THE SOIL AND GROUNDWATER TECHNOLOGY ASSOCIATION

SAGTA REPORT 34 - MAKING EFFECTIVE USE OF STATISTICS IN SITE INVESTIGATION AND MANAGEMENT

Introduction

SAGTA's December 2007 Workshop returned to a theme drawn from a range of previous Workshops over recent years. As a member of DEFRA's Soil Guideline Task Force and the Contaminated Land Forum, SAGTA has been vigorous in actively supporting and part funding related initiatives covering the development of guidance on statistical techniques for assessing land contamination.

This workshop drew together and considered these and other developments in approaches as a basis for reviewing current practice. In developing the day, SAGTA's thoughts developed around the following topics:

- Why do we need statistics?
- Where does statistics make the biggest impact?
- How are they applied?
- What does the output mean?
- Does it make a difference to decisions?

A range of skills are required in the management of contaminated land and it is considered that the level of statistical literacy in contaminated land professionals is mixed. In particular, there is a lack of understanding of the application of CLR 7.

Way Forward – Opportunities / Areas where SAGTA can contribute

Reference was made during the workshop to the development of a "*Decision Support Tool*", the key elements of which are the scope of such a tool, the likely content and the timing of development. Key issues to develop are:

- Nature and scope of outputs
    - How to express how uncertainty will be allowed for.
    - Defining to what extent uncertainty will be allowed?

SAGTA should consider how to interact / support.

The application and use of Field Analytical tools (FATs) and the need to ensure the status of FATs' in investigation is defined and publicised was raised. Experience indicates a need to capture data immediately. The trialling of FATs as collaborative exercise was suggested as a way forward. It was noted that a crucial aspect is one of ensuring the key issues behind uncertainties are not ignored and/or passed over e.g. sample preparation.

A spreadsheet was proposed as a support tool to complement the statistics guidance document. SAGTA should identify areas of the contaminated land community who would be prepared to support. The need for related training and support information should also be considered. The development of a "Bigger Picture" framework into which such tools fit:

- Use a repository i.e. audit trail function (and presentational tool) of data management?
- Potential for interactions with geospatial tools and applications.
- Tie spreadsheet into spatial demonstration of results as part of a larger approach.
- Possible interactions from Workshop topics (e.g. Data Quality Objectives).

Access is needed to real site examples as the basis of illustrative case studies to demonstrate approaches taken with guidance.

Summary of Workshop Presentations

Statistical Theory – An Introduction
The day began with a presentation on statistical theory to set the scene. The presentation provided attendees with an introduction to statistical concepts and with terms that would be used during the day. As in other areas of business, data collected during the management of contaminated land is inevitably subject to variability - the two main sources of variability being variation in contaminant levels across a site and measurement error. The concept of uncertainty, including the ways in which we can measure it, were discussed.

Guidance Initiatives -Triad and England and Wales
The Triad approach is made up of three elements: Systematic Project Planning; Dynamic Work Strategies and Real Time Measurements. In order for this approach to work in the UK it needs the expertise to carry it out, stakeholders (including regulators) to understand the process and buy into it and the commitment to spend money up front. In the Systematic Project Planning stage the Data Quality Objectives are defined through a seven stage process, which begins with stating the problem and works towards optimising the design for obtaining data. Through this planning stage the conceptual site model is developed and refined and a sampling and analytical plan is generated. The Dynamic Work Plan involves taking the sampling and analytical plan and working dynamically, making real time decisions in the field to limit the number of mobilisations. In order to achieve this, Real Time Measurement technologies are employed to meet the Data Quality Objectives.

In the UK we have a number of tools to ensure confidence in decision making, including CLR 11 and MCERTS. CLR11 does not preclude the use of rapid measurement techniques and these techniques could be used in risk assessment, options appraisal and the implementation of remedial options stages. The MCERTS policy has also been modified recently to acknowledge that rapid measurement techniques are not precluded. However, it is important that you (and the person assessing your work) understand what the results are telling you and what the method limitations are and also that standard operating procedures and QA/QC are used to increase confidence in the results.

In conclusion, the Agency supports development and use of on site testing and believes it can be useful at many stages of the risk management process and can lead to time and cost savings and increased confidence. It is important that every step in the process is justified with reference to the Conceptual Site Model.

Way Forward Statistics Guidance Note
An update was given on the production of the Way Forward Statistics Guidance Note and some background to why the Guidance Note is being developed. At a CL:AIRE workshop in March 2006 it was identified that the current guidance on statistics is fragmented; CLR7 is misunderstood/abused and covers only one of the key questions and that statistics is seen as being 'too hard'. A working group was set up which was funded by SAGTA and DEFRA and administered by CL:AIRE.

The aim of the production of the Guidance Note was to:

- Introduce a structured process with signposts to existing guidance;
- Explain scientific basis for testing, including relevant statistical conventions;
- Encourage appropriate scrutiny and treatment of the data; and
- Ensure appropriate [statistical] questions are posed for particular legal context so correct references are drawn.

The guidance Note will include an introduction to basic statistical principles, key aspects of designing sampling strategies, reviewing and creating appropriate data sets and the procedures for the application of statistical tests. The final draft was submitted in April 2007 and was peer reviewed by SAGTA members, regulators and others such as EIC. Following this peer review a number of changes were made, including the title which is now '*Guidance Note on Comparing Land Contamination Data with a Critical Concentration*'. Publication details are now being finalised, but it will not be a DEFRA publication but may be published via CIEH or CL:AIRE. There is also consensus for the need for a spreadsheet tool to accompany the Guidance Note.

Effective site sampling – case study experiences

This presentation outlined two case studies demonstrating the use of statistics. The objective was to explain how techniques can be applied to routine site investigations and to show that statistical techniques can be useful in judging the effectiveness of sampling and analysis and for evaluating on site measurements.

Samples taken from a contaminated site are never wholly representative of the true concentration of the contaminant and will always be wrong to some extent. We can, however, allow for this by estimating the uncertainty of the measurements (from both sampling and analysis). Measurement uncertainty is 'an estimate attached to a test result which characterises the range of values within which the true value is asserted to lie' (ISO, 1993). It is generated by measurement error from the sampling, sample preparation and analysis and can have both systematic and random components. Sampling error is partially due to the heterogeneous nature of the contaminant distribution in soil and is therefore impossible to remove completely.

This measurement uncertainty can lead to false negative and false positives when classifying sites as contaminated or uncontaminated. The random error component is estimated from the precision of a measurement method and expresses how repeatable measurements are. There are a number of different methods for estimating precision. The duplicate method involves taking duplicate samples displaced from the original sampling location by a distance that represents the uncertainty of locating the original sample target. Duplicate analyses are then carried out on these samples to produce estimates of the analytical precision. Analysis of variance (ANOVA) is then applied to the data to estimate and separate the sampling and analytical components of the measurement variance. The systematic error component is estimated from the bias of a method and is usually estimated using certified reference materials.

The first case study involved a former landfill in West London where it was suspected that the topsoil was contaminated with lead. A regular sampling grid was used and 100 samples were taken, with 10 duplicate samples taken 3m from the original. Analytical duplicates were undertaken on the duplicate samples. A review of the data showed good agreement between the analytical duplicates but not between the sampling duplicates, indicating that this was a very heterogeneous site. Only 16 out of 100 samples were above the Soil Guideline Value for lead, with 84% being uncontaminated. However, when the uncertainty is taken into account at least 41% of the locations are at least 'possibly contaminated'.

The second case study was of a former works tip containing unknown materials, which had been dumped in three phases. The suspected high spatial heterogeneity made this an ideal opportunity to evaluate low cost field tools as a means of employing a more dense sampling strategy at the site. The primary objective of the investigative works was to demonstrate the applicability and measurement uncertainty associated with field tools, including Field Portable X-Ray Fluorescence (XRF) and UV-Fluorescence (UVF). A proportion of samples were also sent for laboratory analysis. Preliminary results indicated that the most elevated concentrations were identified in Phase B material, while Phase A was found to be a sandy clay fill from building works and Phase C was made up of demolition rubble. The duplicate method was used to estimate the precision of the laboratory analysis and XRF results, which showed an unacceptable degree of uncertainty on the laboratory analysis.

A Statistical Approach to SPOSH – Why Pictures Matter

This presentation covered various case studies from a local authority and the application of statistics to real data. In particular, a brickworks site was discussed which had been developed in 1981 and now has 450 houses on the site. The site was inspected in 2003 by the local authority and was identified as being of low risk (number 61 on their priority list). The site was subsequently identified for further inspection for a number of reasons, including the fact that a large number of property sales were being jeopardised due to the potential presence of contamination. As a result of this inspection the site was re-ranked as number 43 in the Council's prioritisation system, but no further inspection was felt appropriate at the time. To aid the sale of properties a subsidised self inspection scheme was implemented. Ten such inspections were carried out by home owners and one identified the presence of extensive elevated total PAH. Further detailed review of records identified evidence of localised ash and clinker and local knowledge also indicated that fuel was converted to oil at the site in the 1960s.

A conceptual site model was refined and the site was split into 3 zones. A phase I investigation of the highest risk zone was carried out, which confirmed the revised conceptual model. A statistically based phase II investigation was then carried out to assess the significance of the pollutant linkages. Sample locations were randomly placed using sophisticated GIS techniques to allow the application of meaningful statistics. The outcome of the assessment was the conclusion that the contamination did not pose significant possibility of significant harm (SPOSH).

A number of lessons were learned from the case studies including that information and tools to help make defendable decisions, while moderately expensive, are worth investing in. The tools required to aid decision making are spatial handling (such as Visual Sampling Plan), good statistics and data/process management. The case study also highlights the importance of zoning sites.

Use of Visual Sampling Plan in the Waste Clearance Process
The aim of this presentation was to introduce the USEPA's DQO (Data Quality Objectives) Process and to describe how its principles to characterise construction and demolition waste are applied and can support confident decisions about how it should be handled. The process ensures that a consistent amount of planning and thought occurs before any sampling or analysis takes place. The final sampling strategy is derived from a thorough understanding of the sampling area and potential contaminants and the sampling plan itself is statistically based, and therefore defensible.

A recent example was given which involved the demolition of a number of buildings in a compound which had been built in the same year and had been used as workshops and office facilities. A number of buildings in the area had previously been demolished in 2005 and sampling and analysis had been undertaken at the time. The assessment of the original buildings showed lead and paint in the walls and TPH contamination on the floor surface, but no contamination below 20mm depth. The history of the buildings was very similar, and it was assumed that the principal contaminants would be the same, but others (i.e. PCBs, radioactive material, and VOCs) could also be present. The seven steps of DQO were run through as follows:

Step 1: *State the Problem* - Details of the information we have, and what it means e.g. Scope of work; Legislation and best practice requirements; summary of existing data; scientific justification for including / excluding any contaminants; Summary of conceptual site model.

Step 2: Identify the Decisions - A summary of all relevant decisions i.e. "*Determine whether the waste is suitable to be reused / recycled on-site or if it needs to be disposed of at landfill*."

Step 3: *Identify Inputs* - What data is required, data quality (i.e. accuracy / precision) and a discussion of available measurement techniques. For this particular example the lead and zinc contamination in the brick wall sample can be determined in a laboratory using ICP OES or in the field using a portable XRF. The pros and cons of both methods were assessed e.g. could the less accurate, but cheaper, method of XRF be used to satisfy regulators?

Step 4: *Specify Boundaries* - Is the contamination likely to be homogenous throughout the building / area or can it be divided into zones? For the building in question it was sensible to separate the top 2mm of wall surface from the remaining brick, and the top 20mm of floor surface from the remaining concrete. The external walls and roofs were also considered as a separate zone as the most likely source of contamination on these surfaces was radioactivity from stack discharges.

Step 5: Define Decision Rules - What 'action' levels / limits are we looking to meet to make a decision on how the waste is disposed. For example, the waste must be shown to contain < 0.4 Bq/g artificial activity to meet the Radioactive Substances Act 1993, Substances of Low Activity Exemption Order criteria for free release from a nuclear licensed site.

Step 6: *Specify Error Tolerances* - What level of risk is the managing director or contracting company willing to take that the decision they're making is wrong. There are 2 types of error: e.g. incorrectly sentencing waste as non-hazardous when in reality it's hazardous (this is the ALPHA error) and incorrectly sentencing the waste as hazardous when in reality it is non-hazardous (this is the BETA error). These risks would be assessed and made a corporate decision made as to allow a 5% alpha error and a 10% beta error.

Step 7: Optimising Sample Design – Part of this step is about identifying the most appropriate statistic for your project. Several factors need to be considered, for example do you expect your data to be normally distributed? Are you looking for a trend to prove something, or just to compare an average value? To ensure you are applying the correct statistic you should consult a statistician. In this example we are looking to compare an average contaminant value with an action limit. The data is environmental, and is more likely to be log-normal than normal. So the conclusion was that the most suitable statistic and one of the most conservative was MARSSIM (Multi Agency Radiation Survey and Site Investigation Manual).

A decision needs to be made as to whether the existing data (detailed in step 1) is a suitable representation of what is likely to be found in the area currently being assessed. If so, this data can be used to provide a standard deviation, which can in turn be used to estimate the '*lower bound of the grey region'* (LBGR), which is the concentration at which, the waste can be declared non-hazardous to 95% probability. If not, the LBGR must be calculated. This can be calculated in three ways: Calculating the sum of the analytical and sampling error (one standard deviation of existing data); using the MARSSIM statistic, which suggests the LBGR be set at 50% of the Action level (this is a very conservative estimate) or using the Frequency Distribution Method. This is the most accurate method, but can only be used if existing data is suitable. In this example the LBGR was calculated in different ways for each of the zones. Where there was confidence that the existing data was reasonably representative of what was likely to be found in the building one standard deviation was used. Where there was no existing data, the MARSSIM approach was used. The final numbers are fed into a statistical software package, which generates a sampling plan.

Case Study Application of GIS and Decision Analysis Tools for Design and Implementation of Remediation Requirements for Future Land Use Options

The uncertainty with respect to the exposure characteristics of future land use options can produce unrealistic multiplication of safety factors and, therefore, increase clean up costs. There is an important difference between the implementation of a clean-up level as a '*not to exceed'* level or as an average area. The average area approach may be appropriate when there is adequate data coverage and the exposure units are well defined. The '*not to exceed'* level would be appropriate in situations where, for example, the exposure is non random or acute exposure is an issue. It is therefore important to understand the exposure domain definition i.e. the area over which a receptor may be exposed to a contaminant during the exposure duration.

A spatial statistical method for implementing clean up levels as area averages was described. Following the spatial plotting and block kriging of sample results for each chemical at a site, the OGES (Optimised Grid Excavation Simulation) software can be used to place a user defined exposure domain in random locations and orientation within the boundaries of a site. The OGES tool then calculates the 95UCL of all chemicals for all randomly located exposure domains and identifies and extracts areas driving exceedances until all chemicals are below the clean up criteria. Risk is not driven by isolated point values, but the average exposure over an extended time period. This allows the user to address the uncertainty in location, size and orientation of future exposure domains, pinpointing the nature, extent and sensitivity of risk drivers.

Excavation cutlines are then established by undertaking focused sampling in targeted areas. Once this data has been received the model is re-run to verify targeted areas and make excavation cutlines. Data is put back into the model following confirmation sampling to verify conditions are protective after excavation. The methodology reduces uncertainty and provides valid estimates for remediation requirements, which in turn can be used to evaluate the cost, feasibility and identify gaps to reduce unacceptable uncertainty.