Collecting information for characterizing the catchment and assessing pollution potential

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Sufficient information is key for adequately assessing both the groundwater pollution potential and safety of a drinking-water source. This assessment requires a variety of information, particularly relating to the hydrogeological setting (i.e. aquifer vulnerability), socioeconomic conditions and the range of anthropogenic activities present in the catchment which potentially release pollutants. The establishment of an information inventory is therefore a central tool for developing a sound understanding of potential pollution sources and the likelihood with which pollutants may reach groundwater in concentrations hazardous to human health. The type of information required for assessing groundwater pollution potential is highlighted by the checklists at the end of Chapters 7-13. This chapter addresses general aspects of establishing an information inventory, focusing on the following three questions:

• Which types of information are useful or necessary, and where can they be obtained?
• Who needs to work together to collate the information needed for a comprehensive characterization of the drinking-water catchment area?
• What quality of information is necessary to assess groundwater pollution potential, prioritize hazards and decide on management options?

A key element when compiling an information inventory is to establish adequate data management. This is crucial for viable assessment approaches, regardless of the level of sophistication of data and information that are available and are being used. A well maintained information inventory also supports transparency in the chain from assessment to subsequent management decisions, and is therefore helpful for ensuring acceptance and relevance to all involved parties.

6.1 TYPES OF INFORMATION AND ACCESS TO IT

Information needed for assessing the groundwater pollution potential, i.e. the likelihood that disease agents such as pathogens or chemicals reach groundwater (Chapter 14), can be gained from four types of sources:

• site and catchment inspections;
• public consultation, i.e. communication with the local population;
• collating existing data;
• targeted hydrogeological field surveys (e.g. for aquifer vulnerability mapping as discussed in Chapter 8), and groundwater quality screening or monitoring programmes involving laboratory analyses.

For the most effective use of available resources it is helpful to begin with an initial assessment identifying which information is available. From this, it is often possible to prioritize additional information needed as a basis for making decisions. Such an initial assessment will begin with site inspection and careful evaluation of the available data. Further steps may follow, involving different levels of field surveys including laboratory analysis of samples.

Generally, financial resources and institutional capacity significantly influence both access to different types of information as well as scope and extent of the information collection process. Institutional capacities may be very limited with respect to analytical laboratory equipment or with respect to staff, or both, and this does not necessarily correlate with economic potential. In some settings, financial resources and institutional capacity may allow for regular groundwater monitoring with sophisticated equipment and analytical methods, including modelling of groundwater flows and loading. In contrast, in other settings available options may be limited to visual information gleaned from site or catchment inspection and informal information from communication with the population in the drinking-water catchment.

Assessment strategies that are mainly based on high-tech monitoring easily neglect site or catchment inspection as an important first-hand information sources whereas communities with limited resources can successfully perform pollution potential assessments on the basis of information gleaned from site inspection and public communication. Some countries with excellent laboratory capacity face increasing staff reductions, and site inspection has often been the first activity compromised by structural changes in responsible authorities since they are labour intensive. Other countries with lower labour costs may have more staff capacity for conducting site inspection – in spite
of substantially less developed laboratory capacity – and thus have a high potential for good situation assessments, if the staff are adequately trained.

6.1.1 Site and catchment inspection

Comprehensive site and catchment inspections provide highly valuable first hand information about the area of interest, and in many cases they uncover self-evident pollution problems in a catchment. Inspections often provide an important early warning function as they can indicate the potential of future groundwater pollution which would only be detected by monitoring after the fact.

Sanitary inspections are specifically designed to provide an overview of the status of drinking-water source contamination risks. They identify probable causes of failures when drinking-water contamination is found (Howard, 2002a), and may include, for example, an assessment of the proximity of polluting activities in relation to drinking-water abstraction points and of the condition of wellheads. A more detailed description of sanitary inspection is given in Chapter 18, and further guidance can be obtained from, for example, Lloyd and Helmer (1991), WHO (1997) and Howard (2002a, 2002b).

Inspections on a broader, catchment oriented scale target the collection of information for the characterization of visible activities which may potentially pollute groundwater and of hydrogeological conditions which determine aquifer pollution vulnerability. The checklists at the end of Chapters 7-13 provide examples of aspects to consider when performing site or catchment inspections. Inspections need to be repeated periodically, as conditions and activities in the catchment are not static and change over time as new development occurs in the area, or may be important only seasonally.

Inspections can often gain more information if performed in collaboration with those responsible for, or operating, activities in the catchment which may potentially contaminate groundwater (e.g. farmers, operators of waste disposal sites or sanitation infrastructure, etc.).

6.1.2 Consulting the public

Public consultation and involvement is best undertaken whilst collecting information about groundwater. This is important to establish a basis of open dialogue and mutual trust as well as ownership which is crucial for the implementation of management responses. At this stage, however, public consultation is also important as a potential source of information. People in the community can report how their livelihoods relate to water use and water quality, which sources and wells are used for which purpose and in what amounts, and pressures that have an impact on water uses and on pollution. This helps assess the economic and social values placed upon groundwater in a given community and understand reasons for quality and quantity problems (see also Chapters 5 and 7).

Understanding the community’s perception of issues, e.g. land tenure rights in relation to groundwater use, or performance of government institutions, may be an important source of information for developing successful management responses. Other issues for which this may be important are the perception of quality, e.g. confidence in
public supply and perhaps how this compares to confidence in water from private wells, as well as willingness to pay for better quality of water.

As discussed in Chapter 7, in undertaking community consultation, it is important to ensure that all stakeholder groups are included, and to avoid potential bias in the findings by concentrating on particularly vociferous groups that may have an unrepresentatively negative or positive view of certain issues.

Community consultation is generally an important source of ‘informal local knowledge’. Targeted interviews, questionnaires, telephone or door-to-door surveys are common tools for establishing communication with the local population and thus accessing their knowledge. A wide range of information about technical groundwater issues may be gleaned from interviewing community members, e.g. on water levels in wells, patterns of rainfall and inundations, changes in vegetation cover that might indicate changes in groundwater levels or seasonal patterns relating to groundwater. Communication with the local population may also be a good – though usually incomplete – source of information on potential pollution from human activities (including illicit activities), as discussions can help identify the reasons for which adequate control measures are lacking. Information gleaned from local knowledge may be particularly valuable where those operating polluting activities are reluctant to provide required information or deny access to operation sites for inspection. Consultation can also help identify the numbers and locations of private wells and to map these in relation to public supplies and to centres of population. Further, the community may be able to actively support groundwater monitoring or even conduct elements of it.

In order to maintain open dialogue and trust, it is important to inform the communities of the results of the catchment assessment, e.g. by providing copies of relevant reports and assessments and/or conducting meetings for oral reporting and discussion.

### 6.1.3 Evaluating existing data

Careful evaluation of existing data may prove to be a good basis for assessing groundwater pollution potential. In most settings, current and historical data are likely to be available although often compiled for specific purposes other than groundwater assessments, i.e. for research, land use planning, environmental impact assessments or registration and licensing of commercial activities. Data sources that can be evaluated vary widely but include:

- statistical data (e.g. population, water usage, agrochemical usage, economic activities, land ownership and use, health and epidemiology);
- recorded data from ongoing monitoring programmes (e.g. drinking-water or groundwater quality, drinking-water abstraction, meteorology);
- hydrogeological and geographical information (e.g. area, geologic, vulnerability or land use maps, air photos, satellite images);
- published studies (e.g. from earlier surveys, programmes, inspections, environmental impact assessments).

Water quality data may exist from various types of groundwater surveys or ongoing monitoring programmes. Such data are a highly valuable support for the assessment of pollution. Water quality data for delivered drinking-water are most frequently available and can be helpful for assessing aquifer pollution as contaminants found in drinking-
Collecting information

Water are likely to have their source in the catchment area. Drinking-water quality cannot, however, always be taken as indicative of the quality of groundwater within the aquifer. This is because samples for drinking-water quality monitoring may be taken in the distribution system, which may be after treatment to remove pollutants and/or after mixing of water from more than one source. These data should be used with care, but can provide useful information for many parameters if these potential constraints are taken into account. In particular, data for natural constituents can provide information on the origin and movement of the water and time series data are important for recognizing potential trends of increasing or decreasing pollutant loading.

Generally, when using data from programmes targeted at purposes other than groundwater pollution potential assessments, their limitations must be kept in mind. For example, existing monitoring programmes may be limited in scope and scale (e.g. in selection of sampling sites, parameters tested or sampling frequency), and thus may not provide satisfactory temporal and spatial coverage in relation to the requirements of a comprehensive pollution potential assessment. However, even if information about specific pollutants is lacking, general hydrochemical information can be valuable for assessing groundwater flow patterns and residence times, as baseline quality from which the effects of human impacts may be distinguished, as well as to provide vital information about naturally-occurring groundwater constituents such as fluoride and arsenic. General hydrochemical data can also provide useful information about the likely behaviour of some pollutants (e.g. the mobility of metals), as referred to in Chapter 4.

Data are available from various governmental and non-governmental bodies and thus may be widely scattered. They include, but are not restricted to:

- public authorities or agencies at different administrative levels (i.e. local, regional, national) and different responsibilities such as:
  - health, environment, water management or geology;
  - planning, permission or licensing bodies for commercial enterprises (e.g. industry, mining), sanitation, and traffic;
  - water suppliers and wastewater agencies;
  - health care facilities;
  - university departments and other research institutions;
  - NGOs
  - local community initiatives (e.g. in water supply, sanitation, environment or agriculture);
- statistical bureaus;
- scientific literature or archives;
- aid or development organizations;
- professional associations (e.g. of farmers, industries).

Personnel and time demands on ‘data mining’ may be substantial: the authorities and agencies possessing valuable databases are often scattered across different administrative levels. Also, more often than not, data are likely to be available by administrative areas, rather than by catchments. Thus for the purpose of an assessment of a given catchment, it may be necessary to seek contact with authorities in several different administrative units.
Much of the data will be unpublished, available only in raw form, perhaps not electronically, and possibly even classified as confidential. Distinction between useful and unimportant data is not always self-evident. Considerable effort may thus be needed to extract, process and categorize useful information. The challenge is to organize and critically assess such data, and to document their sources, including suspected uncertainties about data quality. A further challenge is balancing time and effort needed to obtain data against their usefulness.

Data mining may require more than one iteration of filling information gaps by targeted checking for availability of further data that initially were not readily accessible. This is often the case when data are scattered between different public authorities, water suppliers or universities that produce them. Putting further effort into data mining by revisiting the step of searching for information on activities in the catchment area on a more detailed and targeted level may substantially improve the information inventory or even close critical gaps.

6.1.4 Generating new water quality data

In the context of groundwater protection, the term monitoring is usually understood to imply water quality monitoring, and is defined and sub-divided into categories in rather different ways by different authors. Groundwater monitoring tends to be taken for granted in most guidance documents on groundwater protection, e.g. as an “additional and essential component” (Foster et al., 2002). However, in practice groundwater monitoring programmes are often implicitly geared towards scientific investigation per se, and objectives are often not clearly defined and stated. Adriaanse and Lindgaard-Jørgensen (1997) point out the importance of establishing meaningful objectives for water monitoring programmes in order to avoid the data-rich, but information poor syndrome. For providing a basis for management decisions, monitoring programmes need to be tailored to the information needs in the specific setting. Often, the most important information needs for the objective of controlling groundwater quality in drinking-water catchments may not be gained from groundwater monitoring, but rather from monitoring potentially polluting activities and the implementation of measures to prevent them from releasing contaminants to the subsurface.

Water quality monitoring

Regular groundwater quality monitoring programmes have been established in many countries worldwide. Generally, they provide valuable information on groundwater chemistry, groundwater levels, seasonal quality patterns and other trends over time. Thus they are a supportive component for sound understanding of the hydrological environment, for developing conceptual models of groundwater systems or for mapping groundwater vulnerability. However, as discussed above, it is important to realize that comprehensive groundwater quality monitoring is not an essential prerequisite for assessing groundwater pollution potential in a given drinking-water catchment (Chapter 14). Particularly (though not exclusively) in settings where implementation of regular groundwater monitoring programmes is not feasible (e.g. due to limited financial resources or institutional capacities) or is only just beginning, investigations such as site
and catchment inspections and the evaluation of already existing data (Sections 6.1.1-6.1.3) are also highly valuable information sources on which the assessment can build.

In many settings, targeted water quality surveys or screening programmes for selected parameters and/or specific purposes, possibly repeated at more extensive time intervals, may prove sufficient to fill the crucial information gaps and thus confirm and improve pollution potential assessments, e.g. to investigate the extent and severity of suspected pollution ‘hot spots’. In addition, regular monitoring over a certain period of time – often one to two years – may be important to reduce uncertainty of the assessment, particularly in settings where important groundwater parameters show seasonal patterns and trends over time.

Groundwater monitoring in this context can have different objectives:

• Understanding natural groundwater quality (i.e. by installing observation wells in pristine areas). Chemical parameters typically chosen for this objective may include conductivity, pH, redox conditions and natural groundwater constituents including those potentially hazardous to human health, e.g. arsenic and fluoride.

• Provision of data needed for developing groundwater flow models. In this case, monitoring would include tracers or indicators of water movement, e.g. chloride or temperature.

• Characterization of the current level of aquifer pollution. For this purpose, observation wells would be installed in areas of the aquifer considered to be representative of the human activities as well as of the hydrogeological conditions. Parameters for analyses would be selected in relation to contaminants expected from ongoing or previous activities.

Where actual contamination of a drinking-water source is occurring, targeted analysis of the raw water quality will usually identify the pollutant and its concentration. This will then aid in tracking potential pollutant sources and in defining control measures and/or drinking-water treatment requirements. If a pollutant is suspected, but not present in drinking-water wells, water samples from observation wells between the pollution source and the drinking-water well can be used to track movement of the pollutant. In many cases, such observation points are critical in risk assessment of the pollution potential from a known source. Where sufficiently comprehensive programmes can be implemented, they may actually provide quantitative data on microbial and/or chemical contaminants in groundwater to be used in quantitative risk assessments.

Further guidance on specifying information needs in the context of planning monitoring programmes is given by Bartram and Balance (1996), Chapman (1996), UNECE (1996, 2000), Adriaanse and Lindgaard-Jørgensen (1997) and Timmerman and Mulder (1999), provide general guidance and overview on water quality monitoring. Technical aspects of constructing observation wells, sampling and analyses are beyond the scope of this book, and readers are referred to Nielsen (1991), Lapham et al. (1997) and Boulding and Ginn (2003). Because novel sampling and analytical methods are always being developed to improve the monitoring and characterization of subsurface environmental quality, printed material can quickly become dated, and the more technically interested reader should look at the websites of organizations such as US Environmental Protection Agency (US EPA), the American Society for Testing Materials, and US Geological Survey (USGS).
Other types of monitoring

For the purpose of this book, the use and understanding of the term monitoring goes beyond groundwater quality monitoring discussed above. The following monitoring categories, which subsume other technical monitoring categories proposed elsewhere, are used in this book, particularly in the context of Water Safety Plans (WSPs) (Chapter 17):

- Operational monitoring for process control does not focus on measuring groundwater quality but is a planned series of observations or measurements to timely quantify efficacy and changes in performance of a control measure that is established to control the occurrence of pathogens or chemicals in groundwater (for more details see Chapter 17 and for examples Chapters 20-25).
- Monitoring for verification is the application of methods, procedures, tests and other evaluations in addition to operational monitoring to determine compliance with and efficacy of the WSP or the groundwater management system, respectively (for more details see Chapter 17 and for examples Chapters 20-25).

6.2 THE NEED FOR COLLABORATION

Groundwater assessments are typically undertaken by hydrogeologists, potentially supported by sanitary engineers and/or environmental scientists. These qualifications are indeed essential for understanding groundwater flow and potential contaminant transport. For understanding the potential for contaminant loads to the aquifer, broader competence is needed, preferably in a team that integrates hydrogeological knowledge and an understanding of the potentially polluting human activities (e.g. from agriculture, industry, sanitation, etc.).

Also, as discussed above in Section 6.1.3, existing information on activities potentially impacting on groundwater quality is likely to be broadly scattered. For example, while health or environmental authorities may be responsible for assessing the risk of groundwater pollution, information on human activity in the catchment may be available from diverse government bodies responsible for health, commerce, statistics, traffic, tourism, agriculture, mining, etc. Government agencies with executive and policy functions for the environment and groundwater may have different types of information from local government.

Teamwork and intersectoral collaboration is vital for groundwater assessments. This includes cooperation between all institutions that can contribute from various angles of access to information. The task of collecting and evaluating relevant information will in many cases be the responsibility of a core team of public health, groundwater and environmental experts from public authorities, often supported by water suppliers. However, this core team can be expanded by external experts from the scientific community, representatives of the public, and possibly stakeholders from the catchment. Health authorities may take the initiative in assembling such teams and/or in leading them. The example from India provided in Box 20.2 shows how competence for groundwater pollution potential assessments as well as for developing management options can be built by training employees of government agencies.
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Water suppliers can successfully take the initiative in establishing interdisciplinary teams for identifying groundwater pollution problems and implementing protection strategies for their specific supply setting. This is mirrored by the WSP approach in which the formation of an interdisciplinary team is a key requirement (Chapter 16). Box 6.1 provides an example of such an approach in an urban setting and Box 16.1 shows how farmers were involved specifically to control nitrate contamination in a rural setting.


Members of The Hygiene Commission of the Berlin Waterworks include:
- a staff member responsible for resource protection, the technical director and the laboratory director of the waterworks;
- a staff member of the municipal public health authority;
- a staff member of the municipal environmental authority;
- a staff member of the municipal forestry authority;
- a staff member of the local police department;
- invited experts, e.g. from federal agencies.

Tabling information. All of these members report to the Commission any changes that occurred in the water supply and its catchment since the last meeting. For example, the water supply representatives report on issues regarding water treatment and distribution as well as protection zones. The public authority members report any illegal activities in the catchment observed and/or reported, such as illicit waste disposal, construction activity or traffic, newly identified historic waste sites, and any conspicuous changes observed in the catchment. Reporting also includes public complaints about water quality, odour from sewage treatment works, or observations on recipient water bodies.

Discussing solutions to problems. The Commission evaluates all reports and discusses proposed solutions. This includes administrative measures of public authorities such as issuing permits for construction of facilities, new or changed systems for wastewater collection and treatment, as well as direct regulatory measures of the local police directorate such as removing illegally parked vehicles, closing roads to traffic and posting signs and notices.

Targets of the Hygiene Commission are to:
- inform all members about current issues regarding operation of the water supply and sanitation system as well as catchment protection;
- identify pollution potential for management of catchment and supply system;
- coordinate management responses of public authorities from different sectors and develop intersectorally harmonized strategies for sustainable provision of safe drinking-water;
- coordinate contingency planning.

In many settings worldwide, the key challenge will be to build motivation for collaboration. This may be particularly difficult in situations where, for example, data on
contaminant loading to aquifers are likely to be available only from the polluters themselves, who have no primary interest in control and potential restriction of their activity. Creating ownership, for example through involvement of such stakeholders in drinking-water resource protection teams (Box 6.1), may, therefore, be crucial. Motivation and commitment for collaboration are likely to increase if all players fully understand both their individual contribution to, and benefits from, efforts in protecting groundwater as a drinking-water source.

**Accounting for value judgements**

Assessments of the potential for groundwater contamination typically contain a major component of expert judgement rather than being fully quantitative, and they often include substantial uncertainty (Section 6.3). This has two major implications for collecting and compiling information:

- Hazard assessments themselves, but also the information on which they are based, are subject to bias by the knowledge background and the value judgments of the experts involved. It is important to understand implicit value judgements that may drive experts’ assessments, as they are likely to play a role in selecting questions asked, choosing which data are important, assessing data and drawing conclusions. This can be dealt with more appropriately if value judgements are understood, made transparent and explicitly acknowledged.

- Teamwork may be encumbered by implicit value judgements due to differences in scientific background and perception of issues. Both for effective collaboration and for making uncertainties of pollution potential assessments transparent, it is important to be aware of differences in value judgements. In her comprehensive discussion of this aspect of evaluating information for decision-making, Harding (1998) makes the point that ‘even though controversies are typically seen as disputes over “facts”, in most environmental disputes it is the clash between people’s value positions which fuels debate, rather than a disagreement over the “facts”’ (page 61). This applies both to disputes within expert teams and with the general public and is therefore also important when organizing public involvement in the assessment and management of groundwater resources.

For the perception of pollution hazards in groundwater, the general shift to greener or more environmentalist ideology has become relevant in many countries. Environmental protection arguments are often quoted in the context of protecting human health, even where this connection is scientifically unsubstantiated. Perception of health hazards from different classes of substances tends to be linked to the ‘reputation’ the substance has in the media. For example, traces of pesticides in drinking-water may be seen as poisons and therefore as objectionable even at orders of magnitude below health-based guideline values. Specifically for groundwater, the knowledge of the often insurmountable difficulties of removing pollutants from the subsurface has produced strong environmental arguments for protecting aquifers from the impact of human activity.

Often, in assessing information for protecting drinking-water catchments, it will be important to explicitly differentiate between priorities for protecting the environment and priorities for protecting human health. Showing respect for the ethical positions and principles of others may facilitate making motivations transparent. For example,
explicitly acknowledging and respecting the position of a team member who considers any groundwater pollution unethical and incompatible with the target of sustainable environmental management may be the basis for attaining his or her support in prioritizing pollutants for the purpose of keeping drinking-water safe for human health.

6.3 SUFFICIENCY AND QUALITY OF INFORMATION – DEALING WITH UNCERTAINTY

Uncertainty is likely to be an issue in all elements of catchment analysis and groundwater pollution potential assessment. The information base on hydrogeological conditions and on the scale and range of human activities in the catchment are only rarely sufficiently comprehensive to allow a fully quantitative determination or prediction of the pollution potential or contaminant concentrations. For example,

- data about the population’s water needs may be incomplete, e.g. with respect to the amount of groundwater abstracted from private wells, possibly illegally;
- information on human activities in the catchment is likely to be incomplete, for potential loads from on-site sanitation and/or leaky sewers as well as for the range and amounts of hazardous substances used and potentially released to the underground in diverse enterprises, agriculture and traffic;
- the meaning of data gained from groundwater monitoring is dependent on the representative selection of sites for observation wells, and costs for their installation constrain the number of sites that can be sampled.

One consequence of this uncertainty is that the target in most cases is a qualitative or semi-quantitative determination of pollution potential, as discussed in Chapter 14 as a basis for risk assessment.

Understanding uncertainty of the information available

The concept of uncertainty can be classified in different ways. Harding (1998) proposes the following categories that are relevant for assessing groundwater contamination of a catchment:

- Risk is the most quantifiable and measurable type of uncertainty. It implies that the parameters driving groundwater quality are basically understood. Though the concentration of a contaminant may not be fully quantified or predicted, structured analysis of mechanisms and probabilities allows prediction of the likelihood that it occurs or will occur in concentrations relevant to human health.
- Uncertainty implies that the parameters driving the processes are understood, but not sufficiently well to assess the probability of pollution occurring.
- Ignorance means that not even the most important parameters are understood, i.e. ‘we don’t know what we don’t know’.

A key issue for making management decisions is to understand how sound the available information base is for assessing aquifer groundwater pollution, i.e. the amount of uncertainty involved. This is important both for avoiding wasting resources by poorly informed decisions on management options which later turn out to be ineffective, and for avoiding undue postponement of urgent measures in situations where in fact the information base is already sufficient for making adequate decisions. The question to ask
is ‘how much do we need to know to assess hazards for groundwater quality, and how much uncertainty can we tolerate?’ Aspects of information quality in relation to taking management decisions are discussed in Chapter 15. In the following, the aspects of documenting the quality and reliability of information during its collection are covered together with options for identifying and filling gaps.

Systematic documentation of the information inventory and the information sources, including indication of information quality and reliability, is a useful tool for identifying critical information gaps. Earmarking uncertainties in the database or in the assessment of its quality helps to guide further work on the data inventory. This can be achieved by a list of the factors which probably affect the data but are not well known (e.g. heterogeneity of the subsurface environment as a factor affecting data on estimated flow rates, or illegal manure application as a factor affecting nitrate loads). Such documentation may prove important for acquiring funding for targeted programmes to close gaps.

A next step for assessing sufficiency and quality of information as well as of getting improved information on missing, inconsistent or unverified data is to assign a level of confidence to all data sets in the form of an uncertainty score. Low values of uncertainty indicate data of high reliability, whilst high uncertainty scores indicate estimates or unverifiable information. No data (i.e. a gap) should be given the highest uncertainty score. As discussed in WHO (1982) and by Foster and Hirata (1988), assessments of data quality will often be somewhat subjective. This is endorsed and encouraged, provided that subjectivity is made transparent in the report. As assessment progresses, the aim should be to reduce the uncertainty scores by infilling with more accurate and reliable data. The use of uncertainty scores will aid in prioritization of data acquisition. When the data are used collectively, a summed or weighted uncertainty score can be used to indicate the relative confidence in the interpretation. An indication of where uncertainties are most relevant for assessing potential pollution can often be gleaned from targeted inspection of the respective sites and activities in the catchment.

Reducing uncertainty

An effective option for filling information gaps is the design of specific programmes that may prove to be quite feasible if they are properly targeted. For example, where potential pollution sources are known from assessments of activities in the catchment area, but the scale of the activity with regard to the likelihood of the pollutants actually reaching the aquifer is poorly understood or cannot be assessed, a survey of pollutant occurrence in groundwater may prove possible even with limited budgets. Such surveys may be small-scale and well-targeted to address the specific pollutants and limited to localities critical for water supply. For example, in Tajikistan the authorities responsible for drinking-water quality needed information on pesticide levels as a basis for making a decision whether to use shallow aquifers as drinking-water sources. In the face of data showing a substantial decline in the application of pesticides, a small initial survey of pesticide concentrations in the aquifers that were envisaged for providing supplies helped decide which ones could actually be used, and indeed this showed pesticide pollution to be much less of a problem than had been assumed from the historic knowledge of high rates formerly applied.
Hydrogeological information gaps are often perceived as intimidating. However, here also, targeting investigations towards specific questions may narrow down the effort required and thus make programmes feasible. Examples are the use of groundwater temperature to indicate ingress of surface water (applicable in settings with seasonal patterns of surface water temperature), the use of electrical conductivity as a simple indicator of saline intrusion or the use of substances characteristic for sewage (e.g. detergents, ammonia, caffeine) as tracers for sewage ingress.

Another aspect of filling information gaps is checking whether further data may indeed be available, though perhaps initially not readily accessible, as discussed in Section 6.1.

Decisions on investments into improving the information base will depend on the consequences of uncertainty. For example, if the assessment of aquifer contamination is highly uncertain (in ignorance of some polluting activity or because of poor understanding of its vulnerability) and a large number of people use it as drinking-water source, the consequence might be severe, e.g. high incidence of waterborne disease. This would be a strong rationale for improving the information base. Vice versa, consequences in terms of public health would be minor if the population is connected to a central supply using an alternative water source, and improving public health would not be a reason to invest in improving the database.

6.4 SUMMARY – HOW TO PROCEED

Figure 6.1 outlines principal planning steps that may be taken to glean sufficient information for characterizing a drinking-water catchment as a basis for assessing groundwater pollution potential (Chapter 14). Taking the initiative for compiling a catchment specific information inventory may be the role of local or regional public authorities either in charge of surveillance of drinking-water supplies or of overall catchment management (e.g. environmental authorities or departments), but it may also be taken by a water supplier in the context of protecting the supply’s catchment and/or developing a WSP.

The first step for those initiating a programme for catchment characterization and building an information inventory, both a basis for the assessment of groundwater pollution potential, is to outline the scope of the process. This particularly requires a preliminary understanding of:

- What area to assess, i.e. the delineation of the catchment of the water supply or well field. In many settings, some hydrogeological information is available in relation to the water supply. Where this is lacking, the surface profile gleaned from a topographic map and/or a first visit to the site may provide a preliminary indication.
- The type of information expected to be available (e.g. on socioeconomic aspects, groundwater vulnerability and anthropogenic activities). This can be achieved by compiling and reviewing a first overview of the information sources accessible and the stakeholders involved.
- Key issues to investigate within the process of catchment characterization.
Planning and designing the actual investigation requires defining its targets in consideration of the financial, institutional and personnel resources available. For more detailed guidance on how to design a groundwater quality assessment, see UNECE (2000).

The second step is to identify expertise and key players who need to be involved in catchment investigation and pollution potential assessment, and to convene a team for...
collecting both. As discussed in Section 6.2, it is useful to involve public authorities
from the sectors important in the catchment as well as experts, particularly in the fields of
hydrogeology and public health. Often, it is useful to strive for public participation in this
early planning phase by including members of communities affected or special interest
groups. Supportive involvement of stakeholders from potentially polluting activities may
be particularly useful for obtaining sensitive information, e.g. on pollutant loads.

The third step is to carry out the investigation. For gathering comprehensive
information, it may be useful to split the team into working-groups which focus on three
different activities that may be conducted in parallel. These include:

- Site and catchment inspection (Section 6.1.1) to record and map all features
  potentially relevant to groundwater pollution, for example settlements and water
  use practices (Chapter 7), topographic features (such as sinkholes and abandoned
  wells) that could facilitate rapid transport of pollutants to groundwater (Chapter
  8), and human activities that might lead to groundwater pollution (Chapters 9-
  13). Depending on the scope of catchment characterization, this can include
  recording of hydrogeological information for assessing groundwater
  vulnerability, or the latter would be a separate activity conducted by a team of
  hydrogeologists. Templates for checklists to assist collecting this information at
  the end of Chapters 7-13 assist inspection and would be tailored to the specific
  setting. Notes should be included on uncertainties and information gaps
  perceived as potentially relevant to the assessment (Section 6.3).

- Consult and liaise with the local population as a source of information,
  particularly to glean local knowledge about, for example, economic or cultural
  values placed upon groundwater, community perceptions on the use and
  protection of groundwater resources, or information of a more technical nature,
  e.g. on potential pollution sources, location and use of wells, etc. (Section 6.1.2).

- Evaluation of existing information and data (Section 6.1.3) already available
  from previous programmes and investigations into groundwater and drinking-
  water quality, aquifer characteristics which define its vulnerability, and
  anthropogenic activities in the catchment. This information amends the checklists
  from catchment inspection.

Step three is followed by an iterative process as shown in Figure 6.1. It involves
the following elements, the order of which will depend on the situation and the approach
preferred by the team:

- Drafting a groundwater pollution potential assessment as described in Chapter 14.
- Identifying uncertainties and information gaps. The evaluation of information
  available may reveal that the understanding of catchment characteristics is not
  sufficient, or information from different sources is inconsistent, and therefore
  the information inventory needs to be improved for adequately assessing
  groundwater pollution potential as a decision basis for developing management
  responses to protect the drinking-water catchment.
- Improving knowledge. Some of the identified information gaps may be fairly
  readily closed by revisiting specific sites in the catchment for more thorough
  inspection, or by requesting information from, for example, operators of farms,
  enterprises or other activities. If uncertainty is too large to make decisions,
  information gaps need to be closed with specifically targeted groundwater
surveys and or regular groundwater quality monitoring. In many cases the need for this can be limited to selected localities and/or polluting activities in the catchment (Section 6.1.3).

As settlements and human activities in the catchment develop and change, so will pollution potential. Further, the impact of management responses needs to be assessed. In consequence, the topicality of information inventories and pollution potential assessments needs to be reviewed and repeated periodically, and improvement of the assessment is an iterative process. The experience and knowledge gained over time will serve to reduce the uncertainty of the assessment and increase the safety of the water supply in the long term.

6.5 REFERENCES


