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Food and Agriculture Organization of the United Nations

FAO Pesticide Disposal Series

17

Environmental Management Tool Kit for Obsolete Pesticides

Volume 5

O. Pesticide contaminated site identification and prioritization

P. Preliminary risk assessment and design of the detailed site investigation

Q. Data analysis and generic quantitative risk assessment

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Foreword

Within the remit of reducing world hunger FAO has been extensively involved with pests and pesticides management. Based on the experience gained over the past 20 years FAO has developed a series of tools which allow a risk-based approach to dealing with obsolete pesticide stocks considering the potential impact on both public health and the wider environment. This has led to the development and publication of the Environmental Management Tool Kit Series, (Annex 1). The methodologies presented in these tools have been developed to provide a sound technical baseline for implementation of pesticide inventory, obsolete stock site prioritization and safeguarding projects in developing and developed countries in many regions across the globe. They have a solid foundation in international regulations from the US and Europe and so can be considered as complying with international best practice for worker and environmental safety.

Despite the implementation of projects resulting in the removal of the above ground stocks, pesticide legacy problems persist that affect the ground beneath the sites and the groundwater passing through it. In many cases the ground at these sites presents a greater risk to human health and the wider environment than the original pesticide stockpiles which are often sent for environmentally sound disposal. To assess the particular risks posed land contaminated by pesticide, FAO has developed a fifth tool in the EMTK series, the EMTK 5. The conclusions drawn from using EMTK 5 enable the development of a national contaminated land risk management plan and site level risk reduction strategies which together form the Environmental Management Plan. Development of the Environmental Management Plan is examined further under EMTK 6.

Acknowledgements

The EMTK series has been designed to help countries address the complex challenges from hazardous waste based on the adaptation of international best practice in chemicals risk management. FAO would like to express their sincere thanks to Dr Kevin Helps (formerly Senior Pesticide Management Officer in the FAO Pesticide Risk Reduction Group) for his vision in developing the EMTK series. For EMTK 5 (and 6) this vision was put into practice thanks to the efforts of a team of technical specialists under the management of Mr Russell Cobban (consultant). A special mention goes to Dr John Keith (Pure Earth) for his technical support, Dr Paul Nathanail (Land quality expert, University of Nottingham), Dr Eva Kohlshmid (Land and Pesticides expert, FAO Consultant) and Mr Bram de Borst (consultant) for providing invaluable peer review of the finalized materials. Furthermore, development and publishing of the documents was funded by the Global Environment Facility (GEF) to which the development team are indebted.

Acronyms

ADI	Acceptable daily intake
BGS	British geological society
COC	Chain of custody
CSM	Conceptual site model
DQRA	Detailed quantitative risk assessment
DSI	Detailed site investigation
EA	Environmental assessment
EMP	Environmental management plan
EMTK	Environmental management tool kit
FAO	Food and Agriculture Organization of the United Nations
GAC	Generic assessment criterion
GLP	Good laboratory practise
GPS	Global positioning system
GQRA	Generic quantitative risk assessment
HSE	Health, safety and environment
LOD	Limit of detection
MDL	Method detection limit
PMU	Project management unit
POPs	Persistent organic pollutants
PPE	Personal protective equipment
PRA	Preliminary risk assessment
PSI	Preliminary site investigation
PSMS	Pesticide stock management system
PQL	Practical quantification limit
REA	Rapid environmental assessment
SRS	Simple random sampling
SSAC	Site specific assessment criterion
TDI	Tolerable daily intake
UN	United Nations
UNEP	United Nations Environment Programme
USGS	United States geological society
VOC	Volatile organic carbons
WHO	World Health Organization

Introducing EMTK 5

Background

Pesticide contamination of soil and water can arise as a result of the production, distribution, storage, use, spillage and disposal of pesticides. People or animals that come into contact with pesticide contamination can suffer harm. A risk-based approach to managing such contamination seeks to protect people and animals rather than seeking to recover or destroy all pesticide whether or not it is able to cause harm.

The series of tools contained within EMTK 5 are designed to lead users through the contaminated land risk assessment process for sites contaminated with pesticides. There are already a number of guidance documents available that are applicable to more general contaminated land risk assessment, most notably the US EPA[1] system, the Dutch RIVM[2] system and the UK Model Procedures.[3] However, these documents are specific to the people and land in these countries and are designed to be implemented within national policy frameworks and legal systems. The FAO system is based on key principles of risk based contaminated land assessment and has been adapted to emphasize the use of minimal resources. It is intended to be applicable anywhere where FAO funds projects on assessing and remediating pesticide contamination of soil and water.

Resources for most projects are limited however detailed risk assessment and risk reduction need only be carried out for a handful of high priority sites in any country or region. Risk assessment involves defining the level of risk at each site in a series of stages or tiers, where similar tasks are carried out at increasing levels of detail. At each stage of the FAO process, enough information is collected so that assessors can decide whether the level of risk necessitates proceeding to the next tier; only those sites that require further investigation will go further, ultimately justifying whether there is a requirement for risk management. The threshold for the number of sites proceeding from one stage to the next (i.e. through prioritisation, progressively more detailed site investigations to physical risk management measures) is project specific and largely determined by the resources allocated for each country or region at any given time. At the project development stage, the objectives of contaminated land risk assessment and risk management should be clearly set out, including an indication of the number of sites to be investigated at each stage.

Objectives

The principal objectives of this guideline are:

- to provide users with the background, tools and supporting information to identify, prioritize and conduct risk-based assessments of sites contaminated with pesticide;
- to provide guidance that helps focus resources only on activities and sites where the risks are shown to require intervention;
- to ensure that the risk assessment activities are scientifically robust and are carried out according to international best practice and relevant standards and conventions;
- to indicate where capacity building is possible and where external support would be beneficial for member countries.

[1] United States Environmental Protection Agency.

[2] Netherlands Ministry of Infrastructure and Water Management, 2003.

[3] UK Environment Agency, 2004.

Outputs

The principal output of EMTK 5 is a detailed risk assessment and accompanying statement determining whether risk management of a contaminated site is required. The risk assessment report will also summarize the type, quantity and location of contamination and the physical pathways and routes through which exposure is occurring to receptors.

Audience

EMTK volume 5 has been developed for people involved with the planning and execution of risk assessment and risk reduction of pesticide contaminated sites. These include:

- **officers of the Ministries of Agriculture, Environment, Spatial Planning and Health** to support them in the development of objective strategies for the identification, risk assessment and risk management of pesticide contaminated sites;
- **country project managers, project coordinators and PMUs** in charge of the national obsolete pesticide programmes to help them devise and develop Environmental Management Plans for contaminated site risk reduction;
- **individuals and groups within the private sector** who may be seeking to provide services in support of risk assessment and risk management projects;
- **key decision-makers** within government who need final recommendations for budgetary and policy decisions;
- **technicians** involved with the design and implementation of risk assessments.

Presentation

The EMTK 5 consists of the following tools:

Tool O (Site identification and prioritization)
Tool P (Preliminary risk assessment and detailed site investigation design)
Tool Q (Data analysis and generic quantitative risk assessment)

Tool O (Site identification and prioritization) gives guidance on how pesticide contaminated sites can be identified, where records of contaminated sites may be held and how unknown sites maybe located. The tool also provides practical instructions for the prioritization of contaminated sites using the Rapid Environmental Assessment (REA) procedure. The FAO REA system gives a relative prioritization of potentially contaminated sites, those sites that have a higher priority are of higher risk and are therefore more in need of risk assessment and potential risk management and should be dealt with first. This means that resources for projects are committed to those sites that pose the highest risk. The main output of Tool O is a report detailing the prioritization and the reasons for it.

Tool P (Preliminary risk assessment and detailed site investigation design) describes how to conduct a preliminary risk assessment (PRA) by using the source – pathway – receptor approach and the development of a conceptual site model (CSM). The tool then guides users through the steps necessary to design a detailed site investigation for implementation in the field.

The preliminary risk assessment (PRA) of high priority sites is based on a preliminary CSM showing whether sources, pathways and receptors are present. During the PRA contaminant concentrations comparisons can be compared with generic assessment criteria (GAC) to estimate the level of risk however qualitative assessments are more common. Due to the more limited amount of information collected at this stage there is significant uncertainty and scope for wrong decision making. For this reason, assessors err on the side of caution and consider the worst-case scenario: if there is evidence that a risk is present the assessment should proceed to the next stage.

The PRA is based on the basic data from the REA, with additional desk study and site visit by an expert in contaminated land where a limited number of additional soil or water samples may be taken. The preliminary site investigation (PSI) should also generate enough information to

allow the design of the more in depth detailed site investigation that is required for a generic quantitative risk assessment (GQRA).

In countries where there are many contaminated sites all three stages of risk assessment will be required. In countries where there are fewer sites the REA may not be required or could be combined with the PRA stage. This will reduce both the resources required and the necessity for repeated site visits.

Tool Q (Data analysis and generic quantitative risk assessment) details how to check and arrange the data collected from the Detailed Site Investigation into sets relevant to the conceptual site model. It also shows how to derive levels of contamination representative of the site in question for comparison against GAC. The tool also considers factors critical to conducting the generic quantitative risk assessment (GQRA) so that decisions about proceeding to detailed quantitative risk assessment (DQRA) or risk management can be made.

For most pesticide contaminated sites, the GQRA will be the main risk assessment of the site. The significant difference between the preliminary qualitative assessment and quantitative assessment is that the representative concentrations of contaminants are based on the detailed site investigation which provides much more data and data with a much higher level of confidence. At the GQRA stage there should also be enough data to allow investigators to assess the magnitude of the hazard i.e. is there a large or small quantity of contaminated soil and how contaminated is the soil? By further examination of the pathways and pollutant linkages between the source and receptors, assessors will be able to evaluate whether the contamination encountered at the site poses a significant level of risk to receptors and therefore whether some form of risk management will be necessary.

DQRA involves the use of specialist testing (e.g. bioavailability) and modelling to derive site specific assessment criteria (SSAC) to estimate the level of risk, requiring high levels of external support and the use of experts and expenditure. For FAO projects the level of investigation by DQRA is not normally considered and will not be considered in this guideline.

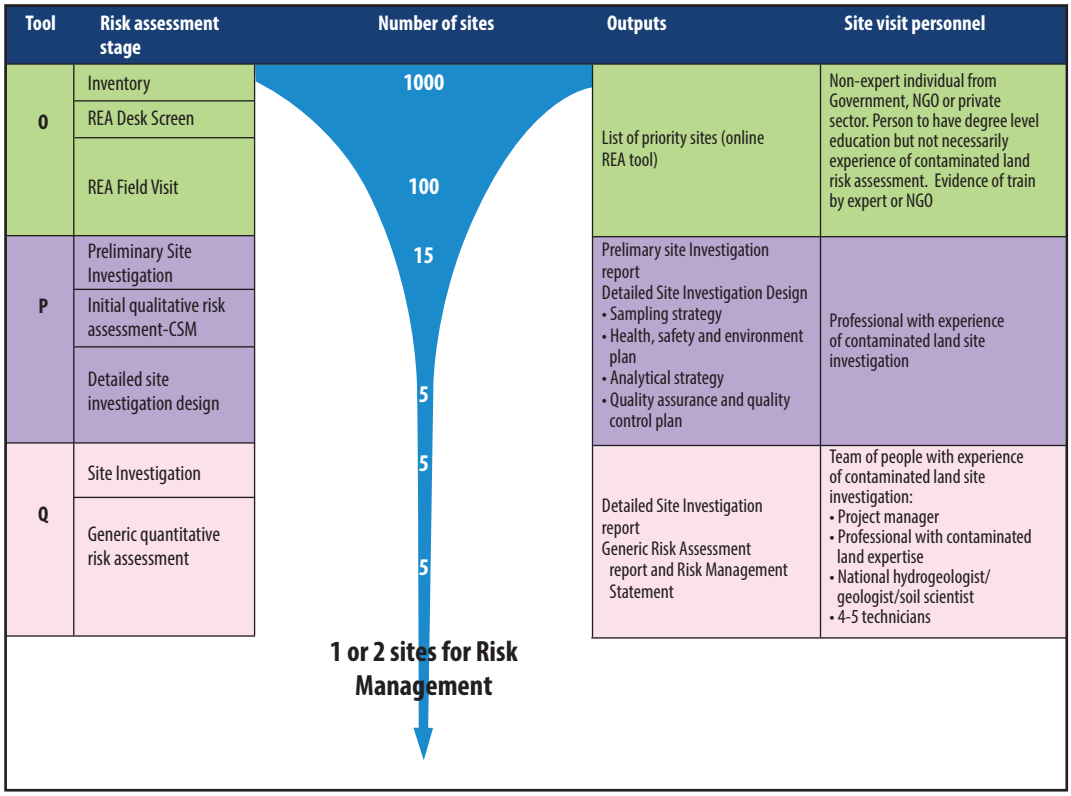
An important aspect of the FAO process is that the staged investigation system allows for the prioritization of sites from one to the next; only those sites determined to be of a higher priority will proceed to the next phase of assessment and potentially to risk management. It is important to realise that:

(i) under most circumstances detailed site investigations cannot be carried out for every site and while the level of detail provided by preliminary risk assessment or the REA alone is not enough as a basis for decisions to be made about risk management;

(ii) at the early stage of the REA, low priority sites cannot be defined as without risk, particularly if there has not been sufficient investigation. It should be acknowledged that these sites should be investigated further at some later stage when resources become available, either directly through government or via some other source, perhaps before development of the land.

Note on document navigation (word users): To navigate between hyperlinks – "Control click" will take you to the next location. To return to your original location, press the "Alt-left arrow" keys.

FIGURE BG1



Principles of contaminated land investigation

BOX 1
Source Pathway and Receptor Definitions

Source-the origin of the potential contamination
Pathway-routes between potential sources and receptors:

- physical migration pathways that carry contaminants between the source and receptors;
- routes through which contaminants can enter the body (ingestion, inhalation, dermal).

Receptor-An entity (something) that could be adversely affected by the contamination

In terms of contaminated land, the principal objectives of a risk assessment are to determine what the risks are from a potentially contaminated area, if any, and whether these risks are acceptable or not. A risk assessment is important not only for the characterisation of the nature of contamination (the hazard) including investigation of the amount, concentration and extent of contamination but also to judge whether the chemicals involved are able to cause harm to human beings and the wider environment.

The basic premise of the FAO risk assessment process, in common with international best practice, is that it is 'risk based' and directly related to the source-pathway-receptor model. For a site to present a risk there must be at least one source of pesticide release to the environment; a pathway for the pesticides to be carried to receptors; and receptors – people or animals – that are exposed to the pesticide to an extent and duration that harm may result (Box 1). In the absence of one of these elements there is deemed to be limited or no risk. These **source-pathway-receptor** combinations are known as "pollutant linkages".

Figure 1
Source-Pathway-Receptor model

The conceptual site model (CSM) underpins both the risk assessment and risk management processes. To formulate the CSM the site is described using the source-pathway-receptor approach. Information about the source, pathway and receptor and anything else that could be used to better describe the environmental conditions is added to the CSM to improve its accuracy. The development of the CSM is an iterative process where information is continually added to provide the most up to date understanding of the site and the possible mechanisms of contaminant distribution.[4,5] To begin with the CSM may be nothing more than a basic sketch (see Figure A3:2) of the site showing the location of sources and receptors and indications of any pathways that may link them (to form pollutant linkages). As the assessment continues, the CSM is continually built up and can become much more complex. Several formats including plans, cross sections or network diagrams may be needed to communicate the information. The CSM may be displayed on paper or as computer models.

An underlying principle of the risk assessment process is to understand whether the 'dose' of a pesticide that people (or animals) are receiving, or could potentially receive, from contaminated materials could cause damaging health effects. "Dose" is a function of the quantity, concentration, time-period and toxicity of the pollutant to which a receptor is exposed. A key objective in the risk assessment process is to gain an understanding of these four "dose" parameters. This is usually completed by chemical analysis of media suspected to be contaminated to determine the type and level of contamination and to enable a comparison with relevant GAC. The amount of contaminant entering a person by the ingestion, inhalation or dermal pathway will depend on factors such as natural degradation, dilution and sorption of the contaminant on to soil. By understanding the total dose that receptors are receiving and how it is occurring and the inherent risks that result, steps can then be taken to manage or reduce these risks.

Capacity building for contaminated land risk assessment

Whilst most low to middle income countries will have at least minimal experience and resources in general environmental and waste management, there is usually more limited capacity in risk assessment of contaminated sites and even less in the specific area of managing pesticide contamination. Although professionals from governments will be able to make a considerable contribution to the management and implementation of projects, it is inevitable that some level of outside expertise will be necessary. For countries where pesticide contamination is less of a problem, the risk management of pesticide contaminated sites will be viewed as 'one off'. In this event, it is clear that capacity building would be of limited benefit. Whilst contributions to management and implementation of risk assessment will be necessary to complete risk assessment activities in the short term, expertise in the risk management of pesticide contaminated land will not be required over the medium and longer term. It is therefore better that technical expertise in areas such as the design of investigation and risk assessment are secured through an external organization. In countries where the pesticide contaminated sites are more common, the necessity for risk management will be ongoing. In this situation countries will require their own resources in all areas of risk management including project design, risk assessment and implementation so that a minimal amount of external input will be required in the future.

[4] American Society of Testing and Materials, 2014.
[5] UK Environment Agency, 2004.

Tool O

Pesticide contaminated site identification and prioritization

Background

The first step in the country wide risk management of contaminated sites is to identify all sites within a country that are potentially contaminated with pesticides, to get an idea of how many sites would potentially require risk management, and where the sites are located.

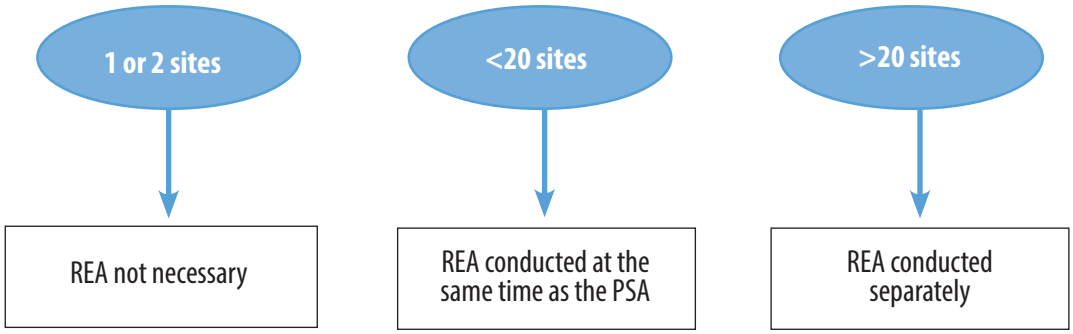
The second step is to prioritize each of the sites that have been identified and to broadly understand the type and amount of contamination at each site. The prioritization will allow assessors to target those sites that are in most need of further risk assessment and will potentially require risk management. For FAO projects where funds are limited the project set-up will have already defined the number of sites. It must be understood, however, that the remaining sites are not without risk and may require further investigation at some stage in the future.

In making the prioritization decision makers are also able to estimate the scale of the problem so that sufficient resources can be committed to dealing with it. The adequate provision of resources will entail ensuring that not only financial provision is made but also that there is sufficient expertise and facilities to deal with the problem, either within the country or region or beyond.

Finally, it must be understood that the prioritized list of sites is the result of a mechanical process. It is important that this list is rationalised according to external priorities set by various stakeholders involved with the process and other factors such as the budget available for risk management.

How the REA is conducted will vary according to the number of sites in any one area or region. Unless there are only 1 or two sites involved, where prioritization is not necessary, prioritization using the FAO REA will normally be conducted as a matter of course. Where there are many sites the REA will be conducted by separate teams of people under the supervision of a project supervisor. Where only a limited number of sites are to be dealt, for example less than twenty, prioritization will be completed by the same person doing the Preliminary Site Assessment (PSA).

FIGURE O1
Arrangement of the REA together with the preliminary site assessment

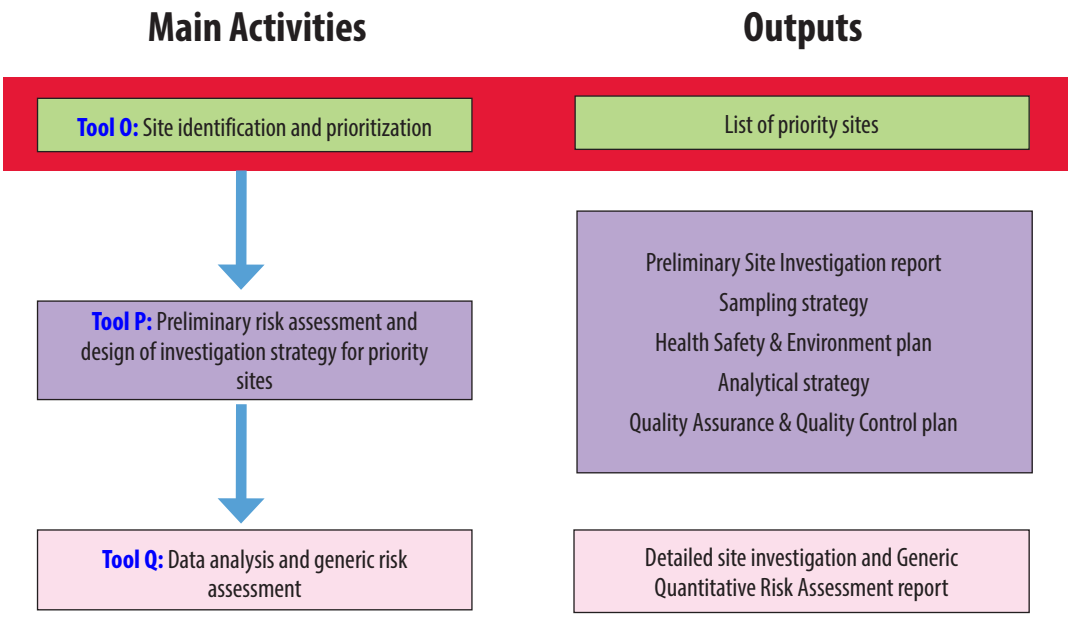


Objectives

- To identify the type and quantity of all contaminated sites in a country or region.
- To conduct a risk-based prioritization of sites.

Outputs

- A prioritized list of all potentially contaminated sites including name and location.
- A report describing which sites the government will address in the project/initiative that is underway and the reasons why.
- A summary of the major risk factors at each site, principal contaminants and quantity of contamination, nature of receptors.



The identification of sites potentially contaminated with pesticides

The first step towards prioritization of sites is to assemble a list of all sites of concern that are possibly contaminated with pesticides. Contributions to this list of contaminated sites may come from a variety of sources including:

- central and local government lists;
- outreach campaign in the private sector, NGOs, citizens;
- information from the FAO Pesticides Stock Management System (PSMS) system.

An example format for the list is shown below:

Site name	GPS coordinates	Owner/ Government department responsible	Contact name	Contact telephone number

The following sources of information are important in the identification of sites potentially contaminated with pesticides.

1. Government records

The primary source of information about contaminated sites are records held by either central government or local authorities. Some governments implement their own process and inventory system for collecting information about potential contamination sites.

FAO obsolete pesticides safeguarding projects, under which pesticide contaminated land and risk management normally arise, usually allow for the formation of a Project Management Unit (PMU) at the start of the project. The PMU has representatives from government bodies and agencies involved; it is recommended that data regarding potentially contaminated sites is collected at this stage in addition to information regarding obsolete pesticides in general.

2. Information from Non-Governmental Organizations (NGOs)

NGOs can be important sources of information about contaminated sites. In many countries, NGOs have extensive contacts with individuals from government and industry who have detailed knowledge of contaminated sites, including pesticide contaminated areas. It is common that the teams making up NGOs are former employees of private and government organizations who can provide a valuable resource for contaminated land risk management projects generally.

3. Publicity outreach campaign

At the start of a contaminated land project, where it is felt that Government records are inadequate or it is suspected that there are more sites than have been recorded, it may be necessary to conduct an outreach campaign. This may involve contacting local radio and television stations to publicise the search for unidentified sites so that people will come forward with information. Other methods such as posters, billboards, mailings, newspapers or internet communications are also often used. Most FAO projects will have a communications strategy as part of the project structure includes an outreach campaign designed for the collection of obsolete pesticides; it is proposed that this be extended to include the identification of potentially contaminated sites.

4. Preliminary Identification of a site as potentially contaminated using the Pesticide Stock Management System (PSMS)

The completion of an obsolete stock national inventory using FAO PSMS (FAO EMTK 1 Tools A–C) allows the identification of locations where there is a visual indication of contaminated soil either in containers or still in place. The inventory process allows surveyors to identify locations where pesticides have leaked and caused contamination in and around stores. By using the 'Contaminated Soil' inventory form assessors can record an estimated quantity of pesticides spilled or released to the environment, either above ground or below ground, as well as the type of contamination suspected including the results of any chemical testing conducted.

5. Interview of witnesses

As the events contributing to contamination may have occurred many years in the past, the evidence of witnesses' present at the time can be invaluable in identifying the locations of contamination and also in the verification of whether contamination actually occurred. Witnesses typically are people who have been present in the area for a long time, and may include workers or managers at storage or formulations sites, areas residents, local officials, and government employees such as inspectors or managers of health, agricultural or industrial development agencies. Witnesses are invaluable in situations where there are no visual or olfactory signs of contamination at the surface. This is because the absence of smell or visual signs of pesticide at the surface does not confirm that ground underlying a site is not affected by pesticides.

It is frequently only the arrival of a team of 'experts' on the ground that will encourage people to come forward with information about the location of potential contaminated places. Formal contact with witnesses or people who know about the site usually occur when visits are made as part of the REA, Preliminary Site Investigation visit or Detailed Site Investigation. Very often

different people will be available at different times and will give varying accounts and information about what happened at the site.

Interviewees should be reassured that their information will not be used against them and that it is simply in order to better understand the nature, scale and distribution of pesticide contamination.

Reasons to suspect that ground is contaminated with pesticides

- Residents complain of unpleasant smells;
- there are empty pesticide containers visible at the site;
- records held by local or central government indicate that pesticides may have been buried or dumped;
- there are odd coloured substances visible at the ground surface of the site or leaching into surface waters on the site (ponds, streams or rivers);
- the site is the location of a former or current pesticide store;
- somebody has information to suggest that the site was heavily involved with pesticide usage i.e. they saw burial, mixing or spillages of pesticides occurring;
- plant foliage is discoloured, or there are bare patches where no vegetation is growing on the ground;
- persons or animals have been taken ill as the result of eating or drinking agricultural products that have been gathered from the site.

It is important to consider that pesticide contamination is one of several possible causes of a deterioration in the land quality of an area; if there is no information or recollection that pesticides have been used at the site then other causes should be also be considered.

Profiles of locations where pesticide contamination commonly occurs

Pesticide contaminated sites can typically be described in one of the following 7 scenarios:

1. Former or current pesticide storage sites

Contamination at these sites results from the mismanagement of stocks that have been placed in a former store or a store that is currently in use. Most contamination is usually the consequence of spilled pesticides or containers that have leaked product into the ground. Often spills happened during transfer activities, such as loading pesticide containers on or off trucks or dispensing pesticides from one container to another. Washing used pesticide containers also often results in

Pesticide storage location where a spillage has taken place

releases to the environment, as the wash waters frequently were simply released with no controls. Sometimes contamination is the result of insufficient environmental safeguards implemented during safeguarding operations or clean-up activities. Typical storage sites may be further defined as the following:

- distribution centres for pesticides prior to being sent out into the field;
- field storage locations;
- airfields where pesticides are kept prior to spraying or distribution;
- national, regional or local collection centres for empty pesticide containers or obsolete pesticides.

2. Pesticide burial locations

Due to the difficulty in disposing of pesticides correctly the only method of risk reduction available in many countries has involved the burial of pesticides. Therefore, at many sites where obsolete pesticides were stored or where they are currently stored there are burial areas. These sites can be very difficult to find. Indicators of buried pesticides are the following:

- mounds of soil indicating that the ground has been disturbed beneath;
- bare earth where the ground has been disturbed;
- dead or dying vegetation;
- depressions indicating that ground has been disturbed or removed from the site.

In some cases, there are records of burial sites and activities, or above ground markers showing where burial has occurred. However, frequently the only method of finding the location of buried pesticides is to find someone who was present during the burial. Detailed interview of such persons can reveal important aspects about the site including the type, quantity, depth and method of burial and type of containers buried.

3. Superficial stockpiles

At some sites a more formal approach to the management of obsolete pesticides has taken place where the obsolete pesticides have been placed in a managed stockpile where pesticides are placed in some form of environmental containment, such as a building, bermed area (an engineered bank or levée), concrete structure, or area underlain and/or covered with an impermeable liner, possibly with bitumen or plastic. In general, managed stockpiles keep the pesticides in good condition where they are protected from the weather. They normally have fences or other means to prevent unauthorized access, rainfall runoff is controlled from the area, there may be records maintained of pesticides stored, and there are regular inspections of the stockpile condition. Whilst this method has benefits in risk reduction both in the short

Photograph of a site with controlled stockpiles

and medium term, in the long term it can result in contaminants escaping into the environment. Eventually, unless built to very high standards, such stockpile facilities fail to prevent release of pesticides due to natural corrosion, erosion, disturbance by people, plants or animals, and lack of funding and institutions to maintain the stockpiles over the long term.

4. Sites where mixing or formulation has taken place on farms or in the field
Spillages can occur during the mixing of formulations for application before use, as well as during transfer and container washing.

5. Pesticide application sites (diffuse contamination)
Diffuse contamination can result from repeated application of non-degradable pesticides over many years. The non-biodegradable nature and low mobility of some pesticides, most notably organochlorines, can result in the gradual build-up of residues in excess of GAC values. Of concern are countries or areas where there has historically been a poor level of education regarding best pesticide usage practices and the risks of over-application. In such locations, over-application of pesticides has often occurred. Spillages that occur during transfer and container washing activities in the field (see previous section) is also a concern at application sites.

Photo of a location where pesticides have been wrongly applied (note the discolouration in the centre of the field)

A dump site of the acaricide "Dinobuton"

6. Pesticide dump sites

At these sites pesticides, have been tipped or poured on the surface of the ground resulting in the infiltration of pesticides into the ground beneath. Dump sites have strong smells, evidence of pesticide containers, visible signs of pesticide including highly coloured compounds.

7. Pesticide production and formulation facilities

These sites are industrial locations where pesticides have been manufactured. These types of sites are usually extensive in size and comprise various industrial plant required for precursor or pesticide manufacture. Pesticide production sites will contain many different chemicals including raw materials required for pesticide production, the pesticides produced and quantities of by products that are produced during the manufacturing process. Off specification products may have been disposed of on site.

As the focus of management of pesticide production facilities, often, involves dealing with industrial problems as well as pesticides, these sites are normally dealt with by agencies other than FAO.

Drums of unidentified raw materials at a pesticide production facility

Process storage tanks located at a disused pesticide production facility

The Rapid Environmental Assessment (REA) tool

The Rapid Environmental Assessment tool was developed by FAO to prioritize pesticide contaminated sites for further intervention.

The REA consists of two distinct phases. The first phase is a "Desk Screen" that utilizes web-based information generated for each site and pre-existing GIS layers which are integrated to automatically prioritize the list of sites to those sites that should be visited first for the next stage of the REA, the REA investigation. The REA is hosted at a web site where the desk screen is conducted once basic site details are entered and where more specific information and analytical results gained from the site visit can be entered.

REA desk screen

The use of the desk screen allows government or other agencies generally to allocate resources for site visits and assessments at those sites more likely to be posing a risk. During the desk screen information about the soil type, nearby populations, the slope of the area, pesticide type and quantity and other information are used in a calculation to determine the priority for the next stage the REA Investigation.[6] For the desk screen to take place, assessors will enter the list of sites formulated at the site investigation stage into the website together with the sites geographical coordinates.

REA investigation

The second phase consists of a site visit during which time sampling is conducted and assessors complete a questionnaire about the site. The questionnaire consists of a series of objective technical questions focussed on collecting information about potential sources (source type and quantity), pathways and receptors on the site and the interactions between each. During a visit, of typically 1-2 days, interviews are conducted with people knowledgeable of the site and then samples are collected, the questionnaires completed, and photographs are taken. Following the site visit completed REA questionnaires and results of the sample analysis are uploaded into a secure online database. From the answers given and input from analytical results, three separate algorithms are used to calculate relative risks; specifically, risks related to source, pathway, and receptor. The second phase of the REA is completed by teams of trained professionals under the supervision of an expert with a detailed knowledge of the REA process. The number of teams used is dependent on the number of potential contaminated sites to be visited. Outputs from the tool include a list of prioritized sites and all the underlying information required for this including, mapping, REA questionnaires, photographs, notes of interviews and the results of any sampling conducted.

REA data entry and validation

The REA data entry area on the web-site has three separate sections which mirror the three sections of the REA questionnaire that assessors complete during the site visits: Source Type and Quantity Risk; Pathway Risk; and Receptor Risk. During data entry web pages' fields are populated according the filled questionnaires completed on-site. Team supervisors checking the data entered. This is required for validation of REAs.

Algorithms used in the prioritization

Each question completed by the assessor is scored according to the answer. The resulting numerical values are used in calculations that underlie the web-site which ultimately result

[6] John Keith, 2013.

in the prioritization. A detailed description of how the prioritization is derived is found in Annex 2.

Given resource limitations, a degree of pragmatism that focuses effort on those sites most likely to pose the highest risk is reasonable.

The REA website and handbook

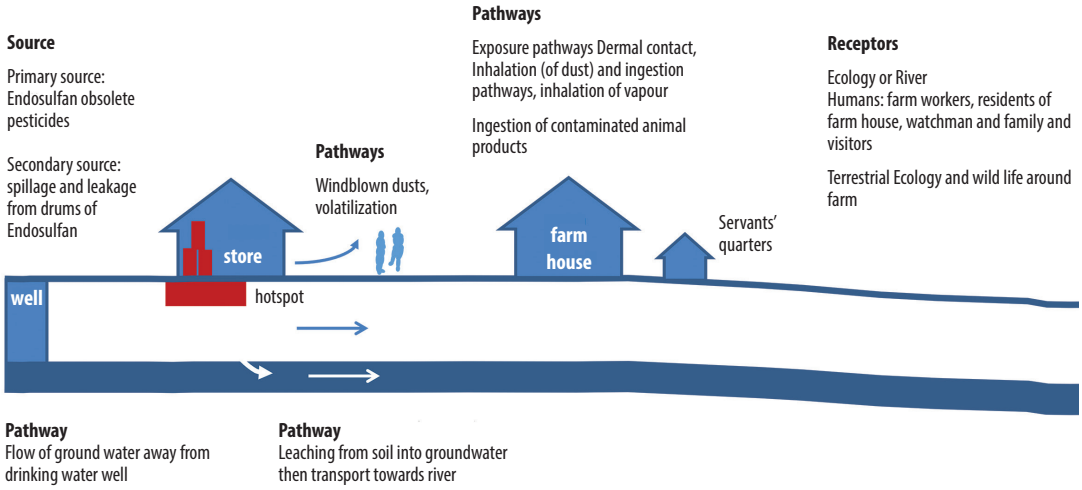
To enable users to carry out REAs, a handbook is available that sets out in step by step fashion the protocol that should be followed. The handbook is available for download on the website at: http://www.fao.org/3/ca5642en/ca5642en.pdf. The website also contains other resources, including blank REA forms to allow users to complete REAs in the field.

Tool P

Preliminary risk assessment and design of the detailed investigation strategy for priority sites

Background

Following the identification and prioritization of sites using the REA, the next step of the process requires a preliminary risk assessment followed by the design of a detailed investigation strategy for sites deemed "high priority". Broadly, the preliminary risk assessment involves developing a preliminary conceptual site model and identifying potential pollutant linkages and exposure scenarios. In the process of the preliminary risk assessment, assessors gather enough evidence to evaluate the risk, that is, to consider whether there is a source, pathway and receptor present and to judge whether the magnitude of the risk to receptors justifies going further.

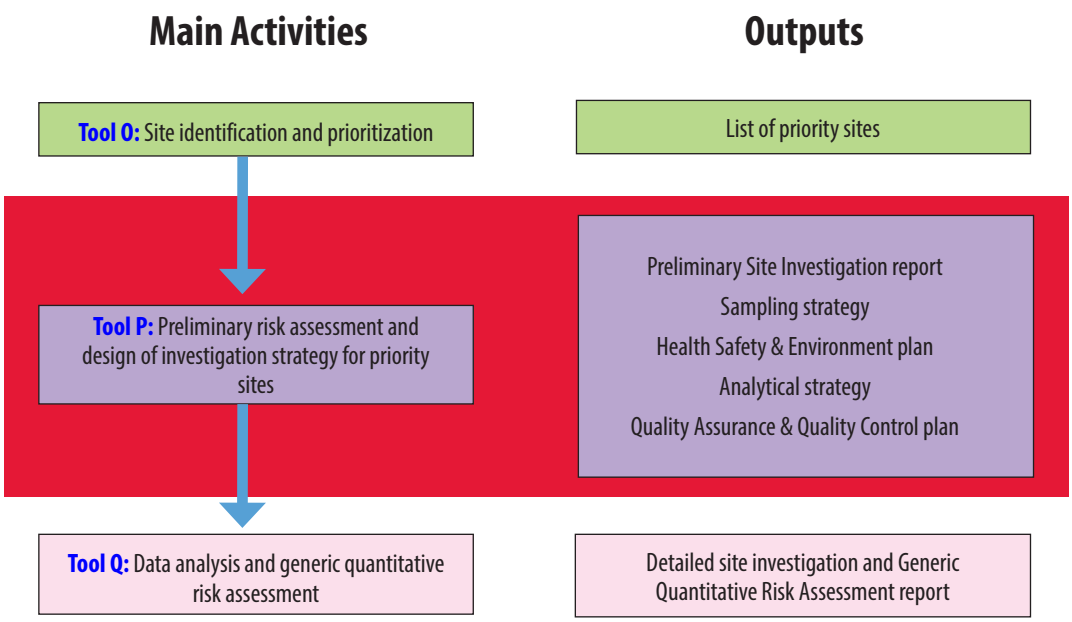


The preliminary risk assessment should generate enough information for the design of the Detailed Site Investigation (DSI). Uncertainties in the preliminary CSM should form the basis for the objectives of the DSI.

Objectives

The objective of Tool P is to give users guidance about how to conduct a preliminary site investigation that allows assessors to evaluate how "risky" a site is, and to decide either whether the risk a) justifies further action or, b) is low enough that no further action is required.

Tool P also assists users in deciding the activities necessary for the Detailed Site Investigation, the next step in the risk management process.



Outputs

Tool P should assist the user in achieving the following outputs:

(i) preliminary (conservative, qualitative) risk assessment;
(ii) a sampling plan for the DSI;
(iii) an analytical strategy detailing any testing of samples taken during the DSI;
(iv) a quality assurance and quality control plan to maintain data quality during the DSI;
(v) an HSE plan which details how threats to human health and the environment during the DSI are minimised.

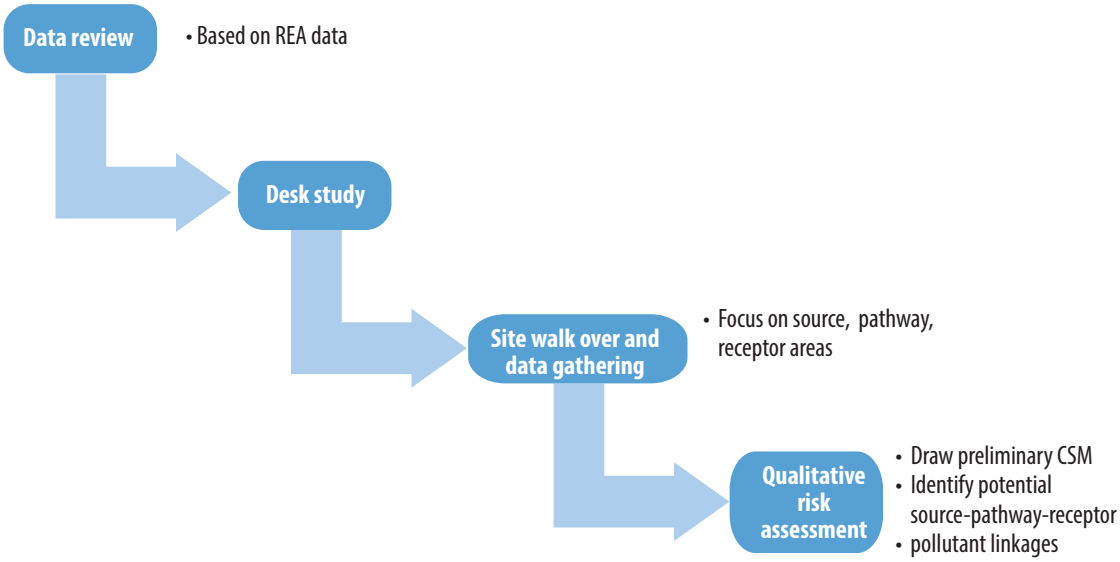
The following sections consider in detail the preliminary risk assessment and the steps involved in the design of the DSI.

Preliminary site investigation

Readers should understand that the REA is a "relative" assessment which provides a mechanism by which sites can be prioritized against each other. Once a risk priority has been established a deeper assessment of the risk can continue, the first step of which is the Preliminary Site Investigation (PSI). The primary objective of the PSI is to gather available information about a site so that assessors can develop a preliminary conceptual site model and so that there can be a preliminary qualitative risk assessment. The PSI consists of a desk study, site reconnaissance and possibly some limited investigation. If the PSI includes even a limited amount of sampling and associated laboratory testing, the advice on sampling, containers and transport provided for the DSI should be followed.

The preliminary site investigation is conducted through the following stages during which time assessors will be continually developing and improving the conceptual site model:

(i) REA data review and desk study;
(ii) on-site data collection during the site visit and walk around, if necessary to include the taking of samples for analysis.



Data review and desk study

The desk study should include the collection of any information the assessor deems necessary to build up a better picture of the site and to improve the CSM. Information can come from a variety of sources. Ideally, the desk study should be done before the visit. However, it is frequently the case that preliminary information required by the desk study can only be gained by visiting the site.

Figure A3:1 in Annex 2 sets out the information and sources usually required for the preliminary site investigation.

At this stage, assessors will have the opportunity to review data generated from the REA. If the REA has been conducted as a separate exercise, there may also have been sampling done and analysis results will be available. If the REA is to be conducted together with the preliminary site investigation and associated risk assessment, the assessor will be able to access information made available from the REA desk screen.

The site visit and "walk over"

An important part of the PSI is a site 'walk over' that gives the assessor an opportunity to carefully observe and note the fundamental site characteristics including:

- current land use and the locations of buildings;
- site topography;
- surface water drainage features;
- soil type;
- ground surface (vegetation or other cover);
- behaviour and type of receptors;
- the type of exposure occurring; and
- position of hotspots, for example.

Ideally the assessor should undertake the walk over as soon as possible after the desk study so that he/she will have an idea of any information that is missing about the site or "data gaps". This will allow him or her to target more specifically the information required by the following stage.

Sampling during the preliminary investigation

If sampling has not been conducted at the REA stage, one of the principal objectives of the PSI will be to supplement the preliminary CSM by taking samples and having them analysed. This is achieved as follows:

(i) identifying the range of contaminants (from the desk study);
(ii) sampling to estimate level of contamination at the source;

(iii) sampling to estimate level of contamination in the receptor and pathway areas of the site.

Assessors should understand that due to the limited number of samples taken at the PSI stage, the high variability in ground conditions and distribution of contaminants that the results of sampling at this stage can be viewed only as an indication of the level and extent of contamination. Assessors should also consider that techniques used to take samples invariably only reach shallow depths. At shallow depths, soils are much more exposed to weathering and potential evaporation of contaminants which could potentially lead to an underestimation of contamination.

Laboratory analysis for the PSI

To reduce costs, it is recommended that a composite sample is formed from the source areas which should be screened for the presence of the widest possible range of pesticides; investigations at large sites where there is more than one source may require more than one sample to be screened. Once the range has been established a second round of analysis should be conducted for those pesticides discovered. This measure will prevent the requirement for all samples to be analysed for all pesticides that could be encountered at the site.

Mapping

It is most important that a map should be made of the site that properly indicates sampling locations and key features. Key features include schools, homes, and the pollution source. Electronic maps are preferable, though a scan or photograph of a hand-drawn map is perfectly acceptable.

Interview of witnesses

A site visit also allows the assessor to interview people who have a detailed knowledge of the site and who may have been present during the events leading to contamination. These people may be able to reveal important information such as the following:

- a more definite location of existing hotspots;
- the depth of burial at a burial site;
- the locations of, yet, unknown hotspots;
- the method of burial; details about the method of burial can also give important information. For example, if the contamination has been buried by hand it is likely to be less than 2 m deep. If, however, it is buried by a wheeled excavator then depth of burial could be 3.5-4.0 m deep. The use of a large tracked excavator on the other hand, may have the capacity to dig down to 5.5-6 m in depth;
- the type of likely contaminants and their original form;
- the date of contamination.

Local stakeholder engagement during the site visit

The site visit is also an opportunity to engage people at the earliest stage in the risk assessment and risk management process. The local community can then be kept informed as to how the process is continuing and will be much more likely to be content with any conclusions that are made; in many cases a successful conclusion of the risk management process will not be possible without engagement and agreement and even help from the people in the nearby surroundings.

More specific and practical details of how to conduct the preliminary investigation are given in Annex 3.

Conceptual site model

This is a tool that is used widely in contaminated land risk assessment to describe the potential pollutant linkages that are operating at a site set against the physical situation of the site and its surroundings in the environment. To formulate the CSM the site is split theoretically using

the source-pathway-receptor approach, factors associated with any one of these elements are grouped together. Information about the sources, pathways and receptors and anything else that could be used to better describe the environmental conditions added to the model to improve its accuracy. The development of the CSM is an ***iterative*** process where information is continually added to it to provide the assessor and other stakeholders with the most up to date understanding of the site available and the possible mechanisms of contaminant distribution.

From the CSM, assessors can identify questions and gaps in understanding (*data gaps or uncertainties*) that should be address by gathering further information to give a clearer idea of the conditions at the site. The objectives for the detailed site investigation are set by reference to these uncertainties and gaps in the data. The detailed site investigation and sample analysis are then carried out to characterise the site more completely and to explain in more detail the systems that are operating. In essence the CSM is a working hypothesis of what assessors think is driving the risks on the site. As assessment continues assessors will test various aspects of this hypothesis to continually improve it.

In developing a CSM an assessor can analyse the relationships between elements (source, pathway and receptor) making up the CSM and the factors affecting them including:

- contaminant source(s)/release and dispersal mechanisms/migration/degradation mechanisms;
- spatial/temporal pattern of contamination (i.e. is it obvious that contamination is occurring in specific places or a particular time, for example during the rainy season?);
- media that are contaminated or may become contaminated; including:
  - groundwater running through the contaminated area;
  - dust at the ground surface containing contaminated residues;
  - air contaminated by volatile or semi-volatile pesticides;
- the location, type and behaviour of human and/or ecological receptors.

The initial development of the CSM is normally based on desk study information augmented by observations made during the initial site visit. To start with an assessor will make a drawing of the basic characteristics of the site. This should include:

- obvious physical features and topography – buildings, surface water features, the location of agricultural fields, trees and other vegetation, the location of drinking water wells and other points of water abstraction;
- information about the source – evidence of the identity of contamination and type of pesticides, type of site (i.e. burial site, spillage location, pesticide dump site etc.), visible signs of obsolete pesticides and any smell;
- notes about receptors (people and animals) on the site or close to the site and their behaviour and the routes of exposure that may be occurring (inhalation, ingestion, dermal/skin);
- notes about the soil type and composition and any underlying geological features;
- the location and type of any samples taken during the visit.

As the investigation continues the assessor will be able to increase the level of detail of the CSM that reflects a greater understanding of the conditions at the site. The investigator can use any means that he/she thinks would be good at illustrating the scenario, including: site drawings (sections and plans), satellite and aerial photography, GIS information, tables and network diagrams and other tools. By examining this information and the relationships between source, pathway and receptor, the assessor will be able to make informed deductions for suspecting that the site is contaminated and to what extent pollutant linkages are operating.

The Figures A3:3 to A3:5 give an example of how a preliminary CSM might be presented for a simple site.

The preliminary "qualitative" risk assessment

At this stage the CSM should help the assessor to identify potential exposure scenarios and the types of exposures occurring; who are the receptors, what is the type of exposure occurring (e.g. dermal, ingestion or inhalation) and how and where is it potentially happening.

During the site visit, assessors may take several soil and possibly water samples. (Detailed guidance for conducting the PSI is given in Annex 3). From the analytical results of the samples the assessor is then able to identify the types of pesticides present which allow the selection of relevant generic screening levels for the contaminants of concern. To select the screening level, the assessor should take into consideration the type of potential exposure, the current and future land use and most sensitive receptor present. The assessor is then able to make a basic comparison with screening levels and to demonstrate whether the test results are above or below the screening levels. This allows the assessor to make a qualitative judgement as to whether any contamination measured at the site presents a risk to human health, i.e. do the measured levels of contamination exceed GAC and is there evidence to suggest a pathway between the source and receptor. If so, then further investigation at the detailed site investigation stage would be necessary. If not, the site can be excluded from further investigation.

An underlying principle of the risk assessment process is to understand whether the "dose" of a pesticide that people (or animals) are receiving, or could potentially receive, from contaminated materials could cause damaging health effects. "Dose" is a function of the quantity, concentration, time period and toxicity of the pollutant to which a receptor is exposed. A key objective in the risk assessment process is to gain an understanding of these four "dose" parameters. This is usually completed by chemical analysis of media suspected to be contaminated to determine the type and level of contamination and to enable a comparison to be made with screening levels. Then measurements are made and/or modelling conducted to estimate the amount of contaminant that reaches the receptor, after considering factors that attenuate the transport of the contaminant such as chemical or biological degradation, dilution and sorption on to soil. By understanding the dose that receptors are receiving and how it is occurring and the inherent risks that result, steps can then be taken to manage or reduce these risks.

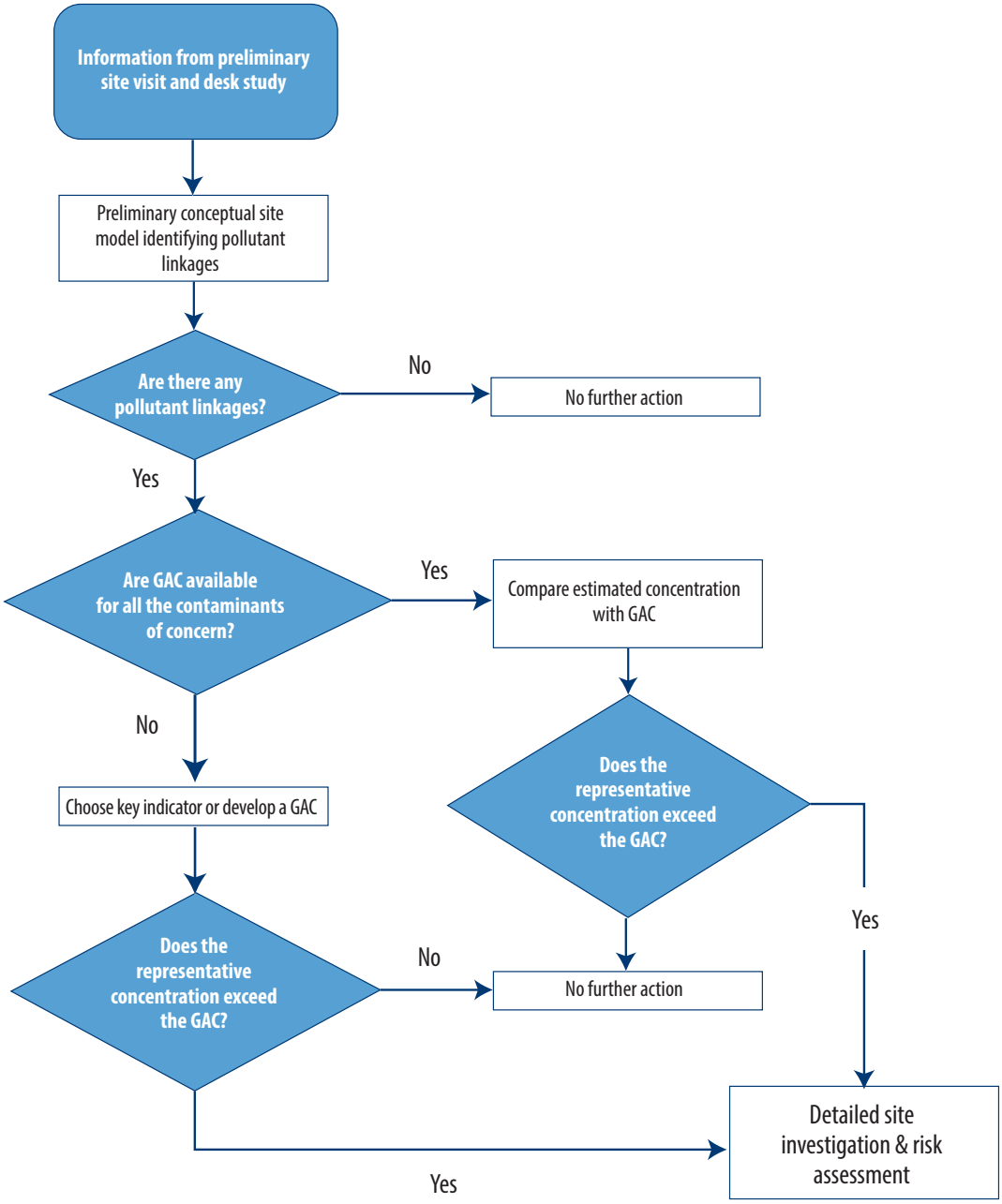
Analytical results from this preliminary stage of the investigation, whilst giving a good indication of factors such as the range of contaminants and the general level of contamination present, are not sufficient, either statistically or conceptually for informed decisions about a site to be made. Any analytical results should be carefully considered and set against the other more qualitative evidence gathered at this stage. It is recommended where levels of contamination are seen to approach or exceed screening levels that the site should be referred to the next Tier of investigation.

Due to the wide spectrum of pesticides present at most sites it is likely that not all the contaminants of concern will have guideline levels. Where a contaminant is encountered for which there is no GAC, it is advised that assessors develop a GAC or select key indicator contaminants present that have similar behaviour and toxicity to those for which guideline values or screening levels are not available.

The preliminary site investigation report

The Preliminary Site Investigation report details the activities and information that has been collected as part of the PSI. It allows the assessor to define the context of the investigation and gives the opportunity to present the background information regarding the site and for the preliminary CSM to be set out, in whatever formats the assessor has chosen to use. The PSI should include results of the REA and where relevant refer to the Prioritization report (under some circumstances prioritization is not necessary). It should explain how and why the site was prioritized and detail input from stakeholders that result in changes to the site's final prioritization. The report's conclusions should provide an evaluation of the CSM (i.e. state and illustrate sources, pathways and receptors, highlight uncertainties), pollutant linkages and relevant exposure scenarios together with any analytical results gained and justification for the relevant GAC used for comparisons made in the risk assessment. More simply put, the report should explain what the principal sources of contamination are, who the potential receptors are and how the receptors are being exposed. Finally, the report should set out what further action is necessary at the site; whether a detailed site investigation is justified, potentially to be followed by risk management measures or no further action is necessary. It may also be the case that that

Figure P1
Risk assessment flow chart, adapted from (Paul Nathanial C. Paul Bardos R., 2005)



no further risk assessment is necessary because the site presents a very low risk but that a limited amount of cost effective risk management would be of benefit. This would forgo the time and expense of a full scale intrusive investigation where none is required.

Assessors should bear in mind that the information put together for the preliminary investigation is fundamental to the next stage in the process, the Detailed Site Investigation and risk assessment. The PSI will allow assessors in the design of the data collection aspects of the DSI

and also to develop the practical aspects of how the detailed site investigation will be carried out such as appropriate investigative methods and the health and safety implications of any on-site work described in the HSE plan.

The following format suggests headings necessary for inclusion into the Preliminary Site Investigation report:

BOX P1
Preliminary site investigation report and contents

1. Executive summary.
2. Table of contents.
3. Introduction.
4. Objectives and scope.
5. Background information including any previous investigation and results of the REA prioritization, if conducted.
6. Parameters describing environmental fate of the pesticides on the site; inorganic and organic compounds.
7. General site description and location of contamination.
8. Future land use.
9. Weather and climatic conditions.
10. Geology, lithology, hydrogeology and hydrology.
11. Preliminary site investigation analytical results.
12. Sources (i.e. what pesticides are suspected of being present).
13. Receptors (people, livestock, wild animals).
14. Pathways.
15. Preliminary conceptual site model.
16. Data gaps and method of collecting data for the DSI.
17. Risk evaluation.
18. Report conclusions and recommendations.

Design of the detailed site investigation

The detailed site investigation should be designed to ensure that all relevant information is collected. Included in the design are procedures to be put in place so that this information is collected in the right way (data collection and sampling plan), that it is done safely (the Health, Safety and Environment Plan), what analysis is to be done and how it is to be done (the analytical strategy) and steps to ensure that the quality of the investigation is maintained (Quality Assurance and Quality Control plan). Based on the CSM, assessors will decide what, where and how much information should be collected in terms of any sampling necessary (usually soil and/or water) and any additional desk study. Assessors will then decide what methods should be used, what equipment will be necessary and the health and safety implications of how the investigation should be conducted. Additionally, investigators need to explain how the quality of the investigation should be maintained and how and what type of analysis will be necessary.

Assessors designing of the DSI should refer to the data gathered and the conclusions from the PSI. The preliminary site investigation provides critical information about the conceptual site model which underpins the development of the sampling plan for the site investigation, this broadly includes:

- the composition of contamination, where it is located and how extensive it is;
- how contamination is suspected of reaching the receptors and how the receptors are exposed to contamination;
- who the receptors are and where they are located and how they behave.

The preliminary investigation is important to define what information is required to improve the CSM and what information should be collected during the detailed site investigation to allow an informed decision to be made about risk management. Information gained from the preliminary investigation will help to define what type of sampling is necessary, where it is conducted, and the type of analysis required.

So that the correct information is collected it is recommended that assessors should consider the following points when designing the data collection aspects of a ***Detailed*** Site Investigation:

1. formulate the objectives of the site investigation from the uncertainties in the preliminary CSM;
2. define where to collect the data and when to collect them;
3. define how to collect the data and what type of sampling strategy will be used;
4. decide how specific and accurate the data you collect should be;
5. decide how much data are required to be collected;
6. define what you are going to do with the data.

Once it has been decided what and how information should be collected, assessors will then be able to consider practical aspects of how the investigation should be carried out.
Guidance on how each should be considered is outlined below:

1. Formulating the objectives of the detailed site investigation

The aim of the DSI is to inform the quantitative risk assessment that follows and where necessary to inform the selection of a suitable remediation strategy.

The DSI should have very clear objectives to direct the focus of the investigation and it is important to set these out systematically before the investigation starts. By defining the investigation objectives decisions can be made about what type of data is required and how much data to collect. There are usually two primary objectives of the DSI:

- to confirm the presence of pollutant linkages at the site (i.e. to establish whether there are links between sources, pathways and receptors); and
- to collect enough information about the site setting, levels of contamination, means and extent of migration and receptor exposure to allow a quantitative assessment of risks.

Secondary objectives, particularly for FAO projects at less complex sites, include the collection of sufficient information to evaluate feasible risk management or remediation methods and to design the risk management/remediation measures.

Types of data to collect

The data to be collected in the DSI falls into two broad categories:

1. Site information, this includes:

a) a good map, to scale, of the site and surrounding area identifying all significant features such as buildings, roads, water bodies (streams, rivers, lakes), drainage routes, topography and human use or other receptor areas;
b) detailed information about receptor areas, such as land use, types of receptors (people, farm animals, crops), populations, distances from the source areas and any special circumstances that impact risk such as the presence of schools or behaviour of receptors that may put them at greater risk (for example, in places where there are people living in houses with earth floors they may be exposed to contamination 24 hrs a day);

c) geological and hydrogeological information if groundwater is anticipated to be a significant pathway, notably such information as soil types and permeability, depth to groundwater and bedrock, groundwater level variation over time, and groundwater flow direction, and users and outlets;
d) detailed site history, if this has not already been obtained, with a focus on the pollutants stored, used or spilled, including types, amounts, frequency of use or spill, time periods and duration.

2. Sampling data

Tests on samples of soil, groundwater and/or surface waters will be required to determine, with good detail, future levels and extent of the contamination at the source, along migration routes, and at receptors.

2. Define where to collect the data

For the investigation, it is necessary to define where information is to be collected on site and in nearby areas (where access is permitted).

The site boundary

The project remit will specify the investigation of the area containing the source area, however in many situations contamination will have spread from here to areas outside the legal boundary of the site or the boundary of the site as specified by the project. If not already specified, the assessor should try to define the extent of the investigation as early as possible. With respect to groundwater, it can be difficult to specify how far down-gradient the investigation should go when considering the potential for groundwater contamination. The following should be taken into consideration when defining the site boundary:

1. Source areas

a) Properties of the pesticides present at the source area–solubility, soil sorption properties, toxicity;
b) source area, soil types and properties–type, permeability, sorption capacity.

2. Potential migration areas and routes away from the source area

a) Area hydrogeology–depth to groundwater, type of aquifer (confined, unconfined, channelled, etc.), water movement rate (e.g. meters/day), seasonal variation, discharge points to surface water, etc.;
b) use of the groundwater–for example drinking, bathing, farm animals, irrigation, and their proximity to source and receptor areas.

In general, it is necessary in an investigation to include areas off the source area or outside the legal boundary of the site, to understand and characterize the extent of contamination and related risks. However, this may not be possible for a variety of reasons, notably funding limitations, legal problems getting access to sampling areas outside the official site boundary, and/or the presence of other pollution sources nearby that greatly complicate evaluation of off-site impacts.

Site zoning

Conditions of the ground and the contamination at most sites, particularly larger ones, will vary immensely from one location to another due to different land uses, levels of development and topography. To make the sampling strategy easier to implement and clearer for stakeholders to understand, a distinct plan is created for each of these areas.

The soil in these zones or areas of interest will contain concentrations of contaminant, which, when averaged across the area are more likely to give a more representative indication of how much contaminant is present however this may vastly underestimate the risk to specific receptors. Once the zones, or areas of interest, have been defined they are then sampled separately with respect to achieving the objectives of the investigation using one or more of the methods described above. In general, there are three categories of areas sampled and there is often overlap between the categories:

Source areas – where the pesticides were stored used, spilled or disposed of. The usual intent of sampling in this area is to understand the severity and extent of contamination (horizontally and vertically) so that the amount and extent of pollutant can be determined. This serves several purposes:

a) to determine acute and chronic risks to people or other receptors (e.g. farm animals, fowl) who frequent the source area;
b) to determine the amount, concentration and extent of pollutant that needs to be remediated or the area for which other risk management measures need to apply;
c) as a starting point for modelling migration of the pollutants to receptor areas, i.e. determining likely migration routes and the amount of pollutant that could migrate.

Migration pathways – areas outside the source area where contamination may have spread. The concern is how far the pollution has spread towards important receptor areas. This sampling is used in modelling risk to receptors-estimating the natural attenuation, including any degradation, of pesticides migrating from the source and then determining if pesticides will impact receptors and if so, to what extent. The sampling also helps determine the area outside the source area that may need remediation or risk management. The sampling is focused on specific migration pathways, notably groundwater, sediments in drainage routes, and sometimes wind-blown dust in soil.

Receptor areas – these are places where people live, work, or gather, as well as places where food animals (livestock, poultry, fowl, fish) may ingest the pesticides creating a food exposure route. The areas may include where a behaviour or exposure of the receptor is occurring, for example a homestead, school yard, agricultural field or home garden area. Sampling may be done for soils, ground water, surface water (particularly in ponds or small streams) and drainage route sediments.

The purpose of sampling in these areas is to determine if pesticides are present and if so, locations and concentrations to:

a) estimate exposure doses and risks to receptors;
b) help confirm pollutant migration models and the CSM;
c) provide a basis for determining areas requiring remediation or other risk management measures if concentrations exceed relevant assessment criteria (GAC may NOT be suitable remediation trigger levels).

Natural geographic features are commonly used to divide the site into these different zones, as this helps everyone understand where they are. For example, a road, railroad track, drainage ditch, property fence line or other physical characteristic i.e. a low spot or a geologically distinct layer underlying the site (for example a clay layer).

Depth of sampling

The depth of sampling depends on the objectives and exposure scenarios set out in the CSM. Generally, the depth of sampling in the receptor and migration pathway areas will be different to the depth of sampling at source or in hotspot areas.

Depth of sampling in source areas

In general, soil sampling at depth is undertaken in the source or hotspot areas to see how far down the contamination has reached and likelihood of reaching groundwater. However, at a site where gross pesticide contamination has occurred it is likely that the lateral and vertical extent of contamination must be investigated. This is because:

(i) the definition of the volume of contaminated material and the chemical and physical characteristics of the material are important in the design of a risk management plan both in terms of the types of remediation possible and for budget development;
(ii) in many countries contaminated ground has an economic value for its toxic properties (i.e. the pesticides) and will be removed for use or sale if not dealt with;

(iii) at many sites, the desire is to have future use or development of the site after risk management measures have been implemented (i.e. "brownfield redevelopment"). This future development may involve disturbing sub-surface areas, such as for digging foundations or constructing roads, resulting in exposure to the subsurface soils and spread of these impacted soils to new areas;
(iv) action is required to comply with international conventions, such as the Stockholm Convention on POPs.

Depth of sampling in receptor areas

Points to consider are the following:

- exposure most often occurs at or near ground level and therefore the strategy will involve taking samples from the top 100 mm;
- if contamination of home grown or agricultural crops are suspected the sampling will be from slightly deeper, 150-300 mm (sampling from the root zone);
- if grazing animals (livestock, poultry, fowl) are suspected of exposure, near surface sampling will be required (top 100 mm);
- if soil turning cannot be excluded ten depths down to 600 mm (i.e. two spade depths) should be explored.

When to collect data

When planning an investigation, it is important to consider when to collect the data and conduct sampling. Sampling is most effectively conducted to collect information about the reasonable worst-case conditions. For example, if it has been estimated in the CSM that flood waters or high ground water are important in transmitting contamination then it would be prudent to arrange collection of water samples during the rainy season. On the other hand, if the CSM indicates that use of wells or farm ponds in dry seasons for irrigation or water supply is a critical pathway, then sampling during dry seasons would be best. Note that it is generally not advisable to take soil samples during very wet weather because high water content in soils can interfere with accurate analysis. Also, it is generally not practical or advisable to collect soil samples when soils are frozen, or snow covered.

The frequency of data collection

For most projects the opportunity to collect data is limited by logistical difficulties and budget restrictions. At many sites, these restrictions will limit site visits to three; the first visit for the REA, the second for the preliminary site investigation and the third for the DSI. The design of the sampling plan and sampling methods should be tailored to reflect this.

If groundwater or ground gas monitoring is required, the repeat visits are needed to establish a time trend.

3. Define how to collect the data; what type of sampling strategy to use

There are two main types of soil sampling strategies; probabilistic non-targeted sampling and judgmental targeted sampling.

Judgmental sampling

Judgmental sampling is the subjective selection of sampling locations at a site, based on historical information, visual inspection, and on best the professional judgment of the sampling team. Judgmental sampling is often used during the Preliminary Investigation to determine:

(i) the "worst case" contamination;
(ii) the range of pesticides making up a contaminated hotspot;
(iii) whether an area suspected of being contaminated is actually contaminated.

Because judgmental sampling is entirely subjective, it does not accurately estimate the variation of contamination and therefore cannot be used over large areas to describe levels of contamination or make comparisons with screening levels with any degree of confidence.

Probabilistic sampling

The use of this type of sampling requires the collection of samples using a predetermined pattern or grid such that each part of the sampling area has an equal chance of being sampled and that there is no bias during the investigation. This type of sampling allows the use of statistics to help maintain the quality of data collected. However, it ignores what is already known about the site and requires many more samples than judgmental sampling.

More details of probabilistic sampling strategies are including in Annex 4.

Groundwater sampling

Ground water sampling is necessary where the CSM determines that groundwater is a potential contaminant pathway to receptors. Also, groundwater should be sampled where it is being used directly for human consumption from wells, at or close to, or downstream of the source area.

The design of the ground water sampling strategy is also dependent on the objectives developed in the CSM. With respect to ground water the sampling strategy objectives are typically to determine if contamination has reached ground water and the extent of contamination or to determine if levels of contamination in groundwater breach guideline levels. Monitoring is needed to explore the extent of any natural attenuation.

In many cases, contaminated sites are close to, often concerned, communities or institutions that rely on groundwater as a water source. It is good practice to include some sampling of produced water even if a technical evaluation based on the pesticide present and its migration potential shows little risk to groundwater: people like to see real data.

As conditions in groundwater are always changing, investigations usually require more than one sampling event to account for parameters such as changes in groundwater level, rainfall and natural attenuation. If conventional sampling is being used, samples should be taken at least 2 or 3 times over a 6-8 week period to account for this. Due to the difficulty in transporting and maintaining the quality of samples, other types of water sampling may be used including the use of passive sampling devices (see the section on sampling methods for further details).

If analysis of ground water is necessary, the installation of at least 3 boreholes is recommended as this allows for the determination of the likely direction and rate of groundwater flow. At larger or more complex sites, or where the local hydrogeology is unknown or complex, more than 3 boreholes are usually necessary. Environmental sequence stratigraphy can help interpret groundwater conditions. Good places for siting boreholes or taking water samples include:

(i) at the source;
(ii) at or within the site boundary;
(iii) at a point of withdrawal downstream of the site-often this is done by sampling existing *in situ* wells;
(iv) between the source and receptors to determine the extent of migration of the pesticides, or if it sorbs and/or degrades before presenting a risk to receptors.

Whenever groundwater samples are taken, depth to groundwater should always be measured and recorded as an elevation about a fixed datum. This provides key information upon which groundwater flow rates and directions are calculated.

Surface water and sediment investigation

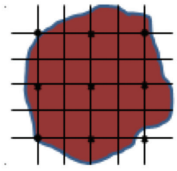
In general, due to the low solubility of many pesticides, large surface waters (big lakes, or rivers and streams with good water movement) present limited risk to human health unless the pesticides have been dumped into them in bulk. In terms of pesticide contaminated sites, slow moving small streams and small ponds near the source area pose the greatest risk. Of concern are near-static farm ponds or ponds used for ducks, geese or aquaculture. Sediments in these ponds and streams present a continuing risk of release into the water and there is a high risk of direct exposure to humans or indirect exposure via farmyard animals or waterfowl. Sampling of surface waters is straight forward, but is more challenging for sediments below the water, in terms of equipment and technique. Where the pesticide use has ceased, fresh uncontaminated sediment

can isolate historic contaminated sediments. Sampling should not mobilise such old contaminated sediments.

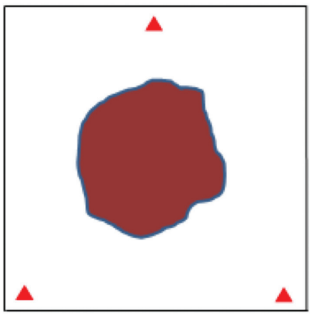
Integrated sampling strategies

Pesticide contaminated sites investigated by the FAO are mostly sources of gross contamination, such as leakage from a store, significant spills during transport or handling, burial of wastes, pesticide dumping on land, or substantial releases from stockpiles that occurred over a period of many years or that occurred many years previously. Under these circumstances there is often a very highly concentrated source that has been releasing contaminants into the environment over a long period of time. Because of this and the inherent physical heterogeneity of most sites, an integrated approach of more than one type of sampling will be required to gather information about the source area, receptor areas and potential migration pathways between them. It is of note that sampling points in an integrated strategy may serve more than one purpose.

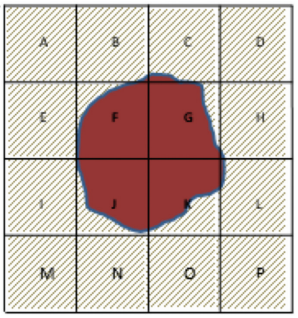
Figure P2
An integrated sampling strategy adapted from Paul Nathanial C., Paul Bardos R., 2005



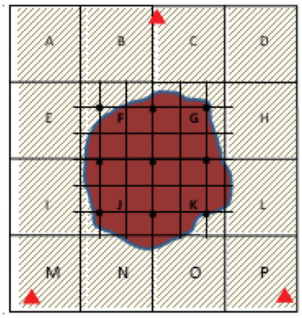
Grid square point sampling of the source area



Borehole monitoring points



Grid Composite sampling



4. Decide how much data is required to be collected

Quantity of samples required

When designing a site investigation, it is simply not practical or cost effective to sample the entire soil mass, neither on the other hand is it suitable to take one or two samples for analysis and to consider the result representative of the whole area. In practice, a statistically significant number of samples are taken to represent an area of interest. Statistical methods can then be used to support decisions about the area being investigated. The quantity of soil samples required for an investigation is based on the objective of the sampling, as determined by CSM and the level of

confidence required for the investigation compared to natural variation. In common with other best practise guidance FAO recommends the use of a 95 percent confidence level. However, it is understood that in many circumstances that achieving a specific confidence limit will be difficult and that professional judgement will be required to guide the investigation and the outcome of any sampling conducted. To achieve the objectives of the investigation, sampling of a pesticide contaminated site will be targeted to determine the level and type of contamination of an area or zone so that it can be compared to a screening level.

For further details regarding how to define the number of samples required, please read the section about data analysis and statistics.

5. Define what you are going to do with the data

Generic Quantitative Risk Assessment

At the stage of the Detailed Site Investigation (DSI), data about contamination in the soil and water on the site is usually collected for Generic Quantitative Risk Assessment (GQRA) where the levels of contamination are compared to pre-calculated screening levels. GQRA is used for the purposes of:

1) estimating the "dose" of contaminant that receptors are receiving;
2) assessment of the level of risk – by determining the lateral and vertical extent of pollution and making a comparison with screening levels, investigators can assess the level of risk to receptors (i.e. is there a large or small quantity of contaminated soil, how contaminated is the soil and therefore how critical is the situation, if at all);
3) to eliminate substance from further consideration;
4) to determine which areas of the site are 'contaminated' – by making comparisons with different areas of the site, assessors can determine which areas of the site may require risk management and to what extent risk management is required. As previously explained, using a "risk-based" approach means that remediation will not always be required. A contaminated area which affects neither a receptors and/or has no relevant pathway is low risk and therefore risk management may not be necessary.

The screening levels used at this stage are calculated by models, some of which use data that refer to specific types of receptor, land uses, geographical area and soil types. To make a comparison the assessors must be aware that the type of data collected during the detailed investigation must be appropriate for the screening level to be used as it intended. The GAC should be relevant to the site-specific circumstances. Values derived in countries should not be used unless the underlying policy assumptions and prevailing environment and social conditions can be shown to be similar.

If groundwater screening levels are exceeded and the CSM indicates that groundwater is used for human consumption it is recommended that the investigation is carried to the next tier of investigation and a Detailed Supplementary investigation is conducted.

Further details regarding GQRA and the use of screening levels are given in the section regarding Data Analysis and GQRA.

Selection of the risk management strategy

Data about contamination is also collected to help the selection of the most appropriate risk management technique. Key areas for which information is important includes the following:

- data about the range of pesticides contaminants (and other chemicals) present, and their concentrations, particularly if *in situ* or on-site bio-treatment is a possibility, as different pesticides have widely varying capability for biological degradation;
- the depth of contamination;
- the volume of contaminated soil to remediate or manage. Important for both *in situ* treatment and any removal or ex situ treatment (e.g. removal to an offsite landfill or incinerator, or excavation and treatment above ground);

- soil properties important for potential *in situ* biological or chemical treatment-such as pH, mineral and organic content, permeability, etc.;
- any impediments to excavation or *in situ* treatment, such as foundations, buried utilities, shallow rock or large boulders, very shallow water table, unstable slopes, etc.

The analytical strategy

The analytical strategy specifies which substances and soil properties are to be tested for, the number and type of samples, the range of analysis and the analytical detection limit required. The analytical strategy together with the laboratory QA/QC requirements are the principal documents on which the analytical services tender is based.
Factors important for the analytical strategy are set out in Annex 66.

Quality Control (QC) and Quality Assurance (QA)

Broadly, quality assurance and quality control procedures ensure that confidence can be placed in the results of an investigation. For the results of an investigation to be as representative as possible, it is required that the correct number of samples are collected according to the sampling strategy, that sampling is correctly carried out in the field and that analysis of the samples is correctly conducted in the laboratory. It is also important that field operations and laboratory analysis are carried out by appropriately qualified and experienced personnel. Together QA and QC should produce credible data of known quality that can be used as a sound basis for decision making.

BOX P2
The relevance of quality control and quality assurance

As quality control sampling is frequently a duplication of work and use of procedures that produce no apparent direct benefits, people sometimes see it as non-essential to an investigation which also causes unnecessary expenditure. However, without good quality control, the results of an investigation can be severely compromised to the point of being wrong. The use of poor quality data can result in wrong decision making, not only requiring repetition of investigative work but also the implementation of the wrong type of risk management, significantly increasing costs of the investigation and potentially the costs of a project.
It is recommended that 5-10 percent of the analytical budget should be spent on quality control analysis.

As suggested in the dialogue box above, 5-10 percent of the budget should be spent on quality control. For sites where a smaller number of samples are generated the significance of quality control sampling can be limited. Where the same laboratory has been selected for all sites, it is recommended that results of quality control samples are examined together so that the performance of the laboratory can be monitored. The management of Quality Control and Quality Assurance is considered in detail in Annex 7.

QA/QC Plan

Measures relating to Quality Assurance and Quality Control should be set out in the investigation QA/QC plan. A format for the QA/QC plan is given in Annex 7.

Analytical laboratory selection and qualification

Selection of an appropriate analytical laboratory that can analyse environmental samples (soil, water and sediment samples) underpins the successful outcome of an investigation and is important in the credibility of any results produced. Laboratories should be selected and qualified prior to collecting samples, preferably at the stage of the designing of the sampling program. This is to assure that the program can be executed by a suitable laboratory, and within available funds; if a suitable laboratory is not available then the design of sampling program should be reconsidered and use of field analytical techniques considered.

A key consideration is whether to use a laboratory close to the site which complies with international standards or whether the samples should be sent to an international laboratory. A more detailed discussion of analytical laboratory selection is found in Annex 7, laboratory selection.

Materials and equipment for the detailed site investigation

Once the type, quantity, location and depth of sampling has been confirmed the assessor will then be able to decide on the appropriate techniques and the equipment required for collecting samples.

Depending on the location of the sampling required, differing methods of collecting the samples can be used. Investigations may use both intrusive and non-intrusive techniques.

The methods used to undertake and operate the sampling equipment should be described in detail from both a health and safety perspective, in the investigation health, safety and environment plan (by using the standard operating procedures), and from a technical perspective in the QA/QC Plan. It is important that persons involved with an investigation have evidence of training in how to use the various types of equipment that are being used. In addition, persons that do not yet have experience in use of equipment or investigative techniques must be supervised so that the methods are carried out correctly.

The Health, Safety and Environment (HSE) plan for an investigation

The objective of the HSE plan is to describe in detail the steps that will be taken to minimise the risk to the health of people undertaking the works during an investigation, as well as the steps to be taken to protect people in the wider area and the environment. Importantly the procedures and methods outlined in this section should be distinct from those set out to maintain the investigation quality as described in the chapter about Quality Assurance and Quality Control. The basis for the HSE plan is described in detail in several EU directives, the US Occupational Safety and Health Administration Regulations (OSHA) and in the United Kingdom Construction Design and Management Regulations (CDM), where production of an HSE plan is a legal requirement for projects of this nature.

Formulation of an HSE plan is also a requirement for UN FAO projects. An HSE plan format for use for the planning and implementation of Obsolete Pesticide Safeguarding Work is described in the UN FAO Environmental Management Tool Kit volume 4 (EMTK 4), Tool N.

It is important to note that most of the information required for the HSE plan should be collected at the preliminary site investigation stage.

The requirements for the HSE Plan are specified in more detail in Annex 10.

Practical steps for the design of the detailed site investigation

Step 1: Using the preliminary site investigation report and preliminary CSM, identify the data gaps.

Step 2: Using the preliminary site investigation report and preliminary CSM determine the DSI objectives and develop a plan for collecting site information and preparing site maps.

Step 3: Define the site boundary – the area to be investigated, notably considering:
a) source areas;
b) potential migration areas and routes away from the source area;
c) nearby receptor areas.

Step. 4: Develop the soil sampling strategy:
a) using the CSM divide the site up into distinct zones, defining the area and depth of investigation, with respect to:
(i) the potential pollutant linkages/exposure scenarios identified (including receptor and migration areas);
(ii) hotspots that need to be characterised (source areas);
(iii) unidentified hotspots that may need to be located;
b) choose a sampling strategy appropriate for each zone using one or more of the above sampling methods;
c) calculate sample numbers required for each type of sampling (see the section regarding statistics and targeted sampling).

Step 5: Develop a groundwater investigation plan using the CSM and the above. This typically includes:
a) construction of boreholes at the site and at least two down gradient locations, separated by some distance to allow determination of groundwater flow direction and rate;
b) use available wells at the source area, receptor areas or in between to supplement (or potentially replace) the investigation boreholes [NB such wells could have been sampled during the PSI];
c) monitoring groundwater levels at all points for a period of time (ideally at least one year). This is the data upon which flow directions and rates is determined;
d) periodic sampling of the wells and boreholes over a representative time, taking into account seasonal variation. This always includes at least samples at the source area and any wells used as a potable water source (this could help alleviate any community concerns).

Step 6: Define the analytical strategy (see the section regarding the analytical strategy).

Step 7: Develop plans for quality control management (the QA/QC) see the section on QA/QC (see Annex 7):
a) training of investigators in investigation methods (if necessary);
b) field sampling quality management, including sampling techniques and preservation;
c) laboratory qualification, see laboratory selection;
d) sample chain of custody procedures;
e) quality control samples, including the number of samples and type of samples (trip blanks, duplicates, calibration samples, etc.).

Step 8: Develop the Health, Safety and Environment plan (HSE plan), see HSE plan section (see Annex 10).

Step 9: Define when the investigation has to take place and the overall DSI schedule.

Step 10: Once the above is done, define resources needed including:

a) consulting firms or investigation team to do the work (including investigation manager, contaminated land specialist, soil scientist, hydrologist, technicians etc.);
b) laboratories, notably laboratories that can perform required analyses using approved methods and meet quality requirements (see section on laboratory selection, Annex 7);
c) key equipment, such as excavators or augers;
d) sampling and health, safety and security supplies.

Step 11: Develop the cost budget for execution of the DSI and compare this to available funds. It may be necessary to revise plans to stay within funding limits. However, care should be taken when reducing plans due to budget concerns; accomplishing key objectives with good quality should not be compromised.

Tool Q

Data analysis and Generic Quantitative Risk Assessment (GQRA)

Background

Once the detailed site investigation has been conducted samples are then sent to the selected laboratory for analysis. On receipt of the results back from the laboratory the assessor is then able to check that all the data has been received and to arrange it in a format relevant to the sampling plan. Depending on the objectives of the investigation, the assessor will then conduct any statistical analysis as required for data quality purposes and, if non-targeted sampling has been carried out, to calculate representative levels of contamination for comparison with GAC.

The Preliminary Risk Assessment requires development of a basic conceptual model, the identification of pollutant linkages and comparison of a limited number of analytical results with generic screening levels. Sites that demonstrate the presence of potential pollutant linkages and evidence that screening levels have been exceeded then proceed to the next tier of investigation; the Detailed Investigation and Generic Quantitative Risk Assessment (GQRA).

For most sites, the GQRA will be the principal risk assessment that takes place. The significant difference between the Preliminary Risk Assessment and GQRA is that the representative concentrations of contaminants are based on the Detailed Site Investigation which provides much more data and hence a CSM with a much higher level of confidence. At the GQRA there should also be enough data to allow investigators to assess the magnitude of the hazard i.e. is there a large or small quantity of contaminated soil and how contaminated is the soil. By further examination of the pollutant linkages, assessors will be able to evaluate, in the context of local laws, whether the contamination encountered at the site poses a significant level of risk to receptors and therefore whether some form of risk management will be necessary.

Under some circumstances detailed quantitative risk assessment will be required following a third stage of investigation, where site specific assessment criteria (SSAC) are formulated. The complexity of DQRA and the associated investigation is such that assistance from experts will almost always be required. DQRA are not be a normal requirement of FAO investigations.

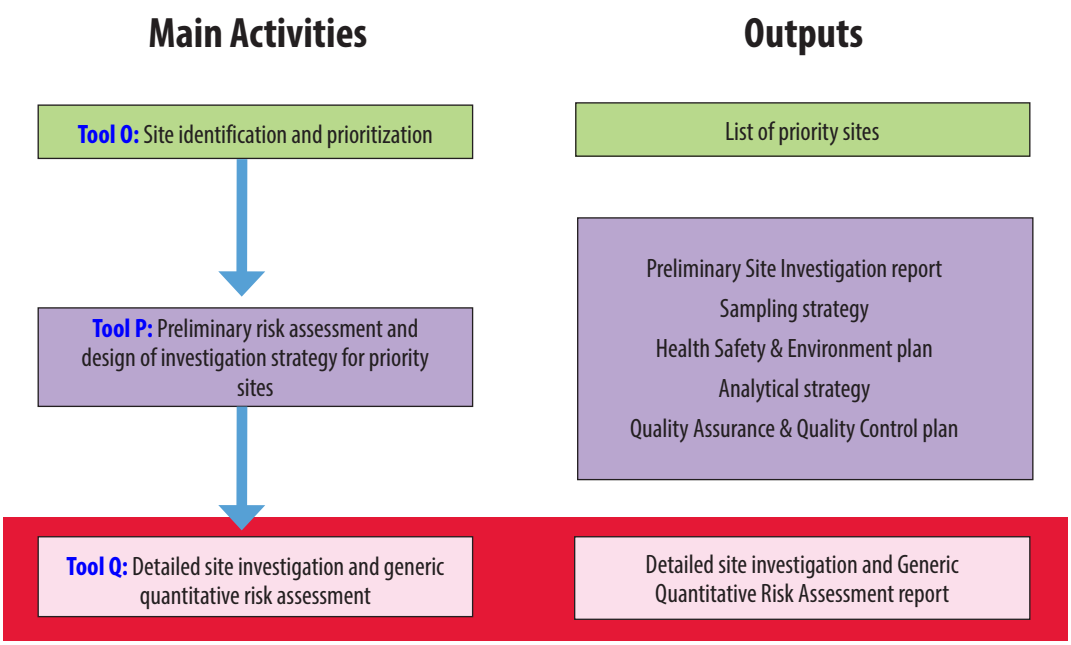
Data analysis and statistics[7]

Data analysis

As part of the detailed site investigation, samples will have been sent to a laboratory for chemical analysis. This will be conducted according to the specification given to laboratory corresponding to the range, type and sensitivity of analysis required. Once the assessor receives the laboratory results there are some steps that should be gone through before more detailed analysis, including any statistical analysis, can be undertaken:

(i) basic data review–checking that all the results that are expected are present and that they are there in the correct format;
(ii) sorting of analytical data into relevant data sets according to sampling strategies and the conceptual site model;
(iii) more detailed review of data quality.

[7] Chartered Institute of Environmental Health, 2008.



Basic data review

If assessors have followed good technical practice when designing the soil sampling strategy, they will already have a view about the number and type of datasets that will be subject to statistical testing. Prior to analysis including the use of statistical methods, assessors should review the data to ensure that they are complete and free from obvious error and that results for all the samples requested have been returned. It is advisable that data from laboratories is supplied in an electronic format, such as a spread sheet or in a standard data interchange format such as the developed by the Association of Geotechnical Specialists (AGS). Data supplied in hard copy format which is then re-typed into a spread sheet, particularly when large data sets are involved, is likely to suffer from data entry errors. Collating the data in a spreadsheet or a database also has several other advantages:

- manual or automatic scrutiny of the data – for example to Identify anomalous or invalid data, missing units etc.;
- sort the data – for example into datasets or individual contaminants, zones, type of sample, sample depth etc.;
- establish data are not clustered or there are no spatial trends that would invalidate any classical statistics;
- calculate the basic statistics needed for statistical testing, such as sample mean and sample unbiased standard deviation.

It also means that data can be presented in a summary form (although it is important to remember that this does not obviate the need also to provide data in its original form, such as Certificates of Analysis and Site log book records). Electronic storage means that it is relatively easy to produce spatial representations of the information, showing contaminant concentrations across the site by depth and in relation to site boundaries and other features. Graphical representations can be extremely useful in helping assessors to better visualise the pattern of contamination on the site, for example whether more than one "population" of soil is present, whether extreme values (outliers) exist and are spatially related, and whether assumptions about the random spatial distribution of data are justified. This ensures that the most robust and meaningful datasets for statistical testing are created.

Where data show a trend across a site, geostatistical techniques may be adopted.

BOX Q1
Dealing with "non-detects"

Laboratories will often report analytical results are being below a method specific Limit of Detection (LoD) or Method Detection Level (MDL). Such **"non detects"** indicate that while the actual contaminant concentration remains unknown, it will lie somewhere between zero and the detection limit. Assuming that the MDL is set at a sensible level (i.e. lower, and ideally no more than 0.1*GAC the assessor intends to use in the data analysis), the presence of non-detects in the dataset nonetheless tells the assessor something useful about the condition of the land, that is, that [parts] of it appear to be uncontaminated. The presence of non-detects, however, also creates practical difficulties for data and statistical analysis since "less than" values cannot be used to compute the key statistics used in the tests. A decision therefore should be made about the value to be assumed for samples presenting as non-detects. A cautious assumption would be to assume that non-detect samples contain the contaminant at the same concentration as the MDL. Less cautiously, a lower concentration such as 50 percent of the detection limit could be used. In practice if the MDL is sufficiently below any GAC the assumed concentration for non-detects should not influence the outcome of the risk assessment.

The presence of non-detects (and the choice of any values as substitutes for them) can have implications for the estimation of key parameters such as sample mean and sample unbiased standard deviation, upon which many statistical tests rely. Where a dataset contains relatively few non-detects, the effect on key parameters, and hence on the outcome of the statistical tests themselves, is likely to be small, however, where a substantial number of the values in the dataset present as non-detects, particularly where the MDL is close in value to the critical concentration used in the test, there could be a much more significant effect on the outcome of testing. The following may be helpful in deciding how to proceed where non-detects appear in the data:

- where the proportion of non-detects within the dataset is less than 10 percent to 15 percent, non-detected values should simply be replaced by a "small" number (e.g. MDL);
- where the proportion of results within the dataset is greater than 10 percent to 15 percent, especially where the MDL is close to the critical concentration, non-detects can be substituted-for as before but note that the values selected may have a large effect on the risk assessment outcome in which case a sensitivity check could be carried out to establish the effect of substituting different values on the outcome of statistical testing. Any future testing should seek to adopt a lower MDL.

NB the presence of large numbers of non-detects within a dataset might indicate that zoning or data sorting decisions may need to be revised. For example, it might indicate that the dataset includes many samples from natural (uncontaminated) ground and a relatively small number of more contaminated "made ground" samples (which may be more appropriately considered as a separate dataset).

Detailed data quality review

Once a basic data review has been conducted and data sorted into the correct datasets based on the conceptual model and the site zoning a more detailed check of the data should be conducted:

- checks on the "completeness" of the data for example, are results available for all sample locations, contaminants, sample types, media, sample depths etc.?
- checks on the accuracy of the data – are results correctly identified, for example, by sample location, depth, type, and sampling date?

- identification of obviously anomalous results such as elevated values that are unexpected given the conceptual model and (say) a field description in a borehole log – this may indicate a labelling or laboratory error;
- identification of invalid data – for example where the field or laboratory record indicates that sample integrity may have been compromised.

Once these more detailed checks have been carried out and the reasons for any discrepancies have been identified, addressed where possible, and documented, the assessor is in a position to move on to the next step in the statistical assessment of the data.

The use of statistics in pesticide contaminated land investigations

Why should statistics be used?

It is often assumed that analytical results received from samples taken during an investigation are representative of the "actual" or "true" concentration of contaminants in the ground. However, the variation in physical characteristics of the site (for example soil type, soil permeability, organic carbon content etc.) and as a of result errors introduced at various stages during the site investigation and during laboratory analysis mean that the results can also have a high degree of variability and uncertainty associated with them. Consequently, the concentration of contaminants measured in samples does not always reflect the level that exists in the ground. There is also the question of the volume of support – the ratio between the volume of sample and the volume of ground it is intended to 'represent'.

At this point it should be noted that statistical tests are an aid to decision making but are not a substitute for professional judgement. Stakeholders should be aware that any data used for decision making has error associated with it and levels of contamination should not be considered as absolute.

When should statistics be used?

Under FAO projects, statistically valid sampling strategies will not generally be required for small sites, for REA or for preliminary risk assessment. A of simple small to medium sites (where rules of thumb and sampling protocols are used to set sample numbers).

Basic statistics for small to medium sites for a detailed site investigation

Statistics for small to medium sites are recommended under the following circumstances:

Circumstance 1: To determine the concentration of contamination in an area[8] or zone[9] of the site (as defined by the conceptual site model and sampling plan).

The following steps are recommended:

Step 1: confirm the units of investigation (this is normally in cubic metres or m^3).
Step 2: calculate the volume of the soil in the zone or sampling unit in question and multiply by 1.3.
Step 3: select the corresponding number of tests required according to the table in Figure A9:1.
Step 4: choose the sampling strategy (for simplicity square grid sampling is recommended).
Step 5: Set out the sampling grid based on the volume for analysis and the number of tests required, take the required samples (NB duplicates may be needed for QA QC purposes) and conduct the necessary analysis.
Step 6: review the data and arrange into data sets.
Step 7: complete the statistical test according to the formulae and calculations in Annex 9.
Step 8: make a comparison against the relevant screening level and decide whether the ground is contaminated or not.

[8] Area: defined by how a receptor will be exposed to a contaminant.

[9] Zone: defined by the extent of land that has similar characteristics in terms of the contaminant (e.g. sand layer).

Further statistical guidance

The use of statistics and steps required to maintain data quality can be a very complicated and involved subject area. The objective of the above guidance is to make it as simple as possible for those involved with risk assessment of pesticide contaminated sites so that some level of data quality is maintained. If further information is required, readers are directed to extensive guidance issued by the United States Environmental Protection Agency in the use of the Data Quality Objectives Process.[10]

Generic quantitative risk assessment

Risk based screening levels

Screening values are generic quality levels developed in many countries and used to assist in the risk-based management of contaminated land. The use of screening values, trigger values or guideline values in risk assessment allows the comparison of site-specific contamination concentrations with risk-based guideline values in relation to specific receptors, pathways and exposure scenarios. When used correctly screening values provide non-specialists and other stakeholders with a clear and simple method of assessing the risk presented by contaminants at a site, or parts of a site, to particular receptors. In addition, the use of generic screening levels during risk assessment can considerably reduce costs as they have a more limited requirement for data and expertise than the use of SSAC. Screening values are specific to contaminants in soil or water and are protective of people, or flora or fauna. As soil and groundwater are the media where human exposure is most likely, these are the ones that are most frequently used. Soil screening values are often further differentiated by exposure scenario based on the intended land use (e.g. residential, agricultural or industrial). Similarly, water screening values may be set differently for drinking water sources, and for water used only for irrigation or saline/ocean waters. The FAO remit for risk reduction is primarily targeted at human health protection and therefore the focus of EMTK 5 is towards this goal. Despite wider environmental receptors not being explicitly taken into consideration, the steps taken towards risk reduction for human health will be of considerable benefit to the other receptors.

Sources of screening levels

The following table provides links to some agencies that provide risk-based screening levels for pesticides.

Table Q1

Sources of various screening levels for pesticides

Agency	Link to screening levels concerned
United States Environmental Protection Agency Regional Screening Levels	http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search
Canadian Council for Ministers of the Environment Environmental Quality Guidelines	http://st-ts.ccme.ca/en/index.html
Netherlands Ministry of Infrastructure and the Environment Soil Remediation Circular 2013	https://rwsenvironment.eu/subjects/soil/legislation-and/soil-protection/
World Health Organization Drinking Water Quality Guidelines	https://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/

[10] United States Environmental Protection Agency, 2000.

A more detailed review and comparison of screening levels used in the European Union is provided at:

https://publications.europa.eu/en/publication-detail/-/publication/206489ef-386d-4bcb-8b39-25b41d4d3c45

The use of screening levels

For the purposes of GQRA, screening levels are used to compare against representative levels of contaminant measured on-site to help assessors decide which areas of a site does not need risk management. Areas with levels of contaminant equal to or below screening levels do not require further intervention. Areas with levels of contaminant above screening levels may require remediation or detailed quantitative risk assessment. It is essential that risk assessors understand the basis on which any screening levels they choose to use have been derived and how those levels are treated in the specific legal context under which they are assessing the risks.

Determination of risk-based screening levels and the regulatory contexts of their use vary significantly from country to country. In addition, screening levels are population and region specific. This means that many countries have their own screening values, the use of external values is required to be justified. However, for countries where screening levels are not available or are not risk based, the use of values from other countries can be a considerable improvement on the existing situation. Countries using external screening levels must be aware of the both the technical and legal constraints of their use. In general terms, the following criteria should be considered when selecting GAC from particular countries:

- whether or not the criteria are "risked based";
- the complexity of the site and the number of contaminants involved. Due to the way GAC are derived, the use of GAC from multiple sources is not recommended. Assessors should try to identify GAC that developed and used in the same way;
- the technical constraints of their use and limitations of use.

Derivation of generic assessment criteria

Developing Generic Assessment Criteria (GAC) involves modelling exposure to contaminants in standard land uses, representing exposure scenarios, that equates to agreed toxicological benchmarks. Values can vary with soil type, pH and organic matter. The way GAC are used varies according to the original country of origin. Generally, they are either used to screen out substances from further consideration (screening levels) or to indicate the need for remediation (trigger, remediation or action levels).

One of the primary reasons for using GAC is that deriving site specific assessment criteria is a time-consuming process requires high levels of technical input and potentially specialised site-specific data (e.g. bioavailability or plant uptake factors) not readily available in many countries.

Selection and use of GAC

1. Select the relevant media i.e. soil, water or air for example.
2. Select the appropriate land use, assessors should take into consideration the longer-term future land use. For example, Residential, Industrial or Agricultural land uses and also a water use if relevant (drinking water, irrigation, for example).
3. Select an appropriate exposure route; most screening levels will already have exposure routes integrated into them, however some agencies publish screening levels for specific exposure routes.

As already mentioned some agencies require a specific method of sampling for the screening level to be used correctly. In this event the assessor must take this into account when designing the site investigation so that the necessary data are collected in the correct way for the GAC to be used.

Some GAC can be made more site specific by measuring variables including soil organic matter content and pH, for example. Again, this will be specified in the instructions for using the screening level and should be considered at the investigation design stage.

Number of available screening levels

There are more than 1170 active ingredients of pesticide formulations that assessors may encounter (including both active ingredients from past production as well as those in present production). This does not include solvents, dispersants or other components of pesticide formulations that also may influence human health and the environment. Most agencies have published GAC for only a very limited number of pesticides. The US EPA, which is the agency with the most comprehensive GAC database, has developed values for 236 pesticides that are encountered in the FAO Pesticide Stock Management System.

It is therefore possible that during the risk assessment process that investigators will encounter pesticide active ingredients for which there are no GAC. In this event the following is recommended:

i. if there is a mixture of pesticides, remediation may be needed for other contaminants;
ii. look at the other pesticides present and decide upon an indicator pesticide with similar physico-chemical and toxicological properties that does have a screening level. This commonly used method of selecting a GAC for compounds without one needs to be done by someone competent in chemistry and toxicology;
iii. if appropriate, break down the pollutant linkage to use a more specific exposure iii. criterion. For example, air quality standards might be used where the route of exposure is inhalation;
iv. if Acceptable or Tolerable Daily Intakes (ADIs or TDIs) are available, GAC values can be derived where ingestion is the primary exposure route. Under these circumstances an exposure assessment can be conducted to estimate exposure to specific receptors which can then be compared against toxicological values. In some circumstances this may be more relevant than using a published screening level. In the case of organochlorine contamination there is some evidence to suggest that modelling used for the calculation of screening levels does not significantly emphasise the effect of the ingestion of organochlorine contaminated foods. In this case the level of contaminant measured in milk, eggs or meat available to receptors from the local area would be compared to the ADI;
v. seek expert guidance to calculate a site-specific assessment criterion. (A useful starting point is the US EPA tool)[11].

The detailed site investigation report and generic quantitative risk assessment

The Detailed Site Investigation (DSI) report sets out the context of the investigation including site background, preliminary conceptual site model defined in the PSI report, critical receptor exposure scenarios and any pollutant linkages identified that require further investigation. It should also refer to data gaps and uncertainties which led to the investigation objectives and the sampling strategies and investigation methods used during the investigation. Importantly

[11] https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search.

it should also specify the screening levels used for risk assessment and the justification for use of each.

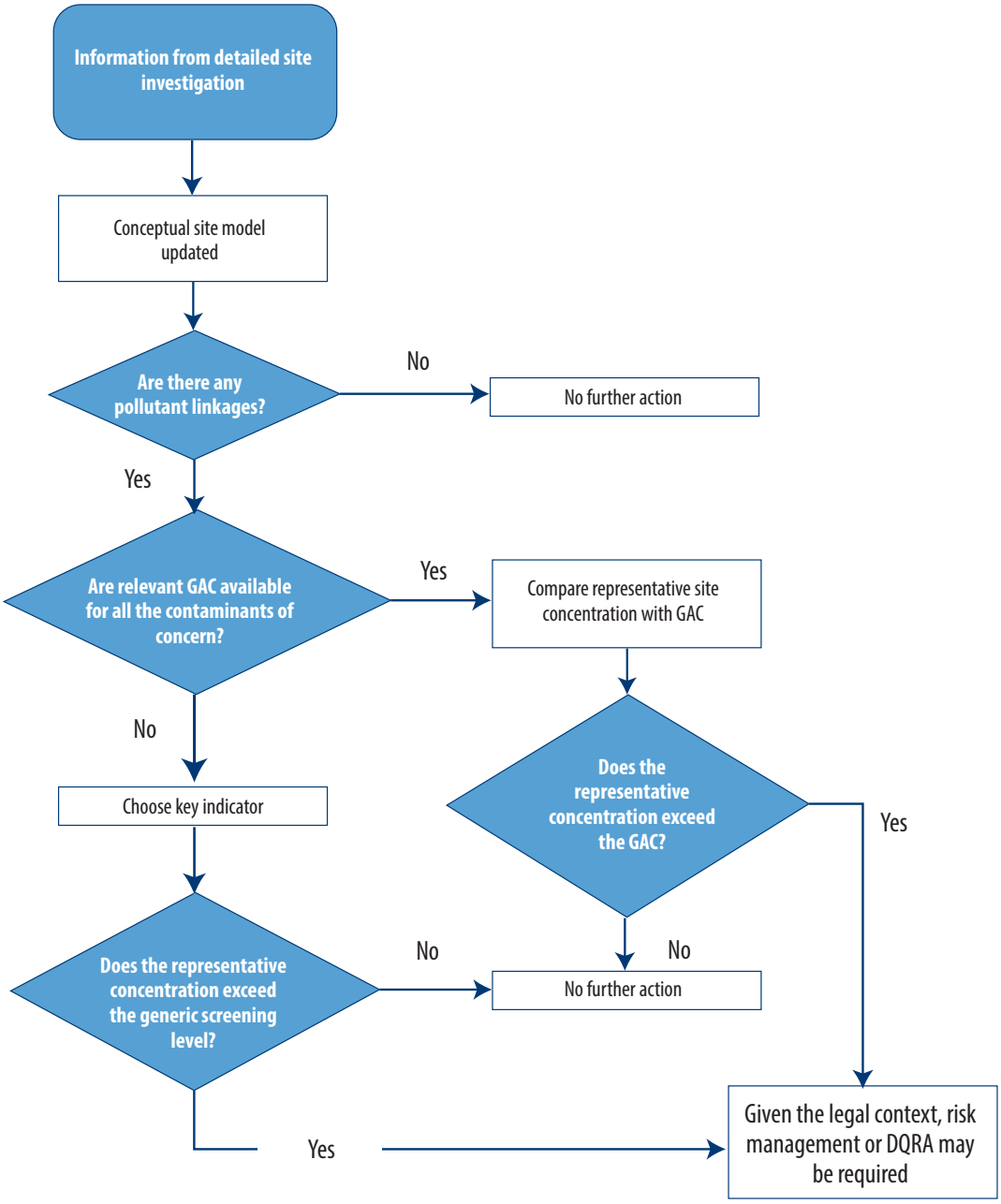
Outputs from the Detailed Site Investigation Report and Risk Assessment are then presented, including the analytical results, data analysis and the generation of representative concentrations for comparison to the screening levels. The report should set out an updated conceptual site model showing evidence of the presence of pollutant linkages in operation at the site i.e. details of the particular receptors affected by the site, details of the source and evidence of pathways in effect. The report conclusion should set out the estimated quantity of contamination and the level of risk posed by areas/zones of the site. Finally, the report should state the requirement for risk management.

Format for the detailed site investigation report and risk assessment

A suggested format for the detailed site investigation report and risk assessment is the following:

1. Executive summary (written for non-specialists).
2. Table of contents.
3. Introduction and legal context.
4. Objectives and scope of the investigation.
5. Site background information.
6. Summary of preliminary site investigation and preliminary conceptual site model.
7. Sampling strategies and investigation methods used.
8. Analytical results.
9. Data analysis including generation of representative concentrations and any QA/QC analysis.
10. Selection and justification of screening levels used.
11. Updated conceptual site model including graphical representations of contamination or results displayed on a map.
12. Risk assessment conclusions and requirement for risk management:
    a) Qualitative description of risks and impacts;
    b) Estimation of the categories and volumes of contaminated soils.
13. Appendices containing supporting information including:
    a) works completed, and contractors used;
    b) outreach and stakeholder engagement activities;
    c) HSE reporting;
    d) certificates of analysis;
    e) logs of material encountered at sample locations;
    f) photographs.

Figure Q1
Detailed risk assessment flow chart (adapted from Paul Nathanial C., Paul Bardos R., 2005)



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Annexes

Annex 1: Introduction to the FAO Environmental Management Tool Kit series, volumes 1 to 4
Annex 2: Detailed description of REA algorithms
Annex 3: Guidance for conducting the preliminary site investigation
Annex 4: Practical guidance for design of the detailed site investigation
Annex 5: Probabilistic sampling strategies
Annex 6: The analytical strategy
Annex 7: Quality control and quality assurance measures
Annex 8: Sampling methods
Annex 9: Statistical methods and worked examples
Annex 10: Requirements for the Health, Safety and Environment (HSE) plan for an investigation
Annex 11: Site investigation materials and equipment

Works cited

ANNEX 1

Introduction to the FAO Environmental Management Tool Kit series, volumes 1 to 4

Regarding obsolete pesticide stocks, FAO supports national management teams in establishing strategies for completing national assessments that result in the environmentally sound management and final disposal of the pesticides. The Environmental Management Tool Kit (EMTK) forms an integral component of that technical support. It is part of a series of guidelines and systems designed to assist countries in assessing the scope of the obsolete pesticides problem and implementing effective prevention and disposal. EMTK volume 1 focuses on issues related to inventory and the prioritization of stores based on environmental risk; volume 2 focuses on the selection and management of stores and collection centres and the transport of waste pesticides to these points; and volume 3 focuses on the development of country environmental assessments and environmental management plan (EMPs). EMTK volume 4 provides practical advice to project management units and partners, such as waste management companies, who are implementing the *safeguarding strategy* presented in EMTK volume 3. More specifically volume 4 provides practical advice on "HOW" to implement the strategy with minimum impact on public health and the environment. The four volumes of EMTK can be used as a planning system to assist governments and cooperation agencies in planning all the steps of a disposal programme for obsolete pesticides that may have an adverse impact on the environment and the health of the public.

The volumes of EMTK 1-4 consist of a series of tools as outlined below:

[12]**Environmental Management Tool Kit volume 1:**

Tool A: Environmental risk assessment relating to obsolete pesticide stocks

Tool B: Prioritization of stores

Tool C: Regional prioritization

This document can be downloaded at: http://www.fao.org/tempref/docrep/fao/011/i0473e/i0473e.pdf

[13]**Environmental Management Tool Kit volume 2:**

Tool D: Selection of collection centres

Tool E: Management of collection centres

Tool F: Transport planning

This document can be downloaded at: http://www.fao.org/docrep/pdf/011/i0474e/i0474e.pdf

[14]**Environmental Management Tool Kit volume 3:**

Tool G: Safeguarding strategy

Tool H: Disposal strategy

Tool I: Environmental assessment report and environmental management plan

12 Food and Agriculture Organization of the United Nations, 2009.
13 Food and Agriculture Organization of the United Nations, 2009.
14 Food And Agriculture Organization of The United Nations, 2011.

This document can be downloaded at: http://www.fao.org/3/a-i2216e.pdf

[15]**Environmental Management Tool Kit volume 4:**

Tool J: Zoning of the work place

Tool K: Risk assessment

Tool L: Standard operating procedures

Tool M: Selection and use of equipment

Tool N: Health, safety and environment plan

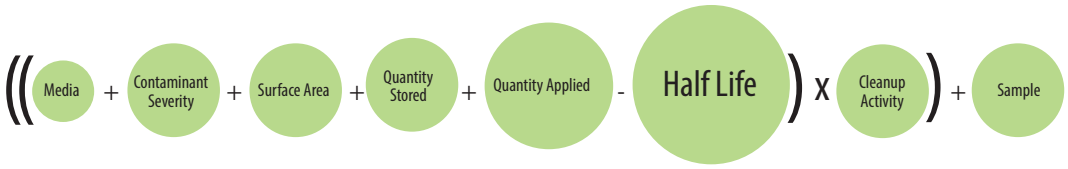
This document can be downloaded at: http://www.fao.org/3/a-i2022e.pdf

[15] Food And Agriculture Organization of The United Nations, 2011.

ANNEX 2

Detailed description of REA algorithms

A. Source type and quantity risk



= ((MD + CS + SA + QU + QA - HL) X CA) + SAtq

Formula and factors	Points	Data source
((Media	1-2	Question in Source Type and Quantity section
+ Contaminant Severity	1-3	Pre-set based on primary and secondary
+ Surface Area Contaminated	1-5	Question on Source Type and Quantity section pesticides entered in Desk Screen section
+ Quantity Used or Stored	1-5	Question on use on Source Type and Quantity section
+ Quantity Applied/Spilled	0-4	Questions in the General Background Source Type and Quantity and Pathway Risk section–see explanation below
- Half Life)'	0 to >20'	Pre-set based on primary and secondary pesticides entered in Desk Screen section
x Clean up Activity)	1	This factor not used–reserved for future risk evaluation after remediation work is done
+ Sample	0-3	Sample results entered on Desk Screen
LOW <= 8	MEDIUM = 9-12	HIGH = >13

Media – Investigators identify if the contamination has spread to more than one medium. Positive responses receive a value of 2, Negative a value of 1.

Contaminant severity – Contaminants present are listed in the desk screen section. Pesticides were assigned to one of three separate groups based on their recommended level in soils and drinking water: High Risk; 3, Medium Risk 2, Low Risk 1. This classification is pre-set in the REA program.

Surface area suspected of being contaminated – Investigators estimate the size of the area suspected of being contaminated based on observations, historical records, interviews with people familiar with the site, aerial photographs, satellite imagery (e.g. Google Earth), sampling

data and any other data available during the REA. Sites are given 1 point if the suspected contaminated area is <100 m^2; 2 points for 100-500 m^2 or 500-1 000 m^2; 3 points for 1 000-5 000 m^2 or 5 000-10 000 m^2 (1 hectare); 4 points for 1 hectare-5 hectares; and 5 points for >5 hectares.

Quantity used or stored – 1 point is given if the quantity of pesticide used (cf question in the Type and Quantity section) is reported as "small" according to the definitions provided in the Rapid Environmental Assessment (REA) Investigator Handbook. 2 points are given for "medium", 3 points for "large", and 4 points for "very large". An additional point is given if significant amounts of pesticides are still used or present (in containers) at the site, based on the "are pesticides still used?" question. The maximum score is thus 5 points.

Quantity applied or spilled – Questions are asked about: site use in the general background section, stains observed in the source type and quantity section, and known spills in the Pathway Risk section. These are all relevant for estimating the quantity of pesticide released into the environment. 2 points are given if the site was a formulation or burial site as investigation has shown such sites commonly had numerous spills; 1 point is given if the question on stains observed is answered showing extensive soil staining or saturation with pesticides; and 1 point is given where a history of spills is reported by people interviewed or historical records found during the REA investigation. The points given for this question is the total from the above, for a maximum of 4 points.

Half-life – Pesticides, once released to soil and in modest concentrations, degrade over time due to biodegradation, photo-degradation and other processes. The reduction is often very significant, because the half-life for many pesticides in soil is quite short. This is accounted for by subtracting a half-life factor from the point total, determined by dividing the soil half-life by the number of days since last use of the pesticide (in days). Soil half-life is pre-programmed into the system for specific pesticides based on literature data. The type of pesticides present is taken from questions on the Desk Screen section; if several pesticides are reported as present, the one with the longest half-life is used. Time since last use is taken from the relevant question on the Desk Screen section; since the answers are in ranges (e.g. 30 days to 1 year, 1 to 2 years, etc.) the shorter time limit in the range is used for the calculation, to be conservative.

However, pesticides present at very high concentration, such as in concentrated spills or bulk piles, do not generally degrade at a rate anything close to the half-lives in the literature. Therefore we may be over-rating this factor, since sites have concentrated pesticides still on site. This would be the case if the site is a burial site (in general information section); there are still significant pesticides on site (in type and quantity section); or the site surface is completely discoloured or saturated with pesticides indicating high concentrations (also in type and quantity section) or uncontained piles of pesticides are reported (in the key pollutant data part of the Pathway Risk section). In these cases, then the soil half-life factor defaults to 0 as it is clear that un-degraded pesticides are present in significant quantities.

Sample – The concern here is the amount of contamination at the source. The highest two sample values are divided by the relevant standard, which is pre-set in the program based on an evaluation of internationally recognized recommended soil or drinking water safe levels. Samples that exceed the recommended level by a factor of 2 or more receive a value of two, those that exceed the recommended level by a factor of 3 or more receive a value of 3. Values less than 2 are given 0 points. These values are then averaged and the rounded (up or down) to an integer to determine the Sample Value. An example calculation is as follows:

The raw data for a DDT contaminated site, reference value of 0.7 mg/kg, are:

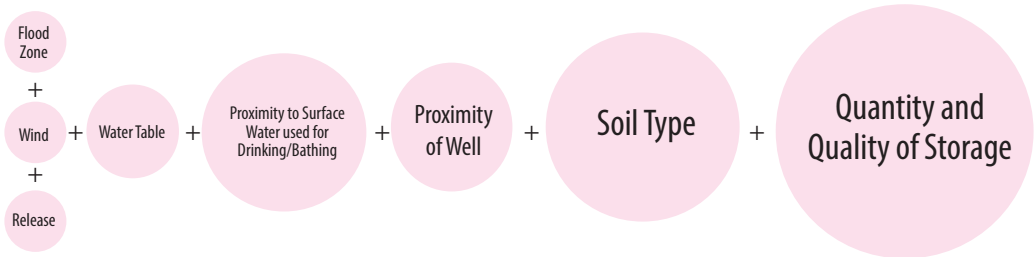
- sample 1-3.87 mg/kg; Sample 2-1.88 mg/kg; Sample 3-1.23 mg/kg;
- sample 4-0.40 mg.kg; Sample 5-0.01 mg/kg; Sample 6-0.0 mg/kg.

Samples 1 and 2 are the highest two values. The point value is calculated:

- 3.87/0.7 = 5.53, give 3 points; 1.88/0.7 = 2.68, give 2 points;
- average of these = (3 + 2)/2 = 2.5, round to 3 points.

Note that this factor is not considered more highly because at the REA stage, sampling data is very limited and may not be representative of contamination present; the other factors are equally or more important in assessing the potential risk.

B. Pathway Risk



= FZ + WD + RL + WT + SW + WL + ST + (QN X QS)

Factors	Points	Data Source
Flood Zone	0-1	Question in Pathway Risk Section
+ *Wind (orientation to receptors)*	0-2	Calculation based on wind direction question in Pathway Risk Section and direction to receptors in Receptor Risk
+ *Water Table*	0-3	Question in Pathway Risk Section
+ *Significant Pathways*	0-2	Significant Pathway question in Pathway Risk or extensive staining or saturation reported in question in Type & Source
+ *Proximity of Wells*	0-4	Questions in Pathway Risk Section
+ *Proximity of Water*	0-5	Question in Pathway Risk Section
+ *Soil Type*	1-3	Data in Desk Screen Section which is taken from GIS data
+ *(Quantity X Quality of Storage)*	1-12	Questions in Pathway Risk – Key (1 if no current Pollutant Section pest. Storage)
LOW <=10	MEDIUM = 11-16	HIGH = > 17

Flood zone – Pesticide contamination in a flood zone presents a risk of contamination being transported widely in flood. Positive responses receive a 1, negative responses receive a 0.

Wind (orientation to receptors) – Wind transport of contaminated dust or vapors contributes to risk to receptors. Wind direction was compared to the relative position of nearby residential areas and water used for drinking or bathing. Perfect alignment (N water, prevailing N wind) receives a value of 2, proximate alignment (N water, prevailing NW wind) receives a 1, and no alignment receives a 0. If no data is available, default to a value of 1.

Water table – Shallow groundwater increases risks that pesticides will get into ground water and that this groundwater is used. 3 points are given if the depth to the top of the water table (in wet seasons, if applicable) is <2 meters; 2 points if 2-10 meters; and 1 point if 10-50 meters; and 0 points if >50 meters.

Significant releases – A knowledge of significant past releases gets 1 point, and clear evidence of past releases such as staining or pesticide saturated soils receives an additional 1 point, for a maximum of 2 points. Spills or releases having occurred obviously increases that chance for migration of contamination.

Proximity of well – Wells close to the contamination area increase the risk that contamination will reach water used by people or animals. No well in the vicinity receives 1 point, a well within 500 meters receives 2, within 100 meters 3 and within 50 meters 4. However, if the answer to the question regarding does groundwater flowing towards receptors is "no", then only 2 points are subtracted (though not going less than 0)

Proximity of water – Surface water on or close to the contamination area increases the risk of contaminated water used by people or animals. Linear increase in values. No water source in the vicinity receives a 1, water running through the site receive a 5. Also, a "Yes" to the question regarding permanent surface water reported on site (pond or stream) gets a 5.

Soil type – The type of soil impacts the risk of mobility of pesticides through the soil – both related to adsorption of pesticides, which reduces mobility, and water permeability, where more permeable soils increase the risk of migration. Point values are:

- highly permeable soil such as sand or gravel (percent sand > 50) 3 points;
- moderately permeable soil such as silt, loams and mixtures of sand, silt and clays (percent silt > 50 or silt, sand and clay all < 50 percent) 2 points;
- highly impermeable soils such as clay and laterite (percent clay > 50) 1 point.

The data is extracted from available GIS data for the countries, tied to the site coordinates; we do not expect investigators to be knowledgeable in soil classification.

Quantity and quality of storage – This factor relates to the potential for new or continuing releases presenting augmented risk. It is broken down into two components: **Quantity** that could still be released, and **Quality of storage** which relates to the risk that pesticides present actually would be released.

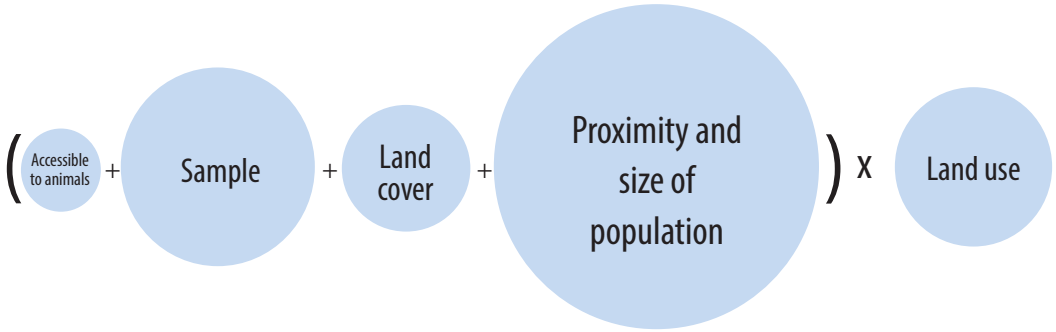
Quantity: The quantity for containers is determined by the size of the containers (in litres) multiplied by their number. The product is then converted to cubic meters by dividing by 1 000. For uncontained piles, a number is given in cubic meters. Fewer than 5 cubic meters is given a value of 1, 5-10 cubic meters a value of 2, and 10 or more cubic meters a value of 3. If there are no containers or piles of pesticides still at the site, but only residues and spillage from past activities, 1 point is given.

Quality of storage – If the answer to the question in the Pathway Risk – Key Pollutant Section is that there are no containers on site, then 1 point is given for residue or spills only, and 3 points for

"uncontained piles." If there are contained materials (drums, bags, pails), the following values for each of the 7 categories are averaged:

- container type (1-6);
- age of Container (1-4);
- condition of Container (1-5);
- formulation (1-3);
- indoors-Good Roof/ Indoors-Poor Roof/Outdoors/Below Ground (1-4);
- if indoors, quality of walls (1-3);
- if outdoors, quality of cover (1-4).

C. Receptor Risk



= (AN + SARec + (LC X 0.5) + PO) X (LU X 0.25)

Factors	Points	Data Source
(Land Use x .25) times	0.25-1.25	Question in Receptor Risk Section the sum of:
(Accessible to Animals	0-2	Question in Receptor Risk Section
+ Sample result	0-3	Calculated from sample data recorded in Desk Screen
+ (Land Cover x .5)	0.5-2	Ground cover question in Receptor Risk
+ Population)	1-5	Question in Receptor Risk Section
LOW = <5	*MEDIUM = 5-9*	*HIGH = >9*

Accessible to animals – Sites that are used regularly by livestock, poultry, or fish (if ponds are on site) get a value of 2, if the animals provide direct (meat) or indirect (milk, eggs) sustenance to people. Sites with no regular use but may be accessible to animals (i.e. they can migrate in and out of the site) get a value of 1. If it is clear that animals cannot access the site as a result of walls and security a 0 can be given.

Sample – The sample results from the REA or other good quality sample data is recorded in the Desk Screen Section. The concern here is to take into consideration contamination to which receptors may be exposed. The result is calculated from all samples with positive results, both

at the source area and in receptor areas. Samples finding no contamination ("0" values) or contamination below detection levels or levels of concern (generally 0.1 mg/kg) are excluded from the calculation. Each positive sample result is divided by the recommended level, which is pre-programmed into the system for specific pesticides based on a review of internationally used standards for soil and water. Samples that are below the recommended level receive 0 points; samples that exceed the recommended level by a factor of less than 2 (i.e. 1 to 2 times the standard) receive 1 point; samples that exceed the recommended level by a factor of 2 tor more receive 2 points, those that exceed the recommended level by a factor of 3 or more receive a 3 points. These values are then averaged and then rounded up to an integer to determine the Sample Value. An example calculation is as follows:

The raw data for a DDT contaminated site, reference value of 0.7 mg/kg, are:

sample 1-3.87 mg/kg; Sample 2-1.88 mg/kg; Sample 3-1.23 mg/kg;

sample 4-0.40 mg.kg; Sample 5-0.01 mg/kg; Sample 6-0.0 mg/kg.

Sample 5 is considered below the minimum concern level of 0.1 mg/kg and Sample 6 is a "0", so both are excluded from the calculation. The point value is calculated:

3.87/0.7 = 5.53, give 3 points; 1.88/0.7 = 2.68, give 2 points;

1.23/0.7 = 1.76, give 1 point; 0.4/0.7 = 0.57, give 0 points;

average of these = (3 + 2 + 1 + 0)/4 = 1.5, round up to 2 points.

Note, that the samples taken should be only samples from contaminated soil or water samples, not for samples of concentrated waste piles or stored pesticides (which of course would far exceed standards) as the intent is to evaluate the risk to receptors from exposure to soil or water. If there is no sample data, a default value of 1 point is given. If good quality soil sampling data shows no exceedance of recommended levels in any sample, further review is needed to determine if the site should continue to be listed in the REA database.

Land cover – Areas where the contamination is covered by impermeable surfaces present less risk to people than less well covered areas. Where the contaminated area is covered by impermeable materials in good condition (most often concrete, but sometimes bricks, asphalt or other materials) get 1 point. Grass or other good vegetative cover gets 2 points, sparse vegetative cover, broken concrete or poor condition paving gets 3 points, and bare ground, where people can be exposed directly to pesticide contamination, gets 4 points. These points are then multiplied by 0.5

Population at risk – People that live or work on the site are a major, even the key factor in receptor risk. For this factor, these populations are summed for affected groups in four categories (on site, within 50 meters, within 100 meters, and within 500 meters). The log is taken for each group and multiplied by a weighting factor. On site populations are weighted by a 1 value; 50 meters by a .5 value; 100 meters by a .25 value and 500 meters by a 0.1 value. These numbers are summed and rounded to the nearest whole integer. An example is (from a real site in Kyrgyzstan):

	On site	Within 50 meters	Within 100 meters	Within 500 meters
Live		50	200	800
Work	20	50	200	800

Population factor = 1 x log 20 + 0.5 x log (50 + 50) + 0.25 x log (200 + 200) + 0.1 x log (800 + 800)

= 1 x 1.3 + 0.5 x 2 + 0.25 x 2.6 + 0.1 x 3.2 = 3.27, round to 3

Note that the populations living and working on or near the site are discreet sets, not the same people.

Land use – The "land" or "site" in question is the same as the "Area of Suspected Contamination" discussed under Type and Quantity, and adjacent generally means within 50 m. The point ratings are generally reflective of the intensity of land use and amount of time that people, particularly sensitive receptors such as children and pregnant women, are at the site.

- Residential (5 points) – there are people living on or adjacent to site, including squatters or temporary housing.
- Critical receptor on or adjacent to the site (5 points) – schools, hospitals, playgrounds and other areas where people, particularly children, routinely gather for extended periods.
- Residential or critical receptor area within 500 m of site (4 points).
- Agricultural on or adjacent to site (3 points) – farms and gardens where people plow, plant, weed, harvest or otherwise work such that they would be exposed to contamination.
- Light industrial and commercial on or adjacent to the site (3 points) – places where people work for extended periods.
- Agricultural, light industry, or commercial use within 500 m but not on or adjacent to the site (2 points).
- Heavy industry on or adjacent to the site (2 Points) – workplaces where workers are likely significantly exposed to other toxic materials beyond pesticides, such that the relative risk of pesticide exposure is less important than other exposure risks. This would include chemical and cement factories, landfill and dump sites, machine or repair shops where there is regular exposure to chemicals, oils paints, etc., and similar high exposure workplaces.
- Vacant land (2 points) – land which people may cross but generally do not remain for any length of time, and for which there is not adjacent uses described above.
- Area with no regular human use (1 point) – wilderness, remote grazing land, unused land, well removed from human use areas (>500 m) and not likely to become used by people.

Many sites may meet several of the above categories, such as a site used for agriculture but having houses adjacent. In this case, the classification should default to highest point value classification.

D. Total Risk Score =

Total Risk Score = T & Q Risk x 2/3 + Rel Risk x 1/3 + Rec Risk, round to integer

Total risk ranking: Low <= 12 Medium 13-19 High = >20

Total risk is a function of source (type and quantity), pathway (release) and receptor risks. A total risk score is developed to allow comparison between sites and the relative overall risk of a site. The formula above multiplies the type and quantity risk by 2/3 and Pathway Risk by 1/3 to normalize point values, as the potential total points for each risk category are different. With this formula, the result is that type and quantity and receptor risk are weighted equally, while Pathway Risk is slightly underweighted. The underweight for Pathway Risk is considered appropriate because, from experience, communities and political leaders in areas where there are contaminated sites generally are most concerned about current people at risk and the amount of contamination at a site and are less concerned about migration potential.

ANNEX 3

Guidance for conducting the preliminary site investigation

Objectives

The purpose of this section is to provide guidance for assessors to conduct the Preliminary Site Investigation. This entails gathering enough information from the site to formulate a ***preliminary*** Conceptual Site Model and also to giving instructions on how to take samples from suspected pesticide contaminated areas. For many sites the REA investigation and Preliminary Site Investigation will be the same, the methods for conducting each are therefore very similar.

Step I: Pre-investigation data review

So that assessors can familiarize themselves with the site they should review information about the site gathered at the Rapid Environmental Assessment (REA) stage and any other information that is available which is relevant to the site. Assessors should have access to the REA output sheet for each site.

Step 2:[16] **Initial Site walk over and data gathering**

As part of the preliminary site investigation, assessors should tour the site and review the site history and records before deciding on sampling needs and strategies. Assessors should note for each site the information necessary to build up the conceptual site model, particularly with regard to the source, pathway and receptor areas. Importantly assessors should note evidence for "pollutant linkages" that is how contamination may be getting to receptors to cause exposure to the pesticides present.

The walkover should be conducted after the desk study information has been used to refine the preliminary CSM and prior to designing the preliminary site investigation. It involves walking (if safe and time permits) around the site and its vicinity to record features that confirm, correct or add to the information collected during the desk study and to assist in the design and planning of the future site investigation works, including identifying access, health and safety issues. Limited sampling of soil, surface water or vegetation may be carried out. Limited on-site testing may also be carried out.

Features to record include:

- source areas: locations where pesticides were/are stored, spilled or spread and if possible visual or olfactory[17] evidence to support this;
- receptor areas: information about people or animals that could be exposed to pesticides from the site, including receptor numbers, age and any behaviour patterns that would affect their exposure to contamination. It is important to note nearby inhabited or other human use areas, key structures and their use on or near the site. Assessors should note what activities lead to receptors being exposed to contamination via dermal (skin contact), inhalation or ingestion pathways;
- pathway areas: information about hydrogeology (groundwater depth, flow direction); wind direction; rain runoff drainage routes, nearby water bodies and wells and any produce grown for human or livestock consumption.

[16] Judith Nathanail, 2007. Which gives further guidance on the site walk over.

[17] Deliberate smelling of potentially contaminated soil should not be carried out as it exposes the assessor to the contaminants.

Step 3: Sketch/make a drawing of the site

Make a detailed drawing of the site noting any information to support the Conceptual Site Model. This should include the general topography of the area; nearby inhabited or human use areas; key structures and their use; roads and paths used by people or animals on or near the site. Example sketches for the preliminary site investigation are given below (see Figure A3:2). These sketches could be supplemented by digital photographs of the same scene.

Based on this, several scenarios may present themselves relative to sampling needs:

• **Source areas**

Land where serious contamination are clearly evident, such as at or near a pesticide storage, disposal or spillage location.

• **Receptor areas**

Inhabited or frequently used land (homes, schools, parks, etc.) that are on or close to the site creating the possibility of direct exposure of people to pesticides on surface soils, spread or carried from the contamination area by people or wind.

• **Pathway areas**

Land on or near the site are used for agriculture or raising livestock that could result in contaminated food

Water drainage routes such as channels, ditches, or washes exist that may be, or have historically been, a route for rainwater run-off to carry pesticides off site, potentially contaminating sediments and spreading pesticides downstream.

Water bodies down-gradient of the contamination area which pesticides may have been carried to by rain runoff or water used at the site. Particularly a concern if the water body is a pond, lake or slow moving stream where pesticides can accumulate, and/or the water body is used as a potable water source, for washing, irrigation or as a source for food-fish, ducks, etc.

Ground water is used in the apparent down-gradient direction, such as wells or springs. Particularly a concern if use is for potable water, although washing and irrigation use may also be a concern.

A simple checklist for information to record during the walkover includes:

- description of vicinity of the site;
- description of the site;
- condition of buildings[18], storage tanks and structures, including potential to be a source;
- surface water features;
- hazards to worker or public safety (e.g. drops, hazmat, illegal waste deposits);
- factors to consider in designing the site investigation (e.g. presence of buried utilities or overhead cables; availability of water and electricity; access to shelter and toilets; areas for parking; steep gradients).

Step 4: Determine pesticides causing the contamination

Determine as best as possible the specific pesticides causing the contamination, based on historical records, past sampling and evaluation, discussion with people familiar with the site history, labels on any containers still present on site, etc. Also determine when the pesticide releases occurred and ended (if they have ended.) With regard to sampling, the type of pesticide and time period of release is important to know so that:

- analytical methods can target the right pesticides;
- sampling plans can factor in solubility and soil sorption;
- sampling plans can factor in pesticide half-life and likely degradation in the environment.

[18] Buildings should only be entered if it is safe and permitted to do so.

If the specific pesticides cannot be determined, identifying at least the type of pesticide can be useful:

- organochlorines – examples are DDT, chlordane, Lindane, Dieldrin, heptachlor, Aldrin, endosulfan;
- organophosphates – examples are malathion, parathion, chlorpyrifos;
- carbamates – examples are carbaryl (Sevin), carbofuran (Furadan), aldicarb (Temik);
- triazine herbicides – the key compound of concern is atrazine;
- pyrethroids – examples are permethrin, allethrin, deltamethrin, cypermethrin and the natural insecticide pyrethrum;
- other herbicides and fungicides – examples are glyphosate (Roundup), 2,4-D, fluometuron (used primarily on cotton) and paraquat, metalaxyl fungicide (for potatoes, vegetables);
- metallic based pesticides – examples are MSMA (monosodium methyl arsenate herbicide and fungicide), copper oxychloride fungicides, arsenic containing wood preservatives;
- rodenticides – examples are coumarins (e.g. warfarin), arsenic, strychnine, zinc phosphides.

Step 5: Choose sampling strategies and the number of samples

The written sampling strategy should be linked to resolving uncertainties in the CSM and should justify where samples are to be taken, the number of samples or frequency of sampling, the depths at which samples are to be taken. The purpose of each sample location, each sample and indeed each analysis should be stated.

The choice of sampling strategy and the number of samples to be collected may be helped by reference to the case studies below. Note that more than one case may apply to a site, so it is likely, that the sampling strategy will include sampling following recommendations from several cases.

Due to practical considerations such as time available at a site, access to areas outside the site, availability of equipment and sampling supplies, weather, and the cost of sample analysis, it is necessary to limit the number of samples collected. Typically, investigators should try to limit the number of samples collected for off-site laboratory analysis to between 6 and 12 samples.

As an example:

10 samples might be collected for a medium size (˜1/2 hectare) fairly complex former pesticide storage site where persistent organochlorine pesticides were stored, located adjacent to a small village and in an agricultural area:

- 2 composite samples from the site, as per Case 1;
- 1 "hot spot" sample from a known spill area, as per Case 1;
- 3 receptor sector samples as per Cse 2-in a nearby housing area, in a garden adjacent to the site, and along a dirt road frequently used by villagers;
- 1 sequential radial sample along a down-wind line towards agricultural land as per Case 3;
- 1 sample of drainage ditch sediments as per Case 4;
- 1 well sample from a village well as per Case 5;
- 1 sample from a farm pond 50 m from the site as per Case 5.

Where possible, field testing should be done to limit the number of samples requiring off-site laboratory analysis and to collect more information and facilitate better site characterization in the REA. Step 5 discusses field testing further. Field testing can be particularly useful for determining:

- where to sample at the site, both for hot spot sampling and defining areas to collect composite samples (Case 1);
- defining and determining the need to sample receptor sectors (Case 2);
- conducting transect sampling and determining how far out from a source zone to go (Case 3);
- testing sediments in drainage pathways and determining how far to sample along these pathways (Case 4); and
- conducting preliminary testing of water bodies (ponds, wells, etc.) to determine the need for sampling, particularly if there are multiple water bodies from which to choose (Case 5).

Once a sampling strategy or a combination of strategies has been decided upon, the assessor should carefully note it on the site sketch/drawing. If at all possible the assessor should use GPS to record the coordinates of how the strategy is set out on-site and from where samples were taken from.

Case 1: Source areas of contamination at a site where there is defined contamination

This case applies when contamination is believed to be present in a reasonably well-defined area. Often this will be a former storage area or the yard outside a former storage area, often defined by fences or other boundaries. The defined area may be a spill location where the area where spills occurred is reasonably well known or suspected. It is expected that this case will apply to almost all sites. The purpose of sampling for this case is to roughly determine the level of contamination at the site, both on average and at apparent "hot spots".

Sampling regimen:

- collect a composite sample of surface soils in the defined contaminated area. This involves laying out a grid, with each grid section being no more than 4 m x 4 m, and less when possible. Samples should be collected from each grid section, with equal volumes for each sample, and then all grid samples should be composited into a single area sample. At least 6 samples should be taken for each composite, which may mean that grid sections may need to be smaller than 4 m x 4 m for small contamination sites;
- for sites larger than 400 m^2, the area should be divided into several sub-areas, based on the most logical apparent division of the site, and two (or more) composite samples should be collected. The site should also be divided into several sub-areas and separate composite samples collected if it appears that there is different types or levels of contamination in different areas of the site;
- specific "hot spot" samples should be collected where there is evidence of spills or concentrated contamination, such as a discoloured area, areas with a mound or other evidence of concentrated spills, or where records show spills or poor storage occurred. The areal extent of such hot spots should be noted. If the hot spot is fairly large, such as >10m^2, then a composite sample from the hot spot should be collected;
- sub-surface soil samples should be collected when:
  - there are reports that areas of contamination have been covered over by clean soil;
  - there are areas at the site where subsurface soil disturbance is likely, such as for gardening, agriculture or construction;
  - there are areas where spills of liquid pesticides are known or suspected to have occurred.

For sub-surface soils, sampling should be done by using a hand auger (if available) or by digging a hole, and then collecting a sample of the soil at depth as carefully as possible to avoid mixing of the sub-surface soil with surface soils (such from spillage from the hole sides to the hole bottom.) Sub-surface soil samples should be taken at a depth of between 15 cm to 1 m, based on information known or visible evidence about the likely depth of contamination.

Samples should only be taken of concentrated pesticides, such as from containers of pesticides or from piles known to be highly concentrated spills when the identity of the pesticides is unknown. It is not necessary to know the specific concentration of such materials, as it is sufficient to simply know that this material is concentrated pesticide waste. However, the volume of such concentrated materials should be estimated, based on the container size and numbers, or estimating the size of concentrated spill piles.

Case 2: Receptors areas close to the contamination site

This case applies when there are receptor areas that are close to the suspected contaminated area, typically within 100 m of the site. Receptor areas include:

- places where people live or frequently gather, such as residential areas, markets, schools, parks, etc.;
- agricultural fields, orchards or woodlands in active use;
- areas where food animals such as cattle, goats, pigs, chickens, etc. are kept or graze.

The purpose of sampling for this case is to estimate the level of exposure to people, either through direct exposure to pesticides in soils at the receptor area or through ingestion of contaminated crops or animals.

The receptor areas should be divided into sectors, or areas of interest, based on type of land use. Composite samples should be collected for each sector, following the procedure described in Case 1 above. Sectors where people gather should typically not be larger than 400 m^2, however, agricultural and grazing areas can be larger and the grid division larger than 4 m x 4 m. Areas more than about 100 m from the site should not be sampled, as experience shows that pesticide contamination spread by wind or physical means (other than by water, which is covered in Cases 4 and 5 below) attenuates very rapidly with distance from a release site. Typically, if a contamination site is adjacent to inhabited areas, the surrounding possible receptors areas would be divided into 4 or 5 sectors for collection of composite samples, based on direction from the site.

Case 3: Determining the extent of contamination around a site when receptors are not present

The purpose of sampling in this case is to determine how far from a site pesticide contamination has been spread by wind, physical spreading of pesticides or contaminated soils, or other physical means (other than by water). In this case, radial sequential sampling should be done. Lines should be sighted from the site in the direction that contamination may have been spread. Then composite samples should be taken along each line, typically one composite for every 50 m, with individual samples taken every 5 m, for a total of 10 individual samples composited into 1 composite sample. Where possible, field tests (see Step IV below) should be taken for the composite sample, to determine if pesticides are present. If the field tests show that pesticides are present in the first 50 m for the site, then another composite sample would be collected along the same line for the next 50 m, and so on until pesticide contamination is not detected or until 200 m is reached (which would indicate widespread contamination; going further is not recommended due to time limitations.)

Choosing the lines from the site needs to be done with care. At a site in the open with no notable features in the area, one would likely choose four lines in the cardinal directions-north,

east, west and south. However, other factors need to be taken into consideration when choosing the number and direction of lines:

- a village or other inhabited area nearby (beyond 100 m away), in which case a line toward that village is desirable to know how close the contamination comes to the village. (Note: water bodies are discussed in Cases 4 and 5 below);
- prevailing wind directions. In areas where wind-spread dust is a concern, such as drier areas or areas with extensive bare ground, a line (or several) in the prevailing down-wind direction is desirable;
- topography. It is generally more likely that contamination has spread from a site in down-hill directions as opposed to up-hill, so lines in notable down-hill directions may be desirable, while lines in significant up-hill directions, particularly if no down-wind) would not be useful;
- large agricultural or grazing fields adjacent to the site. If there are fields that are too large for efficient sector sampling as described in Case 2, then a sequential line sample out across the fields may be a better method to determine the extent that the fields have been contaminated.

In general, no more than 4 sample lines are typically done at a site due to time and sampling resource limitations.

If field testing is not possible at a site (see Step 5 below), then it will not be possible to determine how far out along a line samples should be taken during the visit. In this case, samples should be limited to the first 50 m sample, unless there is a clear reason why sampling further out is desirable along particular lines, such as knowledge gained during interviews or record reviews that pesticide contaminated soils were spread out in fields in a particular area.

Case 4: Drainage ditches or pathways from a site

Many sites have drainage ditches, erosion gullies, ephemeral streams or other pathways where storm runoff may have carried pesticides off a site. Water carried pesticide particles or contaminated soil are a prevalent way that pesticides are carried off-site. Due to the low solubility and/or high soil sorption of many pesticides, accumulation of pesticides in the sediments of rain runoff channels is a particular concern. The purpose of this case is to determine pesticide levels carried off by water and present in drainage pathway sediments.

Similar to the sampling process described in Case 3 above, sequential samples should be taken following the drainage pathway downhill, with individual samples collected every 5 m, and then composited every 50 m. The twists and bends of the drainage pathway should be followed, as opposed to taking samples along a straight line. Sampling collection should be done in dry weather if possible – i.e. not when water is flowing down the drainage pathway. If field tests are possible, then field testing should be done after the first 50 m sample is collected to determine if pesticides are present and the need for sampling further downstream. This process would be repeated after the 100 m and so on until pesticides are no longer found or until practical limitations (access, time, presence of permanent water, etc.) preclude further testing. If field testing is not possible, then generally two composite samples should be taken along the drainage pathway, one from 0 to 50 m from the site, and one from 50 to 100 m from the site.

Case 5: Surface and groundwater sampling

Contamination of surface and ground water is a common question and frequently a key concern around pesticide contamination sites, particularly if the water is used as a potable water source, but also if the water is used for bathing, fishing, raising ducks or geese, or irrigation. Testing or surface or ground water should be done if:

- wells exist at or adjacent to the site;

- ponds or small streams exist at or adjacent to the site;
- wells or springs are present in the down-gradient direction within 250 m;
- farm ponds, small natural ponds, or slow-moving streams are present in the down-gradient direction with 250 m if these ponds or streams appear to receive rain run-off from the site.

The purpose of this sampling is to determine the risk presented (if any) due to contaminated water or pond/stream sediments.

Typically, one water sample should be collected at each of the above types water sources. If there are more than one choice of water body to be sampled, then selection should reflect both the well, pond or stream closest to the site and the sources most likely to present exposure risk (i.e. use as potable water source would be the highest priority). Selection can be informed by field testing if possible.

There may be no need for water samples in a number of situations:

- the water source is not used for potable purposes and the pesticides of concern are extremely insoluble such that they would not be present except as absorbed to suspended particles. This typically applies to some insoluble organochlorine pesticides;
- the water source has a high water turn-over rate, such as a flowing stream or pond with significant flow in and out, there has been years since the last release to the pond, and the pesticide of concern is highly soluble, such that any pesticides have long since been flushed from the water body. This typically applies to highly soluble herbicides such as glyphosate, and some organophosphates such as dimethoate (highly soluble) or malathion (very short half-life).

Sediment sampling should be taken from the bottom of water bodies in certain situations as described below. Of course, collection of sediment samples depends on practical considerations, such as access, having suitable equipment for sediment sampling (which generally depends on knowing in advance that such samples may be needed) and shallow depths to sediments that allow them to be reached. Sediment samples should be taken when:

- open top dug wells are used a potable water source, with bucket or other rough collection methods, close to and down gradient from the contamination site. The concern is that sediments at the bottom of dug wells (as opposed to boreholes) can be stirred up during water collection at such wells;
- ponds or slow moving streams are close to and down-hill from the contamination site, appear to receive rain runoff from the site, and are used as a source of water supply, raising fish, or for raising ducks or geese. The concern is pesticides in the sediments getting into potable water or being ingested by and accumulating in food fish or animals.

However, sediment sampling should not be done if the drainage pathway testing done, as per Case 4, indicates that contaminated sediments likely have not reached the water body, or the pesticide of concern is highly soluble or has a very short half-life, such as glyphosphate, dimethoate or malathion, such that accumulation in sediments is not a concern.

Step 5: Choose analytes – the pesticides to be tested and test methods

In the best circumstances interview of witnesses or information on site will give a clear indication of what pesticides are required for testing. If not analysis should be conducted in two stages:

Stage I: Screening of one or two composite samples from the source area at the site.

Stage II: Analysis of the remaining samples on the basis of the analysis conducted at Stage 1.

As discussed above, where it is possible field testing kits should be used for testing. The results of the field analysis should then be confirmed with testing done in the laboratory, in order to minimize the number and cost of laboratory analytes. Field testing of course depends on knowing the pesticides causing the suspected contamination; field analysis methods being developed and commercially available for those pesticides in the applicable country; and advance preparation to acquire and bring the field testing kits to the site.

Laboratories used for sample analysis should be high quality facilities and capable of performing the analyses using recognized and approved methods. For further details regarding the selection of laboratories, please see Annex 7, laboratory selection.

Figure A3:1
Likely sources of information for pesticide contaminated sites adapted from ASTM, 2014 and Paul Nathanial, C. Paul Bardos R., 2005

Contents	Key Information to include	Likely sources of information for pesticide contaminated sites
Site summary	Site location	GPS coordinates, Google Earth overlay
	Site topography	Topographical maps, site visit and observations
	Site description	Observations from site visit
	Reason for suspected contamination	Observations from site visit, interview with site and government representatives
	Priority of the site within REA, if conducted	REA Prioritisation report
	Type of pesticide contaminated site; burial location, dumping ground, application site, formulation site	REA Report
	Outline of site history and current site conditions	Observations from site visit, interview with site and government representatives
	Main sources of contamination (Potential) significant pollutant linkages	Observations from site visit, REA report
Description of site and surrounding area	Current and future operations	Site owners and Government representatives
	Summary of previous site uses	Interview of personnel involved with the site
	Contaminative uses on or near to the site	Site owners and Government representatives, inspection of aerial photography/satellite data
Geology including possible variations across the site	Geological strata and their significance in terms of source pathway and receptors	Previous reports, reports of other investigations in the vicinity of the site, Government data
	Evaluation of likely pathways via underlying geological sequence	Previous reports, reports of other investigations in the vicinity of the site, Government data
Hydrogeology including possible variations across the site	Aquifer classification of each geological stratum and comments on likely permeability (discharge/recharge zone)	Representative of government water resources department, hydrological maps, internet resources
	Position of water table(s)	Interview of persons involved with the site, official records of well levels, inspection of open well during site visit
	Groundwater flow direction, towards or away from receptors	As above
Hydrology	Surface water/groundwater interaction	As above
Ground conditions	Materials encountered; soil type	Use of hand auger, if available to determine superficial profile. Geological reports.
	Depths to and thicknesses of strata	Previous reports, reports of other investigations in the vicinity of the site. Geological reports.
	Lateral extent of materials	Previous reports, reports of other investigations in the vicinity of the site. Geological reports.

Contents	Key Information to include	Likely sources of information for pesticide contaminated sites
Source identification	Range of pesticides present	Pesticide inventories from PSMS or government sources Information from local population or store keepers derived from interview Pesticide analytical screen at REA stage
	Detail of other likely or suspected of being present	Information from local population or store keepers derived from interview
	Size of plumes or hotspots, depths of contamination	Site visit data, photographs taken, GPS coordinates taken, excavation of trial pit or use of hand auger
Source characterisation	Contamination: soil, leachable soil, groundwater, surface water	Analytical results
	How is the source characterised? i.e. is it a primary or secondary source, if secondary what is its nature; (contaminated soil, groundwater or surface water)	Analysis of CSM
	What are the phases of contamination: sorbed soil, solid pesticide, LNAPL, DNAPL	Visual observation made during the site visit
	Pesticide properties: Solubility, leachability, volatility, density, tendency to sorb, acute toxicity, ecological toxicity, GUS	Data search: http://sitem.herts.ac.uk/aeru/ppdb/en/index.htm http://www.alanwood.net/pesticides/
	Indication of concentration	Obtained from REA report
	Appropriate guideline levels	Examine exposure scenarios and type of receptors
Potential physical migration pathways	Groundwater (dissolved phase)	Analytical results
	Surface water (dissolved phase)	Analytical results
	Contaminated sediment transportation by surface waters	Analytical results
	Vadose (unsaturated zone-the zone of soil below the ground surface and above the water table)	Analytical results
	Drains	Visual observation made during the site visit
	Plant uptake	Visual observation made during the site visit
	Food chain	Visual observation made during the site visit
Potential exposure pathways	Ingestion of contaminated ground water	Visual observations made during the site visit
	Ingestion of contaminated surface water	
	Ingestion of contaminated food stuffs	
	Ingestion of contaminated home grown produce	
	Ingestion of contaminated soil or sediment whilst bathing or swimming	
	Inhalation of volatile pesticides	
	Dermal (skin) contact with contaminated soil	
	Dermal (skin) contact with contaminated groundwater	
	Dermal (skin) contact with gross product	

Contents	Key Information to include	Likely sources of information for pesticide contaminated sites
Potential receptors	Numbers and types of people (adult, child, worker, resident, visitor, trespasser including age and behaviour likely to make them particularly vulnerable) • infants (0 to 6 months), • toddlers (7 months to 4 years), • child (5 years to 11 years), • teen (12-19 years) and • adults (20+ years). • Ecological receptors including animals and plants	REA data, data from site visit observations
Risk drivers	Which substances (and their particular characteristics) are likely to pose the most risk? High toxicity; non threshold substances; threshold substances High solubility' low solubility; persistence What POPs are present	Limited testing of soils/ground for range of contamination during REA
Limitations	What assumptions have been made? What is still unknown-"Uncertainties"	Analysis of the CSM

FIGURE A3:2
Example sketch for a simple site conceptual site model

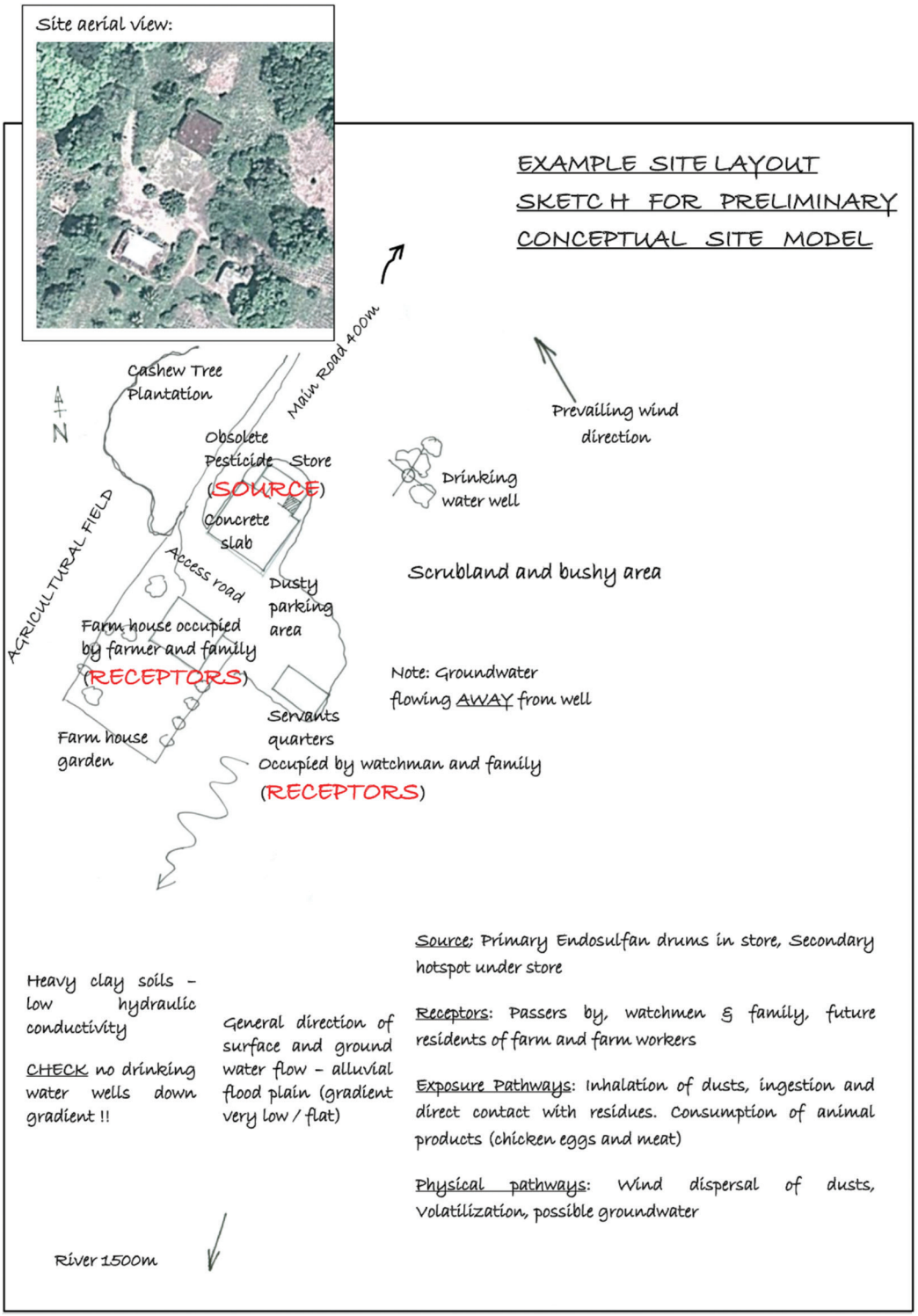


Figure A3:3
Example plan and section sketch for the conceptual site model

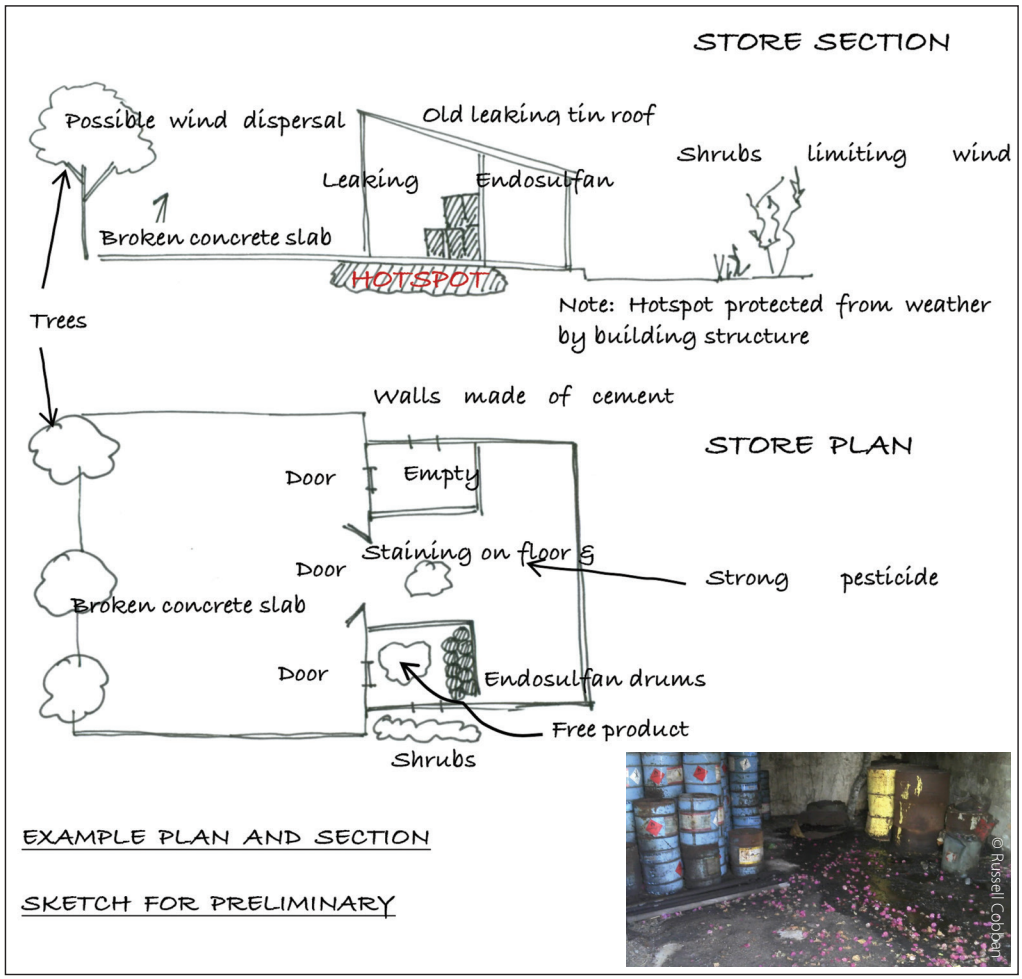


Figure A3:4
Example CSM schematic

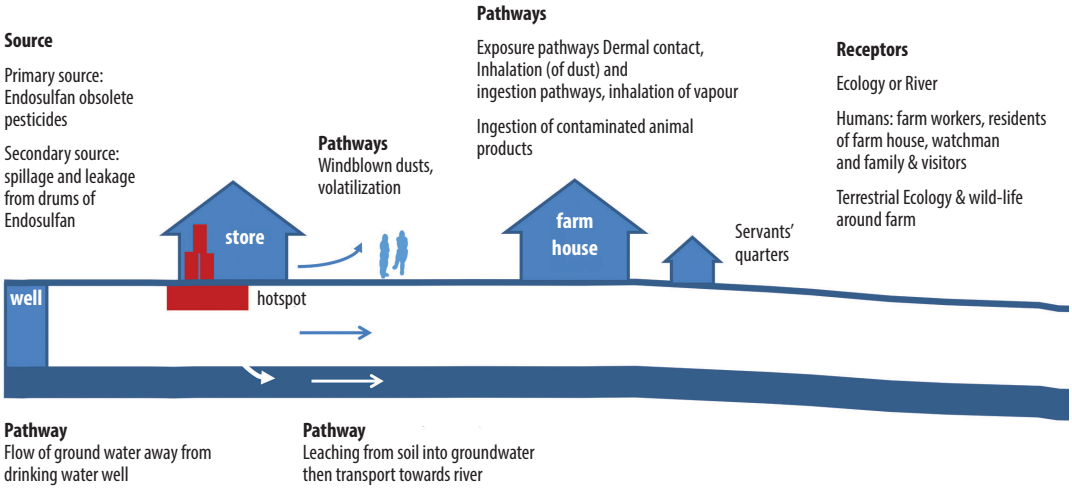
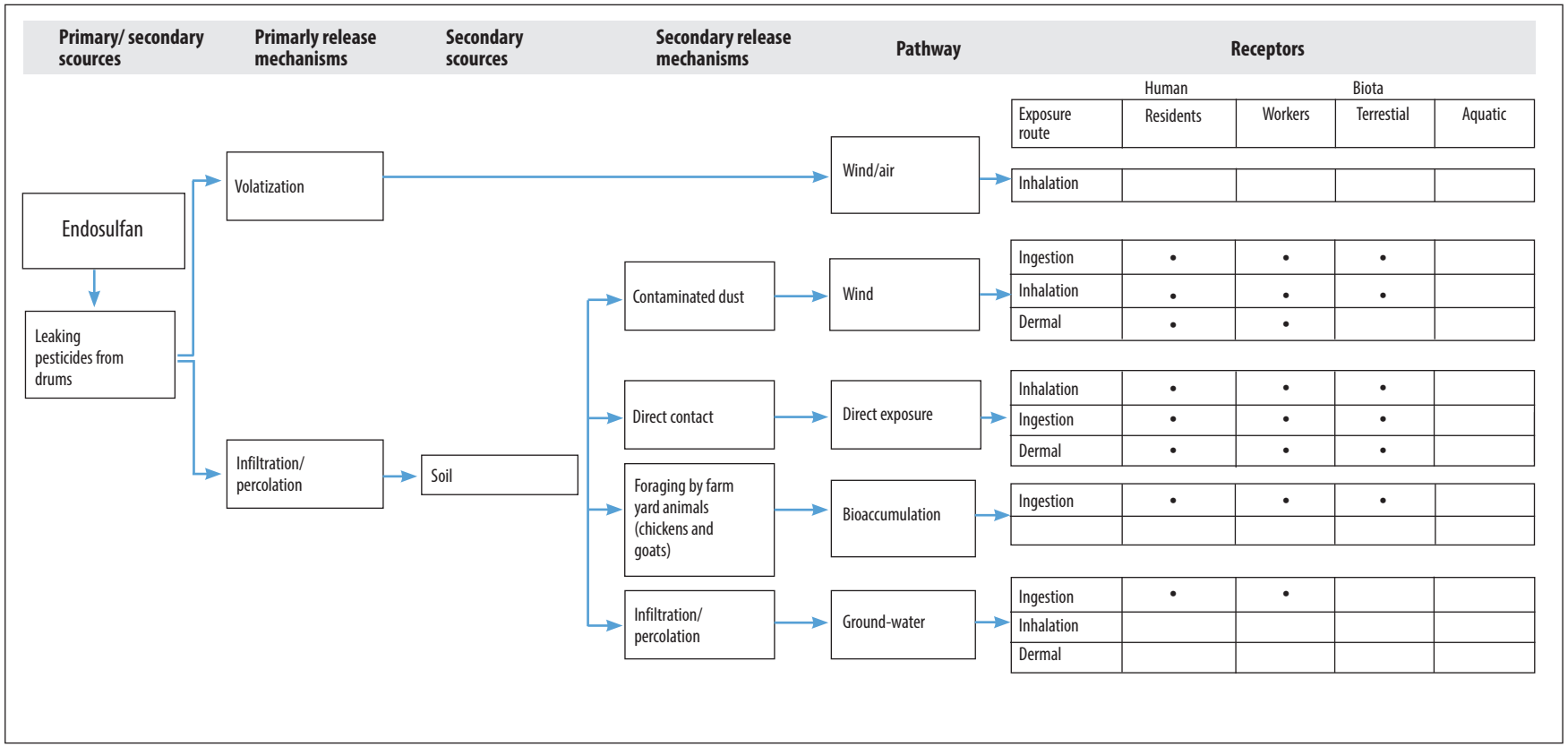


Figure A3:5
Example CSM network diagram adapted from ASTM, 2014



ANNEX 4

Practical guidance for design of the detailed site investigation

Objectives

The purpose of this section is to set out a series of practical steps that assessors should go through during the process of designing the detailed site investigation.

Step 1: Using the preliminary site investigation report and preliminary CSM, identify the data gaps and develop a plan for collecting site information and preparing site maps.

Step 2: Using the preliminary site investigation report and preliminary CSM determine the DSI objectives.

Step 3: Define the site boundary – the area to be investigated, notably considering:

a) source areas;

b) potential migration areas and routes away from the source area;

c) nearby receptor areas.

Step 4: Develop the soil sampling strategy:

d) using the CSM divide the site up into distinct zones, defining the area and depth of investigation, with respect to:

(iv) the potential pollutant linkages/exposure scenarios identified (including receptor and migration areas);

(v) hotspots that need to be characterised (source areas);

(vi) unidentified hotspots that may need to be located;

e) choose a sampling strategy appropriate for each zone using one or more of the above sampling methods;

f) calculate sample numbers required for each type of sampling (see the section regarding statistics).

Step 5: Develop a groundwater investigation plan using the CSM and the above. This typically includes:

a) construction of boreholes at the site and at least two down gradient locations, separated by some distance to allow determination of groundwater flow direction and rate;

b) use of available wells at the source area, receptor areas or in between to supplement (or potentially replace) the boreholes;

c) monitoring of piezometric data – i.e. groundwater levels – at all points for a period of time. This is the data upon which groundwater flow directions and rates are determined;

d) periodic sampling of the wells and boreholes over a representative time, taking into account seasonal variation. This always includes at least samples at the source area and nearby receptor area wells used as a potable water source (due to community concern).

Step 6: Define the analytical strategy, (see the section regarding the analytical strategy).

Step 7: Develop plans for quality control management (the QA/QC) see the section on QA/QC, Annex 7:

a) training of investigators in investigation methods (if necessary);
b) field sampling quality management, including sampling techniques and preservation;
c) laboratory qualification, see laboratory selection;
d) sample chain of custody procedures;
e) quality control samples, including the number of samples and type of samples (trip blanks, duplicates, calibration samples, etc.).

Step 8: Develop the Health, Safety and Environment plan (HSE Plan), see HSE plan section, Annex 10.

Step 9: Define when the investigation has to take place and the overall DSI schedule.

Step 10: Once the above is done, define resources needed including:

a) consulting firms or investigation team to do the work (including investigation manager, contaminated land specialist, soil scientist, hydrologist, technicians etc.);
b) laboratories, notably laboratories who can perform required analyses using approved methods and meet quality requirements (see section on laboratory selection, Annex 7);
c) key equipment, such as borehole drilling rigs or augers;
d) sampling and health, safety and security supplies.

Step 11: Develop the cost budget for execution of the DSI and compare this to available funds. It may be necessary to revise plans to stay within funding limits. However, care should be taken when reducing plans due to budget concerns; accomplishing key objectives with good quality should not be compromised.

ANNEX 5

Probabilistic sampling strategies

Simple Random Sampling (SRS)

The basic probability sample is the simple random sample. With SRS, every possible sampling point has an equal probability of being selected, and each sample point is selected independently from all other sample points.

Systematic sampling

Systematic sampling achieves a more uniform spread of sampling points than SRS by selecting sample locations using a spatial grid, such as a square, herring bone, rectangle, or triangle, in two or three dimensions.

Composite sampling

Composite sampling requires that a group of samples of equal size are taken from a site are mixed together. It is a technique that can be used to roughly determine the mean concentration of contamination from a particular area. It is also useful for the determination of the range of contaminants. Composite sampling is a technique that has very high margin of error and is hard to justify statistically and therefore should not be used for the calculation of risk if possible. It should also not be used for volatile contaminants and for mixtures of different soil types.

Multi incremental sampling[19]

This type of sampling is similar to composite sampling in that it is a combination of sub-samples of equal quantity. The concept is that the final sub-sample taken from this mixture contains potential contaminants in the same proportion as the overall sampling unit.

Point sampling methods suffer from a high degree of statistical error caused by the innate variability of contaminated sites and the distribution of contaminants across it. The common situation at pesticide contamination sites is that the level of contamination varies greatly in soils in both source and receptor areas; a high level may be found at one spot while low levels can be found only 3 or 4 meters away. The protocol for Incremental Sampling is very strict so that sampling error is reduced and that the assessor can be more confident in the result. The sub-samples that are taken are restricted to a homogenous (uniform) and defined area termed the "sampling unit" or "decision making unit". Sampling units are composed of a particular layer in the soil profile which has the same physical consistency and where it is suspected that contaminants have a similar concentration.

In order to ensure that the samples are taken from the sampling unit in an unbiased manner a formal sampling strategy should be implemented e.g. grid, herring bone or random pattern. Advantages of incremental sampling are that costs of laboratory analysis can be significantly reduced and that statistical methods used to ensure data quality are much simpler than those required by discreet/point sampling methods. The major benefit is that an IS sample gives a composite estimate of the true mean and that the IS sample may be used as a substitute for the percent 95 Upper Confidence Limit.

Transect sampling

Transect sampling involves establishing one or more transect lines across the surface of a site. Samples are collected at regular intervals along the transect lines at the surface and/or at one

[19] United States Army Corp of Engineers, 2009.

or more given depths. Transect sampling is often used to delineate the extent of contamination and to define contaminant concentration gradients. This method is most often used to help determine the migration of pesticide-contaminated dust by wind. A variation of this method is to collect sediment samples along drainage pathways, such as drainage ditches, erosion gullies or ephemeral streams to determine the extent that pesticides have been carried off a site by rain runoff. In this case, the drainage pathway is followed for sampling rather than a straight line.

Stratified sampling

Stratified sampling is used to improve the precision of a sampling design. For stratified sampling, the study area is split into two or more non-overlapping strata (subareas) where physical samples within a stratum are more similar to each other than to samples from other strata. Sampling depth, concentration level, previous clean-up attempts, and potential locations of contaminants can be used as the basis for creating strata. Stratification is an accepted way to incorporate prior knowledge and professional judgment into a probabilistic sampling design. Once the strata have been defined, each stratum is then sampled separately using one of the simple methods (e.g. SRS).

Amongst many guidelines and documents available in the literature, further details of the design and use of sampling strategies can be found in the following documents:

(i) [20]United Kingdom Department of the Environment-CLR4: Sampling Strategies for Contaminated Land. 1994.

(ii) [21]United States Environmental Protection Agency-EPA QA/G-5S: Guidance on Choosing a Sampling Design for Environmental Data Collection. 2002.

Sampling below ground level

In general, the above methods are good for surface or near surface (0-30 cm) soil samples. The practicalities of investigation make incremental sampling and other methods that require high numbers of discreet sampling points less viable for deeper sampling. Ideally, the surface sampling and historical records (such as of burial areas) can guide judgemental sampling at depth. Random or grid sampling at depth is also done, if the depth can be reached by a simple tool such as a hand auger or enough sample can be collected using a gouge auger.

[20] Department of the Environment, 1994.

[21] United States Environment Agency, 2002.

ANNEX 6

The analytical strategy

Number and type of samples

The number and type of samples are specified by the sampling strategy. The numbers and types of samples are also needed to determine the type and quantity of QA/QC samples that are required to be taken (see the QA/QC section, Annex 7).

Analytical range

Range of pesticides for analysis

Records kept at locations of contaminated sites such as pesticide inventories can give an indication as to the contamination likely to be present. This is mostly obviously because what has been stored above ground is likely to have penetrated beneath. However, at many pesticide contaminated sites there is little knowledge of the major contaminants before an investigation commences without conducting a minimal amount of analysis. In this case samples from the site will have to be subjected to a screen for the contaminants of concern. Ideally, the screen should analyse for the widest possible range of contaminants and may require more than one analytical technique. Once screening has been completed the detailed investigation can be targeted at the quantification of pesticide identified using the appropriate technique.

The cost of analysis and the effect on the range of pesticides for analysis

The active ingredients of pesticides and other constituents of pesticide formulations include a very wide range of chemical groups. Because of their very different chemical and physical characteristics there is a corresponding large number of analytical techniques that are required for their analysis. The potential cost of analysis can be prohibitive and therefore can limit the range of pesticides for investigation. As suggested in the section above, it is recommended that screening of a very limited number of samples for the widest range of pesticides is carried out. Once the range of pesticides and the numbers of samples for analysis are understood an estimate of the likely cost can be made. Together with the screening values to be used, key indicator pesticides can then be chosen for analysis.

Analytical detection limit

Where possible, the detection limit used should be one tenth of the screening level that has been chosen for risk assessment of each analyte. This will assure that any pesticides present at concentrations of potential concern are detected. However the toxicity and/or environmental behaviour of some pesticides means that the screening level is sometimes lower than the detection limit capability of many laboratories, particularly where the protection of water resources is required, where screening levels may require nanogram sensitivity (10^{-9} g/l). In this event the detection limit should be at least below the human health screening levels being used for risk assessment. For example, the US EPA residential non-carcinogenic screening level in soil for Lindane (gamma-HCH), a common POPs pesticide is 2.3 mg/kg. The detection limit should therefore be 0.23 mg/kg.

The analytical detection limit can be described by laboratories in a number of ways:

Limit of detection (LOD)

This is the absolute physical and chemical limit that the laboratory analytical equipment is limited by;

Method Detection Limit (MDL)

This is the detection limit introduced by the use of prescribed steps of a method, including the analytical step;

Practical Quantification Limit (PQL)

This is the minimum level of measurement at which the numerical result can be assured with some level of statistical certainty, for example 90 percent or 95 percent confidence limits.

Other parameters for analysis

During the investigation other parameters may need evaluation, for example,

- the use and/or specificity of some screening levels depend on knowing the values of certain parameters, for example soil organic carbon content and soil pH. It is important to check the condition of use of the screening levels and to specify any additional parameters required for analysis;
- those parameters that affect the performance of remediation strategies identified in the conceptual model.

Analytical methods

The objective of this section is to give a very brief overview of the analytical methods used for pesticides as a basis for readers to use the references provided and the internet to get further information. At the end of this section is a list of methods commonly used for pesticide analysis; readers should understand that this list is for reference only and provides a starting point for determining a specific method required.

Laboratory analytical methods

Analysis for sub-residue levels of organic pesticides

For organic pesticides the most commonly used techniques are gas chromatography (GC) and liquid chromatography (LC) based separation methods coupled with some form of mass spectroscopy (MS) detection system. The choice of technique is generally dependent on the polarity of substances being measured and their thermal stability. The higher temperatures required for GC and the non-polar nature of analysis mean that this technique is better suited for the analysis of chemicals with lower polarity (those substances that are poorly soluble in water) and those that do not breakdown at higher temperatures. For example, organochlorine compounds such as DDT, are usually non-polar chemicals or very weakly polar and are also thermally stable (i.e. do not breakdown at higher temperatures) and therefore are much better analysed by GC techniques. On the other hand, a large number of pesticide classes suffer from poor gas chromatographic performance because they have a higher polarity (i.e. more soluble in water) and breakdown under high temperature and are therefore better suited to liquid chromatography.

The conceptual model may also show that analysis of the breakdown or transformation products of pesticide parent compounds is important for risk assessment. Transformation products are often more polar and less volatile than their parent compounds. They generally have poor chromatographic performance on nonpolar GC columns or are subject to structural destruction/ decomposition in response to the high temperatures during GC analysis. Very often these are better analysed by liquid chromatography techniques.

Analysis for metal containing pesticides

Analysis of metal containing pesticides is usually conducted by Atomic Absorption (AA) spectroscopy, Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), also

referred to as Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) or ICP Mass Spectrometry (ICP-MS).

ICP techniques are used for the detection of trace metals whereby a plasma generated by exciting the sample is subjected to emission spectroscopy (AES) that measures the wavelengths characteristic of a particular element or mass detection measurements (MS). Both give ICP-MS and ICP-AES give highly sensitive measurements of the concentration and identity of samples. Atomic-absorption (AA) spectroscopy uses the absorption of light to measure the concentration of gas-phase atoms.

Analysis of mercury

It is rarely practical for laboratories to utilize ICP-OES, ICP-MS or flame AA techniques for the analysis of mercury due to their inability to offer the level of sensitivity required for the low limits of detection required. Mercury analysis is more likely to be conducted by Cold Vapour Atomic Absorption Spectroscopy (CVAAS) or Cold Vapour Atomic Fluorescence Spectroscopy (CVAFS).

Field analytical techniques

The low screening levels used for the risk assessment of some pesticides some mean that the accuracy and precision of analysis needed for investigations can be very high. As the accuracy of many field techniques is inherently lower (they are usually only qualitative or semi quantitative) the use of field analytical techniques is not always appropriate. Under circumstances where the accuracy of measurement is less important, field techniques can be cheap and effective methods of measurement, for example:

- where knowledge of the presence or absence of contamination is required;
- where knowing how contamination has been dispersed is important for example where testing is required along drainage runs or field transects.

The advantages of field testing techniques are that they can be very much cheaper than the corresponding laboratory test, they avoid the use of transporting the sample to the laboratory and are usually much quicker to produce a result. Although field tests are normally straightforward to carry out, a high level of expertise can be required for their selection and procurement can be complex, particularly if a variety of kits is required.

Immunoassay (IA)

An Immunoassay is a biochemical test that measures the presence or concentration of a macromolecule (in this case pesticide) in a solution, through the use of an antibody or immunoglobulin. Immunoassays are commonly used for the analysis of contaminants in water but can readily adapted for analysis of samples of soil and other media. Frequently the test results in a colour change, the degree of which can be measured to give the semi-quantitative or qualitative indication of the presence of pesticides. Whilst the cost per test of each analyte can be as low as USD 10-15 per test, the number of different tests required and the ancillary equipment involved means that the overall cost of analysis can be quite high for one-off analysis. In addition to this, the nature of immunoassay means that there is cross reactivity that takes place during the test so that whilst IA can be good for the measurement of groups of chemicals, such as organochlorines, organophosphorus or pyrethroid chemicals, it is often not specific enough for use in site investigation where a range of contaminants within the same chemical group is involved. Immunoassay can be very useful in circumstances where identity of a contaminant is already known or strongly suspected such as the determination of the spread of contamination or the monitoring of levels of contamination during remediation. Any IA testing should be supported by analysis at a conventional laboratory, IA testing is not

recommended for final validation of remediation or during risk assessment where observed levels of contamination are close to the screening level.

Test strips

There are a very wide range of commercially available test strips from a number of manufacturers. These are particularly relevant for making measurements of parameters in water and they can readily be adapted for use in soil. These can provide useful indicative measurements when operating in the field however their accuracy is mostly semi-quantitative at best. More accurate measurements rely on taking of samples or bringing portable analytical equipment into the field.

Table A6:1

Commonly used methods for pesticide analysis

Category	Pesticides	CAS#	US EPA SW-846 Analytical Methods
Organochlorines	DDT	50-29-3	8085, 8270, 8081, 8321
	HCH (BHC)	608-73-1	8085, 8270, 8081, 8121
	Endosulfan	115-29-7	8085, 8270, 8081
Organophosphates	Chlorpyrifos	2921-88-2	8085, 8141
	Dimethoate	60-51-5	8325, 8270
	Malathion	121-75-5	8085, 8270, 8141
	Parathion	56-38-2	8085, 8270, 8141, 8321
	Fenitrothion	122-14-5	8085, 8141
	Profenfos	41198-08-7	8085, 8141
	Glyphosate (Roundup)	1071-83-6	LC/MS/MS; GC/MS
Carbamates	Carbaryl	63-25-2	8318, 8270, 8321, 8325
	Mancozeb	8018-01-7	8318, 8270, 8321, 8325
Triazines	Atrazine	1912-24-9	8085, 8041, 8141
Pyrethoids	Cypermethrin	52315-07-8	GC with EC; GC/MS
	Deltamethrin	52918-63-5	GC with EC; GC/MS
Phenolic or phenoxy	2,4-D	94-75-7	8085, 8151, 8321
	Fluometuron	2164-17-2	8321
Inorganic/other	Metalaxyl	57837-19-1	8085
	Copper oxychloride	1332-40-7	Inorganic analytical methods

Table A6:2
Summary of US EPA SW-846 pesticide analysis methods

US EPA SW-846 Method Number	Description	Application
8085	GC/AED Compound-Independent Elemental Quantitation of Pesticides by Gas Chromatography with Atomic Emission Detection	Semi-volatile organohalide, organohosphorous, organonitrogen, and organosulfur pesticides
8270D	GC/MS Semi-volatile organic compounds by gas chromatography/mass spectrometry	Semi-volatile organic compounds extracted from environmental matrices
8141B	GC/FPD or GC/NPD Organophosphorous compounds by gas chromatography with flame photometric or nitrogen-phosphorous detector	Specific to organophosphorous compounds
8081B	GC/ECD or GC/ELCD Organochlorine pesticides by gas chromatography with electron capture or electrolytic conductivity detectors	Specific to organochlorine compounds
8325	HPLC/PB/MS Solvent extractable non-volatile compounds by high performance liquid chromatography/particle beam/mass spectrometry	To determine benzidines and nitrogen-containing pesticides
8121	GC/capillary column chlorinated hydrocarbons by gas chromatography, capillary column technique	Performed on extracts of chlorinated hydrocarbons from environmental matrices
8151A	GC/capillary column Chlorinated herbicides by GC using methylation of pentafluorobenzylation derivitization	Capillary GC method for chlorinated herbicides
8318A	HPLC N-Methyl carbamates by high performance liquid chromatography	Applicable to methylcarbamates such as carbaryl in environmental matrices
8321B	HPLC/TS/MS Solvent-extractable non-volatile compounds by high performance liquid chromatography/thermospray/ mass spectrometry or ultraviolet detection	Detects pesticides such as fluometuron and other non-volatile compounds

ANNEX 7

Quality control and quality assurance measures

Quality control measures are a set of procedures designed to prevent and detect errors that can be introduced at various stages during the investigation.

Field quality control samples

Errors occurring in the field during sample collection, preservation, transportation and storage are a common source of inaccuracy. These may originate from a single source or a combination of several sources. These include: analyte carry over from sampling equipment, incomplete decontamination of sample equipment between samples, cross contamination between samples, contamination in sample containers and absorption of volatile chemicals from air during transportation and storage. To test for the absence or presence of these errors field quality control samples are collected.

The precise composition and frequency of quality control samples is dependent on the objective of the sampling strategy.

Duplicate analysis

These are intended to identify variability in the analytical results associated with field and laboratory methods and the inherent heterogeneity of the media. Two samples are taken at the same location employing the same collection methods but placed in separate containers for separate analysis. Duplicates may also be sent to an alternative laboratory to assess the performance of the contracted laboratory.

Split samples

Split samples are used to identify variability between sampling handling methods or between laboratories. A single sample material is homogenized in the field and placed into two separate sample containers to be submitted two separate labs.

Rinse blanks or equipment field blanks

These analyses are used to assess the efficiency of equipment decontamination procedures in preventing cross contamination between samples. When multiple samples are collected using equipment such as a shovel, trowel, auger, etc., the sampling equipment must be cleaned between samples to prevent cross contamination. The rinse blank or equipment field blank is a sample of the rinse water used to rinse the equipment after cleaning. The rinse blank should show none of the analyte, proving that the equipment was properly cleaned before or between samples. The rinse blank will be analysed for the same parameters as the investigative samples.

Trip blanks

These samples are normally provided by the analytical laboratory and accompany the field sampling team during the sampling expedition. They are returned to the laboratory and are analysed for the same suite of analysis as the main investigation. The purpose of trip blanks is to determine if samples are picking up any analyte during transit. They are relevant particularly for sampling involving volatile organic compounds. If the subsequent analysis shows analyte present (particularly VOC), this indicates possible interference during the field sampling trip.

Spike samples

A known amount of reference material is added at a verifiable concentration to a clean, uncontaminated sample of soil or water. Spike samples are used to determine sample matrix-based errors by the laboratory. When problems are encountered with a laboratory this can be conducted in the field and submitted blind to the laboratory. It is not recommended that spike samples are applied in the field with pesticides related work due to the difficulty of accurately adding a known concentration of pesticide to a sample at the low concentrations for which analysis is usually done.

Background sampling

Background samples are samples taken from areas that are not suspected of being contaminated and therefore provide a measure of the natural level of the contaminants from the surrounding area. Background samples are important under the following circumstances:

- to provide the basis for comparison between contaminated and uncontaminated areas;
- to help verify groundwater plume direction (i.e. samples taken from upstream of a hotspot should contain little or no sign of contamination);
- to help attribution or understanding of the contribution of possible sources upstream or upwind (in the prevailing wind direction) of the source being investigated;
- for heavy metal contamination sites, to determine if there may be a high natural background level that would influence the final analytical result. Some metals, for example arsenic (which is a common component of a large number of pesticides), have very low levels permitted in soil and in some areas the natural levels encountered may be greater than the screening levels.

Allowance for typical field Quality Control samples

Following the calculation of the number and type of samples to be taken during the design of the detailed site investigation, the assessor can then calculate the number of QC samples required; typical ratios of field QC samples are as follows:

- split samples for every 20 to 50 samples;
- duplicates for every 10 to 20 samples;
- one rinse blank for each type of sampling equipment (auger, shovel, etc.) used to document that the cleaning procedures work;
- one or two trip blanks if Volatile Organic Carbons (VOC) are being analysed. (Note: these are generally not needed for pesticides as most pesticides are non-volatile);
- the number of background samples depend on the specific site. If the pesticide of concern has been used in the area such as on an agricultural field near a pesticide store then some background sampling should be done to define levels of pesticide that may be present in the environment unrelated to the site.

Laboratory analytical quality control

To give an indication of data quality, a number of different types of laboratory quality control samples are made. Laboratory quality control samples ensure that the sample extraction methods in the laboratory produce representative samples of the field-sampled environmental media; confirm that laboratory analyses are reliable; verify that the quality of reported results is suitable to support decisions based on the environmental monitoring data; and provide a means to measure and document the uncertainty and variability in analytical data. For most investigations conducted under FAO projects, checking of laboratory analytical control should be limited to ensuring that the accuracy of laboratory testing, usually through the use of split and duplicate samples, is within specified tolerances.

Quality assurance measures are designed to ensure that the sampling practices used are well carried out and that the methods and equipment being used in the investigation are of an appropriate standard.

The choice of sample containers

Different types of container are required depending on the contaminants to be investigated. Under ideal circumstances projects should buy containers that are certified as "clean". In general, a good working relationship with the selected analytical laboratory will ensure the correct type of sample container is used. The following types of sample containers are recommended:

Figure A7:1
Container choice for collection of samples for different types of analysis

Media	Container type
Soil/sediment containing organic pesticides	Amber glass jar
Soil/sediment containing metal pesticides	Plastic tub or jar
Soil/sediment containing metal and organic pesticides	Amber glass jar
Soils/sediment containing volatile pesticides	Amber glass vial with septum
Water samples	Amber glass jar or bottle

Where it is suspected that sample containers have been cross contaminated they should be discarded. In the event that no other containers are available they should be subjected to the washing protocol.

Note that while amber glass jars are best for organic pesticide soil samples and should be used whenever possible, in practice they can be difficult to get hold of, especially at short notice. In the event that none are available new, clean plastic jars and bags are often used and are generally acceptable, providing the pesticide is non-volatile. However properly planned sampling campaigns should not have to resort to such measures. A key concern is often photo-degradation (as opposed to contamination in the container or adsorption by container walls) and as long as the sample is kept in the dark (such as in a cooler) this concern can be addressed.

Sample labelling

Each sample should be labelled with a unique reference number, in a format that is simple and easy to understand. A record of the unique reference can then be made to which other details of the sample can be referred to in the sample log. The sampling date generally should also be included on the label.

It is important that the identity of the sample cannot be removed, so it should be affixed to or written on the container, as opposed to being attached with a rubber band or just accompanying the container.

Minimising cross contamination

Because of the presence of grossly contaminated materials present at many pesticide contaminated sites there is a high risk of the cross contamination of equipment and samples. The presence of pesticide in concentrations in excess of 1 000s mg/kg on some sites means that it only requires a small amount of material to be transferred inadvertently to 'clean' equipment

or sample containers for cross contamination to occur. Only a very small quantity of cross will potentially produce false positives and inaccurate characterization of the presence and levels of contamination at a site.

In order to prevent cross contamination the following steps are recommended:

(i) the use of[22] clean hands/dirty hands technique. This entails that the sampling team be divided up between those handling the sample i.e. those who take the sample from the sampling device and place it into the sampling container (clean hands) and those handling the sampling equipment i.e. those who touch the shovel or operate the hand auger or mechanical auger (dirty hands);

(ii) those handling the sample (clean hands) should wear a clean pair of disposable plastic gloves that are changed before every sampling event. In some instances this may not be possible. If this is so, the gloves used must be washed using the washing procedure prior to taking the sample;

(iii) before each change in sampling location i.e. from one sampling point to the next, all the equipment involved with sampling should be washed using the washing procedure below;

(iv) implementation of site zoning and environmental protection. Those conducting sampling in grossly or heavily contaminated areas require to be restricted from entering areas that are less contaminated without changing their clothing and footwear first. This ensures that the likelihood of cross contamination is reduced and also that the possibility of spreading the contamination further from the source is also limited.

Washing procedure

The following is recommended:

(i) wash gross signs of soil or pesticide using tap water until no visible signs of contamination can be seen;

(ii) rinse the equipment using distilled (organic compounds) and/or deionised water (metals);

(iii) rinse twice with one HPLC grade organic solvent and then rinse a third time with another HPLC grade organic solvent.

Detailed Site Investigation washing station in the field

[22] United States Environmental Protection Agency, 1996.

The use of organic solvents

Under ideal conditions, analytical grade solvents should be used for washing (99 percent pure). The following solvents are acceptable acetone, ethyl acetate, isopropanol or methanol. As a last resort, industrial methanol is permissible. It is of note that the solvents themselves are toxic and those responsible for washing are liable to have contact with them. It is recommended that those washing wear appropriate PPE such as solvent proof rubber boots, vinyl apron, nitrile rubber gloves and if necessary, an orinasal mask for respiratory protection. Sampling teams using solvents should be made aware of the dangers of handling solvents. The health and safety plan should explain the risks of using any solvents required for cleaning and the mitigation any risks in doing so i.e. reducing the risk of fire and exposure.

Water monitoring well development and purging

If water samples are to be taken for the purposes of analysis, any well used for the sampling must be purged-i.e. pumped clear of its contents until the water removed is clear and free from sediment. If it is a newly constructed well, the well should be left to settle for a minimum period of 48 hours following installation. Prior to sampling, 3 to 5 times the well volume of water should be removed from the well before a sample can be taken. If the equipment for measuring physico-chemical parameters is available including pH, Electrical Conductivity (*EC*) and Dissolved Oxygen (*DO*), the measurements should remain stable before samples are taken for 3-4 monitoring events.

Field Logs

During the investigation a detailed record of events should be kept. This should include:

(i) Borehole/trial pit logs

Borehole logs are records of the structure or formation of the geology of the site recorded as the borehole or trial pit is made. The borehole log should include a sketch of the strata and description of what was observed, for example, soil types, the presence of rock, where the level of groundwater was first struck and where the groundwater level rests. It is also important for the investigation to mark where the samples were taken from. A blank format for a borehole log and example log is given below.

Descriptions of soils and geological strata are most often completed using recognised soil classification systems as described by, for example, the United States Geological Society (USGS) or British Geological Society (BGS). If a soil scientist or geologist who can make a professional description is not present during the investigation, a detailed qualitative description of the material should be made. Information to be recorded typically includes:

- moisture content;
- colour;
- consistency;
- smell (NOTE: smell can be important in the determination of the presence of contamination in a borehole or trial pit. If contamination is suspected, a PID photo ionisation detector or PID should be used as it is not recommended to inhale pesticide vapours);
- estimation of general particle size (e.g. clay, silt, sand; coarse, fine, very fine);
- clay/sand/silt proportion;
- organic matter content and the presence of roots;
- descriptions of rock or stones present (size, colour, type etc.).

A blank borehole log (see Figure A7:2) is given later on in this section.

(ii) Sample Record/Log

A detailed record of each sample should be taken. Each sample should be given a unique reference number that is easy to record and that all those handling the samples in the future will understand. The record should include:

i. sample unique reference;
ii. sample location;
iii. sampling date;
iv. sample media (soil, groundwater, surface water, sediment, concentrated pesticide spill area, etc.).

Weather conditions are usually also recorded at the time of sampling, such temperature, whether raining or not, the presence of snow or frozen conditions, etc. This data can be important in understanding the sampling results.

(iii) Sampling location coordinates

It is very important to make a detailed record of the sampling locations. If at all possible during the detailed site investigation, precision GPS should be used (sub-metre-5 decimal places). If this is not possible a detailed sketch/drawing should be made that includes measurements made so that a more accurate drawing of the sampling locations can be made at a later date.

FIGURE A7:2
Blank borehole log sheet

Project:		**BOREHOLE LOG SHEET**		**Page: of**
Site:				**Date:**
Borehole No#:				**Elevation:**
Location/GPS coordinates:		**X:**	**Y:**	**Supervisor:**
Depth: (m)	**Lithology**	**Water strike**	**Sample record**	**Illustrations/Remarks**

Sample treatment

Soil and sediment samples

Following sample collection, samples should be cooled to between 2 and 8 degrees centigrade (optimum of 4 °C), preferably within an hour or less, and then transported to the analytical laboratory as soon as possible. Sample receipt and extraction at the laboratory within one week should be targeted (two weeks maximum) and the sample should be kept refrigerated the entire time until extraction at the laboratory. However, soil samples can be kept frozen for up to a year.

Water samples

Water samples should be refrigerated as soon as possible after the sampling event. There is a limited time period for which water samples can be held before analysis, they should be kept refrigerated at a temperature of between 2 and 8 degrees (optimum of 4 °C) until analysis. If water samples are not analysed[23] within 7-10 days, while under refrigerated conditions, they should be viewed as compromised and discarded. If a local laboratory cannot be used for the analysis of water samples or it is not certain that the samples can arrive at the laboratory before they expire, it is advised that another method of water sampling is used, such as the use of passive sampling devices.

Chain of custody (COC) procedures

These are procedures and associated documents designed to trace the possession of samples from the point of origin to final analysis, and the conditions under which the samples were held. The intent of using these procedures is to demonstrate that the samples remain intact and that no tampering occurs during transport. Chain of custody procedure and forms is normally the responsibility of the contracted laboratory and should be arranged at tender stage. If not the project should introduce such measures.

Chain of custody method

A sample is defined as being under one's custody if it is in one's possession or in view after being in one's possession, or if that person placed the sample in a designated secure area.

A Chain of Custody form/record should accompany the samples at all times. When transferring possession of samples, the individual relinquishing and receiving the samples will sign, date, and note the time on the record. This record documents transfer of sample custody from the sampler through any intermediary custodians to the laboratory.

The Chain of Custody form will list the sample identification, matrix (e.g. soil or water), date and time of collection, types of analyses requested, name of sample collector(s), and the signature of each person receiving and relinquishing the samples. An example Chain of Custody form is shown below.

The Chain of Custody form should also include the storage conditions during-i.e. whether refrigerated or not and the cooling method (cooler with ice, cooler with CO2, refrigerator, refrigerated shipping container, etc.).

Standard Operating Procedures (SOPs)

An important method of ensuring that the quality of the investigation is maintained is by the issuing of standard operating procedures. SOPs describe in detail the practical steps for each operation so that field operatives are able to correctly carry out operations. Training must be given to people doing sampling or conducting the investigations so that they know and understand the relevant SOPs. Typically, SOPs are written or referenced, they could include for example:

- standard washing procedures for equipment;
- scoop sampling;
- hand auguring;

[23] Laboratories can give specific advice on hold times and procedures. If possible, this should be checked prior to sampling.

FIGURE A7:3
Blank Chain of Custody form

Chain of Custody Number:

CHAIN OF CUSTODY AND SAMPLE REPORT

Laboratory:		**Sender:** **Address:**		**Date Dispatched:** **Sampler ID:**	Sheet 1 of 1
		Tel.:			
		Project/Site Name:			
		e-mail:			

Date of Sampling	Borehole/Trial Pit No./Sample ID	Depth (m)	GPS Coordinates	No. Samples	Soil (S)/Water (W)		pH Value	Total Organic Carbon (Soil)	Organochlorine Screen	Organophosporus Screen	Pyrethroid Screen		
						☐	☐	☐	☐	☐	☐	☐	☐
						☐	☐	☐	☐	☐	☐	☐	☐
						☐	☐	☐	☐	☐	☐	☐	☐
						☐	☐	☐	☐	☐	☐	☐	☐
						☐	☐	☐	☐	☐	☐	☐	☐
						☐	☐	☐	☐	☐	☐	☐	☐
						☐	☐	☐	☐	☐	☐	☐	☐

- use of the gouge auger;
- use of a mechanical auger;
- set up of basic sampling grids in the field (according to the sampling strategy);
- taking of a water sample from a borehole;
- taking a surface water sample;
- taking of a sediment sample;
- container requirements and sampling volumes;
- sample treatment and/or preservation;
- chain of custody procedures;
- use of other sampling devices (for example air monitoring or the use of passive sampling devices);
- waste disposal operations.

In most instances these health and safety based SOPs can be combined with the technical description of methods required in the QA/QC plan.

Laboratory selection

Considerations for laboratory selection are the following:

Technical suitability

Technical capability and availability

For small to medium sized sites, the laboratory should be able to analyse for the pesticides described in the analytical strategy. For larger or more complex sites the project team may specify in the tender that the laboratory uses methods of analysis specified by national or international agencies, for example the US EPA. Specification of laboratory methodology is a highly specialized subject area. If it is undertaken project teams should ensure that they have an expert available or hire an external analytical chemist with sufficient expertise and experience.

Sample extraction and preparation

Under most, if not all, circumstances a certain amount of preparation has to be completed before laboratory analysis can be carried out. This is because in whatever medium the contaminant of concern is being measured, for example, soil, vegetation, water or pesticide formulation, the sample cannot be analysed directly. There are a wide range of extraction procedures, the type of preparation and extraction method used will usually depend on the particular chemical under investigation and to some extent the media involved.

Experience of handling quality systems

There are many methods available for the laboratory analysis of pesticides. In order to ensure quality control, reliable methods are documented and checked and certified by third party organizations at a number of levels; locally, regionally and internationally. Laboratories are certified for specific media and analyses depending on their interest to pursue specific certification categories, as well as their ability to demonstrate compliance with the associated qualifications. Certification by itself does not guarantee that good quality work will be produced; however, it does provide a starting point for the evaluation of a laboratory's technical ability.

For most FAO projects the time, effort and expenditure required to check the working procedures that a laboratory uses cannot be justified. Laboratory selection will therefore depend on proof that the laboratory implements one or more quality systems; Good Laboratory Practise (GLP) and ISO 17025 are the specific quality systems of interest relating to laboratory analysis.

Good Laboratory Practise (GLP)

GLP specifically refers to a quality system of management controls for research laboratories and other organizations that conduct chemical analysis. GLP is implemented at a laboratory to try

to ensure the uniformity, consistency, reliability, reproducibility, quality, and integrity of any chemical testing carried out. GLP encompasses a very wide range of testing, including testing of physico-chemical properties through to toxicity testing. Importantly it also includes the analysis conducted at laboratories that measure levels of contaminants in environmental samples.

ISO 17025

ISO 17025 is the standard of the International Standards Organization that sets out the "General requirements for the competence of testing and calibration laboratories". Laboratories follow ISO 17025 to implement a quality system aimed at improving their ability to consistently produce valid results. Laboratories who follow ISO 17025 and have been audited by an approved auditor regarding their practices can gain ISO certification. This should be looked for in a laboratory as it provides some assurance of the laboratory quality practices.

Analytical detection limit

The analytical detection limit is normally specified in the analytical strategy. Laboratories considered for selection should be able to achieve the limits set.

Laboratory capacity

This is particularly relevant for projects where a large quantity of samples will be generated. It is important to establish that the laboratory has enough resources, in terms of equipment and staff, to analyse the samples within the turnaround time required.

Laboratory experience

Experience in the preparation and analysis of environmental samples, and in particular pesticide samples, is a definite advantage when selecting a laboratory, however, lack of previous experience should not preclude a laboratory from participation. This is an area where, if time and funds permit, project budgets may facilitate capacity building in local and regional laboratories. In general, costs are usually lower and quality may be easier to assure at laboratories that routinely do pesticide analyses.

Analytical turnaround time

The quicker the laboratory can return a result once a sample has been submitted the better. Usually laboratories stipulate turnaround times that they can be contracted to as part of the procurement process; quicker turnaround times will incur a premium rate. Proper planning and project management should prevent the use of premium, fast turn-around analytical services that may double or triple analytical costs.

Location

The closer a laboratory is to the site the better. Smaller distances to the laboratory will allow for lower transportation costs and it will be easier to maintain and assure the condition of samples during transportation.

Sample retention

Laboratories should have adequate capacity to store the numbers of samples needed under the conditions required. In some cases a repeat analysis or alternative analysis of the same sample is required, and the laboratory should be able to store samples (under refrigerated or frozen conditions) for some period of time to accommodate this, such as 60 days from analysis. This storage capability can be a great advantage because revisits to a site to repeat sampling are likely to be logistically difficult and expensive.

Figure A7:4
QA.QC plan format

Introduction	- Project background and reason for sampling
Project team and responsibilities	- Specify the composition of the team conducting the investigation, including: • Technical and logistical support is being given • roles and responsibility of each member.
Analytical laboratory	- Give details of where any samples are to be sent and details of laboratory certification, for example: • ISO 17025 Certification • ISO 14000 Certification • ISO 9002 • certification for Good Laboratory Practice.
Range of analysis	- Specify the different types of pesticides and other parameters that the laboratory be asked to analyse for, • Will the analysis be staged in anyway?
Sampling strategies	- Give details of proposed sampling plans, including: • Provide a drawing of the site • indicate where samples are to be taken from.
Field sampling methods	- Specify how is the sampling to be conducted • Technical SOPs (as opposed to health and safety orientated SOPs)
Sample quantities	- Specify the quantities of sample to be collected, for example: • Soil • water • Sediment • Other.
Equipment cleaning procedures	– what systems are to be used for cleaning any equipment and how is this to be maintained?
Waste disposal	– how is the waste arising to be managed during the investigation? • Soil • water • rinse washings • used/dirty equipment • decontamination solvent/water disposal.
Sample containers and labelling	• Specification of container type for each type of sample • specify how the samples are to be labeled correctly.
Field documentation	- Specify how operations in the field are to be recorded, including: • Borehole logs • what field notes are required; date, temperature, GPS location • variations from the SOPs.
Sample handling procedures	• Sample storage and holding methods • sample holding times
Chain of custody (COC) and shipping procedures	• Sample Shipping Procedures • use of chain of custody.
Analytical quality assurance and quality control	- What types of QA.QC samples will be taken, for example: • Trip blanks • background samples • duplicates samples.
Data evaluation and analysis	- Laboratory reports-how are the laboratory reports to be presented and in what format? - Specify how will the data be checked that it is all present

ANNEX 8

Sampling methods

Site investigation techniques

Non-intrusive techniques

Geophysical techniques

Where information about the site is required from depth more complex non-intrusive geophysical techniques can be used to locate where buried items are, delineate the sources of contamination and provide information about groundwater and geology without causing disturbance. This is particularly useful where intrusive techniques could worsen potential contamination by the penetration or damaging of buried containers filled with pesticide. Geophysical methods include techniques such as: ground penetrating radar, resistivity, microgravity, conductivity infrared thermography and infrared photography. It should be born in mind that these techniques are not commonly available in low to middle income countries and their use will significantly affect the cost of any investigation.

Intrusive techniques

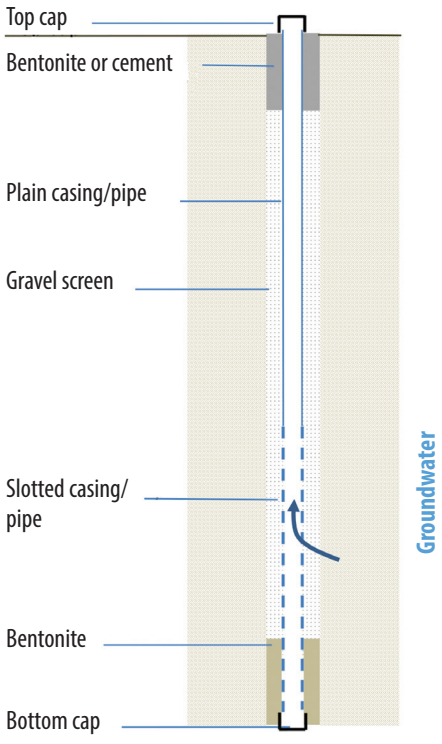
Intrusive techniques require penetration of the ground to collect samples for analysis or for monitoring purposes. The method selected depends on factors such as the media to be sampled, the project budget, depth of the investigation and the accessibility of the site. Intrusive techniques are used to collect soil and water samples.

Water sampling

Water samples at contaminated sites are usually taken from boreholes. The same equipment used to take soil samples from depth is used to form water monitoring wells.

As the borehole is dug, or shortly after, well casing is installed around the borehole to ensure that the sides of the well do not collapse inwards. The well casing is slotted or perforated to allow water to enter the borehole, screening and gravel are packed around the casing to ensure that soil particles and sediment are excluded from entering the borehole and that the water is as clean as possible. If necessary the perforations or slots in the well casing can be installed at different depths to allow groundwater from different geological strata to enter the borehole for sampling.

FIGURE A8:1



Groundwater water sampling

In order to take groundwater samples a bore is sunk to below the groundwater level, monitoring equipment can then be inserted to measure any required parameters or a pump can be used to collect water for sampling. Various types of equipment are used to maintain the quality of water inside the borehole and to ensure the sides of the well do not collapse.

Hand driven points

Where ground conditions are not too hard and rocky and the ground water level is not too deep, shallow well points can be driven into the ground by hand. A hollow iron or steel pipe is hammered into the ground using a sledge hammer or heavy duty mallet. Monitoring equipment can be inserted into the pipe and be used to collect information about required parameters.

Scoop samples

This is the most basic form of sampling and is very cheap and easy to use. Samples are take directly and placed into sample containers using a stainless steel or iron trowel or shovel. The only necessity is to have clean sampling equipment and containers (for example plastic pots or glass jars). Scrapings of contaminated materials can be taken from contaminated building materials and placed into sampling containers. The effectiveness of scoop samples are the limited by the depth of penetration and the difficulty of preventing unwanted soil from around the sampling area falling into the sample.

Trial pitting

A basic method of investigation involves the digging of trial pits to take samples either by using a shovel, if ground conditions allow and the depth of excavation required is not too deep, or by mechanical excavator. An excavator can be used to take samples from a significant depth however there are serious health and safety issues resulting from pit collapse if the pit is entered and ground conditions are not suitable. It is strongly recommended that investigators do not enter trial pits that are more than 1.2 m deep or less if the ground conditions are wet or the soil is unstable in any way. When using a mechanical excavator it is very difficult to keep the cutting blade of the excavator clean and to prevent soil from higher up the soil profile from falling down into the sample and therefore to limit cross contamination. Another drawback of trial pitting using a mechanical excavator is that the excavator normally makes a very large hole in the process of excavation which means that a significant volume of spoil is generated. Where investigations into ground contaminated with pesticides are concerned this can lead to a great deal of ground disturbance and a high risk that the ground at the surface is further contaminated placing local receptors at risk if undue care is not taken. If at all possible it is recommended that other forms of sampling are used.

Sample collection by trial pitting[24]

[24] http://c2936519.myzen.co.uk/?page_id=47.

Hand auger

A hand auger is a basic manual agricultural/geotechnical tool used for taking of soil samplings and the installation of water wells. Hand augers consist of a cutting bit connected to a threaded "T" bar, by which the tool is turned into the ground by a series of extenders. By withdrawing the tool and adding additional extensions the hand auger is able to penetrate to depths of more than 10m. A number of cutting bits are available for use depending on the soil type, for example sand, clay, general soils etc. The hand auger is a cheap, compact and is relatively easy to clean. It is a very effective tool for taking samples from a depth of less than 2 m deep, particularly in remote areas. For the purposes of site investigation however, the time and effort involved with taking samples from more than 2 m is not productive, unless the ground conditions are very easy.

Sample collection using a hand auger[25]

Gouge auger

A gouge auger in action[26]

Gouge auger construction[27]

The gouge auger is similar in construction and assembly to the hand auger. The bit used is of a much smaller diameter. Samples are taken by hitting the head of the auger using a hammer to drive it into the ground. Advantages of using the gouge auger is that the small diameter allows easy penetration into many ground types and that it is very easy to transport and clean. However the quantity of sample is not large and may be insufficient for some types of analysis. Because of

[25] Image courtesy Victorian Resources Online website, Department of Jobs, Precincts and Regions. http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_acid_sulfate_soils.

[26] http://commons.wikimedia.org/wiki/File:Tari%C3%A8re_gouge_dans_la_boue.JPG.

[27] https://en.eijkelkamp.com/products/augering-soil-sampling-equipment/gouge-auger-model-p.htm.

the small diameter, a gouge auger can be effective in situations where it is thought that the hand or mechanical auger would disturb the ground or objects beneath, such as where samples are required from a burial site. Samples from burials frequently contain concentrations of pesticide at high levels and therefore much smaller sample sizes are required which makes the gouge auger and ideal tool for burial site sampling.

Mechanical auger

A mechanical auger uses a percussion action, normally via a petrol driven road hammer, to hammer a sampling bit into the ground. The sampling bit is connected to the hammer also through a series of threaded extensions. The power of the hammer allows for penetration of the sampling bit through the majority of types of ground down to depths of around 10 m, exact depths depend on the make of the equipment. The size of the hammer and associated equipment means that it is much less mobile than the other methods mentioned and also means that much effort must be expended in keeping the equipment clean during sampling to minimise cross contamination.

Light cable percussion tool

Cable percussion is the most common drilling method used for site investigations and for the drilling of water wells. Depending upon access and ground conditions boreholes up to 50 m depth can be dug. Light-cable percussion drilling uses a mobile rig with a winch of between one to two tonne capacity driven by a diesel engine and a tripod derrick of about 7 m height. The sides of the borehole are supported using steel casing which is lowered into the ground as the boring proceeds. The material recovered from the borehole is generally sufficiently representative to determine the depth and description of the geological strata.

Sample collection using a cable percussion rig[28]

[28] www.chandosremediation.com.

Rotary rig

Rotary boring equipment uses a rotating cutting head to cut down into sub-surface layers inside casing. This type of drilling can penetrate depths of many hundreds of metres and is able to drive bores through hard layers impenetrable to the other methods used. The rotational movement of the cutting head means that it not generally used for taking samples due to the severe homogenisation of material making up the sample. It can be used effectively for the installation of water monitoring wells and gas monitoring points. This type of drilling equipment is normally available for hire. However it is very expensive and is not commonly available in low to middle income countries.

Sample collection using a rotary rig[29]

[29] http://www.environmentalsampling.ltd.uk/services.html.

Figure A8:2
Comparison of sampling methods, adapted from Paul Nathanial C., Paul Bardos R, 2005

Method	Advantages	Disadvantages	Typical depth limit
Scoop samples (soil)	Very quick and cheap.	Loss of volatile organic compounds; shallow samples only	0.3 m
Trial pits (soil)	Allows detailed inspection of ground conditions; rapid and low cost compared to boreholes and probe holes.	Contamination brought to the surface; holes may be unacceptable on occupied sites; cross contamination between horizons; questionable results from installations for gas or groundwater; health and safety issues.	3.5-4 m
Hand auger	Quick and cheap; able to obtain good soil profiles for recording. Possible to install monitoring points.	Very slow and physically demanding; only suitable for some types of soils.	2 m
Handriven well points (groundwater)	Cheap and quick.	Questionable results from installations for gas or groundwater	3-8 m
Probe holes/window samplers(soil/vapour/ gas/groundwater): use of percussion hammer to drive small diameter sampling tube into the ground to collect samples and/or form a hole for an installation of groundwater monitoring point	Require minimal space; rapid compared to boreholes; relatively little contaminated material brought to the surface; relatively little disturbance to operating site; virtually continuous recovery of soil profile; reduces losses of volatile compounds; can be used to install groundwater monitoring points.	Small sample hinders examination of materials; difficulty penetrating coarse or dense soils; reinstatement backfill difficult. Equipment difficult to get hold of in middle income and low income countries	3-5 m
Light cable percussion boreholes (soil and weak rock/groundwater): large diameter holes (150-250 mm) created by removing materials using a cable percussion drilling rig.	Collect deeper soil samples (compared to trial pits and probe holes); good quality groundwater monitoring points can be installed.	Limited penetration of rock; not suitable for groundwater sampling during drilling; relatively slow and expensive compared to trial pits and probe holes.	50-80 m
Rotary rig: Rotary boring equipment uses a rotating cutting head to cut down into sub-surface layers inside casing	Penetrates to many hundreds of metres and is able to drive bores through hard layers impenetrable to the other methods used.	Not suitable used for taking samples due to the severe homogenisation of material making up the sample. It generally used for the installation of water monitoring wells and gas monitoring points. Very expensive and not generally available in middle income and low income countries	Hundreds of metres

ANNEX 9

Statistical methods and worked examples

Definition of sample numbers[30]

Calculate the number of samples required to determine that a particular zone or area has been well characterised.

When calculating the number of samples required, it is recommended that enough samples are taken to determine the mean level of concentration at the Upper 95th Percentile Confidence Limit (95 percent UCL), that is to say that the assessor can be 95 percent certain that the mean contaminant concentration is beneath the level calculated.

Assessors should refer to the following table (the source is available in the above reference):

Figure A9:1
Soil sampling frequency to determine that a particular area or zone has been well characterised

Soil volume in m3	Number of samples
25 or <25	3
50	3
75	4
100	5
125	7
150	8
175	9
=>200	10
3 000	12
4 000	16
4 500	18
5 000	20

For example:

Example 1: You have a 2 500 m^2 area where you think that direct exposure may be occurring. You decide that the top 100mm require analysis. The total volume is therefore 250 m^3 (2 500 m^2 area x 0.1m deep = 250 m^3). From the table above you select that the minimum number of samples to generate a percent 95 Upper Confidence Level of the mean, assuming there is no spatial trend in the contaminant concentration, is 10 samples.

[30] Australian Environmental Protection Agency Industrial Waste Resource Guidelines, 2009.

The maximum value test to test for the presence of outliers[31]

The assessor should check whether the highest recorded value can be considered part of the original population of samples, in which case the result of the mean value test remains valid, or whether it is considered an "outlier", i.e. outside this population. Outliers should be examined in further detail as they give reason to suspect an area of elevated contamination and therefore indication of the location of a potential hotspot. The statistical test that is suggested for use is the "Maximum Value test", for this test the following steps should be used:

(i) calculate Log_{10} values of individual analytical results making up the original data;

(ii) calculate the sample mean $\bar{y}$ and unbiased standard deviation S_y from the log transformed values;

(iii) use the following equation to test the data:

$$T = \frac{y_{\max} - \bar{y}}{S_y}$$

Where

$\bar{y}$ = sample mean

S_y = unbiased standard deviation

$y_{\max}$ = the highest sample value occurring

If the value of ***T*** is smaller than the corresponding critical value as displayed in Table R-3, the maximum value may be accepted (at the prescribed level of confidence) as a member of the underlying population from which the other measurements were drawn. If ***T*** is greater than the critical value the maximum value is treated as an outlier, which may indicate a localised area of contamination. Outliers are also identifiable on cumulative histogram plots. Of course, the outlier might instead be the result of a recording error; but in any event it flags up the need for possible intervention.

Managing outliers

For FAO projects the opportunity to revisit sites to conduct further investigation is limited, therefore dealing with outliers will have to be considered further at the risk management stage.

Calculation of a representative concentration for comparison to a screening level or guideline value[32]

The Mean Value Test

Due to the highly variable nature of contamination, even amongst zones of a site with similar characteristics, the use of a simple arithmetic mean is not likely to give a good estimate of the actual concentration in the ground. Consequently, assessors need to state, with a given level of confidence, that the population mean is less than the guideline value being used. This is particularly relevant to locations where levels of contamination are close to the screening levels being used.

Assuming samples are evenly spaced and there is no spatial trend, the necessary calculation involves 5 simple steps as follows:

(i) calculate the arithmetic sample mean, $\bar{x}$

[31] UK DEFRA and Environment Agency, 2002.

[32] UK DEFRA and Environment Agency, 2002.

(ii) calculate the unbiased sample standard deviation, ***s***

(iii) select an appropriate '***t***' value from standard tables. Table a. give **t** values for a 95th percentile limit. ***t*** values for other confidence limits are given in Table R-2. It should be noted that when using Table b. the number of degrees of freedom is one less than the number of samples, i.e. if n = 8, v = 7.

(iv) calculate the upper 95th percentile bound of the sample as:

$$US_{95} = \bar{x} + \frac{t.s}{\sqrt{n}}$$

Where:

s = the unbiased standard deviation

$\bar{x}$ = arithmetic mean

t = t value from table **XX**

n = number of samples

(v) compare the upper bound value, (US_{95}) with the screening level in use. If the upper bound value is less than the screening level, then the mean value test has been passed i.e. if the representative concentration calculated does not breach the screening level therefore the area or zone being tested is not likely to be causing harm to human health.

For example:

Example 1:

Ten samples taken on a regular grid are sent to the laboratory and you receive the following results:

	Dieldrin	Units
Sample 1	101	mg/kg
Sample 2	76	mg/kg
Sample 3	92	mg/kg
Sample 4	64	mg/kg
Sample 5	51	mg/kg
Sample 6	72	mg/kg
Sample 7	18	mg/kg
Sample 8	19	mg/kg
Sample 9	88	mg/kg
Sample 10	76	mg/kg
Arithmetic sample mean $\bar{x}$	**65.7**	
Unbiased standard deviation, **s**	**28.6**	
t value taken from table **XX**	**1.833**	
Number of samples, n	**10**	

$$US_{95} = \bar{x} + \frac{t.s}{\sqrt{n}}$$

Formula to calculate the normalised upper bound for the 95th percentile

$$US_{95} = 65.7 + \frac{(1.833).(28.6)}{\sqrt{10}}$$

Normalised upper bound for the 95th percentile = 52.9 mg/kg

Note that the ***t*** value used in this calculation is ***t= 1 833***, which is derived from Table R-2 for single tailed t tests.

Figure A9:2
Relationship between sample number (n) and t

Statistical tables

n	t	n	t	n	t
1	-	11	1 812	21	1 725
2	6 314	12	1 791	22	1 721
3	2 290	13	1 782	23	1 717
4	2 353	14	1 771	24	1 714
5	2 132	15	1 761	25	1 711
6	2 015	16	1 753	26	1 708
7	1 943	17	1 746	27	1 706
8	1 895	18	1 740	28	1 703
9	1 860	19	1 734	29	1 701
10	1 833	20	1 729	30	1 699

Figure A9:3
Critical values to test for the presence of outliers

N	5%	10%
4	1.46	1.42
5	1.67	1.60
6	1.82	1.73
7	1.94	1.83
8	2.03	1.91
9	2.11	1.98
10	2.18	2.04
12	2.29	2.13
14	2.37	2.21
16	2.44	2.28
18	2.50	2.33
20	2.56	2.38

ANNEX 10

Requirements for the Health, Safety and Environment (HSE) plan for an investigation

Person responsible for the HSE plan

The HSE plan should be written by the person responsible for carrying out the investigation in the field who has knowledge of the investigation methods and risks involved.

When should an HSE plan be written?

The detailed investigation stage of FAO contaminated land risk reduction projects frequently involves visiting a number of sites which are spread over a wide geographical area. For high risk sites it is recommended that site specific HSE plans are written for each to be visited. In the case of medium and low risk sites generic plans may suffice for all sites to be visited.

Format of the HSE plan

Background

This should contain:

a) the context of the investigation;

b) the number of sites to be visited and their locations;

c) details of each site to be visited including;

(i) a brief description of how and why the ground is contaminated;

(ii) specific details of particular issues of the site of concern specifically regarding health and safety and environmentally sensitive areas or features.

The background should reference and summarize the work plan for the investigation or investigations and should detail, for example:

- when procurement for the investigation(s) should start;
- when investigations are to take place;
- dates by which key events are required to occur.

Command structure

The management of multi-disciplinary teams at a hazardous work site requires a clear management or command structure. This is echoed in the [33]US Occupational Safety and Health Administration emergency response guidance and in the [34]UK Construction Design and Management (CDM) Regulations. The command structure should clearly indicate via an organisational diagram the various HSE roles assigned to named personnel. The complete structure for management, supervision, implementation and technical support/advice functions for work at the site should be clearly set out and personnel should be briefed as to who is responsible for fulfilling what HSE role in the project.

For each of the posts included in the structure, simple terms of reference (TOR) should be prepared which stipulate the role and responsibility, line reporting relationship and qualifications.

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[33] These include, but are not limited to:
US Occupational Safety and Health Administration (OSHA) regulation 29 CFR (1910.120 Regulations for management of Hazardous Waste Operations and Emergency Response, appendix C, section 7 (Site Safety and Control Plans).

[34] A free download of the UK Health and Safety Executive publication "Managing Health and Safety in Construction" can be found at http://www.hse.gov.uk/pubns/books/l144.htm http://www.hse.gov.uk/pUbns/priced/l153.pdf.

Any personnel appointed in any of the positions listed below must be assessed against the relevant TOR and demonstrate through qualifications and experience that they are competent to complete the role as presented in the TOR:

- management;
- technical Support and Supervision;
- site Supervision;
- implementation.

The command structure should also include details of all training that personnel have received prior to implementation and provide expanded details on all training to be provided to project staff during implementation.

Responsibility for HSE

It is essential that the person with overall HSE responsibility is identified in the command structure. This may not be the person who writes the HSE plan but is the person who approves all the methods and activities that are being conducted. For large and medium sized projects this is usually the person with responsibility for managing the project who will be present during the investigation. For very large projects a specific HSE officer may be required particularly if there is extensive work, many people involved with the sampling, very toxic materials being sampled and handled, and/or dangerous conditions at the site (such as confined space entry, elevated areas risk of falls or a high risk of hazardous chemical exposure).

Supervision of HSE

As referred to above, third party oversight and supervision is necessary to ensure that all activities and operations are being carried out correctly. This will include the review of HSE plans submitted at tender stage and supervision of activities that occur on-site. The command structure should clearly state which organizations and individuals are responsible for this.

Communications

Effective communication will be a critical aspect in ensuring safe project implementation. For ease of reference, communications can be divided into *on-site* and *off-site*.

(i) Off-site communications

Off-site communications will form a part of the overall project communications strategy, which is in general implemented in parallel to the project activities. This can include briefing of local communities, notification of local authorities (police, hospital, fire, local government) and the general population in the vicinity of the site and preparation of emergency response as outlined in the section on SOPs in tool L. Even for one-off standalone projects, it is necessary to invest time in this element. Cooperation with government focal points, national NGOs and community leaders may play an important part in this element of the project. The off-site communications should state where the nearest medical facilities are and the contact details of each facility.

(ii) On-site communications

The management of communications on-site will be achieved through the adoption of a series of morning briefings and evening reviews of progress. The site supervisors will take responsibility for the conduct of these meetings with the local labour force and will record all findings on the formats provided. A system of Daily briefings, Daily progress reports and Weekly summary reports are used to ensure adequate documentation of the project progress. The daily briefing is the main mechanism by which persons working on the project are given instructions as to what will be occurring during the day including a review of standard operating procedures and risk assessments. Daily briefings should always include a review of hazards and HSE risk protection

measures. The system is a proven methodology commonly adopted in all FAO managed safeguarding projects.

Formats for daily briefing, progress reports and incident reporting are provided in the example HSE plan at the end of this document.

Risk assessment

EMTK 4, Tool K provides guidance on the preparation of risk management strategies and task-based risk assessments (TBRA). Key outputs of these two elements should also be included in the HSE plan.

(i) Risk management

The PMU should have completed a risks analysis of the implementation of investigation activities as part of the production of the Environmental Monitoring Plan. Risk management includes a variety of risks associated completing the project successfully including issues related to liabilities and insurance requirements. All risks associated with health, safety and the environment highlighted should be brought forward so that they can be considered in more detail in the HSE plan.

(ii) Risk assessment

As indicated in tool K, the process of the *task-based risk assessment* (TBRA) is based on standard risk assessment methodologies which aim to identify the hazards, identify who could be harmed/affected, evaluate the risk (probability of intensity of occurrence), document all actions and constantly review and revise the assessment during implementation. The TBRA records all of the above and is designed to assist the operator in making objective decisions on project implementation with an emphasis on worker and environmental protection at all times. The format also provides a methodology for prioritisation of safeguarding activities to reduce risk in a progressive, step-by-step method.

Standard Operating Procedures

The TBRA does not give detailed instruction to supervisory or operational personnel on how to actually complete the investigation operations. This detailed instruction is provided through the system of standard operating procedures (SOPs) as presented in tool EMTK 4, Tool L. As indicated, SOPs are provided in two formats aimed at different levels of personnel within a command structure.

Activity specific Standard Operating Procedures

These types of SOPs are typically a written instruction to supervisory staff on how to safely complete an activity or task. It is important that all activities listed in the TBRA have a SOP. New SOPs are needed when new activities are completed as part of a site investigation exercise. As noted in EMTK 4, tool L, the format provided is an example and formats can vary based on who is completing the preparation (contractors may have alternative formats based on their own ISO standard systems of working). The aim is to strengthen the capacity of field management personnel and site supervisors to develop SOPs based on the generic templates and actual field conditions. For a specific site covered by the HSE plan, a set of activities will be identified in the TBRA and each activity will require an activity specific SOP. They should be listed here and annexed to the HSE plan for the site.

Site or zone specific *Standard Operating Procedures*

These are standard format based on posters and illustrations to include warning signs and aims to provide simple instructions to workers on where they should be working, what activity they should be completing, what PPE they should be using and what they should do in case of emergency. As with the instructions to supervisors it is anticipated that the generic format presented in tool L will be adapted based on field conditions to allow site – and zone – specific SOPs to be prepared

by field managers and supervisors for the site under consideration. The site/zone specific SOPs should be listed here and annexed to the HSE plan for the site. Cross reference to the TBRA and SOPs are essential components of the on-site communications element outlined in the section on-site communications section above. It is critical for workers to completely understand their roles and responsibilities during implementation of the SOPs.

SOPs should clearly set out:

a) how any equipment for a particular task is to be operated safely;

b) the use of any dangerous materials including solvents;

c) the risks involved during the particular operation (as specified in the Task Based Risk Assessment);

d) any mitigation measures that should be put in place to deal with the risk such as:
   (i) implementation of any site zoning relevant for the particular operation (for further details read EMTK 4, Tool J);
   (ii) the use of personal protection equipment by operators working in a pesticide contaminated area (EMTK 4, Tool M).

Typical SOPs

Typical standard operating procedures for use during site investigation are the following:

- set-up and use of site zoning;
- entry and exit of the contaminated area;
- use of Personal Protective Equipment;
- washing procedures and maintenance of hygiene during works;
- use of mechanical equipment including mechanical augers and backhoes/excavators;
- transport of persons and equipment between sites.

Emergency procedures

This section should state the steps that operators are to take when events in the field do not go according to plan or if there is an emergency.

Categories are:

a) emergency procedures in the event of fire;

b) emergency procedures in the event of a road accident driving between sites;

c) emergency procedures in the event of an accident or injury on-site;

d) emergency procedure on encountering unexpected contamination.

Personal Protective Equipment (PPE)

The type and amount of PPE required for a safeguarding project is defined by the TBRA and the SOPs. They both take into account the hazards posed by the chemicals to be repackaged (the WHO hazard classification), the possible exposure route, the likelihood of exposure, the duration of exposure and frequency of the activity as well as the number of personnel involved in the handling of each pesticide. The chemical reactivity and subsidiary hazards such as corrosive, flammable or oxidising properties are also considered. The TBRA and SOPs also take into account the location where an activity is carried out. In this way, it is possible to use the zoning of the work place to demarcate the PPE to be worn.

The project manager will also be required to factor in the number of workers and supervisors in each working area. The need to make provision for visitors to the site may also influence the numbers of sets of PPE allocated to a specific operation.

The numbers and types of PPE have a direct impact on the project budget. There is a temptation to have PPE to cover every possible eventuality (however unlikely) at a site. Whilst this will address the needs of the risk assessment, it may well result in a significant budget over spend. Care is therefore needed when calculating PPE requirements to ensure that the risks are adequately addressed but that budget limitations are factored into the final decision. The project manager must, however, ensure that the risk assessment is adequate. In cases where the scope of work changes during implementation, such as when a new risk is identified, (s)he should ensure that the risk assessment is updated, and any new PPE and other equipment requirements are addressed.

As the nature of the hazard is not determined until after an investigation, a minimum of PPE is normally required. PPE for site investigation normally includes using the following types of equipment:

- respiratory protection; three quarter face and full-face masks;
- hand protection (gloves);
- eye protection (goggles and glasses);
- foot protection (boots);
- bodily protection (including overalls and coveralls).

EMTK 4 Annex 4 provides further advice on the selection and use of PPE. The guidance focuses on the use of disposable PPE in order to eliminate the need for maintenance and decontamination of equipment. FAO can provide further assistance through training of project teams in the specification of the various PPE used for safeguarding.

ANNEX 11

Site investigation materials and equipment

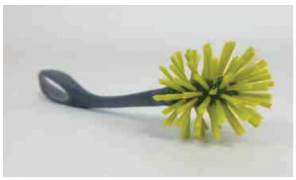
General equipment

Sampling

Wooden stakes 1m long for setting out sampling areas	
Spray paint for marking sample points and making stakes visible	
Measuring tapes 100 m long for setting out sampling grid squares	
GPS receiver accurate to 5 decimal places	
Stainless steel trowel	

Stainless steel mixing bucket	
Mallet for driving wooden stakes into the ground	
Note books	
Wooden stakes for setting out sampling grids and sampling points	
Pens and pencils	
Clip board	

Cleaning

Heavy duty brushes	 
Detergent (non-phosphate if possible)	
Paper towel and holder	
Solvents including methanol, acetone, isopropanol	
Deionised water	
Distilled water	
Tap water	

Jerry cans for carrying water	
Polyethylene sheeting	
Large bowls for washing equipment	
Wash squeezy bottles for holding solvents (this is important to keep the solvents clean and reduce the amount used)	
Hand soap	

Sample handing

Cooler boxes	
Ice pack for use in cooler box	
Refrigerator (short term storage of soil and water samples)	
Freezer (for storage of soil samples following the investigation for up to a year)	
Sample pots, glass jars or bags as specified by the QA/QC plan and the advice of the analytical laboratory	
Marker pens	
Labels	

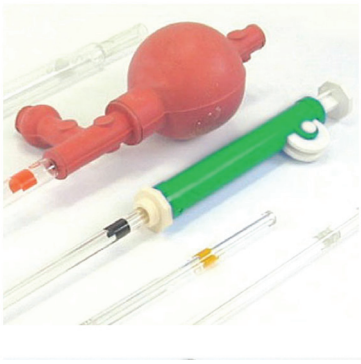
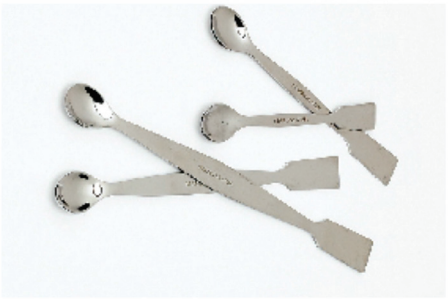
Cardboard boxes for shipping of samples	
Heavy duty tape	
Vermiculite (certified asbestos free)	

Site Clearance

Spades and shovels, if possible stainless steel with no paint	
Pick axe	

Hoe	
Saw for clearing brush and vegetation	

Bulk pesticide sampling

Drum spanner	
Pipette bulbs and/or fillers	
Stainless steel spatula	

Health and safety equipment

as specified by the TBRA and SOPs but generally to include:

Cotton overalls	
Type 5/6 disposable coveralls suitable for protection from light splashes of liquid and dusts	
Wellington boots acid/alkaline resistant with steel toe cap and mid sole	
Site boots with steel toe cap and midsole (preferably no laces)	
PVC apron for washing of dirty equipment	

PVC rigger gloves	
Nitrile gloves heavy duty	
Thin nitrile gloves	
Respiratory equipment specifically required for the work	
Ear defenders	
Disposable ear plugs	

First aid kit	
Safety glasses and/or goggles	 
Eye wash fluid	
Hard hat	

Plant Production and Protection Division (AGP)
Food and Ariculture Organization of the United Nations (FAO)

Pesticide-Management@fao.org
www.fao.org/agriculture/plant-production-and-protection/en/

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