampling – strata (e.g. different batches) are identified within the population, and specified numbers of samples are spread randomly within each stratum. Benefits of this approach are that each stratum within the population is sampled adequately, whilst the advantages of random sampling are retained within each stratum.
- Example of systematic sampling – as per stratified random sampling except that the samples are taken at the same time or location from each of the identified strata or batches. This approach could lead to bias if there is a systematic component of variation within the process that runs in step with the chosen sampling interval.
- Example of judgemental sampling – this type of sampling can follow any type of sampling pattern or frequency. Where possible, however, it should follow as many as possible of the principles of the probabilistic approach. In our example, it is clear that option 1 provides a more comprehensive coverage of the waste, for the same number of samples, than does option 2. Option 1 effectively represents a systematic sampling approach for the identified sub-population (chosen, for example, because access restrictions may limit sampling to the outside perimeter of the waste), and so because this is a form of probabilistic sampling, the uncertainty in the parameter estimates can be calculated.. If it can be assumed that this sub-population is likely to be little different in the characteristics of interest from the overall population, then this method of sampling can still provide information on the entire population of interest, despite the fact that access limits sampling to a small part of the population.

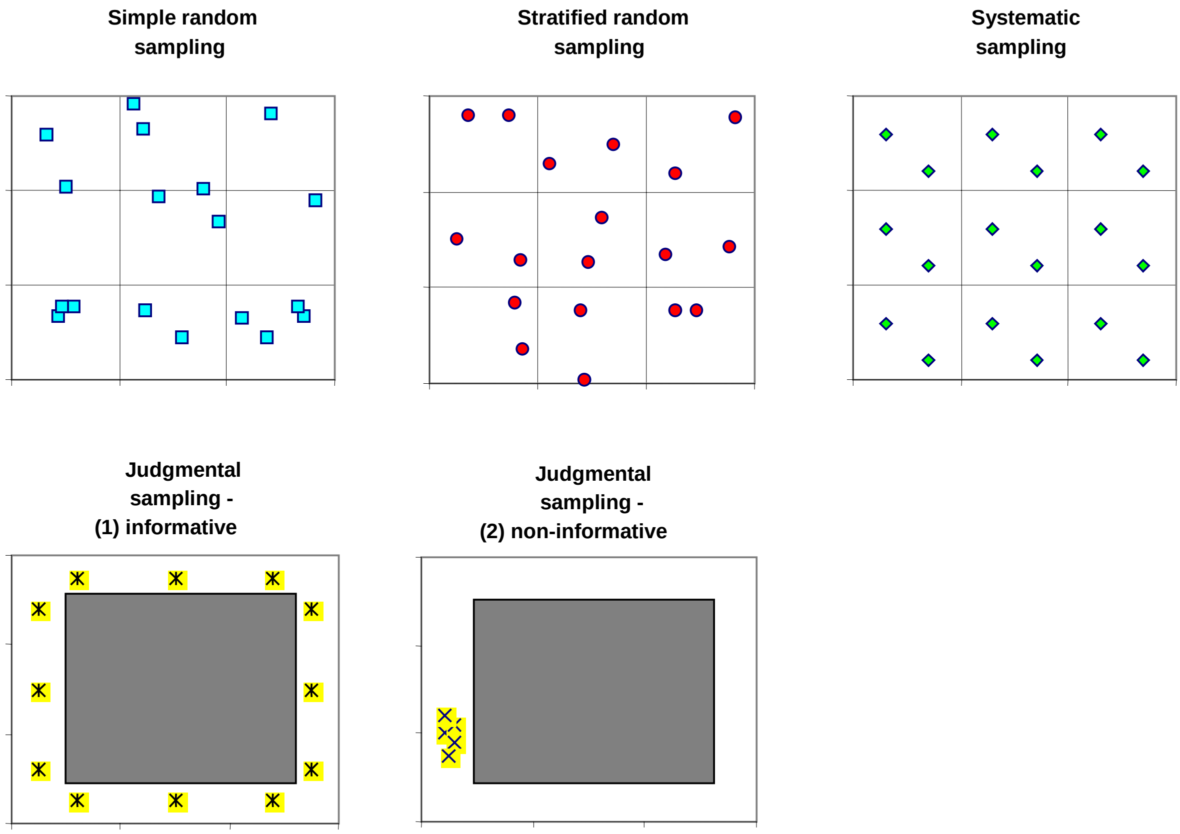



**Figure 4.7 Possible patterns of sampling**

NOTE: The figure illustrates the patterns for the context of a two-dimensional spatial area. However, the concepts apply as equally to temporal as they do to spatial components of variability.

### 4.8.3.3 Determining the size and number of samples

The minimum sample size is only really relevant to particulate wastes[15] and is governed by the need for the sampling device to accommodate all particle sizes. But in all sampling the size of sample should be sufficiently large to minimise errors caused by the fundamental variability of the waste being sampled. Where it is important to obtain a measure of variability within the waste, samples should be analysed on an individual basis. Samples numbers will depend on the selected statistical parameter, and detailed procedures are provided in Annex C of TR1.

[15] An exception is the need for a monolithic waste specimen of 40mm in any dimension for testing using the diffusion ('tank') test NEN 7345, for example, for testing compliance with the monolithic landfill waste acceptance criteria.

## 4.9 What are the selected sampling techniques?

Define the sampling plan

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 : Identify sampling techniques |
|---|---|---|---|---|---|---|---|

The sampling technique is the physical procedure employed by the sampler to collect part or parts of a discarded or secondary material for subsequent investigations. As previously discussed two main approaches to sampling are recognised:

- Probabilistic sampling - the preferred method of sampling or recovering material where a quantifiable level of reliability is required in the results for the population being tested. The basis for probabilistic sampling is that each element within the population being sampled has an equal chance of being sampled. This means that the Sampler has access to the whole population and can collect a sample that is representative of that population.

- Judgemental sampling – this is used where representative sampling from the whole population is practically impossible, given available resources (time or money) or when sampling is required to target a specific item or point within the population.

The second technical report supporting the Framework Standard prEN 14899 (TR2 'Sampling Techniques') is dedicated to guidance on the choice of sampling techniques. It is structured such that the selection of sampling techniques and equipment is dictated by physical form – liquid, viscous liquid, sludges, paste like substances, fine grained solids and coarse grained solids. A series of flow-charts then direct the reader to appropriate clauses within TR2 which relate to the nature of the arising (e.g. drum, hopper or pile). Figure 4.6 is an example of one of these route-maps.

The sampling technique adopted depends on a combination of different characteristics of the material and circumstances encountered at the sampling location. These determining factors are:

- the type of material / the physical state of the material (e.g. solid, liquid, paste, sludge);

- the situation at the sampling location / the way in which the material occurs (e.g. in a tank, a stockpile, on a conveyer belt);

- the (expected) degree of heterogeneity (e.g. homogeneous liquids, layered liquids, segregated sludges, mixtures of solid materials);

- the level of testing, which may influence the approach to the selection of composite or individual samples as detailed in TR1.

Equipment selection is also based on the sample matrix, a generic look-up table illustrating suggested applications for sampling equipment is provided in Table 4.3.

**Table 4.2 Suggested applications for generic types of sampling equipment**

| Generic sampling apparatus | Liquid | Sludge | Pierceable solid | Dry solid (fine powder) | Dry solid (coarse grained) | Dry solid (massive) |
|---|---|---|---|---|---|---|
| Bailer | | | | | | |
| Dipper | + (1) | + | - | - | - | - |
| Weighted bottle | + (2) | + | - | - | - | - |
| Depth sampler | + | + | - | - | - | - |
| Pond sampler | + | + | - | - | - | - |
| Column sampler (liquid) | + | + | - | - | - | - |
| Pump | + | + | - | + | - | - |
| Auger | - (3) | - | + | - | - | - |
| Corer | - | - | + | - | - | - |
| Sampling drill | - | - | + | - | - | - |
| Sampling tube | + | + | + | - | - | - |
| Spatula | - | - | + | + | + (4) | + (7) |
| scoop | - | - | + | + | + (4) | + (7) |
| Trowel | - | - | + | + | + (4) | + (7) |
| Thief/trier | + | + | + | + | + (5) | + (7) |
| Tap | + | + | - | - | + (6) | - |

**Key**
+ appropriate
- not appropriate

**Notes**
(1) For liquid depths < 3.5 m
(2) Not suitable for viscous liquids
(3) Does not collect undisturbed core
(4) Not suitable for deep containers
(5) May be difficult to retain the sample with very dry granular material
(6) If gravity fed
(7) If crushed prior to sampling

TR2 does not present a definitive process but a toolbox of sampling techniques that reflect current practice, this, however, does not mean that other solutions are not available. The selection of an appropriate sampling technique will depend on the objectives for sampling and the physical form and chemical characteristic to be sampled. The route maps should be used in conjunction with the guidance provided in prEN 14899 - Framework for the preparation of a sampling plan.

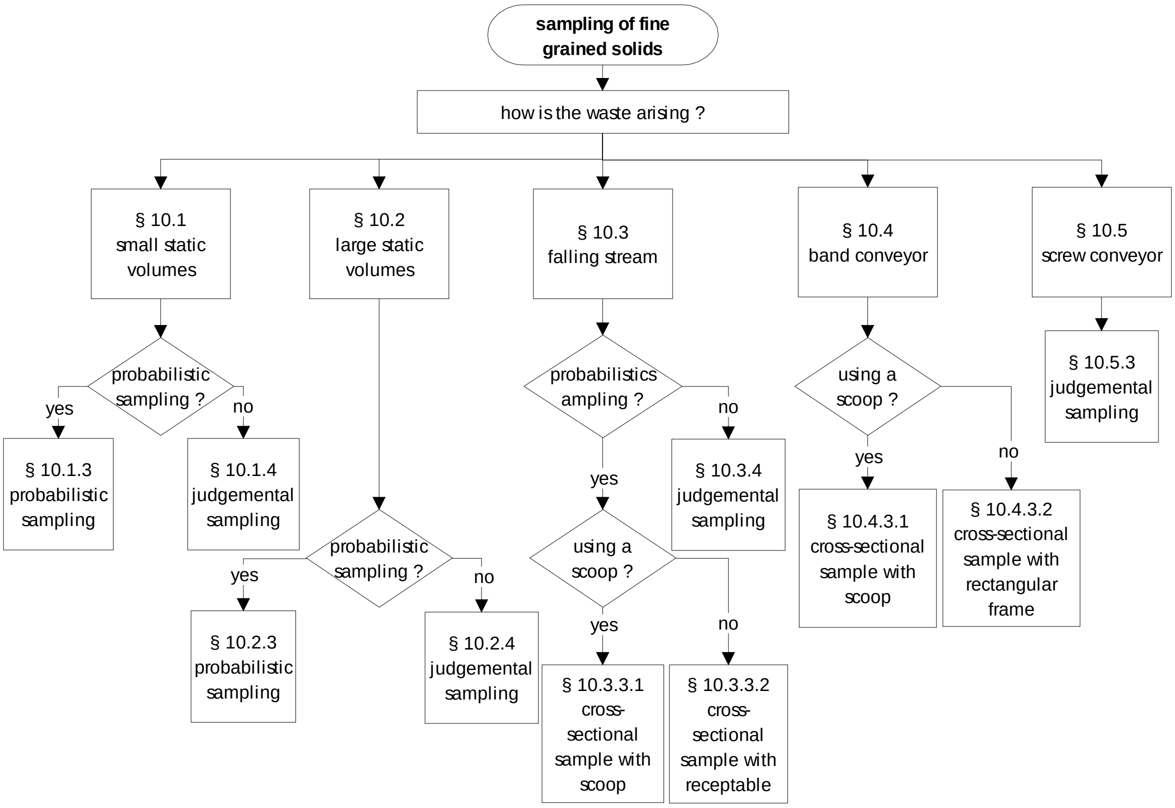



**Figure 4.8 Example of a route-map from TR2 (fine grained solids)**

A quick-look up guide to generic methods of sampling relating sample matrix to the waste arising is provided in Table 4.4. For example, a probabilistic procedure for the collection of coarse-grained particulate samples from a block, drum or small container can be found in section 11.1.3 of TR2.

**Table 4.3 Matrix look-up guide to TR2**

| | Location of waste arising | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Waste matrix** | **Falling stream** | **Conveyor** | **Vertical tank** | **Horiz-ontal tank** | **Block or drum** | **Small container** | **Small pile** | **Large pile** |
| Sludges | | | 5.3.3 P<br>5.3.4 J | 5.4.3 P<br>5.4.4. J | 5.1.3. P<br>5.2.4 J | | | |
| Pastes | 9.2.3 P<br>9.2.4 J | | | | 9.1.3 P<br>9.1.4 J | | | |
| Coarse-grained particulates | 11.2.3 J | | | | 11.1.3 P<br>11.1.4 J | | | 11.3.3 P<br>11.3.4 J |
| Fine-grained particulates | 10.3.3 P<br>10.3.4 J | 10.4 P<br>5.3 P 10.4<br>P 5.4 J | | | | | 10.1.3 P<br>10.1.4 J | 10.2.3 P<br>10.2.4. J |

Note:
P – probabilistic approach,
J – judgemental approach

# 5. COLLECTION AND DELIVERY OF SAMPLES

As discussed in Section 2, preparation of a Sampling Plan (Key Step 1) is the fundamental activity that must be completed prior to undertaking any sampling exercise. The complexity of the plan will vary with the testing programme, but as a minimum should record the information that will allow any results to be interpreted in an appropriate context and at which a comparable programme could be repeated, if required, in the future. A worked example Sampling Plan is provided in Annex A2 and the basic structure (and which can be added to as appropriate to the specific testing programme) in Figure 5.1

This section covers the collection of all designated samples and the delivery of those samples to the laboratory according to the instructions specified in the Sampling Plan. This stage of the testing programme represent Key Steps 2 and 3, the key activities of which are listed in Table 5.1.

**Table 5.1 Points to be addressed in Key Steps 2 and 3**

| | |
|---|---|
| **Taking the sample** | • The sample(s) should be taken and collected in accordance with all instructions provided in the sampling plan. Before sampling undertake a visual check of the material to be sampled and compare with against any information in the sampling plan. Potential problems should be discussed with the person responsible for developing the plan prior to sampling. |
| | • A record should be made of the location and status of the material to be sampled, a photograph may be useful. |
| | • Having obtained the sample, it should be either directly stored in a suitable sample container or stored after appropriate sub-sampling in the field. |
| **Delivery** | • The sample(s) need to be delivered to the testing laboratory at the address provided in the sampling plan, with a copy of the chain of custody form and the sampling record. |
| **Reporting** | • On completion of sampling a sampling record and chain of custody form should be completed by the sampler. An example is provided in Figure 5.2. The sampling record should document all procedures undertaken and any observations from the sampling exercise it will reiterate much of the sampling plan but contains space for recording visual observations made in the field and any deviations from those procedures identified in the sampling plan. The key information that must be recorded include:<br>o a unique sampling number (e.g. reflect site location, material and date);<br>o date and time of sampling;<br>o place and point of sampling;<br>o persons present (if witnesses are present, including name and address); |

| | |
|---|---|
| | o difficulty of access (obstacles), including information on those areas or volumes of the material that sampled or not sampled;<br><br>o condition of material:<br><br>o colour;<br><br>o consistency/homogeneity/grain size (uniform or diverse);<br><br>o observations during sampling (e.g. gassing out, reactions, development of heat, odour);<br><br>o details of on-site determinations;<br><br>o identify sample amount (estimate volume and mass);<br><br>o sub-sampling methodology (recording which samples are mixed, in what volumes, time and date) (if undertaken);<br><br>o name of sampling personnel;<br><br>o place, date and signature. |
| **Documentation of Variations** | • Any changes to the agreed final sampling plan must be recorded in the sampling record. such alterations to the sampling plan can be categorised in two ways:<br><br>a) firstly changes which do not affect the objective of the testing programme in that the required samples are obtained and remain representative at the pre-defined level. the sampler in the field may carry out this level of change.<br><br>b) secondly, changes which (could) affect the objective of the testing programme (e.g. resulting in a different quality of samples / results). this level of alteration to the sampling plan should only be carried out with written prior agreement. if, due to unforeseen circumstances, changes are required to the sampling plan at the time of sampling, verbal confirmation of any changes should be written on the sampling record and authorised on return from the field.<br><br>Unforeseen practical considerations can make it necessary to changes to the sampling plan in order to carry out the sampling activity. It is therefore important that the person undertaking sampling is in a position to know what changes are possible without affecting the testing programme. |

**Figure 5.1 Example of a short-form Sampling Plan**

| **SAMPLING PLAN** | |
|---|---|
| **GENERAL INFORMATION** | |
| Sampling Plan completed by: | On behalf of: |
| Client (Company):<br>Contact: | Material producer:<br>Contact: |
| Other involved parties: | |
| Sampling to be carried out by (Company): | Specify name of sampler: |
| **SAMPLING OBJECTIVE** | |
| **MATERIAL** | |
| Type of material: | Location: (address) |
| Form and nature of arising: | |
| Detailed specification: | |
| Identify access problems that may affect sampling programme: | |
| **SAMPLING METHODOLOGY** | |
| Specify detailed sampling location: (e.g. a specific chute or conveyor or pile) | |
| Define batch or consignment to be sampled: | |
| Define place and point of sampling: | |
| Specify date and time(s) of sampling: | |
| Specify persons to be present (record name and address): | |
| Identify sampling technique (ref. TR xxxx-2): | |
| Identify equipment: | |
| Specify no. of increments/samples to be collected (ref. TR xxxx-1): | |
| Specify increment size/sample size (ref. TR xxxx-1): | |
| Detail requirements for on-site determinations: | |
| Identify sample coding methodology: | |
| Identify safety precautions: | |
| **SUB-SAMPLING** | |
| Detail procedure: (ref. TR xxxx-3) | |
| **PACKAGING, PRESERVATION, STORAGE AND TRANSPORT REQUIREMENTS** (ref. TR xxxx-4) | |
| Packaging: | |
| Preservation: | |
| Storage: | |
| Transport: | |
| **ANALYTICAL LABORATORY** | |
| Company details:<br>Contact: | <br>Delivery Date: |

**Figure 5.2 Example of a Sampling Record**

| SAMPLING RECORD | |
|---|---|
| **Sample code:** (Reflect site location, material type and date of collection) | |
| **Date of sampling:** | |
| **Signature of sampler:** | |
| **GENERAL INFORMATION** | |
| Waste producer and Contact: | Client (Company) and Contact: |
| Location of sampling: | Carried out by (Company):<br>Sampler: |
| **SAMPLING OBJECTIVE** | |
| **MATERIAL** | |
| Type of Material: | Estimated moisture content: |
| Description:(colour, odour, consistency/homogeneity/grain size – uniform or diverse) | |
| **SAMPLING METHODOLOGY** | |
| Describe/define batch or consignment sampled: | |
| Place and point of sampling: | |
| Access problems that affected areas or volumes of material sampled: | |
| Date and time of sampling: | |
| Persons present (record name and address of witnesses present where appropriate): | |
| Procedure (describe procedure adopted): | |
| Equipment used: | |
| Number of increments/samples collected:* | |
| Increment size/sample size:* | |
| Observations during sampling: (e.g. gassing out, reactions, development of heat) | |
| Details of on-site determinations: (if undertaken complete field record sheet and append to Sampling Record, see Table B.2) | |
| Safety measures taken: | |
| **SUB-SAMPLING & PRE-TREATMENT** | |
| Identify location: e.g. on-site or fixed laboratory facility (describe whether open air or enclosed) | |
| Procedure: | |
| **PACKAGING, PRESERVATION, STORAGE AND TRANSPORT DETAILS** | |
| Packaging: | |
| Preservation: | |
| Storage: | |
| Transport: | |
| **DEVIATIONS FROM SAMPLING PLAN** | |
| Detail: | |
| **DELIVERY TO ANALYTICAL LABORATORY** | |
| Company: Delivery Date: | |
| Received by: | Signature: |

# 6. EXAMPLE SAMPLING PLANS

Annex A, B and C present worked Sampling Plans for three waste disposal scenarios that are likely to involve sampling and testing to obtain characterisation or compliance data.

- *Primary waste producer/landfill operator* - industrial waste production and in-house landfill;

- *Secondary waste producer/merchant treatment plant operator/landfill operator* - treatment of solid and aqueous wastes prior to landfilling at own sites as non-hazardous waste;

- *Landfill operator* - waste producer and owner of inert waste landfill.

The scenarios were identified in conjunction with ESART, to cover some of the key inter-relationships in the management of residue streams that have been outlined in earlier sections of this Practitioner's Guide.

Candidate companies were met at least once. A dataset of sufficient relevant information was not available therefore it was not possible to commence development of the example sampling plans with an evaluation of a detailed dataset. The following approach was taken to make the output from this project relevant to the majority of UK practitioners.

- A brainstorm exercise was conducted to identify potential objectives for sampling and testing the wastes.

- A testing programme to deliver against those objectives was designed. Often this involved a series of small steps, screening exercises to identify the sources of variability in waste quality or characteristics with time, input streams and/or operational factors. Only then could a more comprehensive investigation be proposed, based upon leaching behaviour and the desired ability of the waste to meet waste acceptance criteria.

Although this Practitioner's Guide aims to provide guidance on a range of waste testing scenarios, the three sampling plans were focused primarily on acceptance of waste to landfill, in particular the options available after July 2004 (end of codisposal) and July 2005 (introduction of landfill waste acceptance criteria). In particular the two sampling plans for the primary waste producer and secondary waste producer (treatment plant operator) required identifying potential landfill disposal options for one or more residue streams. A schematic of this process is presented in Figure 6.1. Background to the potential testing requirements for 'hazard assessment' and 'demonstrating compliance with waste treatment/acceptance criteria' are covered in Sections 3.2.1 and 3.2.2 respectively.

In the case of the landfill operator of an inert waste landfill, the basic approach was very different. Not all inert wastes require testing by the landfill operator. For those wastes that do require testing, they are often highly variable in nature and attract only a low profit margin. A spreadsheet tool was therefore developed to indicate the level of risk of missing non-compliant loads for a given compliance testing scheme i.e. against numbers of samples tested

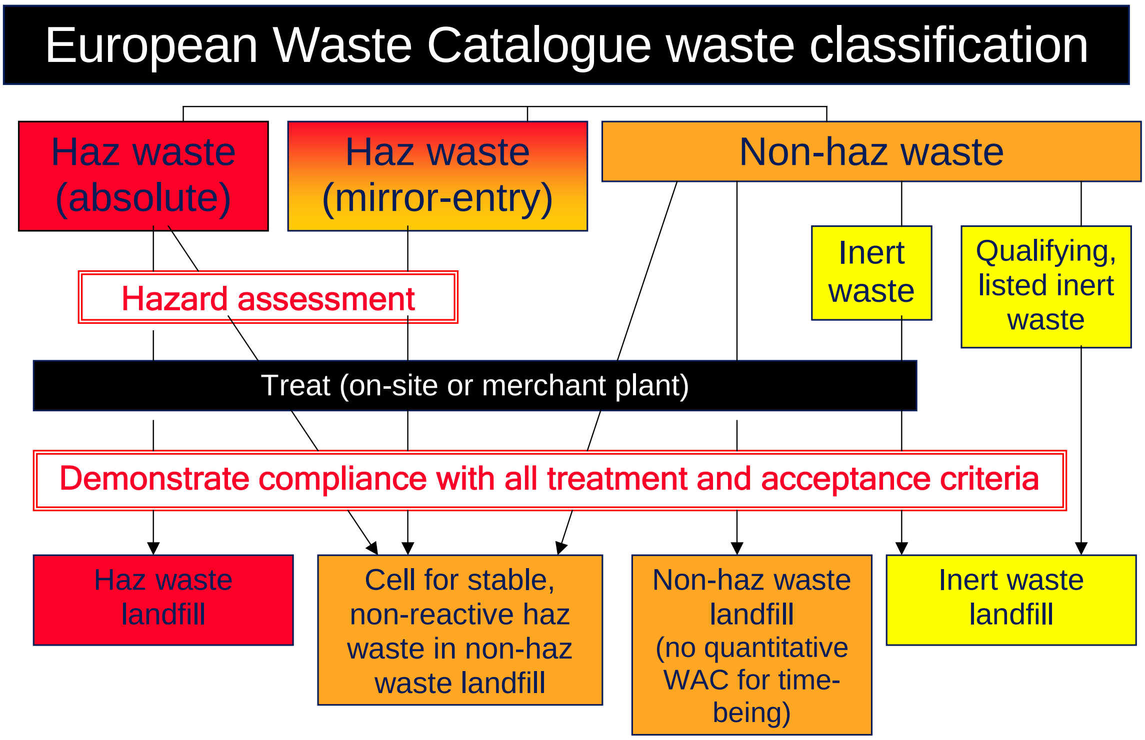



**Figure 6.1 Schematic of landfill options post-landfill WAC introduction**

and the impact of notional testing costs against potential profit margin.

The three example Sampling Plans are appended as follows:

- ANNEX A : Example Sampling Plan 1

  Primary waste producer: operator of industrial process producing regularly-generated waste at multiple sites.

  Short-form Sampling Plan as an example of how the full Sampling Plan can be translated into brief instructions for the sampler.

- ANNEX B : Example Sampling Plan 2

  Secondary waste producer: operator of merchant treatment plant (regularly-generated waste, variable inputs.

- ANNEX C : Example Sampling Plan 3

  Operator of an inert waste landfill: compliance testing).

# 7. CONCLUSIONS AND RECOMMENDATIONS

- *Universal approach*: the sampling plan approach set out in prEN 14899 is valid for all reuse testing scenarios as well as for sampling and testing to determine treatment or disposal options.

- *Auditable approach:* A Sampling Plan will help to ensure that clear and appropriate objectives are defined for any given testing programme and that the subsequent sampling exercise is well executed so that it provides relevant data to meet those objectives. Importantly it provides an audit trail of the sampling exercise and sampling should only be carried out when an agreed plan is available.

- *Statistical basis of sampling exercise:* A key component of the auditable approach will be the demonstrable attention given to the statistical elements of the sampling exercise. These include: defining the waste population to be sampled, defining the type of sampling ('probabilistic' sampling being greatly preferable to 'judgemental' sampling), identifying the scale, selecting the statistical parameter (e.g. mean or 90%ile), choosing the desired precision and confidence, and selecting a sampling frequency consistent with these criteria.

- *Complements site quality assurance plans*: most QA plans for processes or landfill operations will require documentation of a whole range of site-specific or generic procedures. The use of the sampling plan and sampling record to document the objectives, level of testing, constituents to be tested and sampling approach for any waste sampling and testing programme will fulfil the requirements of any overall QA plan.

- *Brainstorm:* this approach is recommended at the outset of any testing programme to identify all appropriate reasons for waste testing so that sampling programmes can be rationalised.

- *Phased approach:* the existing dataset may not always be sufficient to allow for a level 1 or level 2 testing programme to be undertaken immediately. In many instances it may be appropriate to undertake a series of screening exercises to close specific gaps in knowledge. Information on key factors that affect waste quality or information on variability will then be an important part of the characterisation dataset. Analysing the results against the programme objectives to verify that those objectives have been met is a key part of the process and may trigger further testing.

- *Timescales:* A characterisation programme can take several months, longer if a series of screening steps are needed. Some tests require may require additional time for involved sample preparation techniques or the test itself may be prolonged (e.g. 64 day tank leaching test). Where the testing is driven by the need to comply with end use specifications or acceptance criteria, time should be allowed for the testing, interpretation and potential modifications to the process to ensure compliance.

- *Waste producers' compliance testing*. Compliance monitoring undertaken periodically following characterisation will provide early warning of any trend in waste quality towards non-compliance with end use specification or acceptance criteria before failure is reported (e.g. WAC failure reported by the landfill operator).

- *Segregate problematic component streams*: removal of component streams of erratic quality may yield improvements in overall waste quality. This may generate a small quantity of potentially hazardous waste but increase the reuse potential or ensure compliance with appropriate limit values for the remainder.

- *Leaching behaviour tests*: these can be used to identify factors which control the leachability of key variables that compromise compliance with landfill acceptance criteria. This knowledge can be used to develop treatment options for the waste.

- *Coordinated testing*: there is potential for the burden of waste testing to shared among waste producers within the same industry sector, where the characteristics of specific waste streams are similar, particularly if this reduces costs in the face of international competition. Trade associations are well placed to coordinate stratified sampling and testing programmes for their industry.

# 8. REFERENCES


BS DD ENV 12920, 1998. *Characterisation of Waste - Methodology for the Determination of Leaching Behaviour of Waste under Specified Conditions.* British Standards Institution (CEN/TC292/WG6).

BS EN 12457-3. *Characterisation of waste – leaching - compliance test for granular waste materials and sludges. Part 3: two stage batch tests at liquid to solid ratios 2 and 8 l/kg with a high solids content and with particle size below 4mm.* Comité Europeén de Normalisation. CEN TC292/WG2. October 2002.

CEN 2002. prEN 14429. Characterisation of waste – leaching behaviour tests – influence of pH on leaching with initial acid/base addition. Comité Europeén de Normalisation CEN TC292/WG6, Brussels.

CEN 2003. prEN 14405. Leaching behaviour test – upflow percolation test. Comité Europeén de Normalisation CEN TC292/WG6, Brussels.

CEN 2004. prEN 14899 Characterisation of Waste - Sampling of waste materials: Framework for the preparation and application of a Sampling Plan

CEN 2004. TR 1 xxxx (WI 292002): Sampling of waste materials: Selection and application of a basic statistical approach to sampling under various conditions

CEN 2004,TR 2 xxxx (WI 292017): Sampling of waste materials: Information on sampling techniques.

CEN 2004.TR 3 xxxx (WI 292018): Sampling of waste materials: Information on procedures for sub-sampling in the field.

CEN 2004.TR 4 xxxx (WI 292019): Sampling of waste materials: Information on procedures for sample packaging, storage, preservation, transport and delivery.

CEN 2004.TR 5 xxxx (WI 292041): Sampling of waste materials: Guidance on the process of defining the Sampling Plan.

Council of the European Union (1999) Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Official Journal of the European Communities, L182, pp1-19.

European Council (2003) Decision 2003/33/EC of 19th December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 and Annex II of Directive 1999/31/EEC on the landfill of waste. Official Journal of the European Communities L11 16.1.2003.

Environment Agency 2002. National Interim Waste Acceptance Procedures, Environment Agency Consultation Draft, August 2002.

Environment Agency 2003a. Hazardous waste. Interpretation of the definition and classification of hazardous waste. Technical Guidance WM2, Environment Agency 2003b. Draft guidance on the Sampling and Testing of Wastes for Waste Acceptance Procedures. Consultation draft.

Landfill (England and Wales) Regulations 2002. SI No. 1559.

Landfill (England and Wales) (Amendment) Regulations 2004. SI No. 1375.

SEPA. 2002. Draft Interim Guidance on the Use of Composted Material at Licensed/Permitted Landfill Sites. Version 5. 30 August 2002, SEPA 2002.

NEN 7341 (1995) Leaching characteristics of solid (earth and stony) building and waste material. Leaching tests. Determination of the availability of inorganic components for leaching. ICS 13.030-70, 91.00 Netherlands Normalisation Institute (NEN).

NEN 7345 (1995) Leaching characteristics of soil and stony building and waste materials. Leaching tests. Determination of leaching of inorganic components from building and monolithic waste materials with the diffusion test. Netherlands Normalisation Institute (NEN).

# ANNEXES

# ANNEX A EXAMPLE SAMPLING PLAN 1 (PRIMARY WASTE PRODUCER: OPERATOR OF INDUSTRIAL PROCESS PRODUCING REGULARLY-GENERATED WASTE AT MULTIPLE SITES)

# ANNEX B EXAMPLE SAMPLING PLAN 2 (SECONDARY WASTE PRODUCER: OPERATOR OF MERCHANT TREATMENT PLANT (REGULARLY-GENERATED WASTE, VARIABLE INPUTS))

# ANNEX C EXAMPLE SAMPLING PLAN 3 (OPERATOR OF AN INERT WASTE LANDFILL : COMPLIANCE TESTING)

## ANNEX A : EXAMPLE SAMPLING PLAN 1

# *PRIMARY WASTE PRODUCER: OPERATOR OF INDUSTRIAL PROCESS PRODUCING REGULARLY-GENERATED WASTE AT MULTIPLE SITES*

### *Background*

A steel manufacturer operates at a number of locations in the UK. Following segregation of material for re-use much of the residue stream is landfilled at in-house sites. Although the company is both a primary waste producer and a landfill operator, this example sampling plan is focused on the company's role as a producer of a regularly-arising non-hazardous[1] waste stream from multiple sites.

The residues that are covered by this sampling plan are currently produced at several UK plants. They are generated as a by-product of the steel manufacturing process in essentially the same way at each site. The residue stream is currently partially re-used, with the remaining rejected material disposed of to on-site non-hazardous landfills. The worked example provides an approach for undertaking a comprehensive level 1 waste characterisation exercise for the steel-making residues as required under Annex II of the Landfill Directive and UK Regulations[2]. This Sampling Plan is largely focused on the need to dispose of part of the residue stream to landfill and therefore for the purpose of this example, the term waste is subsequently used to reference this material.

The following example Sampling Plan follows the structure provided in prEN 14899 'Framework for preparation and application of a Sampling Plan'.[3]

A considerable amount of technical information has been rationalised in this example, in order to protect the anonymity of the waste producer. However, the detailed technical terminology would normally be appropriate in a Sampling Plan to avoid confusion.

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[1] EWC code 10 02 : wastes from the iron and steel industry – "wastes from the processing of slag" (10 02 01) and "unprocessed slag" (10 02 02)

[2] Environmental Protection Act 1990; Landfill (England and Wales) (Amendment) Regulations 2004.

[3] CEN 2004. prEN 14899 Characterisation of Waste - Sampling of waste materials: Framework for the preparation and application of a Sampling Plan. CEN TC292/WG1.

## *Identify involved parties*

- *Waste producer:* Representatives with technical process expertise and the Environmental Team responsible for ensuring compliance with UK legislation were identified at each UK plant that generates this type of steel-making residue.

- *Landfill operator:* The waste producer is also the landfill operator. However, in this example the sampling plan is focused primarily on the requirements of the waste producer.

- *Consultant:* A consultant with waste sampling expertise was used to produce the Sampling Plan.

- *Regulator:* At this stage there is no need to involve the regulator (UK Environment Agency).

## *Identify objectives and define technical goals*

The key objective of the proposed testing programme is:

> **to identify the available options for on-site landfilling of non-hazardous steel-making slags with due regard for imminent changes in UK regulation following implementation of the Landfill Directive.**

The residue addressed by this Sampling Plan comprises a mixture of steel-making slags and works debris as detailed in the section below on 'research background information'.

This overall testing objective can be translated into several general technical goals, each of which is then further developed into specific technical goals which quantify a number of key statistical parameters (see worked example, Phase 1 testing).

It is these specific technical goals that are translated into practical instructions for sampling and analytical requirements. Three such general technical goals have been identified by the consultant following a discussion with the waste producer. These are developed into specific technical goals in the worked example provided in relation to Phase 1 testing (see below). The results of the brain-storming exercise used to identify these goals are shown in Figure 1.

### 1. Determine residue quality

Knowledge of residue quality is required for the following reasons:

- *Duty of Care:* demonstration of lack of potential hazardous properties for transport and disposal as a non-hazardous waste. For wastes classified as non-hazardous on the European Waste Catalogue this can be done from previous knowledge of the waste characteristics;

- *Environmental Risk Assessment to obtain IPPC permit:* ERAs will be required for the in-house landfills (for example to determine loading criteria) before 2007. This information is needed to support existing landfilling arrangements, but could also be used to pre-empt introduction in the UK of WAC for non-hazardous wastes (see below).

- *Confirmation of whether or not the current disposal route (landfill) is under threat.* There are currently no landfill waste acceptance criteria (WAC) for the landfilling of non-hazardous waste in the UK, but this situation is not expected to persist. Comparison of test data with the appropriate WAC requires average total and leachable concentrations for loads that are typical of ‘worst case’ as well as normal or optimal conditions. A database of expected ranges of total and leachable concentrations would assist this exercise.

**2. Establish whether the waste producer has identified the most appropriate class of landfill for his waste**

After removal of some of the slag for reuse, three residue streams are combined and landfilled. The combined slag could be accepted at a landfill for non-hazardous wastes with little or no testing. However, a preliminary examination of existing data indicates that a portion of the component residues meet the landfill WAC for inert wastes and could therefore be accepted at a landfill for inert wastes. Stream separation and/or more formalised treatment options may be required to improve consistency of the waste such that it was always acceptable at an inert waste landfill.

**3. Use knowledge of waste characteristics to review waste management and disposal options and identify potential cost savings.**

Characterisation of the residues will provide increased knowledge of how the waste production process affects the basic chemistry of the waste and in turn how this impacts upon the leaching characteristics of the waste. Characterisation will help to identify where the problems are. Removal of hotspots, treatment or size separation may be needed to improve the re-use potential of treatment plant output and reduce current landfilling requirements. In-depth characterisation of the residue would include assessing the leaching behaviour of the slag generated under normal conditions. Average concentrations of parameters of interest within residue would therefore need to be determined.

Currently the steelmaking residues are disposed as a mixed waste at a landfill for non-hazardous wastes. Removal of contaminated hot-spots, retaining segregated component streams and treating the cleaner fractions may allow:

- diversion of the least contaminated fraction from landfill altogether (reuse option);
- diversion of a proportion from non-hazardous to inert waste landfill; either
  - through normal WAC compliance testing scheme (all samples must meet all inert WAC at the landfill gate); or
  - inclusion on a landfill site-specific list or national list for single-source, single-stream, inert wastes which are exempt from testing (e.g. Table 1, Landfill Amendment Regulations, 2004).

***Note:*** Although outside the scope of this sampling plan the results of the intended characterisation testing may highlight an opportunity for the UK steel industry as a whole to participate in further coordinated testing. This could provide the necessary dataset to support the case for inclusion on a national or site-specific listing of testing-exempt wastes.

Regular compliance testing to meet the inert WAC represents an increased testing burden. However, where merchant rather than in-house landfills are used, there could be significant cost savings associated with disposing the waste as inert wastes rather than non-hazardous wastes.

(In addition, if and when the landfill tax bands for inactive/active waste are brought in line with waste classification under the Landfill Regulations, there could be a reduction in landfill tax chargeable. The forecast differential for inactive/active tax bands in the medium term is £28/tonne).

## *Determine generic level of testing required*

### Level 1 – comprehensive characterisation

This sampling plan supports a level 1, comprehensive waste characterisation scheme, that could be applicable on a between-plant basis, for a routine production waste. Level 1 characterisation may be achieved using a number of initial screening initiatives to improve a small historic dataset prior to carrying out more extensive testing. This sampling plan outlines the following phased approach to the level 1 characterisation.

- Initial screening exercises are advocated to improve existing knowledge of the variability of the individual component streams of the residues that are currently landfilled.

- Phase 1: A further phase of testing using leachability and 'total' concentrations of parameters of interest will provide data on the composition of each individual waste stream. This will highlight parameters that might present challenges to acceptance at the appropriate class of landfill.

- Phase 2: Leaching behaviour tests to complete the comprehensive characterisation exercise will be based on a number of composite samples. These will be subjected to a range of leaching behaviour tests to corroborate the information on the chemical characteristics of the waste from the screening tests. In addition, the leaching test to be used in the level 2 compliance testing programme will be included in the characterisation programme.

### Level 2 compliance testing

Guidance is also provided on how a level 2 compliance testing programme could practically be carried out by the waste producer (and the landfill operator) to check that the quality of the waste remains within agreed boundaries over time.

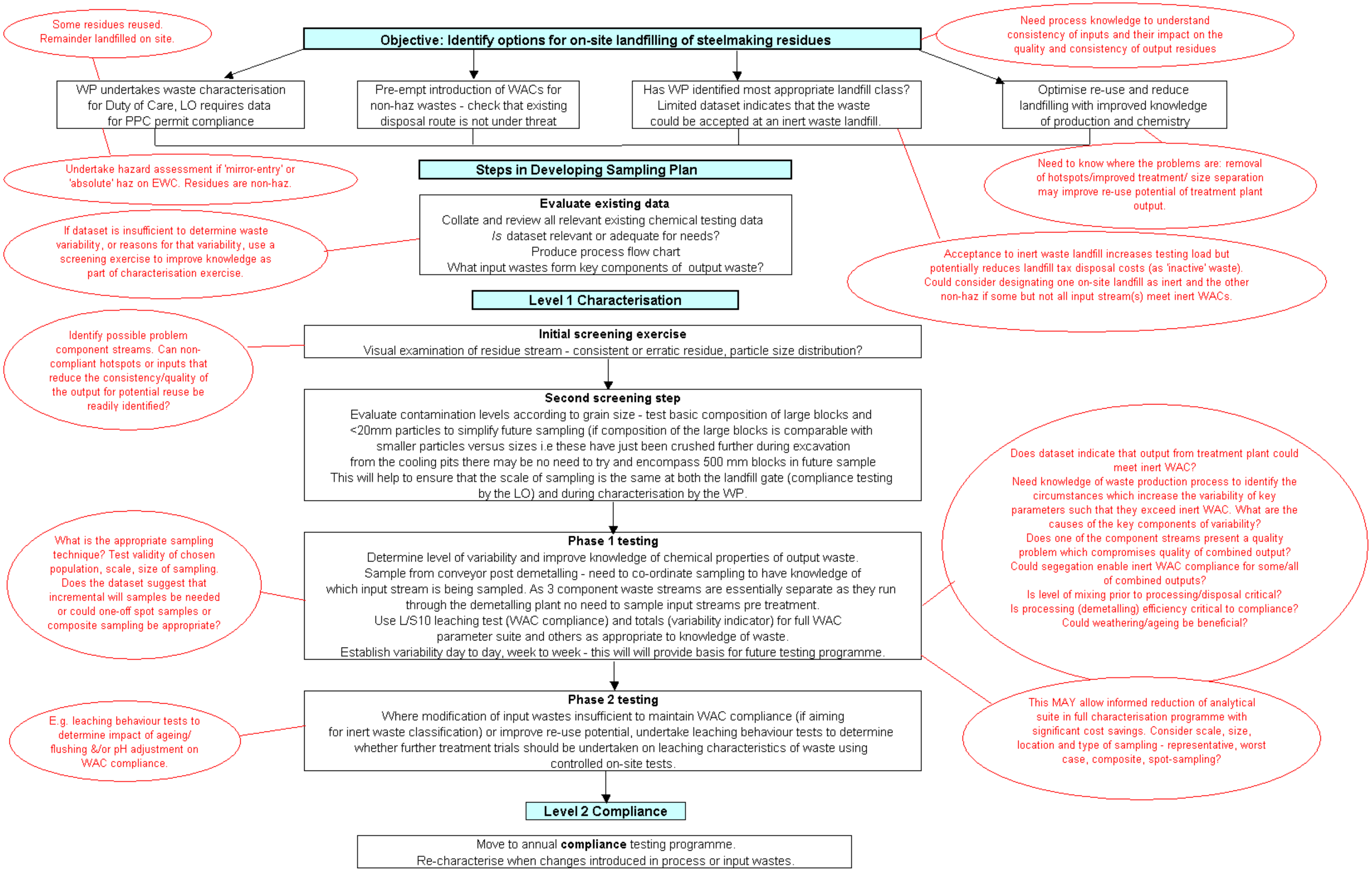



**Figure 1 Overview of brainstorm exercise to design sampling plan for primary waste producer**

### *Identify constituents and characteristics to be tested*

The following testing is to be undertaken during appropriate phases of the level 1 characterisation.

1. Surrogate ' total' elemental composition using *aqua regia* digestion.

2. Waste acceptance criteria parameters for landfills for inert waste.

The Landfill Regulations (2004)[1] lay down UK requirements for waste acceptance testing under the Landfill Directive.

The operators of all landfills, with the exception of normal non-hazardous waste sites, will be required to undertake compliance monitoring of all wastes accepted at the landfill site on a regular basis to be agreed with the Agency.

After the introduction of the WAC compliance scheme at landfills for inert waste, all samples must contain less than 3% TOC (total organic carbon) and meet maximum concentration limits for total concentrations of organic contaminants - BTEX, mineral oils, PCBs and PAHs. The samples must also all meet leachability limit values at L/S10 for As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Sb, Se, Zn (hereafter referred to as 'WAC metals'), Cl, F, $SO_4$, TDS (total dissolved solids), DOC (dissolved organic carbon) and phenol index.

The UK is regulating against L/S10 data from the two stage compliance leaching test for granular wastes (BS EN 12457-3) which generates eluates at L/S2 and L/S2-10 (cumulative L/S10) rather than the single step LS10 test BS EN 12457-2. Test samples must be crushed to <4mm particle size before testing.

Acid neutralisation capacity (ANC) data will also be required by the landfill operator to ensure that the landfilling of wastes with differing buffering capacities and pH values are properly managed.

**Level 1 – comprehensive characterisation**

- Historic data evaluation
  - 10 samples at three operating facilities tested with aqua regia digest, and 2 samples using BS EN 12457-2 single step test for a restricted WAC determinand list.
- Initial screening
  - Visual examination of individual input streams.
- Second screening step
  - Particle size screening exercise.

- Phase 1:
    - leachability at L/S10 using BS EN 12457-2 single step test as a screening tool for characterisation (not as a compliance tool) and determination of As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Sb, Se, Zn, Cl, F, $SO_4$, TDS, DOC and phenol index in the eluates.
    - aqua regia total concentrations.
- Phase 2:
    - Leaching behaviour tests:
        - maximum availability for leaching under worst-case environmental conditions (NEN 7431)
        - pH dependent leaching of metals (prEN 14429). (This test would also provide information on acid/base neutralisation capacity over the pH4 –14 range).
    - WAC compliance testing using the same tests as to be used in the level 2 compliance programme. The data would be used as the benchmark for the routine compliance monitoring dataset. Significant deviation from this set could trigger re-characterisation.
        - BS EN 12457-3 and determination of eluates for WAC parameters. As well as being the preferred test for assessing compliance with the WAC at L/S10, the two-step test also provides additional leaching behaviour information with leaching under different liquid-to-solid ratios (L/S2 and L/S10 cumulative).
        - Other WAC parameters of interest (e.g. TOC and total trace organics) for use as benchmark data for the routine compliance monitoring dataset.

**Level 2 compliance testing**

WAC compliance testing as above (e.g. leachability at L/S10 and total organic concentrations).

## *Research background information on waste*

### –*Site details*

The steel slags are produced at three sites in the UK. All use a similar primary production process and post-production waste separation scheme.

*Process generating the residue streams*

Steel-making slag is a by-product of the conversion of pig iron to steel. Refining of the pig iron to remove or control various impurities is achieved by fusion with a flux such as dolomite or limestone under oxidising conditions. Impurities present in the pig iron in excess, such as carbon, silicon, manganese, phosphorus and sulphur, are either oxidised to gases or pass into the slag as complex oxides. The main components of the steel slags being considered in the sampling plan are shown in Figure A1.

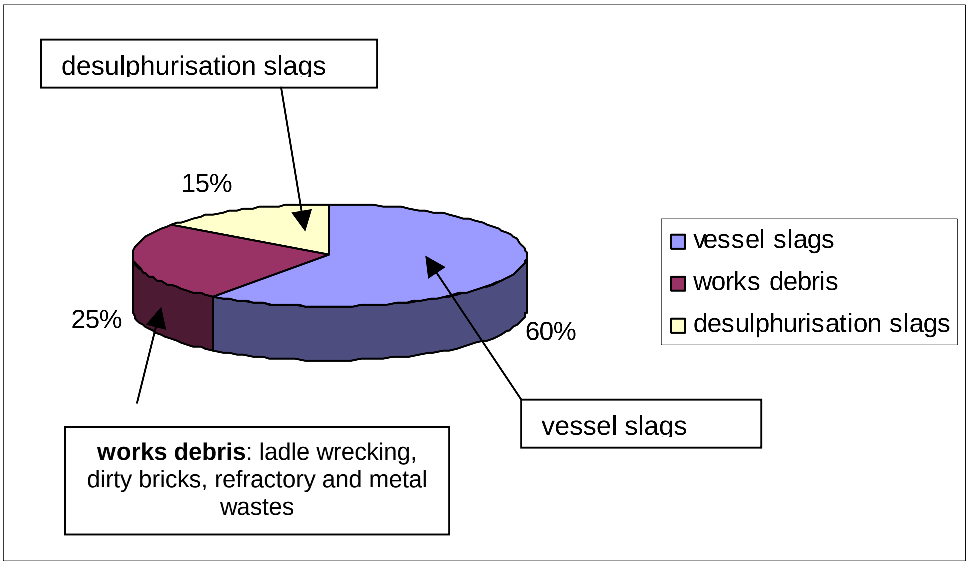



**Figure A1 Principal components of steel-making slags**

Following de-metalling of all three streams the combined slags are primarily sent to a third party for re-use. The remaining slags and debris are currently landfilled.

Whilst the chemical composition of these input streams will vary from cast to cast, the collection and transportation of the various streams affords various opportunities for mixing and homogenisation of residues from the individual casts. Figure A2 provides a basic representation of the residue production process.

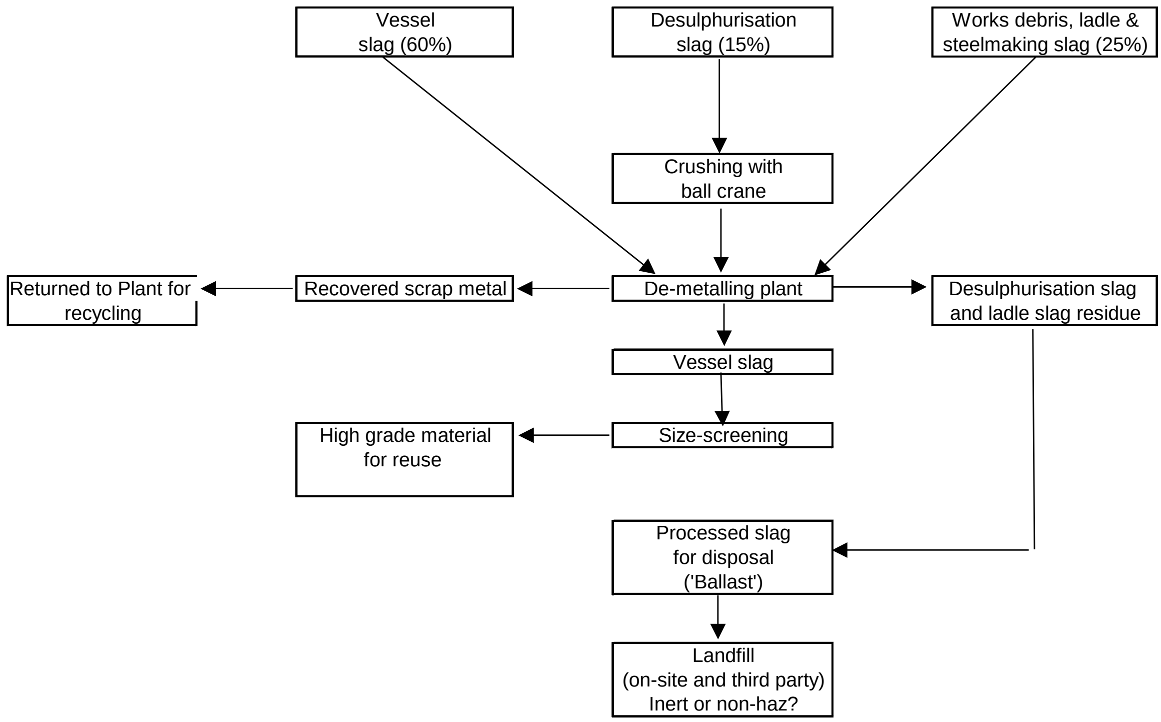



**Figure A2 Generic process for steel slag production**

- Vessel slag pre-processing: The largest component of the stream, the vessel slags, are stored in a single pit. Addition and removal of slag provides a degree of blending with time. The vessel slags are air and water cooled over a period of approximately 2 days to produce a dense crystalline material. This is excavated with a front loader and placed in adjacent stockpiles for further cooling, prior to loading in 40T trucks for transport to the de-metalling plant. This operation leads to further mixing of the slag. At this stage the material is of mixed grain size varying from fine dust to chunks up to 1.5-3m in size. The main cause of volume expansion in the steel slag is free lime. Stabilisation of the lime by hydration is reported to take years rather than weeks or months.

- Processing (de-metalling) plant: Before de-metalling the vessel slags are tipped again and stockpiled at the processing plant where further turning over of the material is achieved. Ladle and de-sulphurisation slags are stockpiled separately at the de-metalling plant, direct from the production process.

  After the desulphurisation slags have been crushed with a ball crane, all three residues are re-loaded onto a conveyor and tipped in the next tier of stockpiles. It is at this point that initial mixing between the various input streams could occur. The slags are processed separately i.e. a run of vessel slag will be processed through the de-metalling plant followed by one of the other streams, but there is currently no deliberate move to keep the streams entirely separate. Timescales for storage prior to de-metalling are variable but range from a day to a month.

- Following the de-metalling operation, the vessel slag is further crushed and screened, and separated for re-use. Residual waste together with the de-sulphurisation slags and works debris is disposed to an on-site non-hazardous landfill. This last stage of processing (i.e. re-loading onto a conveyor and formation of the final tier of stockpiles) provides the final point of mixing.

Material processed in the de-metalling plant over a working day may be taken from a number of stockpiles and may therefore represent production over many days or even weeks depending on the standing time of input material at the plant and how the stockpiles are compiled. Recovery of the slags from the pits, stockpiling, de-metalling, screening and further stockpiling provide a reasonable level of mixing/blending and the combined residue is therefore potentially reasonably consistent in composition with time.

– ***Evaluate existing compositional data***

The EWC lists slags from steel-making as non-hazardous wastes. The waste producer also knows from processing the slags and from chemical analysis that no H1-H14 properties are exhibited by the residues.

A preliminary sampling programme has been undertaken by the waste producer (WP) at three manufacturing sites to determine the basic composition of the slag to conform with existing Duty of Care requirements for on-site landfilling of non-hazardous wastes.

Two samples (two shovelfuls) were collected at random times within a month for a period of five months (i.e. a total of ten samples) at the landfill following discharge from the truck. The samples were analysed for ‘total concentrations’ for a comprehensive suite of metals (although not the full list of WAC metals) and sulphate. No organic parameters were determined. These samples provide a useful means of identifying the variability of important constituents of the mixed residues, although these analyses cannot be directly used to assess leachability. Two of the ten samples were selected at random and subjected to the single step L/S10 test BS EN 12457-2. Eluates were analysed for a restricted list of parameters (again not the full WAC list). Concentration ranges (based on the totals analysis) were obtained for each constituent, together with a mean and relative standard deviation. These samples represent composites of unknown proportions of the three streams processed by the de-metalling plant. The existing dataset is not sufficiently comprehensive for full level 1 characterisation, but can be used to guide the testing programme. The current data cannot be used to identify the specific variability of the three component parts of the slags or causes of that variability. A further screening step is therefore required to improve the level of knowledge.

The historic database indicates that the slags are broadly consistent between each of the plants. The variability in chemical characteristics between residues from the same plant (within-plant variability) is not noticeably different to that from residues from different plant (between-plant variability) and there are no substantial differences in mean concentrations of each parameter between plant. It was therefore decided that further testing could be carried out at a single plant, although subsequent compliance checks would be needed to show that waste from other plants were in compliance with the level 1 characterisation from a single plant.

*The available dataset is very variable (based on totals analyses) and more sampling is required to test the composition of the component streams and improve confidence and precision of the results. From the limited leaching test results it is impossible to identify which of the component streams might meet the inert landfill WAC, if not all, and there is a need to* *confirm/improve the apparent concentration range with further leaching test work. This testing should be carried out on the full list of WAC determinands.*

Although the relative standard deviation (RSD) of the 'totals' analyses for each component can not be simply translated into expected RSDs relating to leaching components, it is not expected that the RSDs would be any larger. Therefore in the absence of suitable L/S10 data, totals for the most variable component of the waste, 'determinand x', was used as a worst case for calculation of sample numbers, with a mean concentration of 150 mg/kg and a standard deviation of 36 mg/kg.

## *Select sampling approach*

- **Initial screening**

Observe the ballast stream, for a continuous period of approximately one week (process knowledge indicates this time period will allow all normal variations in the process to be observed) as it exits the conveyor. NOTE: The de-metalling plant operates a 8 to 6 shift so this should be the period of observation. Can visual anomalies be identified?

- **Second screening step**

Collect 6 separate swipe samples (two for each input stream) over the course of a working week and estimate approximate particle size distribution using sieve sizes of 5mm, 20mm, 10cm and 100cm.

Crush a representative sample of each size fraction and analyse for total metals (a relatively straight-forward and inexpensive and assessment using in-house laboratories).

The results of this exercise showed that there is no significant quality difference between the <5mm to the >100cm fractions (if anything the <5mm faction provides a worst case for comparison with WAC), so it is acceptable to ignore the large particle sizes when undertaking the characterisation programme. Sampling should therefore involve collecting two shovelfuls of material (of whatever volume stays on the shovel) to ensure that the scale of sampling is the same at both the site of production and at the landfill. *Note*: In-house expertise might be used to corroborate these findings.

One purpose of Level 1 characterisation is to build up information to help determine whether the waste is likely to comply with the landfill operator's WAC compliance testing. It is therefore important to know the 'scale' at which sampling will be undertaken by the landfill operator. This is the minimum volume of waste below which variations in quality or other characteristics are deemed to be unimportant. A sample taken at the identified scale will provide an average value for the characteristics under test, at that scale. Thus the scale defines the volume of waste that may legitimately be mixed, prior to sampling; and it is the L/S10 leachability values for all 'mixed volumes' of this size through the year that must meet the operator's maximum-type limit.

For example, if the landfill operator sets the scale of sampling at 1 cubic metre, this means that he will not be concerned if there are occasional hot-spots of poor quality within any one cubic metre of waste, provided these are compensated for by larger amounts of good quality material within that same volume. He must take a sample that provides an average for the 1 cubic metre. The waste producer then has three options for level 1 characterisation:

The waste producer takes samples from a volume of waste that is greater than 1 $m^3$. This may provide useful information for some purposes - such as third-party re-use - but will not provide a secure means of assessing the likelihood of compliance, as the sampling will tend to smooth out variability that may be critical from the operator's standpoint.

The waste producer takes samples from a waste volume of 1 m3. This mimics the scale determined appropriate for sampling that the operator will use, and so provides directly comparable data for assessing compliance.

The waste producer takes samples from a waste volume of less than 1 m3. This is the ideal option whenever sufficient resources are available, samples collected at a smaller scale would be expected to exhibit greater variability than at a larger scale. The waste producer can analyse sub-samples taken from the individual samples to gain a detailed understanding of variability at his chosen scale. In addition, he can form composite samples at the operator's scale by pooling sub-samples taken from consecutive groups of samples, and then use these to assess compliance as per option 2.

If, on the other hand, the operator indicates that he will base each compliance sample on a single scoop with a trowel, then option 3 would no longer be available to the Producer. It would also be unwise for the waste producer to adopt option 1 unless he already had a good understanding of the degree of heterogeneity of the waste generation process at the required scale.

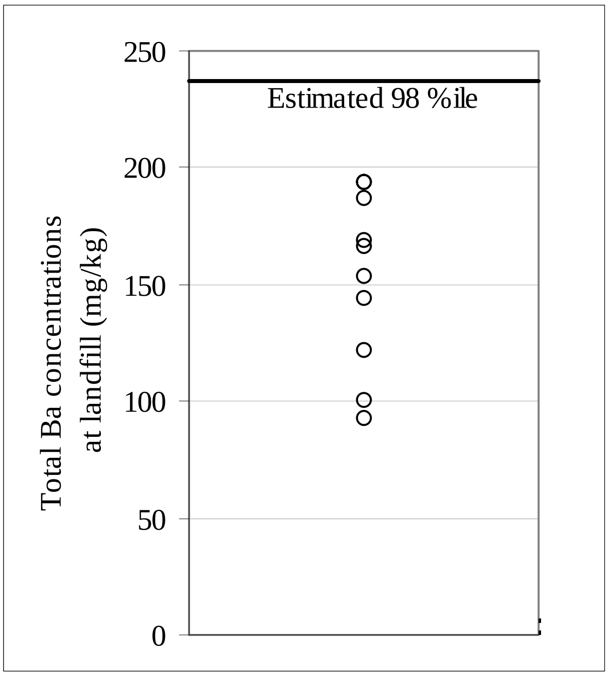
Where the waste consists of small particles of various sizes (e.g. contaminated soil), it is important to ensure that the increment and/or sample size is sufficiently large to capture an adequately representative mixture of 'normal' and contaminated particles.

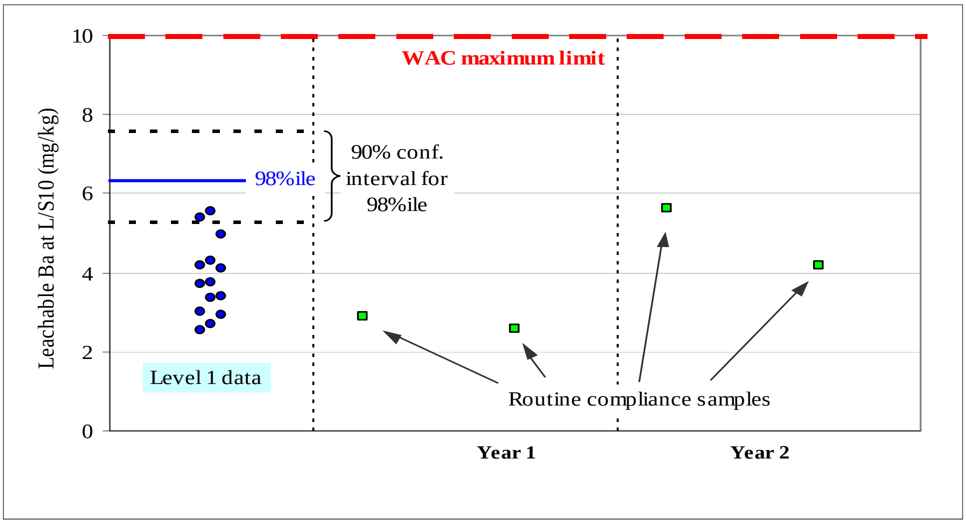
Detailed guidance on this is given in Annex B of TR1[4]. However, the 'micro methodology' given there does not apply in the present circumstances (although the basic principles are still important), because the relevant dimensions here are orders of magnitude greater. The main question to ask is whether there are likely to be any intrinsic systematic differences between the properties of big lumps, small lumps and the finer material, or whether it is simply a matter of chance which parts of the slag stay in big lumps and which break down into smaller-sized pieces or fines.

[4] TR 1 xxxx (WI 292002): Sampling of waste materials: Selection and application of a basic statistical approach to sampling under various conditions. CEN TC 292/WG1. 2004.

- **Phase 1 Testing**

| | Step | Outcome |
|---|---|---|
| **Specify the objective of the testing programme** | | |
| **1** | **Identify the overall testing objective** | Identify the available options for on-site landfilling of non-hazardous steel-making slags with due regard for imminent changes in UK regulation following implementation of the Landfill Directive. |
| | **Develop the general technical goal** | Waste producer to carry out an assessment to identify compliance with proposed landfill targets for each of 3 component streams of the steel-making residues. |
| **Develop the specific technical goal from the objective** | | |
| **2** | **Identify the overall population** | The entire mass of each of the three component streams in a given year. Knowledge of the performance of the residues with respect to the WAC is required under worst-case as well as average conditions and therefore samples must include those that are representative of expected worst-case conditions.<br><br>(Nothing is known about which parts of the year produce worse slag than others, so there is no opportunity to focus on a known problem period.) |
| | **Choose the population to be sampled** | The sub-population is the entire volume of slag produced over a particular four-week period, excluding unmanageably large lumps (see step 5).<br><br>(As detailed above there is no reason to suppose that a four-week period of slag production will not be typical of production overall.) This time frame covers 4 batch changes each of which cover the 4 main production processes used at the plant. It will therefore give us an adequate view of variability of process over one year and year to year with current production system. |
| **3** | **Assess variability** | Temporal variation not considered to be significant. Large long-term batch runs and consistency of end-product requirements not likely to significantly change slag composition. The plant is in continuous operation producing consistent rather than erratic waste streams, so the presence of hot-spots would not be expected. Shift changes cannot be linked to operational changes. No reason to suspect step changes in waste constituents. Variability day by day, likely to be similar to week by week etc. The selection of a relatively short sampling time frame is therefore a valid one and will produce a microcosm of the expected variability. Spatial variability is reduced by the numerous effective mixing steps as the material is discharged from the process into cooling pits and subsequent excavation into stockpiles, trucks and further stockpiling prior to processing at the de-metalling plant.<br><br>Existing leaching test data (2 samples) indicates that the constituent exhibiting the greatest RSD is 'determinand x'. Therefore the required |

| | Step | Outcome |
|---|---|---|
| | | sample numbers are calculated on the basis of this parameter, using totals data derived from the 10 samples collected at the landfill. Mean concentration was 150 mg/kg with a standard deviation 36 mg/kg, giving a relative standard deviation of 0.24. Also, the data suggests that the assumption of logNormality is reasonable.<br><br>The sample values (for Ba) from the historic dataset are shown in Figure A3.<br><br><br><br><br>Figure A3. Historic total 'determinand x' data for combined residue. |
| 5 | **Identify the scale** | The scale is assumed to be ' the volume of a 9m$^3$ skip'. (See discussion.) |
| 6 | **Choose the required statistical parameter** | The required parameter is the 98-percentile L/S10 for each determinand on the WAC list. This provides a measure that is close to the worst-case performance, as it will be exceeded in the long run for only 2% of the slag volume.<br><br>The estimated 98%ile for the historical population is shown by the black line in Figure 3.<br><br>**Note:** It is impossible to plan a sampling programme to estimate the maximum, as the true underlying population maximum will always exceed the observed maximum by some unpredictable amount *however many samples are taken*.<br><br>The recommended approach is therefore to plan to estimate a high percentile (the 98%ile in this example) to a specified level of precision and |

| | Step | Outcome |
|---|---|---|
| | | confidence, and then check that there is a reasonable safety margin between this and the WAC limit. |
| **7** | **Select the sampling approach** | Probabilistic sampling is feasible because there is good access to the slag as it is being moved from the stockpiles at the end of the conveyor at the de-metalling plant and into 40T trucks for transport to the landfill. On each scheduled sampling date, a series of shovel samples ('increments') are taken during the time it would take to transfer a volume of slag equivalent to a small skip. The shovel contents are accumulated in a separate stockpile prior to mixing, followed by coning and quartering to produce the required sample.<br><br>(Note that, even though the sample is a composite of an agreed number of increments, it should be thought of as a spot sample in the context of the required scale of sampling. Thus, each sample is one of the hundreds of possible skip-sized volumes that could have been selected over the year's production.) Spot samples are needed rather than composites because the required parameter is not mean concentration. |
| **8** | **Choose the desired reliability (i.e. precision and confidence)** | The required parameter (i.e. 98-percentile) is to be estimated to a precision of 20% with 90% confidence.<br><br>This width of confidence interval is depicted by the pair of dotted lines in Figure A4.<br><br><br><br><br>**Figure A4 Illustrative data for a Level 1 characterisation**<br><br>**Note:** In this example, that the estimated 98%ile (for 'determinand X' as an example) is not much more than half of the WAC, and even its upper confidence limit is only about three-quarters of the WAC. This probably gives adequate assurance in the light of the limited amount of sampling likely to be undertaken by the landfill operator. |

| Determine the Practical Instructions | | |
|---|---|---|
| **9** | **Choose the sampling pattern** | There is no reason to suppose that the slag properties change systematically according to either the hour of the day or the day of the week i.e. no step change within or between batch. Thus systematic sampling can be used both for the taking of increments for each sample, and for the selection of sample dates over the sub-population. |
| **10** | **Determine minimum increment size and sample size** | **Increment size**<br>As discussed above, it is assumed that a separate exercise has established that bias will not be introduced if only the 'small' fraction of the slag population is sampled. Thus, at this level the slag will be sufficiently homogeneous for a hand shovel to provide an adequate increment size.<br>**Sample size**<br>No historical data is available to show the extent of increment-to-increment variability within a $9m^3$ skip (the required scale of sampling). Thus the number of increments should be determined as the maximum number that can conveniently be taken over the relevant time period – that is, the time taken for one $9m^3$ skip volume to be transferred from the stockpile to the tipper truck. |
| **11** | **Determine required number of samples** | The approximate number of samples needed is 14.<br>A 20% precision is equivalent to a multiplicative factor of 1.2. This translates in the log-e world into a required precision of d = 0.182. Also, the CoV of 0.24 translates into a log-e standard deviation of 0.237.<br>Thus, from Annex D, the approximate formula for n is:<br>$n = [u_a \times s/d]^2 \times (1 + u_p^2/2)$<br>$= [1.645 \times 0.237/0.182]^2 \times (1 + 2.054^2/2)$<br>$= 14.2.$ |
| **12** | **Define statistical elements of Sampling Plan** | Select a random starting point within the first two days of the assessment period, and then take a sample every 2 days thereafter until the required 14 samples have been collected. Sampling should be timed to coincide with expected worst case operating conditions. |
| **13** | **Analysis and Testing** | Analyse each sample separately. Undertake 2 step L/S 2 and L/S10 (cumulative) compliance leaching test for full WAC parameter list. |

**Results of Phase 1 Testing**

The tests undertaken in Phase 1 were evaluated before moving to any further testing programme to ensure the waste was subjected to the most appropriate testing regime.

Phase 1 testing data highlights a number of specific issues:

- The L/S10 leaching tests confirm that 'determinand x' is the most variable leaching parameter, and therefore the basis for sample number calculation was a valid one.

- Desulphurisation slag: the L/S10 leaching tests indicate that the de-sulphurisation slag does not meet inert landfill WAC for a range of components and will need to go to a non-hazardous landfill. No further characterisation testing is advocated for this stream, and the landfill operator could move to a regime of compliance testing, although any significant changes in the process would require further level 1 testing.

- Vessel slag: this stream is largely re-used, so although landfill compliance with WAC is less of an issue, when demand for re-use falls it is occasionally landfilled. However, the vessel slag is compliant with the inert landfill leachability WAC. Phase 2 characterisation tests are needed to characterise the material to optimise its re-use potential. These tests will be based on average concentrations (there is considerable mixing /blending prior to re-use), as it is the generic properties of the material that are of interest rather than worst-case concentrations.

- Works debris: leaching data highlight sporadic exceedance of an inert landfill leachability WAC for a pH-dependent metal. This exceedance cannot be linked to a production change. Phase 2 tests are required to assess available treatment options to reduce leachability e.g. by controlled weathering or flushing to reduce the pH and ensure 100% compliance with inert WAC If this cannot be engineered the waste would need to be landfilled as a non-hazardous waste. Average concentrations rather than worst case are acceptable for this exercise.

- **Phase 2 Testing**

*Objective:* To use leaching behaviour tests e.g. pH dependence and Maximum Availability Leaching Test to optimise re-use of the vessel slags and achieve compliance with inert WAC for the works debris. Additional L/S 2 and 10 tests would be required to allow full interpretation of the data.

*Sampling:* This phase of testing is directed at determining the average leaching behaviour of waste streams 2 and 3. Undertake a further round of sampling and collect as many samples from the stockpiles post de-metalling as will fit into a single shift. The level of mixing during processing of the works debris and vessel slag streams smoothes out short term, and small scale variability to give an averaged product. Sampling over a single shift provides a set of samples that encompasses the variability within the plant in a given week. The advocated approach is therefore to produce a single composite sample from the incremental samples (for compliance and leaching behaviour tests). In the case of the works debris which appears to exhibit borderline compliance with inert WAC, it would be necessary to analyse the individual increments for the L/S 2 and 10 tests to get a better handle on the natural variability of the waste and to avoid smoothing any problems; which is obviously critical in this case. The behaviour tests can be undertaken on a single composite sample.

*Note:* During this sampling phase, ‘normal’ rather than worst case operating conditions could be targeted.

▪ **Compliance testing by the waste producer**

Figure 5 shows the statistical consequences of the compliance testing carried out by the producer. Each curve relates to a different sampling frequency. The 'horizontal' axis plots the percentage of the year's waste that is truly failing to meet the WAC, and the 'vertical' axis plots the corresponding chance that at least one sample will be obtained above the WAC.

Take the case of N=2 samples per year (the second curve up, marked with the hollow squares). Suppose 80% of the waste is truly satisfactory. This means that 20% of the waste is *not* satisfactory. At this point along the horizontal axis, the N=2 curve has reached a value of 37%. Thus there is barely a 1-in-3 chance that the waste will appear to the producer to have failed. The curve shows how much worse the waste would have to be before a failure became very likely. For example, if as much as 70% of the waste was truly failing to meet the WAC, there would then be a 90% chance of at least one of the two samples producing a failure.

This underlines how limited a degree of protection the waste producer would gain from a compliance programme of just two samples per year.

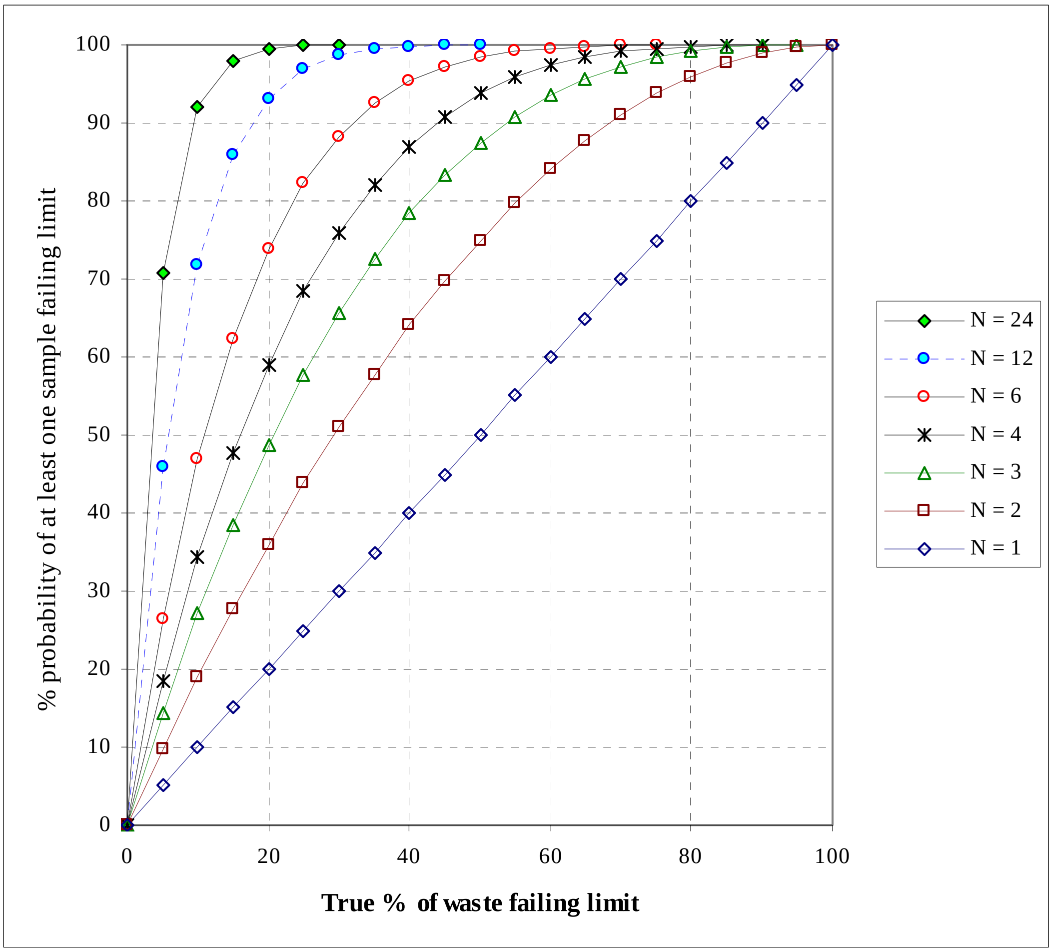



**Figure A5 Detecting failure to comply with a maximum-type waste limit**

Note: Take the case of N=6 samples per year, as recommended in the Environment Agency guidance[5] for compliance sampling by the landfill operator, (the third curve from the top of the figure). Suppose 90% of the producer's waste is truly satisfactory - which means that 10% of it is not. The chance of the waste producer being found non-compliant is just under 50%. In other words, he has an even-money chance of escaping detection in any one year - although if the waste persists at that level of non-compliance, the landfill operator is likely to pick it up after six or seven years at the most. But if the proportion of unsatisfactory waste rises to 30%, the N=6 curve shows that there will be about a 90% chance of the landfill operator correctly reaching a non-compliance conclusion in the first year of monitoring.

[5] Guidance on Sampling and Testing Wastes for Waste Acceptance Procedures v 4.3. Environment Agency 2003. Draft for external consultation.

# ANNEX A2 EXAMPLE SHORT-FORM SAMPLING PLAN

| SAMPLING PLAN | |
|---|---|
| **GENERAL INFORMATION** | |
| Sampling Plan completed by: R Mogul | On behalf of: EnConsult |
| Client (Company): WasteMan plc, Tomerton<br>Contact: Mr J Jacobs Tel: | Material producer: Steel UK ltd, Brinwater<br>Contact: Ms. C Swarf Tel: |
| Other involved parties: None | |
| Sampling to be carried out by (Company): EnConsult | Specify name of sampler: F Frank |
| **SPECIFY THE OBJECTIVE OF THE TESTING PROGRAMME** | |
| **Overall Sampling Objective:** To identify the available options for on-site landfilling of non-hazardous steel-making slags with due regard for imminent changes in UK regulation following implementation of the Landfill Directive.<br>**Technical Goal:** Waste producer to carry out an assessment to identify compliance (98%ile) with proposed landfill targets for each of 3 component streams of the steel-making residues. Testing to be representative of good and worst case production conditions at the demetalling plant over an annual period. | |
| **DEVELOPING THE PRACTICAL INSTRUCTION** | |
| **MATERIAL** | |
| **Type of material**: Steel-making slags<br>• Vessel<br>• Desulphurisation slags<br>• Works debris | Location: (address) Breakneck Rd, Tovington, Devon |
| **Form and nature of arising**: Residue stockpiles for each designated residue stream generated at the end of the demetalling conveyor belt. | |
| **Background information:** Each residue stream is transferred from the production facility to the demetalling plant and stored in separate stockpiles. When a sufficient volume is available, each residue stream is loaded onto the conveyor at the plant and processed to remove ferrous metal. The processed material, in a stockpile at the end of the conveyor is then excavated into 40T trucks for either re-use or disposal in the on-site landfill. | |
| **Identify access problems that may affect sampling programme:** Access to the stockpile post demetalling is good. | |
| **SAMPLING METHODOLOGY** | |
| **Scale**: Each sample to be collected from a volume of waste required to fill a 40T truck. | |
| **Sampling population**: Sampling to be carried out for wastes generated over a 4 week period. | |
| **Specify detailed sampling location** Samples to be collected from the stockpile at a time when it represents a pure residue stream the end of the conveyor as it is reduced in size through excavation to the 40T truck. | |
| **Specify date and time(s) of sampling:** Four week sampling programme to start on the 5th July 2004. Select a random time to collect the first samples within the first 2 days of the assessment period. Collect a further sample approximately every 2 days thereafter (sampling will be dictated by the rota operated at the demetalling plant). Repeat for each residue stream. | |
| **Specify persons to be present:** F Frank | |

| |
|---|
| **Identify equipment:** Stainless Steel Spade. |
| **Specify no. of samples to be collected:** 14 from each residue stream. |
| **Specify no.of increments per sample:** 20 |
| **Specify increment size/sample size:** Spadeful |
| **Description of sampling event:** It takes a total of 20 grab or excavator shovels to fill a 40T truck from the stockpile. Take the 1st, 5th, 10th ,15th and 20th grab samples and place them individually to one side. Take 3 spade-fulls from the outside edge to the middle and two from the centre of each pile and place in a separate stockpile for mixing and sub-sampling in the field. Repeat for each residue stream using the schedule specified above to collect 14 samples of each stream. |
| **Detail requirements for on-site determinations**: |
| **Identify sample coding methodology:** Each sample should have an indelible label on the outside of the container and a paper label inside a polythene bag placed inside the container pre-sealing. The following coding should be adopted: Site Code: Stream code V (Vessel) or DS (Desulphurisaion ) or WD (Works Debris): Time (of sample collection): Date: Initial of Sampler. |
| Identify safety precautions: Sampling must only be carried out when the conveyor is stopped. |
| **SUB-SAMPLING** |
| **Detail procedure:** Each individual sample consist of 20 (same mass/volume) spade increments, of an approximate total weight of 25kg. A sub-sample of approximately 2.5kg is required for delivery to the laboratory.<br><br>On a clean tarpaulin, mix the material by forming a conical heap,by taking a spade of the material and put it on the top of the preceding one. The size of the scoop or spade should be of such size that this action should be repeated on at least 20 occasions in order to transfer the full amount of material. Now transfer the material from this first cone and form a new cone. Deposit each spadeful on the peak of the new cone in such a way that the sample runs down all sides of the cone and is evenly distributed so that different particle sizes become well mixed. Repeat. Flatten the third cone by inserting the shovel repeatedly and vertically onto the peak of the cone to form a flat heap which has a uniform thickness and diameter. The height should be less than or equal to the height of the shovel or spade used. Quarter the flat heap along two diagonals intersecting at right angles. Quarter the flat heap along the two diagonals intersecting at right angles using a shovel inserted vertically into the soil. Discard one pair of opposite quarters and shovel the remainder into a stockpile. Repeat the process of mixing and quartering until the volume of remaining sub-sample is equal to 2.5kg (i.e approximately 4 times). Transfer the sub-sample to the sample container. |
| **PACKAGING, PRESERVATION, STORAGE AND TRANSPORT REQUIREMENTS** |
| Packaging: Use 25l screw top container provided by the laboratory and label using the sample coding given above. Securely attach a paper label (with tape) sealed in a plastic bag to the outside of the container. Place a similar label inside the container. Confirm that the containers have been pre-soaked in a preparatory cleaning solution e.g. Decon and rinsed 3 times in de-ionised water or its equivalent prior to use at the laboratory prior to dispatch. |
| Preservation: The addition of chemical additives is not required. |
| Storage: Store in a cold-store until all the samples are collected. |
| Transport: Deliver the samples to the laboratory using a proprietary courier. Specify a 24 hour confirmed delivery date. |
| **ANALYTICAL LABORATORY** |
| Company details: Media Analysis, Rock Rd, Blatherington, Devon DE07 6TF<br><br>Contact: G Digest Delivery Date: 26.July 2004 |

# ANNEX B : EXAMPLE SAMPLING PLAN 2

## *SECONDARY WASTE PRODUCER: OPERATOR OF TREATMENT PLANT PRODUCING REGULARLY-GENERATED WASTE WITH VARIABLE INPUTS (LEVEL 1 CHARACTERISATION)*

### *Background*

In this example a secondary waste producer (operator of a merchant plant facility – MPF) takes hazardous powder wastes from a number of waste producers to effect treatment of routine hazardous aqueous chemical wastes prior to landfilling as a non-hazardous waste. In such circumstances the requirements for testing the treated wastes become quite complex and the variability of the final product may often be difficult to control.

The treatment process operator's approach to information gathering should be the same as that of a primary waste producer. It is important to identify the inherent variability of the process with respect to process inputs and operational conditions in order to determine whether the waste is of consistent or erratic quality. The MPF operator would then need to establish the boundaries and reasons for any variability in the final product (i.e. know what circumstances lead to samples of normal and worst case quality) to be confident in the data he is supplying to the landfill operator. No failure of waste acceptance criteria (WAC) is acceptable in the UK, a zero tolerance stance that presents a challenge to both the landfill operator and waste producer. If on examination of testing data the variability of the treated wastes presents a problem, attention might then need to be focused on controlled mixing of waste inputs and placing further controls on the waste treatment process. It may even prove necessary to reject waste streams that compromise this objective.

The treatment process is complicated and the existing dataset indicated a high degree of variability of input and output wastes. It was recommended that the existing knowledge should be supplemented by information from a series of screening steps. This information would also allow any subsequent Level 1 characterisation programme to be appropriately targeted.

This following example Sampling Plan, details a possible approach to acquiring that background dataset and enable planning of the Level 1 characterisation exercise. It follows the structure provided in prEN 14899 'Framework for the preparation and application of a Sampling Plan'.[1]

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[1] CEN 2004. prEN 14899 Characterisation of Waste - Sampling of waste materials: Framework for the preparation and application of a Sampling Plan. CEN TC292/WG1

## *Identify involved parties*

- *Waste producer:* Representatives with technical process expertise and the Environmental Team responsible for ensuring compliance with UK legislation.

- *Landfill operator:* The operator of the Merchant Plant Facility is also the landfill operator. However, in this example the Sampling Plan is focused primarily on the requirements of the plant operator.

- *Consultant:* A consultant with waste sampling expertise was used to produce the Sampling Plan.

- *Regulator:* At this stage there is no need to involve the regulator (UK Environment Agency).

## *Identify objectives and define technical goals*

In order to identify and define the objectives of the testing programme a brainstorming exercise was held with site representatives and the consultant. This exercise was used to define a number of potential iterative steps to gather background data on which to plan a subsequent Level 1 characterisation exercise. The development of the programme objectives and identification of possible screening steps are outlined in Figure B1.

The overall objective of the proposed testing programme is to maintain a landfill disposal route for wastes from the MPF after the end of co-disposal in 2004. Two potential options for future landfilling have been identified:

1. The treated waste is classed as non-hazardous:

    - NOW (after July 2004) – To be accepted at a landfill for non-hazardous waste the waste must not exhibit hazardous characteristics (from basic knowledge of waste inputs this could require a reduction in free lime to <10% to remove H4 hazard (irritancy)).

    - FUTURE (no timetable yet) – Expect WAC for non-hazardous wastes at non-hazardous landfills to be introduced.

2. The treated waste is classed as hazardous:

    - At some point after July 2005 – Batches of output wastes that remain hazardous and cannot be treated further to be non-hazardous must go to landfills for hazardous wastes and meet WAC for hazardous wastes.

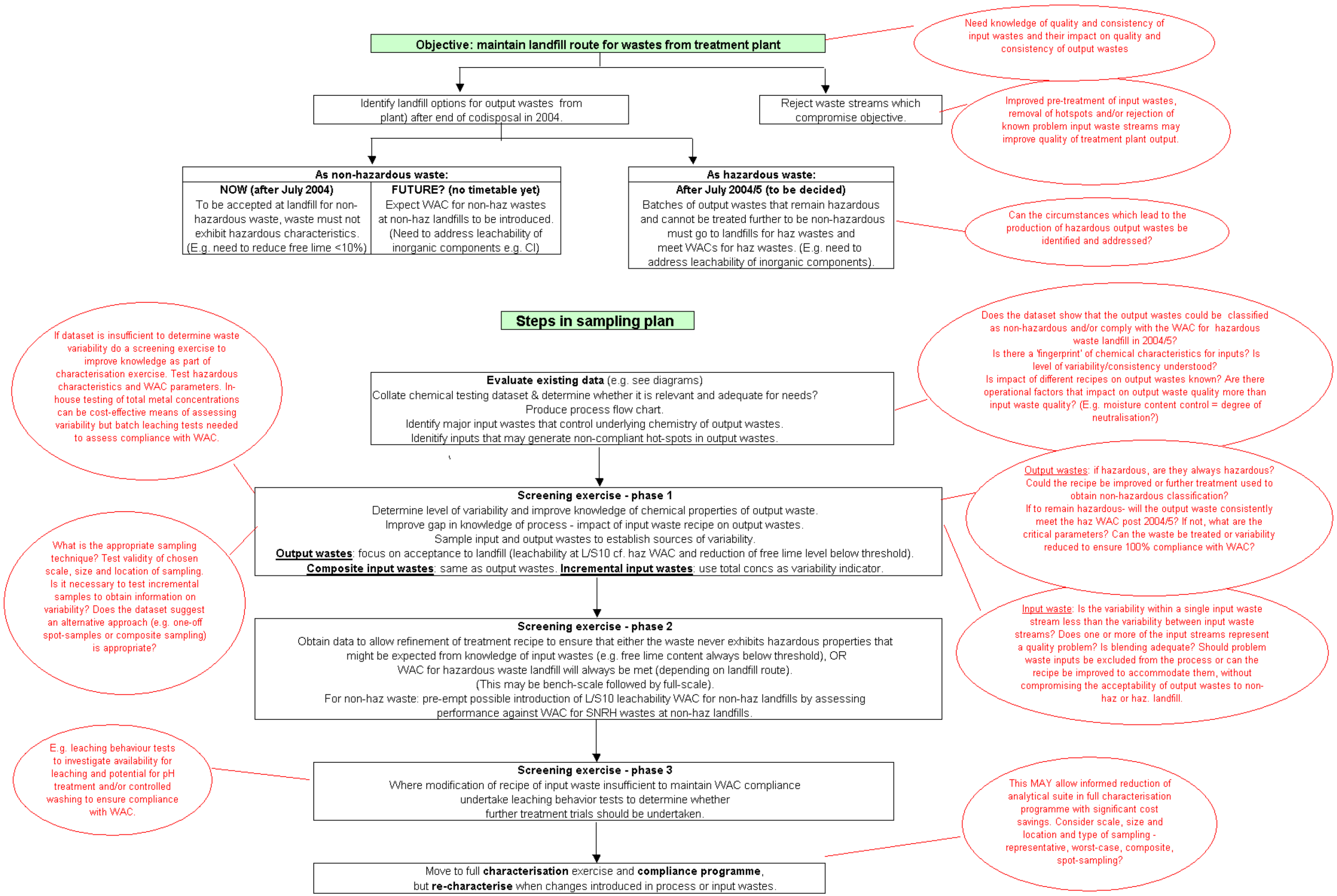


**Figure B1. Overview of brainstorm exercise to design Sampling Plan for secondary waste producer**

The overall testing objective can be translated into a number of practical Technical Goals, which in turn can be linked to specific sampling and analytical requirements, the Technical Goals are:

- Improve knowledge of quality and consistency of input wastes and their impact on quality and consistency of output wastes to provide confidence in achieving 100% compliance.

- Can the circumstances which lead to the production of hazardous output wastes be identified and addressed? (The use of a range of leaching tests to investigate whether improved pre-treatment of input wastes, removal of hotspots and/or rejection of known problem input waste streams may improve the quality of the treatment plant output).

## *Determine generic level of testing required*

This Sampling Plan supports the initial planning stages of a Level 1, comprehensive characterisation testing scheme, that is specific to the MPF providing the data. However, the basic steps used to develop this Sampling Plan are widely applicable. Level 1 characterisation will ultimately be achieved following a number of initial screening steps to improve a small historic data set prior to more extensive testing.

## *Research background information on waste*

### *I. Site details*

A merchant plant facility (MPF) treats a wide range of hazardous aqueous chemicals using alkaline incineration and power station residues, prior to landfilling.

### *II. Process generating waste*

Powder residues are bulked in large storage silos, which feed directly to the production line, as they are received at the plant. The input feedstock is therefore a variable and random mix of approximately eleven source streams.

Mixed aqueous wastes are bulked depending on product type (e.g. acids and a restricted list of solvents) and stored in bulk storage vessels. When required, these bulked waste acids are diluted pre-processing. The aqueous wastes, fed from the various storage tanks are sprayed onto alkaline dry powder streams travelling on a short open conveyor where there is only a limited potential for mixing. The rate of addition is controlled to give a moist final powder (approximate ratio 1 liquid: 4 powder).

The plant utilises approximately 11 separate powder streams to effect treatment of the aqueous wastes, which consist of small, often one-off batches. The individual powder residues remain relatively constant in composition, whereas the concentration and chemical make-up of the spent acid and components of the aqueous waste are inherently extremely variable.

Processed material from the conveyor is collected in 14 tonne batches in dumper trucks, prior to landfilling. Note: To protect plant anonymity the total volumes processed are not disclosed however, in practice this information would be useful to determine an appropriate scale of sampling.

### *III. Evaluate existing compositional data*

The evaluation of existing data represents an extremely important step in the development of a Sampling Plan. Commonly, despite sparse data, a well-planned information evaluation exercise can yield a significant amount of information pertaining to the variability of the waste itself and the production process. This exercise can be used to guide the testing programme. An initial brainstorming exercise (Figure B1) demonstrated that a number screening steps would be needed to answer some crucial questions to avoid the costs of a potentially ill-focused full characterisation testing scheme.

In common with many UK waste producers, the MPF operator undertakes only limited testing of input and output wastes. (n some cases prior knowledge can often be restricted to chemical screening tests completed during the quotation process). In this example the waste acceptance procedures for the plant require the tanker driver to provide a sample of the waste at the weighbridge. Free lime and pH are determined on each 250g jar of input wastes before the driver may discharge his load to a silo. In addition each dumper truck of treated output waste is sampled at the same scale (i.e. a 250g sample jar collected from the top of each truck). This is tested for pH and temperature (the latter for H&S requirements). Two samples per day (randomly selected) are submitted for a broader laboratory analytical suite, which whilst comprehensive is less extensive than the list of determinands for waste acceptance to landfill (WAC).

No routine testing has been carried out to link specific input data with output quality. A limited one-off programme was undertaken in 2003, to improve process characterisation based on 15 samples, which were subjected to single step L/S2 and L/S10 leaching tests (BS EN 12457).

Available information on input loads arriving at the plant and chemical data were collated and evaluated to assess relevance and adequacy. This historic data set was evaluated with the aim of answering a number of key questions:

i. Can we quantify/ validate the assumption that variability between input streams is likely to be the significant issue rather than within-stream variability?

ii. Does the dataset show that the output wastes could be classified as non-hazardous and/or comply with the WAC for hazardous waste landfill in 2004/5?

iii. Is there a 'fingerprint' of chemical characteristics for inputs? Is the level of variability/consistency understood?

iv. Is the impact of different recipes on output wastes known? Are there operational factors that impact on output waste quality more than input waste quality? (e.g. moisture content control and degree of neutralisation?)

In an attempt to answer these questions, plots were used to provide a graphical representation of waste inputs with the aim of identifying:

- major input wastes that may control the underlying chemistry of the output wastes; and
- potential mixes of wastes that could cause non-compliant hot-spots in the outputs wastes (see Figure B2 and B3).

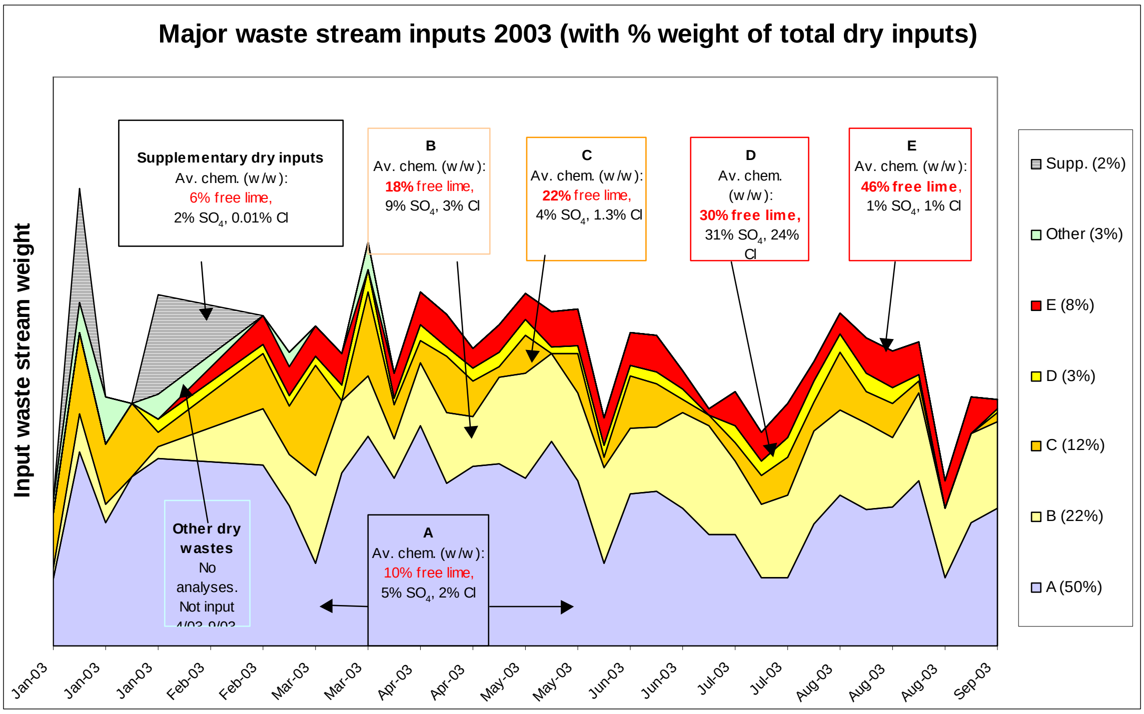


**Figure B2 Plot of weights of input streams to plant 2003**
(No x-axis to protect site anonymity)

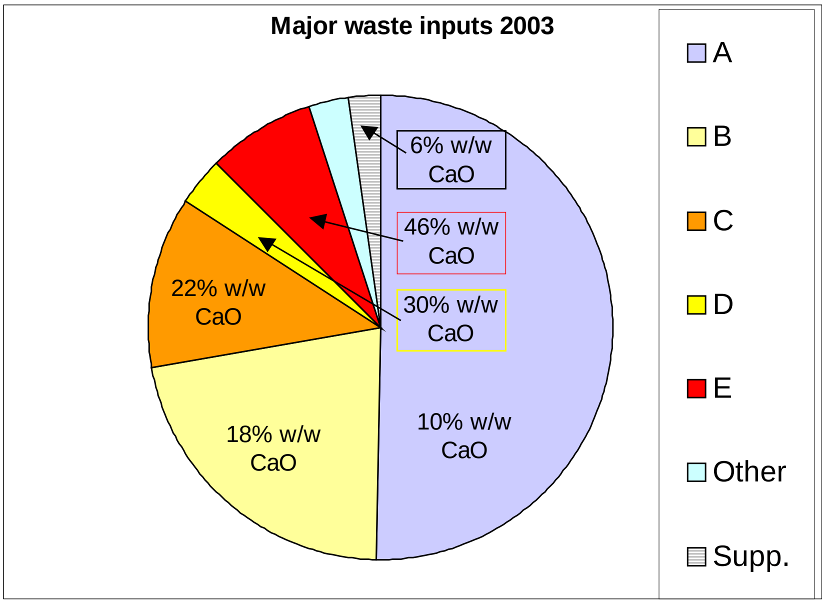


**Figure B3 Major dry inputs as percentage of total dry inputs Jan-Sept 2003** (Average free lime content of major streams is indicated (as %w/w CaO))

Lastly a comparison of limited LS 10 data (mixed output wastes only) was made with WAC to identify potentially problematic components in the output waste. In addition discussions with MPF personnel were used to create a process flow chart, which was then utilised in developing a step-wise approach to the screening/ characterisation testing (Table B1).

**Table B1 Initial leachability trials of product from merchant treatment plant**

| Leached product known to contain mix of inputs (June 2003) | pH | Leached concentration at L/S10 from BS EN 12457-3 in mg/kg leached | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | As | Ba | Cd | Cr | Cu | Mo | Ni | Pb | Zn | Cl | F | $SO_4$ |
| 'Supp' | > 11 | < 20 | 35 | < 0.2 | < 1 | < 1 | 12 | 1 | < 1 | 2 | 21,000 | 4.9 | 150 |
| 'A' + 'supp' + 'C' | > 11 | < 20 | 3 | < 0.3 | 3 | < 2 | 7 | 2 | 2 | 1 | 39,000 | 7.1 | 6,500 |
| 'A' + 'C' | > 11 | < 20 | 2 | 8.7 | 26 | 48 | 9 | 25 | 47 | 29 | 39,000 | 9.5 | 26,000 |
| 'A'+ 'supp' + 'other 1' | > 11 | < 20 | 2 | < 0.2 | 3 | < 1 | 8 | < 1 | 1 | 2 | 38,000 | 4.3 | 28,000 |
| 'Supp' + 'other 2' | 9.6 | < 20 | 3 | 0.4 | 4 | 7 | 10 | 1 | < 1 | 2 | 28,000 | 98 | 4,900 |
| Supp' + 'other 3' | > 11 | < 5 | 80 | 0.1 | 1 | 6 | 8 | 1 | 1 | < 1 | 28,000 | 5.1 | 100 |
| **Shading notes leachability exceeds:** | | WAC leachability limit values at L/S10 (mg/kg) | | | | | | | | | | | |
| L/S10 WAC for inert wastes | | 0.5 | 20 | 0.04 | 0.5 | 2 | 0.5 | 0.4 | 0.5 | 4 | 800 | 10 | 1,000 |
| L/S10 WAC for SNR haz/non-haz wastes | | 2 | 100 | 0.1 | 10 | 50 | 10 | 10 | 10 | 50 | 15,000 | 150 | 20,000 |
| L/S10 WAC for haz wastes | | 25 | 300 | 1 | 70 | 100 | 30 | 40 | 50 | 200 | 25,000 | 500 | 50,000 |

Commentary

Improved limits of detection may indicate that WAC compliance is not generally an issue for As and Cd.

If product remains hazardous due to CaO>10%, treatment process must be further refined so all parameters always meet haz WAC.

- Cl leachability main issue (inherent in dry inputs) but high Cl of 'supp' (<0.01% Cl in input) may be from aqueous wastes
- Cd exceedance of haz WAC from 'A+C' mix may indicate contamination from aqueous wastes
- Pb in 'A+C' close to haz WAC

Comparison with SNRH WAC pre-empts likely introduction of these WAC for all non-haz wastes

- 'C' contributes to exceedance of Cd, Cr, Cu, Ni, Pb, Cd, Cl
- 'Supp' (supplementary input) exceeds Mo WAC (unless due to aqueous wastes)
- L/S2 leaching data for other mixes indicates that 'C' and 'other 2' likely to cause exceedance of SNRH $SO_4$ WAC

## Data analysis

The analysis of waste input by volume/percentage focused on the period January – September 2003 after inputs to the plant appeared to stabilise. Inputs labelled A-E represent the major dry granular wastes streams. 'Other' relates to all the other minor sporadic streams (4) that were accepted in early 2003. When dry waste supplies are low, supplementary dry materials are purchased to ensure that plant operations can be obtained. This stream is abbreviated 'supp' in other charts.

Average major element chemistry ("av. chem.") data was obtained from samples collected between February and June 2003.

The hazard associated with most of the inputs is irritancy (H4) on the basis of free lime content in excess of 10%w/w. Red shading is used to denote the input stream with the highest free lime content.

The following factors can be inferred from the review process:

i. Sampling effort needs to be focused on determining between rather than within-stream variability to identify the major causes of variability in output wastes.

ii. Aqueous and solid wastes are generally hazardous pre-processing and post treatment (as a result of free lime >10% and pH>11). There is an extremely comprehensive database of free lime levels on all input and output loads, unfortunately there is no information relating to the mix of input wastes that relate to a specific output waste.

iii. The current output stream would still be classified as hazardous (H4, irritancy) on the basis of free lime content exceeding 10%) Therefore the MTP product m could not be accepted at a non-hazardous landfill site post-July 2004 without further treatment to remove the H4 hazard. In addition, the output waste failed a number of hazardous WAC and therefore could not be accepted at a hazardous waste landfill after the introduction of hazardous landfill WAC (July 2005).

The existing dataset is useful but insufficient to fully understand the variability in the input and output wastes and impact of the process on this variability, therefore further screening exercises are required to acquire targeted data. A number of questions still need to be answered:

- Does the process recipe always need to be adding acid to bring pH and free lime within acceptable range?
- Can we identify the circumstances that lead to non-compliant loads?
- Do shut-downs lead to variations in product?
- Do different process operators influence the product?
- Does one or more of the input streams represent a quality problem?
- Are current levels of blending adequate?
- Should problem waste inputs be excluded from the process or can the recipe be improved to accommodate them, without compromising the acceptability of output wastes to non-hazardous or hazardous landfill.
- Are output wastes consistently hazardous or could the recipe be improved or further treatment used to obtain non-hazardous classification?

A number of screening steps were identified to address this deficit in information.

## *Identify health and safety precautions*

Generic Health and Safety requirements for each site prevail.

## *Select sampling approach*

- ***Screening exercise - Phase 1***

This screening exercise was designed to gather data to support a number of Technical Goals and supporting specific instructions for sampling, these are outlined below. The suggested step-wise approach to screening prior to full characterisation is presented pictorially in Figure

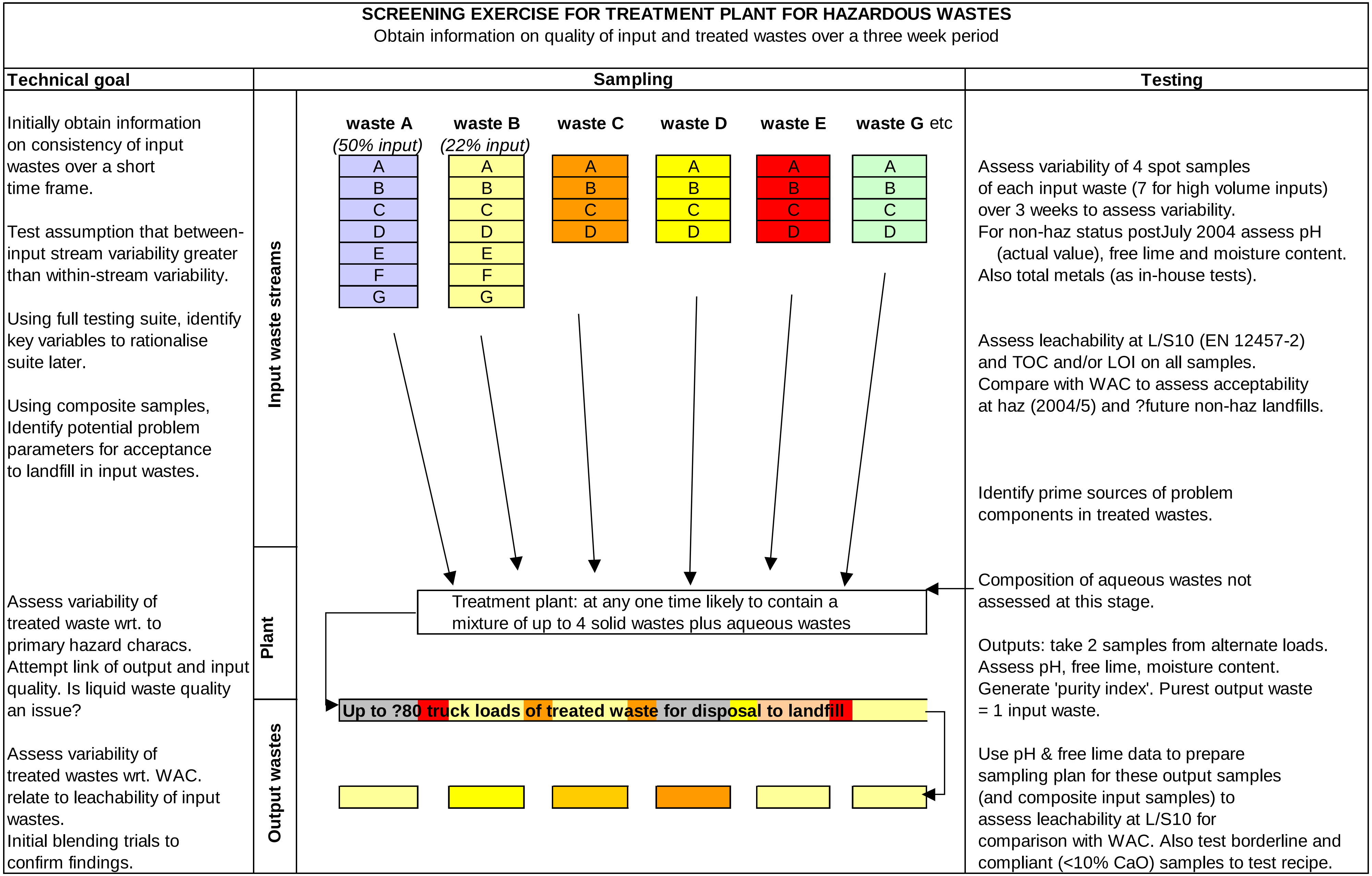


**Figure B4 Screening Exercise for Treatment Plant for Hazardous Wastes**

B4. Initial screening is focused on getting a better understanding of the issues associated with the dry powder inputs. When the sources of variability and any problems associated with this side of the process are evaluated further screening tests will need to address further the level of variability introduced by the addition/treatment of aqueous wastes in the process 'recipe'.

*NOTE*: During the various screening steps advocated in this Sampling Plan, no attempt was made to collect worst case samples as the purpose of testing was to establish basic information pertaining to the overall process, and indeed identify what combination of circumstances lead to worst case conditions. Sampling was undertaken at the finest scale possible with regard to the available budget. In-house testing of total metal concentrations can be cost-effective means of assessing variability, however, this is ultimately no substitute for undertaking a number of batch leaching tests to assess compliance with WAC (and determine the level of variability of each parameter in the eluate – which can be different to the variability exhibited by total metal concentrations).

The data gained from the screening steps should be used to plan the full characterisation programme which is outlined below.

**General Technical Goal:** Obtain information on the consistency of individual input powder wastes over a short time frame.

**Specific Technical Goal:** The powder input wastes are all produced at large production facilities operating a standardised generic process, a three week trial period, whilst relatively short, would encompass variability within each stream in the short-term, and it is expected that this variability will be of a similar order of magnitude to that encountered on a month by month, or year by year time frame. The selection of a relatively short time frame will assist the WP in expediently improving his knowledge of his input wastes and process.

**Specific Instruction:** Collect up to 4 spot samples (7 for high volume inputs) for each of the input streams as they arrive over a period of 3 weeks to assess natural variability. These wastes arrive in 30t bulk tankers, the selected scale of sampling, a 250g sample jar, is taken at the production plant during tanker-filling, and is representative of average conditions within the waste. Each sample should be analysed for total metals for the parameters on the WAC metal list (easy to achieve as testing can be undertaken in-house) in addition to residual moisture, pH and free lime (to assess H4 irritancy property).

**Technical Goal:** Test the assumption that between-input stream variability is greater than within-stream.
**Specific Instruction:** Do analysis of variance on data collected above.

**Technical Goal:** Improve gap in process knowledge by starting to identify the effect of the input waste recipe (powder + aqueous) on the resulting output wastes i.e. do some matched sampling. Note: with this knowledge it should be possible to assess the criticality of liquid waste additions.
**Specific Instruction:** During the 3 week test period above collect two output samples from alternate dumpers and record corresponding input wastes. Where possible operate the process with single or simple input recipes so that variability in the output samples can be attributed to the impact of specific inputs. Replicates should be collected on all outputs from the process, as a minimum on at least every other load rather than single increments on every load to allow some assessment of variability (with a single result it is impossible to know whether you have determined the true value – see Annex C in CEN TC 292 WG1, TR1). Test all input and output samples for pH and free lime.

**Technical Goal:** Test waste inputs and outputs against WAC parameters.
**Specific Instruction:** Test all input samples using single step L/S10 leaching test for full WAC list and free lime (existing data shows that free lime levels are potentially hazardous in the majority of mixed output wastes, need to identify the circumstances that lead to non-hazardous output wastes or where if a hazardous waste (on the basis of EWC code or properties), which recipes would comply with hazardous WAC. To limit budget expenditurescreen out those output samples where mixed inputs potentially complicate the cause and effect relationship, and test those output samples that have the highest purity index. Use the same analytical suite proposed above. Preparing composite samples is not considered to be appropriate at this stage as the purpose of the exercise is to assess primary levels of variability.

**Technical Goal:** Although full WAC suite testing will ultimately be required for Level 1 characterisation, further screening tests (leaching tests) could be completed, as a cost saving measure, on a restricted but rationalised suite. Identify a potential suite.
**Specific Instruction:** Analyse leaching test results for samples taken above to identify restricted list of components which exceed or are borderline with appropriate WAC, and that exhibit greatest variability.

**Results:**

i. Waste producer collected a total of 19 powder samples and 67 output samples during 3 week test period.

ii. During the three week screening exercise no wastes were obtained from category 'Supp' , a further duplicate exercise to that detailed above, should be carried out, as and when these wastes arrive at the plant to fill this knowledge gap.

iii. Primary analytical suite for screening purposes should focus on free limepH and Cl, it is these parameters that currently make the inputs and outputs from the MPF hazardous and/or fail the hazardous waste landfill WAC.

- Total concentration data attributable to single source output wastes was subjected to a statistical examination to make a preliminary identification of 'high' concentration parameters and range of variability exhibited within and between-stream. With the exception of Cr and Ni where no statistically significant difference was identified between data for 5 of the waste streams, a strong and highly significant difference was found between input streams. This dataset is useful in that it raises the opportunity for blending streams (unless Cr and Ni are the cause for concern) to smooth out levels of potentially problematic constituents. It also means that sampling effort needs to be focused on determining between (of greater magnitude) rather than within stream variability to identify the major causes of variability in output wastes. These results are presented graphically in Figure B5 and B6.

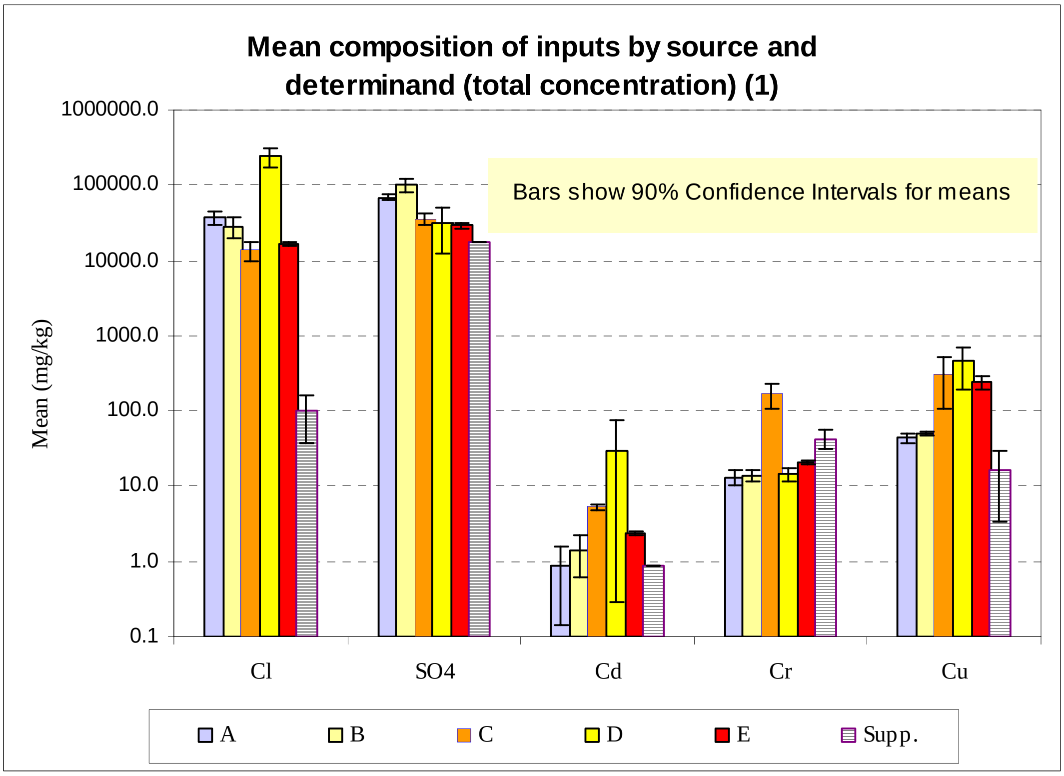


**Figure B5** mean composition (total concentration) of inputs by source and determinand (1)

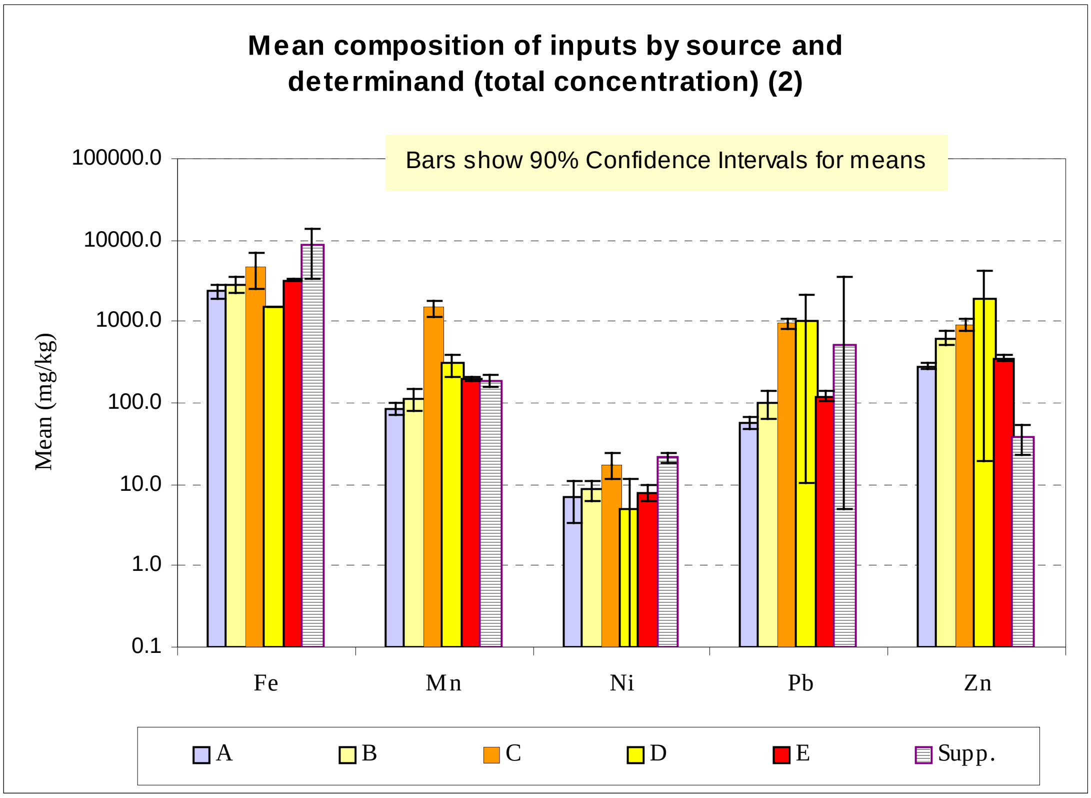


**Figure B6** Mean composition of inputs by source and determinand (2)

- An examination of the pH and free lime data for the three week sampling trial can be used to gain a better understanding of the impact of input wastes (Figure B7) on output (product) from the MPF (Figure B8).

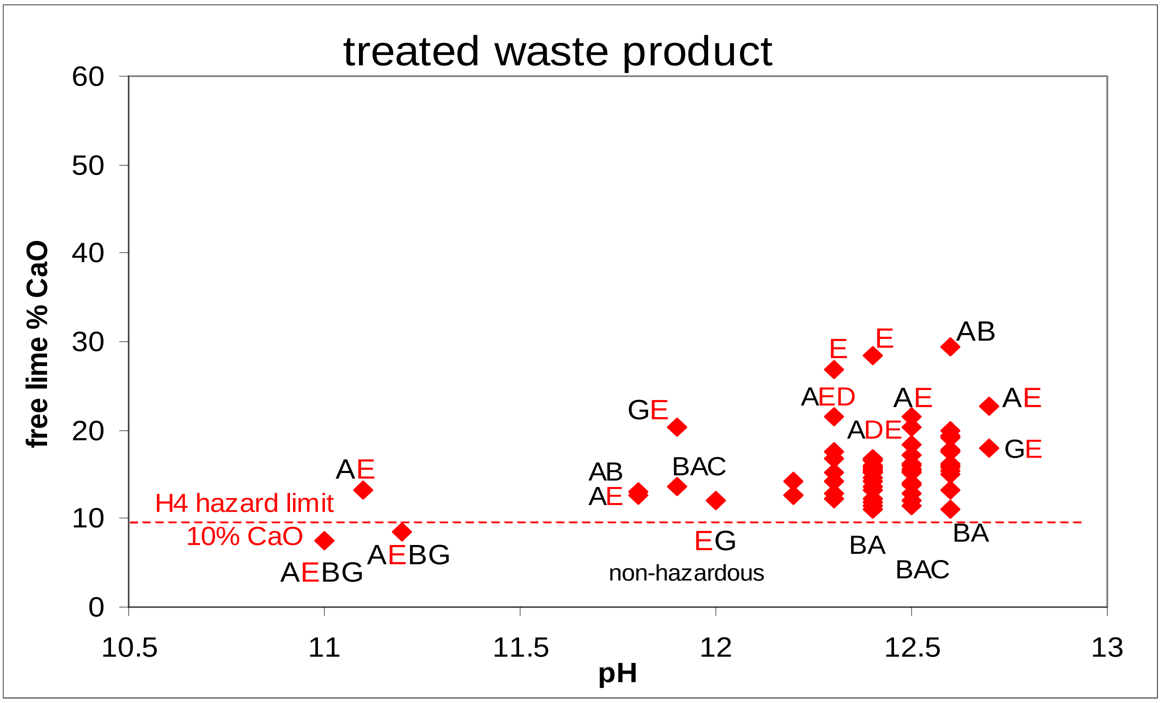


**Figure B7** Plot of pH versus free lime content for dry input streams

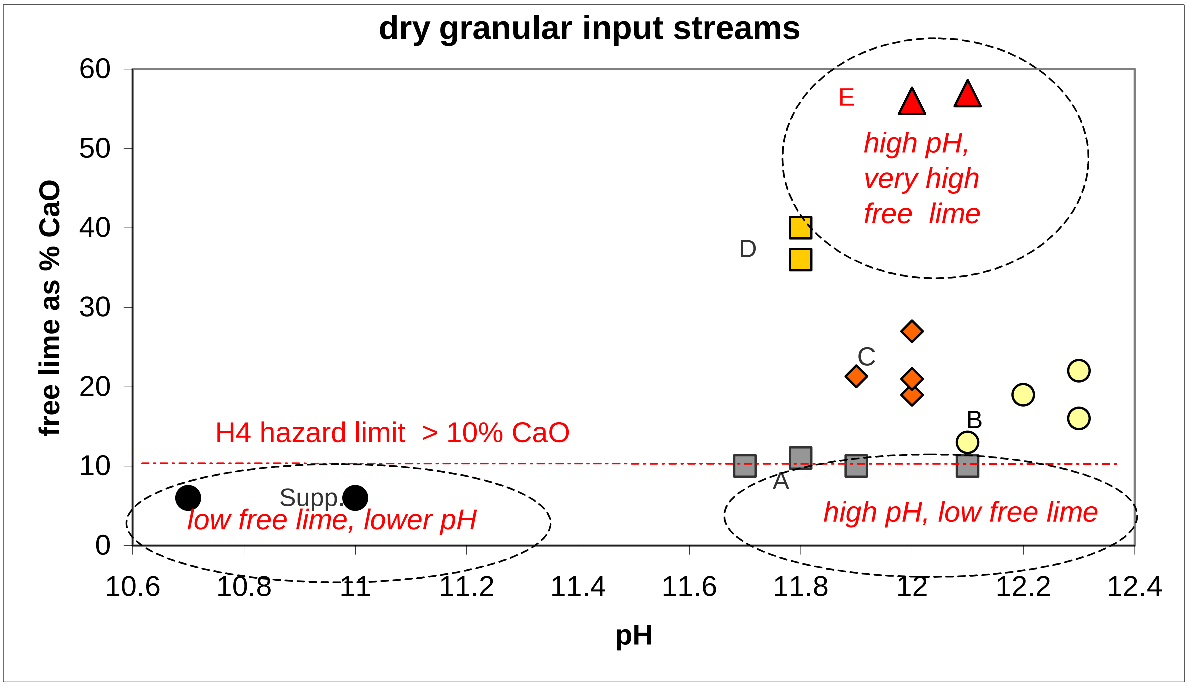


**Figure B8** Plot of pH versus free lime content for treated waste product

(Note: red font used for highest free lime wastes/residues containing E and D)

iv. This analysis shows that:

- There is a significant reduction in free lime concentration for the worst case samples (60%CaO reduced to 30%).
- The very high free lime content of waste E can be successfully countered with the low lime content of waste B or the bought in supplementary materials.
- All but 2 of the products tested exceeded the 10% H4 threshold and were therefore hazardous.
- Judicious mixing to prepare a more effective recipe could be conducted at bench-scale.

▪ The leachability of the compliant and marginal residues should be assessed against the WAC for hazardous and SNRH wastes to aid further refinement of the recipe.

▪ ***Screening exercise - Phase 2***

Figures B7 and B8 provide hope that for some of the waste inputs it should be possible to manipulate/ refine the treatment recipe (at a level of accuracy/control achievable at full-scale) to ensure that the waste never exhibits hazardous properties that might be expected from knowledge of input wastes (e.g. free lime content always below H4 threshold), and that the WAC for hazardous waste landfill will always be met (depending on landfill route). A series of bench scale tests should be carried out using the information gained from the Phase 1 Screening exercise. These tests could initially be carried out on the basis of pH and free lime. When confidence has been gained in the process recipe samples should be tested against the full WAC list. Tests would then need to be replicated at full scale. In the case of non-hazardous wastes this is an opportunity to pre-empt the possible introduction of L/S10 leachability WAC for non-hazardous landfills by assessing performance against WAC for SNRH wastes at non-hazardous landfills.

▪ ***Screening exercise - Phase 3***

Where modification of the recipe of the input waste is insufficient to maintain WAC compliance undertake leaching behaviour tests to determine what treatment options are a viable option to improve classification. For example investigate the availability for leaching and potential for pH treatment and/or controlled washing to ensure compliance with appropriate WAC.

# ANNEX C: EXAMPLE SAMPLING PLAN 3

## *LANDFILL OPERATOR COMPLIANCE TESTING SCHEME (LEVEL 2)*

It is likely that many operators of inert waste landfills may take the commercial decision to accept only single-stream, single-source inert wastes listed in Table 1 of the Landfill (England and Wales) (Amendment) Regulations 2004, or those where characterisation data is available for the entire consignment of waste requiring disposal. In these circumstances the responsibility for waste evaluation is clearly with the waste producer, and there is no requirement in the Regulations for the landfill operator to undertake compliance checks. Suspect loads (identified by level 3 checks) would be rejected at the gate.

For the purposes of this example it is assumed that in addition to any inert wastes that do not require testing, the inert landfill operator also wishes to continue taking wastes for which there will be a requirement for compliance testing to be undertaken by the operator. Sources of such wastes might include: potentially contaminated or multiple-source listed inert wastes; regularly arising wastes; and non-regular wastes where it is not possible to undertake characterisation testing on the entire consignment. The example plan provides a practical approach to deciding on a compliance testing programme for the landfill gate. It is assumed that waste inputs vary from relatively small one-off loads (e.g. 10 to 20, 18 tonne trucks) to large-volume more 'standardised' arisings.

Landfill waste acceptance criteria (WAC) at existing UK inert waste landfills will be implemented as the landfills are permitted under IPPC. For this example Sampling Plan, the landfill operator wishes to trial run the proposed testing scheme before the introduction of WAC at inert landfills. Meeting the current UK zero tolerance stance for WAC failure (maximum values for all listed parameters for all samples)[1] will be a considerable challenge for the waste industry. There are concerns that some virgin waste materials e.g. mineral extraction wastes and sub-soils from site redevelopment may fail the inert WAC on the basis of their natural composition. This proactive programme of testing should allow for informed discussions with the regulator prior to the introduction of WAC for inert wastes in the UK.

The following example Sampling Plan follows the structure provided in prEN 14899 'Framework for the preparation and application of a Sampling Plan'.[2]

### *Identify involved parties*

- *Landfill operator:* a representative with operational expertise.

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[1]Except where site or waste-specific derogations have been agreed with the Environment Agency.

[2] CEN 2004. prEN 14899 Characterisation of Waste - Sampling of waste materials: Framework for the preparation and application of a Sampling Plan. CEN TC292/WG1

- *Consultant:* a consultant with waste sampling expertise was used to produce the Sampling Plan.

- *Regulator:* at this stage there is no need to involve the regulator (UK Environment Agency).

## *Identify objectives and define technical goals*

In order to identify and define the objectives of the testing programme a brainstorming exercise was held with site representatives and the consultant. The exercise was used to gather background data on which to plan a scheme that is widely applicable to any landfill operator (not just the inert operator) trying to establish a level 2 compliance programme.

In an ideal world the operator of an inert waste landfill would be in a position to accept wastes that are either

- single-source, single-stream listed inert wastes which are exempt from testing, or

- demonstrably consistent or well-characterised and are not borderline classification cases - that is, they do not carry any risk of non-compliance with inert WAC

In order to pre-select such wastes the inert landfill operator is reliant on waste producers adequately characterising their wastes prior to landfilling.

Under the new regulatory regime[3] waste producers need to designate their wastes as either hazardous or non-hazardous wastes and to determine the appropriate class of landfill for the disposal of those wastes (hazardous, stable non-reactive hazardous, non-hazardous or inert waste landfill). In most cases, compliance with the regulations will require the waste producer to undertake laboratory testing to produce compositional and leaching test data for all wastes that are not on a list of exempt wastes, prior to securing appropriate landfill disposal. Irrespective of the size of the load (whether 1 or 100 or more vehicles), this must be undertaken in advance.

The objective of this example Sampling Plan was to produce a risk-based methodology for assessing the likelihood that a non-compliant load could be accepted (i.e. not rejected) for any given compliance sampling regime. In other words, this approach enables the operator to assess the risk of inadvertently accepting a load that does not comply with the inert WAC based on a given number of compliance samples.

[3] Landfill (England and Wales) Regulations 2002; Landfill (England and Wales) (Amendment) Regulations 2004.

## ***Determine generic level of testing required***

This Sampling Plan supports the initial planning stages of a generic level 2, compliance testing scheme, but will compliment level 3 checks (examination of waste transfer documentation and 'visual' checks') at the landfill gate.

## ***Research background information***

### *I. Waste generation*

The waste producer is responsible for the provision of the basic characterisation information required by Part 2 of The Landfill (England and Wales) (Amendment) Regulations 2004, including the need to demonstrate that the appropriate class of landfill has been determined for the waste's disposal.

In this example, two main scenarios are considered in designing the landfill compliance programme:

1. <u>Listed inert wastes</u>. If the operator is accepting single-stream, single-source wastes that are on the list of inert wastes[4] (e.g. uncontaminated sub-soil – covered by EWC code 170504) then no action (i.e. testing) is required, other than to demonstrate that it is uncontaminated, single-stream waste from a single source. However, if the waste is predominantly a single stream from the inert waste list, but is contaminated with other wastes to a level that may alter its environmental risk, testing would be required. The results would allow the landfill operator to judge whether future loads of the waste should be rejected (i.e. be sent to a non-hazardous waste landfill) or whether a risk assessment would be needed prior to acceptance at the inert landfill.

2. <u>Non-listed inert wastes</u>. In the second scenario the wastes are not on the list of exempt wastes and evidence is required to show that wastes meet the inert WAC (the timetable for introduction is not yet finalised). The UK is regulating against L/S10 data from the two stage compliance leaching test for granular wastes BS EN 12457-3 which generates eluates at L/S2 and L/S2-10 (cumulative L/S10). For inert sites, compliant wastes must essentially be inorganic (<3w/w% TOC), with very low levels of organic contaminants (BTEX, PCBs, PAHs and mineral oil), very low leachabilities with respect to the listed metals, anions and phenol index and containing low eluate levels of dissolved solids and dissolved organic carbon. Such wastes are classified as either regular or non-regular arisings (see Note below)

[4] The full list is given in Table 1 of the Landfill (England and Wales) (Amendment) Regulations 2004.

**NOTE**

Guidance on the terms and implications for testing requirements for regularly generated and non-regularly generated wastes is provided in the EC Council Decision 2003/33/EC[5].

- Regularly generated wastes: are wastes that are regularly generated by the same process. The process(es) generating these wastes are well known and the input materials well defined. The waste(s) may be from a single installation or different installations that produce a stream that **is consistent,** with common characteristics and known boundaries (e.g. bottom ash from the incineration of municipal waste).

  For these wastes characterisation will comprise compositional analysis, determination of characteristic properties and leachability tests. The dataset should be sufficient to enable the variability of those characteristics to be assessed and in particular to demonstrate that the waste is consistently below the appropriate WAC. Compliance, commonly limited to a restricted list of key variables, should then be undertaken at regular intervals by the waste producer to ensure the process remains within the identified boundaries.

- Non-regularly generated wastes: non-regular wastes can effectively divided into two main categories:
  - Those wastes that are not generated by a primary process (although they may subsequently be treated using a process e.g. building materials from a site demolition, or soils recovered from a site excavation).
  - Those wastes that are generated by a standardised process, but one that generates an inconsistent end product. This could, for example, be due to either inconsistent inputs or a variable process recipe. For example, an aggregate recovery plant or merchant waste treatment plant.

  Single-source, single stream non-regular wastes that are identified on a list of exempt wastes will not require testing. However, where mixing of sources (at a processing plant or transfer station) or source contamination is a possibility (for example, demolition waste may contain asbestos or 'clean' sub-soil from a plating works that has not been adequately separated from contaminated areas) then testing by the waste producer would be required to quantify the levels of contamination and position with respect to the inert WAC.

  For non-regular wastes if characterisation can be undertaken on what is effectively the entire population (i.e. the total batch or consignment destined for landfill, even if disposal is as a number of loads), as the entire consignment has effectively been tested no compliance checks would be required by either the waste producer or landfill operator. In the specific example of land investigation, where access is available to all materials requiring excavation a comprehensive site investigation report that follows a probabilistic sampling approach, with due regard to the calculation of samples numbers, sizes and sample locations (see Section 4.2.8) and which is compliant with the Landfill Regulations in terms of parameter suites and testing methods could become the characterisation report. The investigation would also need to be 3-Dimensional in nature (i.e. samples collected laterally and at depth). However, specific to this example, if either the site history or site investigation report identifies the presence of material that would exceed the WAC for disposal at an inert site, and segregation of waste is required, the Landfill operator is likely to require compliance checks by the operator to show this has been satisfactorily carried out.

  In the situation, where characterisation can only be undertaken on a sub-population of the total population to be disposed (e.g. only part of a site has been demolished/excavated or only arisings from a non-regular process in any given week or month are being considered) there are two potential testing routes, either:
  - Undertake a comprehensive characterisation exercise and repeat this as new material is generated, or (in the case of a process) when it is known or suspected that the waste characteristics are likely to have changed. This approach effectively divides the waste into a number of loads (each requiring characterisation), OR;
  - Undertake characterisation when knowledge of the activity indicates that sampling will encompass

[5] EC Council Decision 2003/33/EC of 3rd January 2003 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 and Annex II of Directive 1999/31/EEC on the landfill of waste. OJEC L11 16.1.2003.

the expected variability in the waste stream, then undertake regular compliance checks over the period of the process or activity to check that the waste stream is within the ranges previously determined. Characterisation would be for a comprehensive determinand list (e.g. WAC determinand) to identify the key variables and concentration ranges that might be expected. Even where prior use of the site indicated that a sole contaminant might be expected, initial compositional and leaching tests would be needed to confirm this to be the case.

***There will therefore be a need to undertake compliance testing on non-regular wastes, where it is not possible to 'characterise' the entire population or consignment of waste requiring disposal.***

The level of compliance checks (where checks are required) at the landfill will be at the discretion of the operator. The level of testing would need to be assessed on the basis of the expected variability of the material and proximity of these determinands to WAC limits, but at a minimum would include a sample from each batch or annual production volume.

For both the aforementioned scenarios wastes will be a combination of one off-loads (e.g. construction and demolition wastes), or regular arisings (e.g. inert wastes from the mineral extraction business or manufacturing process).

A key problem faced by the landfill operator is to identify those loads that are contaminated with non-inert material and at what level that contamination is unacceptable; a further complexity is that it is usually not possible to predict when non-compliant loads will arrive at the landfill gate.

### *II. Evaluate existing compositional data*

A historic database may be available for large volume routine wastes, and although this may not be extensive in terms of the constituents tested or types of test applied it could provide a valuable start for assessing key constituents (in terms of WAC compliance) and expected variability. For small volume one-off consignments any data evaluation would need to be carried out on a load-by-load basis, using new data generated immediately prior to excavation / generation.

## *Identify health and safety precautions*

Generic health and safety requirements for each site prevail.

## *Select sampling approach*

### *I. Using a level 3 testing procedure to support a level 2 testing programme*

A thorough and pragmatic level 3 spot-checking programme must support the compliance-testing programme. An example of such a process might be to carry out visual checks on all loads prior to and post deposition. For example, a spot check carried out on loads arriving at the site (ideally with the aid of overhead CCTV after removal of sheeting), will enable suspect loads to be turned away. Reasons for this might include obvious ‘hot-spots’ of unrecognisable material or non-compliance of waste appearance with the Waste Transfer Note. Radio communication between the weighbridge and tipping face would allow confirmation of the material in the load during off-loading for chosen loads (using vehicle registrations). In this way visually unacceptable loads could be reloaded and sent back to the waste producer. Such a policy serves to deter the unscrupulous waste producer from attempting obvious deceit.

Using this approach, rather than sampling for hot-spot loads *per se* (as these are generally rejected) effort can therefore now be focused on testing the quality of the majority of loads that would pass the visual inspection. For example, consider a sub-soil that is contaminated with visually non-detectable contaminants. As recommended in the Guidance (Environment Agency, 2003) this approach can still target suspected non-compliant loads (i.e. targeted worst case sampling) whereby the landfill operator deliberately focuses sampling effort on occasions when he believes the waste has the greatest risk of failing the limit. Note that once a worst-case load has been identified, a sample must be taken that is consistent at the agreed scale; that is, it should be consistent with the scale used to generate any characterisation data. If the agreed scale is ‘one skip full’ then a sample must now be collected that is representative of average conditions within that skip.

Ideally targeting relies on the landfill operator having useful information from the level 1 characterisation (and waste producers must start to gear up to producing such data) about the factors affecting waste quality. However, without such data past experience of that waste can be used to guide testing. In addition, the results of the routine level 3 checks can be used to flag up occasions where a targeted compliance sample could be advantageous. However, there will be many circumstances where the landfill operator has insufficient knowledge about the waste to take a targeted approach - or has good reason to believe that the waste is sufficiently homogeneous over time for leaching test results to be similar whenever the samples are taken. In that case some form of random or representative sampling may be used instead. A convenient option then would be systematic sampling, whereby samples are taken at regular intervals (e.g. one sample every 2 months, or one sample every 40 skips).

### *II. A compliance testing programme*

In principle, compliance may need to be assessed over a period that may be only weeks or which might extend to months. Thus, the more critical the waste (whether on account of the expected concentrations of critical parameters or the quantities arriving at the landfill), the shorter (or condensed where large numbers of loads arrive in a single week) the landfill operator might wish to make the assessment period. For landfills where the high proportion of inputs are non-regular, short time-span wastes, this may mean assigning variable assessment periods to each job. However, where inputs are more regular, for operational simplicity a standard period of one calendar year is recommended as a reasonable default[1].

The Landfill (England and Wales) (Amendment) Regulations (2004) recommend that only a single compliance sample be taken per stream per year. This minimal amount of testing may initially appear to be an attractive cost saving approach and this frequency of testing has been used as a basis for developing the assessment methodology described below. However, to put this level of sampling in the context of the “risk of accepting a non-compliant load” this approach is compared with a 6 sample per year regime. This is the level suggested in recent guidance from the Environment Agency (2002 and 2003), where it is stated that 6 compliance samples should be undertaken per stream, per producer, per year. This approach represents a large amount of testing for the operator, in a low margin business.

The methodology developed in this example Sampling Plan is based on statistically designed look-up tables that can be used to assess the likelihood of failing to reject a non-compliant load. It has been developed as a simple spreadsheet model, called SPOILS (Simulated Performance Of Inert-Load Sampling). With this, the user specifies the 'true' characteristics of up to four input streams, together with the associated sampling regime. The model then calculates the consequences, as measured by the tonnages expected to be accepted and rejected over the course of a year. These could also be interpreted in monetary terms, assuming notional sampling cost and revenue rates.

**The scenarios**

First, we define four distinct types of waste stream that arrive at the landfill. Two of them are relatively low-tonnage one-off loads - one of reliably good quality, the other more doubtful (in relation to the appropriate WAC). The other two are routine streams of much larger tonnage; again, one stream is assumed to be of good quality, and the other less so. (The terms 'good' and 'doubtful' are defined more clearly in the next section.)  In summary:

- ***One-off – good***: low volume (250 t) waste stream of reliably good quality (i.e. expected to meet the inert WAC);

- ***One-off - bad:*** low volume (250 t) waste streams, little information and/or inconsistent in quality, and/or performance with respect to the inert WAC is dubious;

- **Routine – good**: high volume (10000 t) waste stream for which comprehensive characterisation exercise has been completed and data shows waste is not borderline for any determinand with inert WAC.

- **Routine – bad**: high volume (5000 t) waste stream, leaching test data shows erratic excedence for inert WAC.

To cover a variety of different mixes of input streams, we have set up six scenarios - A to F. The stream proportions for these are shown in Table C1. Under Scenario D, for example, roughly equal tonnages arrive via all four streams, whereas in Scenario F all inputs are one-off batches - 80% of which are thought to be 'doubtful'.

**NOTE:**

The concept introduced by this example could be tailored to fit any mix of inputs that are site specific.

**Table C1 - Definition of the six scenarios used in SPOILS**

| Stream | Tonnage | Scenario proportions (% tonnage) | | | | | |
|---|---|---|---|---|---|---|---|
| | Per batch | A | B | C | D | E | F |
| One-off - good | 250 | 5.0 | 0 | 50 | 23 | | 20 |
| One-off - doubtful | 250 | 12.5 | 0 | | 24 | 50 | 80 |
| Routine - good | 10000 | 45.0 | 80 | | 26 | 50 | 0 |
| Routine - doubtful | 5000 | 37.5 | 20 | 50 | 27 | | 0 |
| | | 100.0 | 100 | 100 | 100 | 100 | 100 |

### Detailed inputs

To illustrate the detail behind each scenario, Table C2 shows the input for Scenario A. The shaded cells are the user inputs. Thus, the total annual input is 200,000 tonnes, and this is split between the four streams in the proportions already seen in Table C1. Knowing the assumed tonnages per batch, SPOILS calculates the numbers of batches that will arrive through the year in each of the streams.

For each of the four streams, the user specifies three plausible alternative options for the quantity *'true proportion of the material in the batch that fails to meet the WAC'*. For the 'Routine - good' stream, for example, the three chosen options are that 0%, 2% or 5% of the total material in the batch is non-compliant.

Finally, the user specifies the number of samples to be taken per batch for each stream. Here the number of samples is assumed to be 1 for the (non-regular) consignments, and 6 for the (large) regular routine batches.

**NOTE:**

The example provided in this Sampling Plan serves to demonstrate the dramatic increase in risk of accepting a non-compliant load as the number of compliance checks is reduced. If the operator is accepting wastes where compliance checks are required he will need to assess the potential risks of non-compliance for each consignment of waste accepted at the landfill on a case by case basis and adopt a level of compliance testing that provides an acceptable level of insurance to guard against the acceptance of non-compliant loads. The key to this decision making process is knowledge. The judgement will depend on issues such as:

- professional confidence in the primary or secondary waste producer;
- the source of the waste arising;
- the existence of good quality extensive waste characterisation data;
- the variability of the waste stream; and
- proximity to WAC limits of key variables.

It is easy to see that the risks associated with 10 loads from the demolition of a school building might be very different to those posed from purportedly uncontaminated sub-soil from a plating works, where it is possible that hot-spots have been missed during the site investigation or are mistakenly excavated with uncontaminated material. In this instance the landfill operator should ask the WP for a comprehensive site investigation and require a regular level of compliance checking from the WP. This situation may change if the school is known to contain asbestos or if documentary evidence is provided by the waste producer to show that the expected consignment is not adjacent to any areas of potential pollution.

**Table C2 - Detailed specification of Scenario A**

| **Scenario:** | | **A** | | | | |
|---|---|---|---|---|---|---|
| **Type of batch** | **Tonnage per batch** | **% of total year's input** | **No of batches per year** | **Total annual tonnage** | **Options for '% non-compliant'** | **No of samples/ batch** |
| One-off - good | 250 | 5.0 | 40.0 | 10000 | 0<br>2<br>5 | 1 |
| One-off - doubtful | 250 | 12.5 | 100.0 | 25000 | 0<br>20<br>50 | 1 |
| Routine - good | 10000 | 45.0 | 9.0 | 90000 | 0<br>2<br>5 | 6 |
| Routine - Slightly doubtful | 5000 | 37.5 | 15.0 | 75000 | 0<br>5<br>10 | 6 |

| | |
|---|---|
| Total annual tonnage | 200000 |

| | |
|---|---|
| Assumed income (£/tonne) | 1 |
| Assumed full inert WAC testing costs (£/sample) | 350 |

**Method**

To illustrate the SPOILS method, it is useful to start by looking at Scenario B: this is one of the simpler scenarios as it only involves two streams. For each of the two streams the model explores the consequences of three possible ‘true’ levels of non-compliance. Thus there are 3×3 = 9 total combinations of circumstances, or ‘mini-scenarios’, as listed in Table C3.

From the viewpoint of the operator, the effectiveness of the compliance monitoring is an important issue. In other words, how successful is the monitoring at identifying waste that is truly failing to meet the WAC? This is addressed by SPOILS for each of these nine mini-scenarios in turn. There are two things to determine. The first is the proportion of the incoming waste that truly complies. Note, that if *any* part of the population (i.e. batch or consignment) of waste exceeds its WAC, then the entire population is by definition non-compliant - as indicated in the Environment Agency’s guidance (EA, 2003). This states that any indication of failure during compliance sampling (even where compliant samples have already been tested) means that the entire population is non-compliant. Thus we see from Table C3 that the true overall compliance can be 100% only in the extreme case of B1; it is 80% in cases B2 and B3; 20% in cases B4 and B7; and otherwise 0%.

**Table C3 - The nine combinations covered by Scenario B**

| Stream | % of total input | Assumed % of waste stream non-compliant | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **B1** | **B2** | **B3** | **B4** | **B5** | **B6** | **B7** | **B8** | **B9** |
| Routine - good | 80 | 0 | 0 | 0 | 2 | 2 | 2 | 5 | 5 | 5 |
| Routine - doubtful | 20 | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 |
| | Hence % of tonnage that truly complies: | 100 | 80 | 80 | 20 | 0 | 0 | 20 | 0 | 0 |

Secondly, SPOILS calculates the actual proportion of the total year's waste that will on average be judged to be non-compliant[6]. It is assumed that, on average, the samples are taken at even intervals through the batch. *Thus, a single sample will be taken halfway through the batch, whilst a 6-sample programme will break up the batch into 7 equal parts.* Furthermore, when non-compliance is found SPOILS assumes that:

- all batch material prior to the failing sample will have already been accepted by the landfill (albeit incorrectly), but

- all of the remaining material will be rejected (at a consequent loss of income).

For example, if the fifth of six samples happens to trigger non-compliance, SPOILS assumes that 5/7th of the total batch has already been accepted, and 2/7th will be rejected (with no need for the final sample to be taken).

**Results**

**Compliance performance**

The results for the nine Scenario B combinations listed in Table C3 are plotted in the top right-hand panel of Figure C1. The x-axis plots the tonnage that *truly* meets the WAC, whilst the y-axis plots the tonnage that will *actually* be accepted, on average, by the landfill site. With perfect monitoring, the points would all fall on the 45° "y = x" line. In reality, however, the picture is very different: it is clear that the great majority of the tonnage will be accepted by the operator, even in cases when the true proportion of compliant tonnage is only 20%, *or even zero*. This is a direct consequence of the small sample numbers used for the compliance assessment.

SPOILS evaluates the other scenarios in just the same way. Note however, that there are rather more than nine mini-scenarios to be considered in Scenarios A and D, in which waste is assumed to arrive in all four streams. For each of these streams there are three possible options for the true percentage of non-compliant material, and so this gives a total of $3\times3\times3\times3$

[6] From binomial sampling theory, the probability of non-compliance for each batch in each stream depends on (a) the number of samples to be taken per batch, and (b) the true proportion of the batch that is unsatisfactory.

= 81 combinations.  For all six scenarios, however, Figure C1 shows a broadly similar picture: the proportion of non-compliant waste that actually gets detected and rejected is very small.

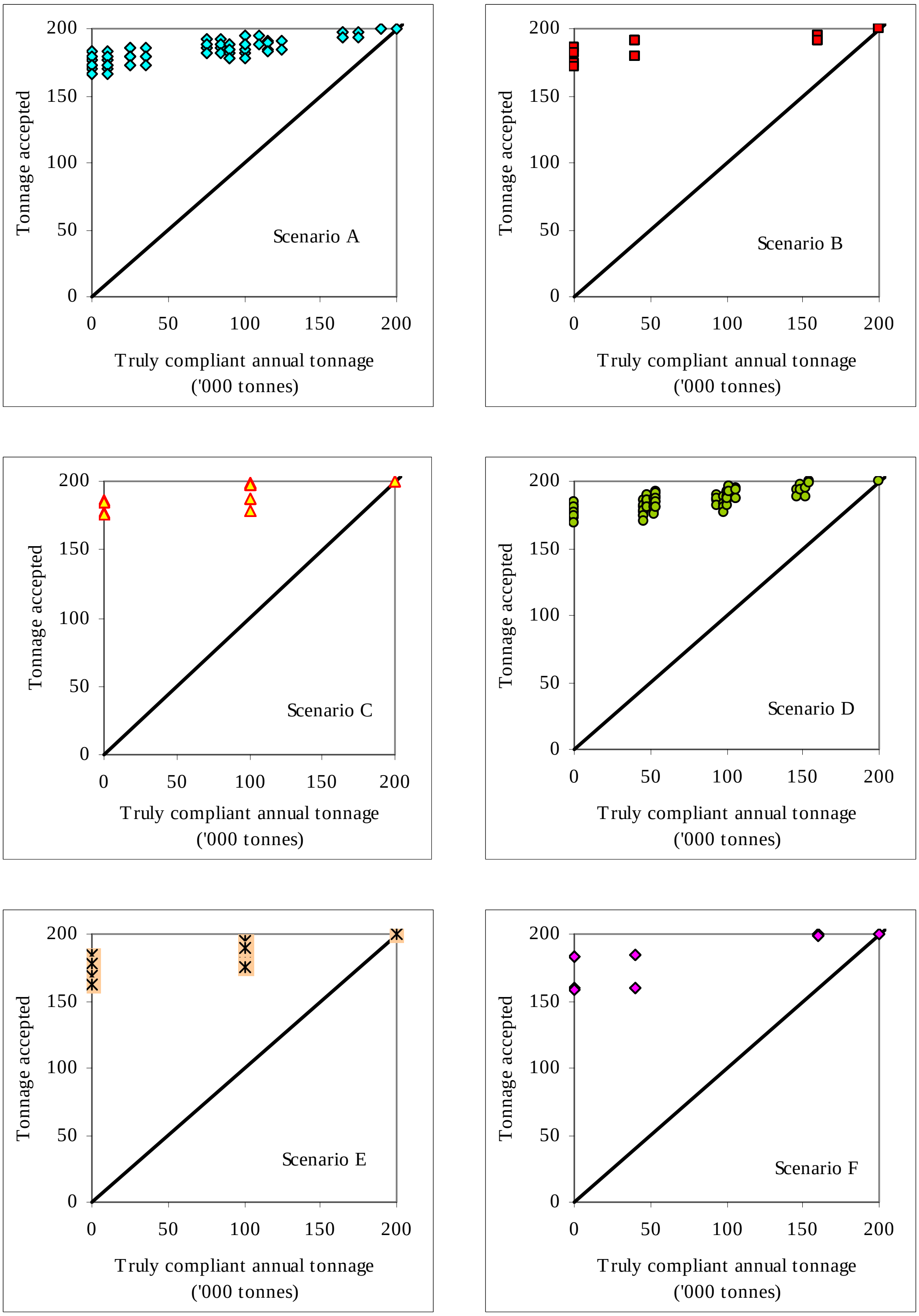


**Figure C1 - SPOILS compliance results for the six scenarios**

The six plots in Figure C1 have been combined into one grand plot in Figure C2. This reinforces the general message that the low non-compliance detection rate is much more to do with low sample numbers than the precise characteristics of the waste streams arriving at the landfill.

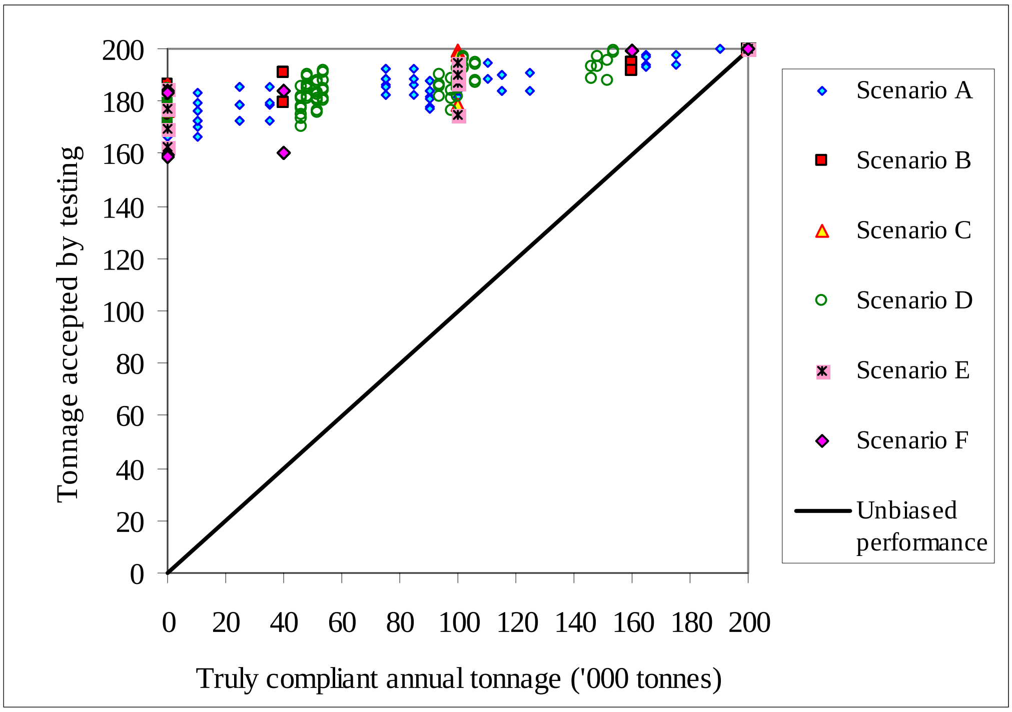


**Figure C2 - Overall compliance results from SPOILS**

**Cost implications**

From the landfill operator's standpoint, the compliance considerations discussed above are probably less important than the cost implications. SPOILS gives some insight into the profitability of each scenario by using the notional figures shown in Table C2 - i.e. a revenue of £1/tonne on average and testing costs of £350 per sample (for full inert WAC testing including trace organic compounds). The results are summarised in Figure C3. The y-axis plots marginal profit (i.e. revenue less sampling cost) for the various combinations within each of the six scenarios. Thus we see that the most profitable scenario is B (routine stream, 80% 'good' 20% 'doubtful'), with the marginal profit ranging between £125K - £150K according to the true amounts of non-compliant material in the four streams. Conversely Scenario F (one-off streams, 20% 'good', 80% 'doubtful') is makes a typical loss of around £100K.

The profitability is extremely sensitive to the compliance sampling frequency: the greater this is, the higher the cost *and* the lower the likely income (because the detection rate of non-compliant material will increase). To demonstrate this, we have re-run SPOILS assuming that one-off batches are sampled not once but six times. Figure C4 shows the dramatic effect this has on the scenarios. Now only Scenario A is profitable, whilst Scenario F in particular goes seriously into the red.

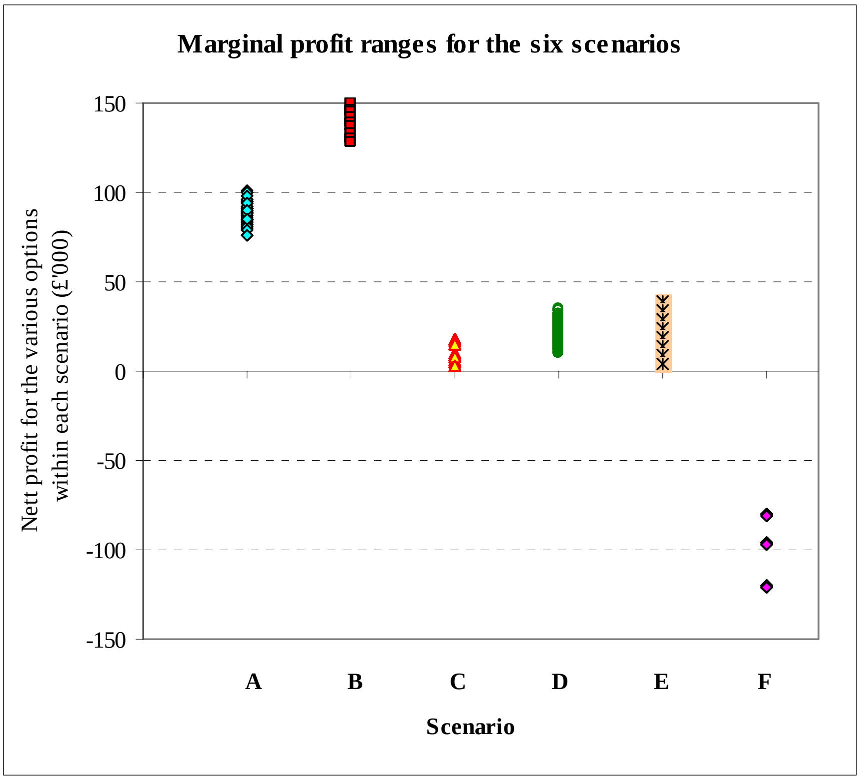


**Figure C3 - Cost implications - one-off batches sampled just once**

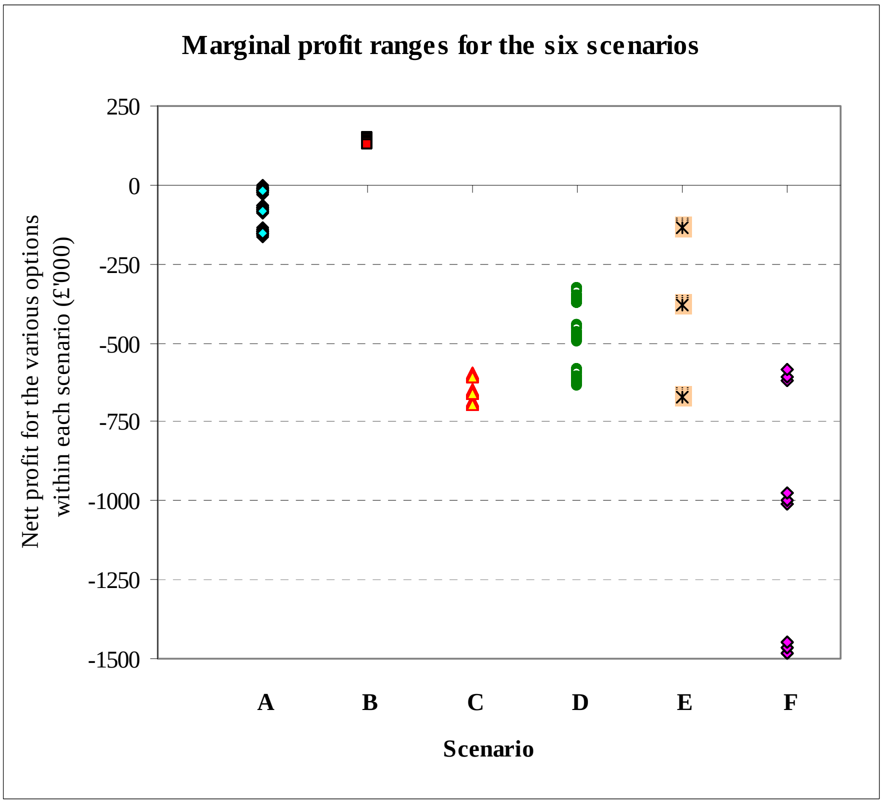


**Figure C4 - Cost implications - one-off batches sampled six times**

At the ‘inert’ end of waste disposal, some waste producers have often undertaken rapid site excavation and waste haulage at low profit margins and have traditionally had access to low cost landfill disposal. In some cases wastes that would have traditionally been classed as ‘inert’ would now require disposal at sites for non-hazardous wastes. The operator of an inert landfill is therefore faced with the dual challenge of ensuring he gets adequate characterisation data from such waste producers in order to have confidence that he is accepting WAC-compliant loads and the need to make regular compliance checks which carry the risk of breaches of permit conditions should any of the parameters exceed the limit values.

It is likely that the acceptance of small loads of non-routine waste streams with an appreciable risk of non-compliance will be of marginal profitability after the introduction of the inert WAC.

The operator of an inert waste landfill will wish to increase the proportion of single-stream single-source listed inert wastes that are exempt from testing. In addition he may also accept regularly arising wastes that are consistently below the WAC. He will therefore seek contracts with proactive waste producers who can provide characterisation data that demonstrate this.

## REFERENCES

CEN 2004. prEN 14899 Characterisation of Waste - Sampling of waste materials: Framework for the preparation and application of a Sampling Plan. CEN TC292/WG1.

Environment Agency (2002). Guidance on National Interim Waste Acceptance Procedures, Interim Waste Acceptance Procedures Version 1.2, External Consultation Draft 160802

EC Council Decision 2003/33/EC of 3rd January 2003 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 and Annex II of Directive 1999/31/EEC on the landfill of waste. Official Journal of the European Communities L11 16.1.2003. (http://europa.eu.int/eurlex/en/dat/2003/1 011/120030116en00270049.pdf).

Environment Agency (2003). Guidance on sampling and testing of waste to meet waste acceptance procedures v4.3 December 2003, draft for external consultation. Environment Agency 2003.

The Landfill (England and Wales) (Amendment) Regulations 2004. Statutory Instrument No. 1375.