VII. MONITORING

Information obtained by repeated analytical monitoring of the affected area is essential to evaluate how contamination evolves with time, owing to both natural phenomena and human actions ~~first, during the emergency, and later during rehabilitation~~.

~~At the end of an emergency,~~ An accurate picture of environmental contamination will help in deciding on the most appropriate measures to be taken for rehabilitation. ~~Moreover,~~ Evaluating the public and environmental impacts of an accident, as well as the consequences of changes with time within the affected area by a long-term monitoring programme is essential for effective handling of the post-emergency phase, and for determination of the effectiveness of rehabilitation. Measures adopted previously may have to be modified as circumstances change.

The objectives, approach and design of this post-action monitoring are considered in this section.

1. Design of Monitoring System

Measuring and monitoring the environmental behaviour of a pollutant ~~chemical~~ should be based on:

- Experimental design — based on information available, define sample media, contaminants, effects, analytical requirements, ~~to achieve desired objectives~~;
- Sampling plan — set up studies or use previously obtained results to determine an optimum sampling plan, taking into account natural variations and controls within the affected area;
- Analytical measurement — choose analytical methods with small sources of bias and adequate precision to fulfill analytical requirements;
- Measurement errors — initially determined by all laboratories ~~carrying out measurements~~ to provide estimates of precision (within-batch errors), followed by

  Quality control — to determine between-batch errors during the programme of monitoring;
- Sequential, flexible procedure — continuous appraisal of data, followed by revision and amendment of surveillance studies were necessary;
- Hypothesis testing — use data to test hypotheses, or to verify environmental models, (as opposed to deliberately designing sampling programme to 'prove' hypotheses).

1.1 Choice of parameters to be monitored

Determination of contaminants in air samples must consider those substances present in the gas phase, those present in aerosols, and in suspended particulate matter; each one requires different methods of sampling and analysis.

Collection of water samples ~~would~~ requires a consistent systematic approach throughout a monitoring programme. If the contaminant is known, concentrations of dissolved substance and concentration in or associated with suspended solid matter would need to be taken into account ~~particularly for surface waters~~. Where the contaminant has not been identified, factors such as taste, odour, visual appearance, toxicity testing (e.g. using fish) could provide useful indicators of changes in the degree of contamination. ~~In surface waters, continuous changes in contaminant level could also be obtained using biological monitoring devices - e.g. fish monitors.~~ The use of a monitor which measures the ventilation frequency of captive fish provides a broad-spectrum pollution detecting device capable of indicating the presence of ~~a chemical or combination of~~ substances in the water distressing to the fish and potentially harmful to human consumers of the water. Other continuous biological monitors such as luminous bacteria may also be usefu

Considering biological monitoring the intrinsic complexity of the ecosystem involved may require an "ad hoc" investigation in the field. The biological monitoring of a toxic chemical accidentally introduced in the environment requires careful experimental design. Available data needs to be considered, together with environmental behaviour data. A pilot investigation is recommended to define objectives and methodologies.

Indicator selection should result from a theoretically-oriented data reduction procedure, aimed at identifying the most relevant and informative parameters, suitable for time, space and inter-species extrapolation. Available information, relating to other environmental accidents, and other available studies ~~carried out before the introduction of new chemicals in the environment for industrial purposes~~ should be taken into account in indicator selection.

For each identified contaminant or measurement of effect ~~(e.g. Where the contamination is not known)~~, a programme of analysis should be set up to ensure that any results obtained in the programme of monitoring are capable of providing the required information.

This implies the need to clearly define the determinand or effect, the range of concentrations or variations of interest, and the precision required of the results. The latter should be set so that with a given confidence level, it is possible to monitor the least meaningful difference in the samples under test. Precision of analyses and quality control are emphasized in this section, as the objectives of long term monitoring of the environment may have more stringent analytical requirements than those required for the initial identification of the problem.

The choice of method of analytical measurement ***should*** be made after carrying out preliminary studies which provide a sound statistical basis for meaningful comparison between alternative methods which could be used. Analytical methods should be chosen which have a satisfactorily small source of bias, and adequate precision. When adequate methods are not available, these may need to be developed. Careful consideration should also be given to the nature of the samples under investigation. Often analytical methods are developed using materials of simple composition. Highly polluted environmental samples generally are not simple mixtures, and these could give rise to unforseen analytical complications which should be anticipated by consideratin in preliminary analytical studies, rather than discovered at a later date.

Where more than one laboratory is involved in analyzing samples, each laboratory should determine analytical precision, and where necessary laboratory procedures should be improved to give the desired precision. Laboratory standards should also be compared to ensure satisfactory agreement. During a programme of monitoring, quality control procedures should be set up. Compilations such as Standard Methods for the Examination of Water and Wastewater (APHA) or Methods of Soil Analysis (Page et al 1982) should be refered to when designing analytical control proceedures.

1.2 Design of a sampling plan.

Once suitable methods have been chosen, it will be necessary to design a sampling plan to ensure that the accident has been contained, and to establish long-term trends in time and space. Factors which need to be considered include density ~~of sampling,~~ and periodicity of sampling. ~~(frequency of sampling in time)~~.

The extent of the area to be investigated will have been defined in earlier studies, allowing for the area affected by an accident and a surrounding zone to allow for growth of the contaminated area. It is generally recommended that a broad sampling scheme is employed.

Inevitably there will be a dilemma over the sampling required to reach a desired objective, and the sampling dictated by practical considerations. This could be resolved to some extent by redefining objectives, by making reasoned assumptions, or by carrying out further studies to describe further the distribution of contamination and to aid in sampling design. In many cases, pilot studies to establish a statistical basis for determination of the density and periodicity of sampling may be deemed necessary. These studies ~~would aim at determining also whether systematic or random sampling is required to determine long-term trends, and~~ should take careful account of local variability in the media under study, and any bias which may be introduced into the data as a result of the choice of sampling scheme.

Because there are a number of assumptions and uncertainties in any programme of sampling, a regular appraisal of monitoring data should be carried out, if necessary followed by adjustment of sampling programme. This flexible approach would also allow a quick response to changing circumstances within the contaminated area.

It may also be advisable to follow simultaneously two different approaches with frequency of sampling in both space and time:

- a high frequency monitoring of indicator parameters, to allow a continuous follow-up of the most important features of the phenomenon;

- a low frequency monitoring, extended to a range of parameters, to provide information on broader variations in space and time; indicator analysis of this data may also provide a better control over the high frequency monitoring programme. ~~and is described in more detail above.~~ The analysis of temporal trends of most of the relevant parameters may be of help to determine whether the system or some part of it is moving away from the original ~~equilibrium.~~ status.

2. Air - Pollutants

In cases where there is a possibility of contamination of air or soil atmosphere, for example, where chemicals identified in any accident are volatile, or are considered to give rise to volatile breakdown products, or are associate with dispersed particulates, then there will be a need to assess the dispersion of contaminants within the gas phase around a contaminated area.

Both above-surface and sub-surface gas phases would need to be considered, comprising:

a) Atmosphere ~~(s)~~ overlying the contaminated and adjacent areas, where contaminants are dispersed;

b) Atmospheres in industrial and domestic buildings where air circulation and dispersion of contaminants would be restricted.

c) Soil atmosphere, where vapours more dense than air may accumulate near the soil surface interface, or where contaminated atmospheres may develop and migrate laterally (e.g. waste disposal sites).

d) Atmospheres in sub-surface drainage systems and other voids such as in tanks ~~as sub-surface~~ basements, ~~cellars~~ and around foundations of buildings. ~~which may act as gas traps.~~

Gas spaces in the soil are always connected with the outside air. Attempts to keep oxygen out of abandoned near-surface mines to reduce pollution of water have been uniformly unsuccessful. Therefore changes in barometric pressure will pump gases and vapours from the soil greatly increasing transport beyond what would be calculated from simple diffusion. The only practical way to prevent gas escape is to flood the soil and carefully control the flood water.

The clay seal on completed landfills is sometimes impermeable enough to force gas produced by biological action to migrate laterally. Such gas has caused problems in adjacent buildings and it is standard practice when building on or near a landfill to provide for positive removal of the landfill

gas (Stearns et al. 1984). Where there is no, or little natural connection, and where lateral migration of gas is taking place, conditions for accumulation of dangerous atmospheres in building structures or sub-surface voids would be expected. A programme of monitoring should consider the possibility that both of these conditions exist within the contaminated area.

2.1 Monitoring atmospheric and climatic conditions, and contaminant distributions within air throughout and after the rehabilitation stage (ie. over an extended period and over a wide area) should be carried out to give as wide a coverage as possible of emissions of gaseous or suspended particulates to the atmosphere. This study could also provide background or baseline data, and would relate time/spatial variations to variations in climatic conditions with particular attention to wind velocity and direction.

Concurrently, short-term space-limited investigations could be carried out to study in more detail the intermittent release of contaminants to atmosphere during rehabilitation operations e.g. during excavation of contaminated areas, or emissions associated with climatic events (e.g. the resuspension of particulate matter in air during high winds). Careful account should also be taken of atmospheres in buildings during and after rehabilitation, where human or other activities could give rise to intermittent contamination. Several studies indicated that contamination can occur from disturbance of dust on surfaces in the interior of buildings or from contaminated clothing of workers entering buildings, and these sources should be given careful consideration. It would also be important to repeat systematically these short-term studies as necessary during the monitoring programme to give an indication of long-term trends and clean-up.

In permeable soils, where vertical diffusion through the soil/air interface might be expected to predominate, intermittent water-logging from high rainfall, or freezing during winter could reduce the permeability of the upper soil layers, giving rise to lateral spreading and dispersion of gaseous contaminants in soils over a wider area than initially predicted. ~~Systematic investigation of building structures, such as basements or foundations, cellars below ground level, where potentially dangerous atmospheres could accumulate (acting as gas traps) should also be investigated, and would provide useful additional monitoring points~~.

3 Water Pollutants

Because of the wide usage of water, and interconnections between various forms of water resources, monitoring should consider all aspects of the water cycle; the reintegration of the affected area into the local fabric will be greatly assisted if provision is made for broad sampling.

Water within a contaminated area which would need to be considered includes:

- Precipitation (rain and snowfall);
- Surface waters (streams, rivers, lakes, reservoirs, open drainage channels) subsurface drainage networks discharging into surface waters;
- Soil water and pore water in the unsaturated zone;
- Groundwater at different depths within the saturated zone beneath the regional water table, and in perched layers of saturation above the regional water table;
- Water supply, distribution and wastewater disposal systems;

The interrelatioships between these different pathways are summarized in Figure VII.1 Some or all of these waters may already be monitored by Regional Agencies, who could provide valuable background data and further monitoring support.

3.1 Water monitoring

In water monitoring, a balance must be kept between sampling to discover the contents of a discharge, which would mainly be carried out during the initial emergency, and sampling to discover the extent and dispersion of a discharge within the water cycle. Because of the constraints on early accuracy, sampling and analysis may tend to concentrate on the immediately detectable high volume problems and neglect the longer range sampling that might reveal at a later stage a much broader degree of contamination than was first considered likely. As emphasized above, attempts should therefore be made to implement a broad and thorough sampling programme of the water cycle, especially in areas where little previous monitoring data is available. Even data from unaffected local areas may be of use in

FIGURE VII.

ENVIRONMENTAL PATHWAYS FROM A GENERALIZED HAZARDOUS WASTE SITE

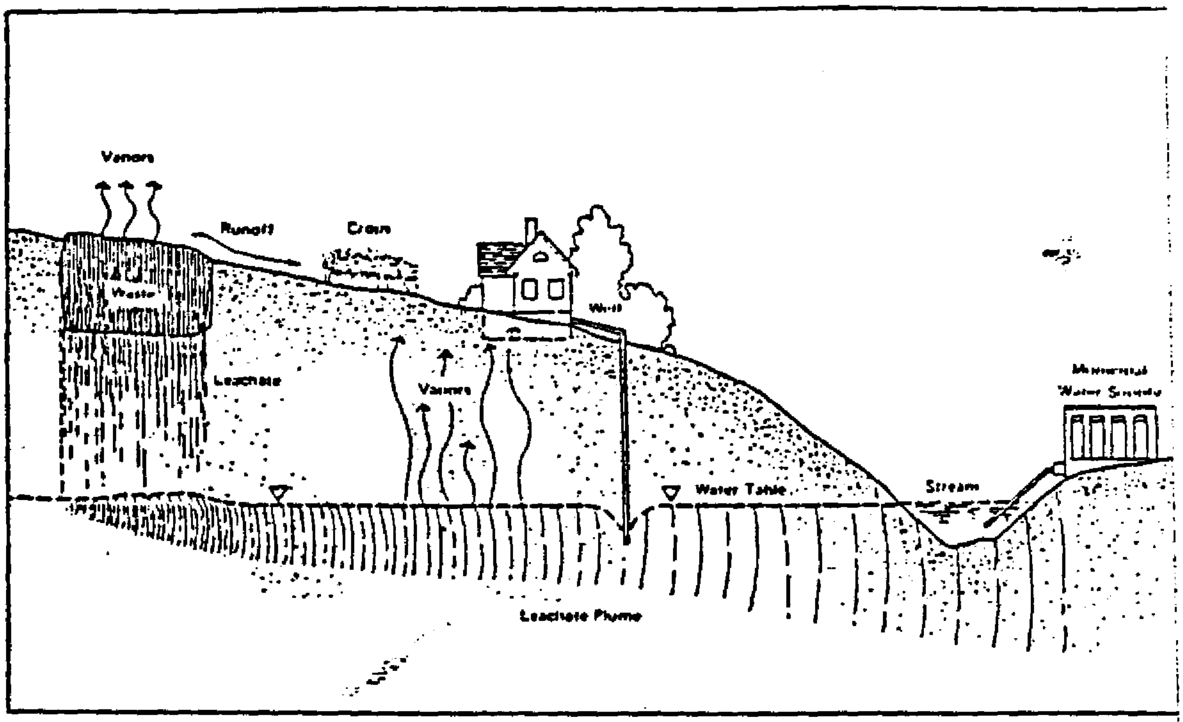
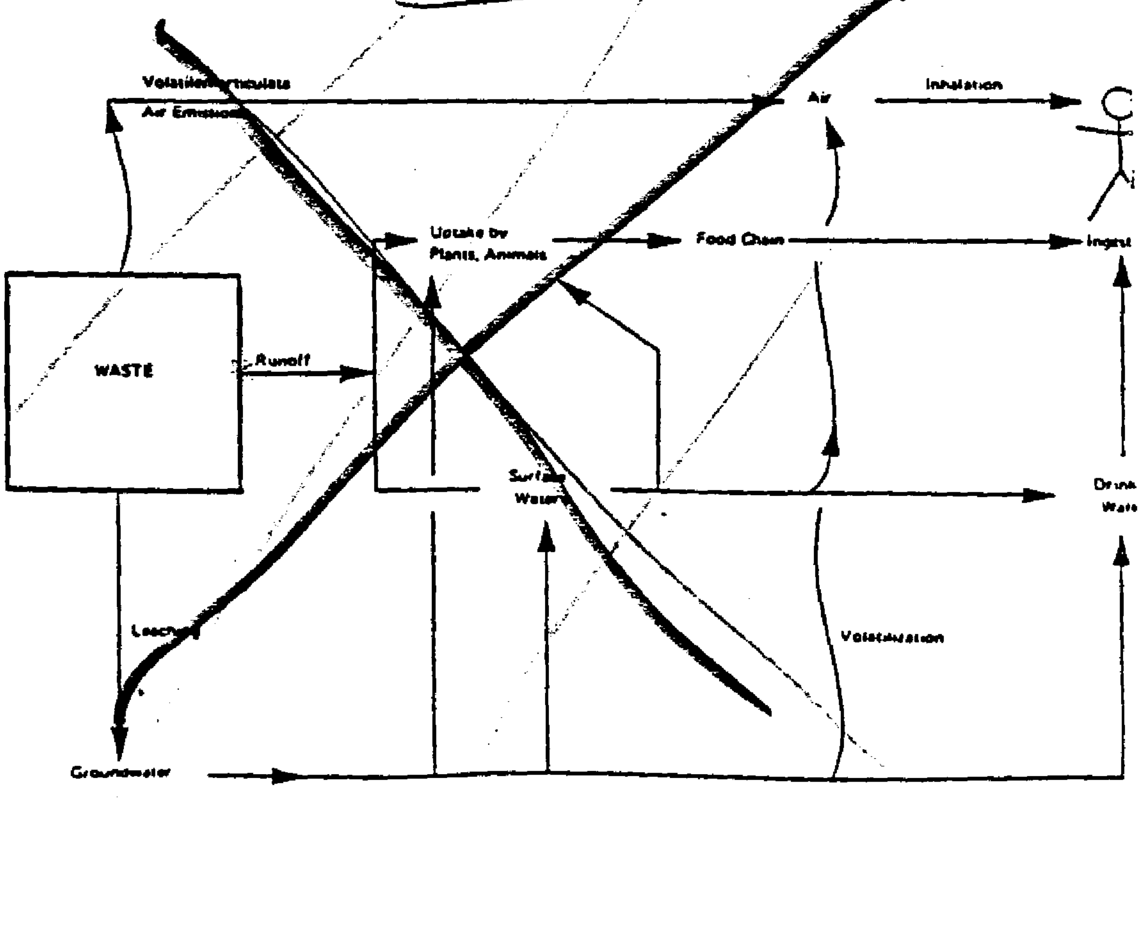


FIGURE VII-3

SCHEMATIC DIAGRAM OF EXPOSURE PATHWAYS (1)



building up a picture of background levels and service controls. This type of space-extended, possibly low periodicity, water quality survey carried out during the emergency and post emergency phases would identify contaminated water resources and monitor the increase or decrease of contamination with time, but would not necessarily identify those resources at risk from later contaminants within the water cycle.

An assessment of this may only be arrived at by more detailed studies of particular resources, within the contaminated area, taking into account their sources and sinks. These studies could be systematically repeated as required to determine long term trends. For example, groundwater contamination and contamination of supply wells may not be initially apparent from surveys carried out immediately following an accident. Later effects on groundwater quality could take place from percolation of contaminated rainfall through soil and the unsaturated zone, from slow percolation of soil water through contaminated strata, or from subsurface migration of groundwater away from a point source.

It will also be necessary to monitor not only quality, but to estimate the flow of water from one water body to another.

Water monitoring and rehabilitation thus requires a thorough knowledge of the dynamics of the water cycle/pollutant system, which may only be obtained by extensive field investigations and laboratory studies.

Collection, collation and interpretation of data relating to groundwater pollution should start as soon as possible after the accident. Suitable sampling points for both groundwater (existing wells and bore holes) and surface water may exist in the affected area, but frequently it will be necessary to drill boreholes to provide additional groundwater monitoring points within the prescribed areas. The costs of groundwater monitoring and rehabilitation may thus be high, and because groundwater movement is often slow, monitoring may need to be extended over long periods of time (e.g. years rather than months).

As with most environmental media, water systems are dynamic and subject to constant change. Without proper appreciation of the controlling influences on the water system, neither accurate diagnosis of the situation, nor prognosis of future contaminant behaviour will be possible.

The data collected should be collated by appropriate experts and assembled to explain the measured distribution of contaminants and their observed behaviour at the site of the accident. Working hypotheses may be either conceptual models or may involve the use of mathematical simulation techniques. In any case, they should be validated as fully as possible.

The information and time required for the construction of a mathematical model is generally considerable and it is unlikely that such a procedure would be followed except in the case of a serious accident involving a major water resource of high value. Nevertheless, once calibrated and verified, a model has the advantage that the potential effectiveness, and hence cost, of alternative control and management options may be tested relatively easily. This facility enables the rehabilitation procedure to be optimised if external constraints remain constant or to changed in the most effective manner if the constraints change.

Although it may be considered to be necessary to concentrate monitoring effort on sources of water in the affected area, surveillance of the supply distribution system should not be neglected whether resources feeding the supply are found to be contaminated or not. This would not only provide assurance to the consumer, but would give warning of contamination which might occur in the distribution system itself. An example of this was found at Lekkerkerk (See Case Studies published in this WHO series) where contamination occurred by diffusion of organic pollutants in soil through polyethylene service pipes carrying drinking water to domestic dwellings. Effects such as this should be anticipated in any long-term surveillance programme.

Planning for monitoring of water resources and their possible rehabilitation requires a thorough knowledge of the dynamics of the surface/groundwater/pollutant systems, which may only be obtained by extensive field investigations and laboratory studies. Collection, collation and interpretation of data relating to groundwater pollution should start as soon as possible after the accident. Suitable sampling points for both groundwater and surface water may exist in the affected area, but frequently it will be necessary to drill boreholes to provide additional groundwater/soil pore water sampling and monitoring points within the prescribed areas. The costs of groundwater monitoring and rehabilitation may thus be high; and because groundwater movement is often slow, monitoring may need to be extended over long periods of time (eg years rather than months).

3.2 Sampling underground water

In the case of surface waters, monitoring points may be established relatively easily at places accessible for sampling equipment and personnel, whether from the stream or lake bank, or from boats. In selecting such sites attention should be paid to the representativeness of each site in respect to the body of water in question, account being taken of possible disturbing confluences such as the proximity of effluent discharges to the water, or the relationship to confluences with streams draining other catchments possibly subject to contaminating influences. The siting of sampling (wells/boreholes).

points (wells/boreholes

~~quality~~ can only be specified adequately once a certain level of understanding of local hydrogeological regimes, including contaminant dispersion patterns, is achieved. It is therefore almost inevitable that any initial array of observation boreholes, drilled during the emergency phase, will require subsequent modification. ~~extension or adaptation~~. In general, the results of the initial sampling and monitoring will reveal the broad outlines of the contaminated zone and may indicate those areas and levels at which maximum pollutant concentrations are to be found in the aquifer system. The same surveys should also indicate whether significant hydraulic head differences are present between different layers of the aquifer. Where such differences do exist, vertical flows and mixing of waters of different qualities may occur in open boreholes, rendering the results of such measurement difficult to interpret and of dubious value.

Boreholes should be constructed in such a way that they do not provide pathways for rapid transfer of surface contaminants to the groundwater zone, nor act as bypassing fissures between waters of different qualities in the saturated zone. Consideration may also need to be given to the types of materials used in borehole construction as, for example, many plastics used to make well lining tubes and screens continue to leach soluble organic carbon at concentrations in the range 5-20 mg/l for considerable periods of time, and analyses of waters collected from such wells may indicate spuriously high levels of organic contamination.

¶ The need to optimise the information obtained from specially drilled observation boreholes, or from existing boreholes adapted to use as monitoring points, is emphasised by the relatively high cost of such installations, when compared with the cost of obtaining surface water samples. As a

~~relatively soft consolidated material by open hole methods in which~~

~~no intact core is recovered. The latter price would be representative of holes drilled from which continuous cores were obtained for pore water analysis. In addition, in situ groundwater~~

The choice of drilling techniques is controlled largely by the nature of the material to be drilled and by the requirements of the sampling programme. The most important consideration is that the methods employed should not introduce extraneous fluids into the samples. Normal water- or mud-flush techniques are not, therefore, generally satisfactory. See Fenn et al (1977) for well designs suitable for monitoring contaminants in water. (and Naylor et al 1978)

During the investigations, samples of solids and fluids should be collected systematically for both physical and chemical analysis. The first stage of the analyses is the preparation of descriptive lithological logs of the samples. In the auger method, drilled material is carried upwards and sampled at the surface. The precise depths from which the bulk samples were obtained therefore cannot normally be determined. More accurate sampling may be carried out by withdrawing the augers at selected depth intervals and recovering material from the auger flights, or by using hollow stem augers.

Recovered rock cores should be inspected to distinguish lithological changes and identify zones of high or low permeability. For example, high permeabilities may arise through fissuring or where coarse-grained horizons occur in mainly fine-grained formations. Low permeabilities are associated with clay or silt horizons. Determinations of porosity, bulk and grain densities, moisture contents and permeability, both horizontal and vertical, can be made on core samples. Grain size analysis may be performed on both unconsolidated and softer consolidated samples and used to assess the permeability of the formation.

Soil and Vegetation

Surveillance of soil and vegetation is particularly important where accidents have affected above or near-surface environments. Monitoring programmes would generally consider:

- the distribution of contaminants in soils, the soil types and land use within the contaminated area and variation with time in these parameters.

- the availability of contaminants in soils to vegetation (whether contaminants are present in soil solution, sorbed, or present in poorly soluble solids and therefore relatively unavailable to plants)

- the effects of contaminant uptake on plants (phytotoxic effects, seed germination, plant development, general health of plant including root systems.

- long term adjustment of flora in response to contamination and its recession (disappearance or reappearance of species, development of tolerant species).

The aim of such studies would be to determine long-term trends in contamination and its effects, and would inevitably involve extensive field studies, but could also include laboratory studies, e.g. pot trials of different soils to study phytotoxicity.

The general appraoch to monitoring these media are discussed in detail below.

4.1 Soil Monitoring

A first step in the monitoring of soils is to establish a sampling scheme taking account of both depth and area. When sampling soils for agricultural purposes e.g. to assess fertility it is usual to sample only to a shallow depth, (10 - 15 cm) whereas for a full agricultural assessment it is necessary to sample to greater depths. This is particularly important where a rehabilitation scheme involves covering the polluted substrate with a layer of uncontaminated material, and checks for upward migration of the pollutant are necessary. To examine the entire cross-section of a soil including both top soil and sub soil it may be necessary to dig a pit (or take repeated auger samples) permitting visual inspection and sampling of the soil at different depths down the profile.

For the assessment of surface contamination it is desirable to examine the very uppermost layer of the soil. Although plant roots will quickly penetrate below this layer, contamination at the surface may be enough to inhibit seed germination and therefore prevent plant establishment. Dust or soil splash during rain can pollute crops with contaminated surface soil even if the crop roots are growing beneath the contaminated layer. Surface contamination can also be important with respect to grazing animals which inadvertently ingest soil together with grass. Soil may contribute 10 per cent or more to the diet of sheep for instance and may therefore contribute significantly to diet intake of contaminants.

In the case of polluted land where the distribution of the contaminant is unknown, there will be an acute sampling problem. A scheme must be drawn up to sample the area as efficiently as is permitted by constraints such as the maximum number of samples which ~~can~~ can be analysed. Before any samples are taken it is important that those responsible for sampling, analysis and evaluation become familiar with the special problems of sampling such an inhomogenous material as soil. For example see Page et al (1982)

~~to what extent future monitoring could be restricted both by taking fewer samples (area and profile) and by judicious bulking of sub samples to reduce the analytical burden and improve the efficiency of monitoring without detracting unacceptably from the usefulness of the results. However,~~ Centres of contamination within a polluted area may be known either through knowledge of the history of the site and the pollution incident itself, or by visual inspection of the site. For instance, plants may be chlorotic or absent in one corner of the site or the soil may be coloured by high concentrations of the pollutant emanating from one centre. In this case, a sound approach would be to devise a sampling grid ~~based on a logarithmic design~~ to intensify sampling and analytical effort on the most contaminated area, taking progressively fewer samples away from centre of pollution.

Organic micropollutants present a special problem and advice should be taken on sample handling from appropriate experts in this field. Analysis of contaminants such as toxic metals should also be designed to assess their availability in the soil using, for example, soil water extraction (soluble metal), selective chemical extractants (sorbed or available metal) and total metal analysis.

4.2 Vegetation Monitoring

Sampling of vegetation may have one or two purposes:

(a) To assess the health of the plant
(b) To assess the impact on animals which may eat the plant.

In the case of (a) the aim must be to sample tissue of uniform physiological type and age from each plant. Green growing leaves are often particularly useful for assessing the health of plants. Details of leaf analysis procedures for particular crops should be sought from an agricultural specialist. Visual inspection of plant cover can be useful in forming an impression of the pollution. Unhealthy plants often display a yellowing of the leaves or chlorosis and this is likely to be most acute near the centre of contamination.

With regard to obtaining a representative sample the same general principles apply to plant sampling as to soil sampling. see AOAC 1984 The area can be divided up into graded areas on the basis of visual inspection of the plants and composite samples obtained from each area. Where no visual evidence of contamination is evident in the vegetative cover, either the whole area can be sampled intensively on the grid basis at the same time as soil samples are taken, or a limited plant sampling programme can be undertaken after the results of soil analysis have defined the extent of pollution.

Plant samples are normally dried in a draught oven at 80-100°C and milled to pass 1 mm before analysis. Again care must be taken to avoid contamination and the procedure must be modified if it would lead to losses in the determinand of interest during sample preparation.

4.3 Animals Monitoring

Monitoring of animals within a contaminated area may be done to measure the spread of pollution, e.g. in earthworms, or in birds at the top of food chains.

Autopsies of dead or obviously diseased animals may be useful especially if combined with chemical analyses for pollutants. The choice of animals for monitoring depends on the type of pollutant and it is very important to have local background-reference analyses for comparison.

Fish and other aquatic animals are useful indicators of water pollutio Not only fish kills, where a count is made of dead fish, but also disappearance of species caused by interference with juvenile development should be monitored.

Monitoring of animals within a contaminated area could be aimed at the investigation of three taxonomic levels - the individual, the species (population), and the community (fauna). The programme of surveillance would be carried out to establish when recovery of pre-accident conditions was complete, or when a new, balanced and stable community had developed in response to changes brought about by contamination or by rehabilitation activities.

Surveillance itself would involve a programme of exercises where a set of standard observations are systematically taken within a short period of time, these being repeated at intervals to provide a time series of observations to determine trends in damage and recovery of fauna. It would also be necessary to attempt to define pre-accident conditions, using either historical records of the area, or using results of studies of fauna in physiographically-similar, uncontaminated areas. It may be necessary to carry out investigations of the latter areas if no data are available.

Surveillance at different taxonomic levels would require different approaches, and these are discussed below.

Surveillance of individual live animals could involve the study of physiological parameters such as rate of heart beat, respiration, analysis of blood or urine, determination of growth rate, or investigation of appetite, general health and behaviour. Investigation of dead animals, for example individuals which have died from natural causes or possibly as a result of contamination, or which have been deliberately sacrificed, could be subject to rigorous histological and biochemical investigation. Incidence of tumours and accumulation of

Individual animals may be captive (e.g. domestic animals or farm livestock) or at liberty. In both cases, they would need to be identified by tagging so that individuals could be captured (if live) to provide information on variation with time in physiological conditions, or identified and subject to post-mortem analyses if dead to complete case studies within selected fauna.

~~mine the extent or intensity of the effects of contamination on the population.~~

At the community level ~~(using only animals at liberty)~~ diversity studies could be carried out involving the acquisition of data which describes the restitution of a balanced community and reappearance or growth in population of 'sensitive' species. The availability of colonizing organisms within or adjacent to the affected area should be considered in this context, and reintroduction of some species into the environment may be considered where these are lacking.

All these studies should aim at the definition of the likely eventual community structure following rehabilitation (similar to the development of a climax community in plants), and would be used as an aid in defining the progress of the rehabilitation process, and to provide information on the short and long-term effects of exposure to a chemical release on the environment. The latter is particularly important to document, to aid future studies of similar accidental releases.

4.4 Monitoring of Locally Produced Food/Feed

Monitoring of locally produced food and animal feed ~~would normally~~ be required to protect human and animal populations from exposure to contaminants via their respective food chains. Where necessary, alternative uncontaminated sources of these would need to be provided.

In the long-term, it would also be necessary to continue this surveillance, to monitor possible clean-up of the contaminated area, and to assess the advisability of recommencement of agricultural and/or horticultural activities in the affected area which may have been curtailed following an accidental release. Where locally produced crops, food and feed are consumed by the resident human and animal populations (whether as a result of a decision to recommence production of these, or where advice to individuals growing crops for their own consumption is not heeded), then monitoring of crops will be required to continue to protect the consumer, and to provide a record of diet and levels of contaminant ingestion, e.g. for use in epidemiological studies.

Surveillance of feedstuffs and food ~~however~~ may need a more rigorous approach than monitoring of vegetation in general, and could include:

- uptake of contaminants into edible parts of crops
- effect of varying contamination on crop yield
- investigation of seed germination, plant development and damage in relation to rehabilitation of the affected area.

Although the general approach to monitoring of these have been discussed in section 3.1 it is particularly important to take into account surface contamination of plants, for examle, from dusts or soil-splash. Sampling of grassland used for grazing should also take careful account of the ~~species composition of sward and~~ composition of topsoil, which may be ingested by animals.

5 Buildings and facilities

Development of an overall decontamination strategy revolves around the proper identification and evaluation of the contaminants present. This knowledge is necessary for selection of decontamination methods that will effectively reduce the contamination to acceptable levels while providing adequate protection to workers. Remedial site investigations of buildings and structures should include a records search, visual inspection, and sampling survey to determine the nature and level of contaminants present. Equipment used in removal operations should routinely be decontaminated before leaving the site to minimize the spread of contamination. (EPA 198-)

5.1 Records Search

A knowledge of past operations at the site will generally yield information regarding the nature of contaminants likely to be present. Such information may be available through onsite records (operating logs, manifest records), reports of Federal or state site investigations, local fire and police departments, former employees of the facility, and neighboring residents or business employees.

5.2 Inspection

Visual inspection can identify areas of gross chemical contamination as well as reveal the condition or soundness of a building or structure. Such an inspection will help determine whether a building or structure has any potential for future use or should be dismantled and disposed of. ~~(see Identification of Future Use, p. 9).~~

During the inspection, rafters, ventilation ducts, sumps, crawl spaces, window wells, tanks, etc., should be inspected for evidence of deterioration as well as chemical residues or contaminated dust/particulate matter. Buildings that are suspected of containing asbestos should be inspected for ~~[illegible]~~ fiber contamination as well as for chemicals.

5.3 Sampling Survey

Complete characterization of the contamination in or on buildings, structures, and equipment requires that a detailed sampling survey be performed as part of the overall site remedial investigation. Standard sampling techniques can often be used to determine the presence of solid, liquid, or airborne contamination. Methods for sampling and analysis of contaminants in solids and liquids can be found in EPA's Test Methods for Evaluating Solid Wastes (EPA SW-846). and other national standards.

Sampling methods for determining the nature and extent of contamination on building and equipment surfaces are not yet standardized. Variations of wet-wipe and dry-wipe techniques that have been used in the field are described in EPA 198_ . In some instances, it may be necessary to determine the depth of penetration of contaminants into porous materials such as wood, wallboard, or concrete. This information may be used to determine when dismantling or demolition are appropriate. In these cases, small sections of the contaminated structural materials (e.g., corings) should be collected for analysis and handled as a solid waste

During sampling, the maximum level of personal protective equipment commensurate with the hazard should be worn (see Section VI). Representative samples should be collected and analyzed in accordance with . quality control guidelines,
Several locations at the site should be sampled in order to identify all contaminated areas. The survey results should identify all contaminated substrates and report contaminant levels by sampling location. Surface sampling generally employs a variation of the wet-wipe or dry-wipe technique as a means of assessing the nature and extent of contamination.

An appropriate area is chosen for each sampling and then subjected to horizontal and vertical wiping with a cotton swab imbibed with a suitable solvent; then swabs are put in glass jars to be further used for extraction and assay of the chemical contaminant(s).
The extent of chemical contamination of external surface may be established by means of assays in the material scraped off from about a 0.25-m^2 area of each wall. See also Di Dominico et al. 1978.

The applicability and effectiveness of the methods described above were developed specifically for the U.S. Army's Installation Restoration Program and have not been applied or tested on all ~~of the~~ contaminant/structural material combinations. ~~encountered at Superfund sites~~. Pilot-scale testing of the methods on a site-by-site basis prior to full-scale implementation is recommended. Surface wipe proceedures are inherently incapable of providing absolute values of contamination but are useful for relative investigations if proceedures are carefully standardized.

There will often be considerable merit in assuring that future owners of decontaminated buildings and structures on contaminated sites are made aware of the nature and levels of any residual contamination and of the cleanup methods used. Ensuring the transfer of such information from one site owner to the next will require a method for permanently recording this information. Regulations requiring the addition of such information to the property deed or zoning document may be a workable solution.

During the monitoring of contaminated water, it is necessary to take precautions to limit changes in the physical, chemical and biochemical state of samples before analysis. Some changes occur rapidly, and in these instances it may be difficult to maintain sample integrity by preservation. In-situ determinations or on-site processing and analysis, where storage time is at a minimum, is consequently an advantage and logistic problems of sample transportation are thereby avoided.

6.1 Preservation of water samples

All samples require some preservation to retain sample integrity prior to analyis unless the analysis is carried out in-situe or immediately after the sample is taken. ~~In general, specific methods of preservation, directed at the properties of the sample being determined, may be required and appropriate experts should be consulted on the most efficient methods which can be used.~~ Methods for the preservation of water samples are given in Standard Methods -

There is presently no one preservation method suitable for all determinations. The choice of preservation method depends on the type of the water sample, the parameters to be determined, the analytical determinations to be carried out and the probable duration of sample storage.

Containers for storing samples must be made of suitable material which remains unaffected by the sample or the preservation technique adopted. Glass bottles are nearly always appropriate, ~~but sample~~ containers made of plastic materials are not ~~always~~ recommended; certain constituents of the sample (eg. organic solvents, pesticides etc.) may diffuse into the bottle material whilst other substances (eg. plasticizers) may be dissolved out of the container.

6.2 Sampling of air and vapors

For gases and vapors, explosivity and toxic levels may be measured in-situ using portable electronic equipment. Other specific constituents can be analysed semi-quantitatively by gas detection tubes, around contaminated areas, in confined spaces (eg. manholes) or in the vicinity of boreholes. Some of these determinations may not respond specifically to a single gaseous constituent and care should be taken to avoid errors from interference effects using these methods. It is generally recommended that more extensive laboratory analysis is carried out to confirm in-situ determinations.

6.3 Field analyses

Simple physical and chemical tests such as pH, Eh, temperature, conductivity and dissolved oxygen are best measured in-situ (for example in surface water, or in borehole water) as most of these parameters are subject to change during sampling.

¶ Tests run in a mobile field laboratory have the additional advantage of quick answers without the delays caused by transportation and waiting in a busy central laboratory. However, field laboratories must be checked by sufficient duplicate samples, preferably taken at random, to confirm their reliability wherever possible.

no ¶ — The use of analytical instrumentation in a field laboratory should be restricted as far as possible to these determinations requiring the minimum of sample preparation, and for determination of parameters which are unstable. In general, the sensitivity of instrumentation will not function as well under field conditions as under more stable ~~condit~~ conditions.

7. Reliability and Use of Data

"A single observation is worth nothing.". This free translation of a classical German aphorism emphasizes the fact that one measurement gives no information about the variability and therefore the reliability of a parameter. Two observations tell a little more but half the time both numbers will lie on the same side of the median or average value of the population from which they were drawn. Therefore before taking action on the results of an analytical determination, it is necessary to evaluate its reliability.

7.1. Sampling

Probably more false analytical data is caused by inadequate sampling than by any other cause. Taking samples at the convenience of the technician, e.g. close to the bank of a stream instead of out where the water is well mixed, is only one of many errors that can negate a well planned statistical survey. The place and time that samples should be taken as well as the sampling technique must be carefully planned to eliminate bias due to natural gradients in the system.

Samples must be properly labelled with place time and name of the pers taking the sample or with an individual sample number keyed to full details in a log. Inadequately labelled samples should not be analysed.

7.2. Analytical Quality Control

The best estimate of the reliability of an analytical measurement including sampling is the analysis of a duplicate sample that is sent through with a different, non-related, sample number. Obvious duplicate samples can introduce subconscious bias as well as blatant "corrections". A significant fraction of "blind" duplicates is essential when using an outside analytical laboratory and in many cases duplicate analyses by more than one contract laboratory are desirable. Studies of the reliability of analytical measurements invariably show that within-house differences between related samples are less than differences between laboratories. ~~See ASTM 1986~~ (See Perket 1986)

A quality control programme should be set up to evaluate any analytical programme that will be used as a basis for decisions involving health, public relations, money or research. Such a programme can identify data that cannot be supported and should be repeated before use or release. In the emergency phase there may seem to be little time for such refinements and quick confirmation of a suspected pollutant may suffice. In the rehabilitation phase where pollutant concentrations will hopefully approach background levels careful analytical control is essential.

7.3 Limitations on Data Collection

Automatic sample collection and mechanized analytical techniques can quickly lead to more data than can be utilized even with the aid of large-scale data processing. Careful attentions should be given to the utility of data. For example most of the pollutants in a ~~landfill~~ leachate are usually highly correlated and a single simple analysis, such as conductivity, might be used to establish the boundaries of a leachate plume. Confirmation of pollutants that are difficult and expensive to detect could then be done near plume boundaries or other critical locations.

Before a sampling programme is changed, either in location or content, some attention should be given to auxiliary uses of the data, such as prospective epidemiology or environmental research. Arbitrary changes, in procedure, especially if they are not properly recorded, can destroy, or even worse, lead to incorrect conclusions from research projects that take advantage of the special situation created by a chemical accident.

Eventually, any chemical accident should provide "previous experience" for future accidents. However, the "long-run" effects are subtle, complicated, difficult, and expensive to study.

If adequate records are kept and a good report is made available in at least one publically accessible place near the accident, subsequent studies of effects not anticipated at the time of the rehabilitation will be greatly aided and further rehabilitation, if necessary, will be facilitated.

7.4 Statistical Evaluations

Statistics enters as an essential part of quality control but proper statistical evaluation of voluminous data calls for more than modern computer printouts. The distribution of pollutants in water or air does not follow classical gausian statistics but is more closely fitted by log-normal distributions (Dean 1981). Failure to observe this fact has led to lower limit concentrations being reported as negative values and more seriously to erroniously low upper limits.

Many conventional statistical proceedures are strictly applicable only to normal populations. If they are applied to populations that are highly skewed or have more than one mode the probability conclusions will be erroneous. Any effort to "improve" data by deletion of excessively high values destroys confidence in the calculated probability of the result.

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