5. Data analysis and interpretation

5.1 Introduction

The objective of surveillance is not simply to collect and collate information, but also to contribute to the protection of public health by promoting the improvement of water supply with respect to quality, quantity, coverage, cost and continuity.

Clearly, the aim of a surveillance programme is to generate data that lead to optimization of activities and investment and thence to improved drinking-water supplies. Data analysis and interpretation are therefore fundamental components of the surveillance process.

5.2 Results of community surveys

5.2.1 Evaluation of water-supply systems

As outlined in Chapter 1, the evaluation of community water supplies requires the consideration of a number of quantitative factors. The quantitative nature of the evaluation makes possible the meaningful comparison of systems, and assists in the assignment of relative priorities to those requiring improvement. The indicators most commonly used to evaluate community water supplies are quality, quantity, coverage, cost, and continuity, as defined in Chapter 1. Each is discussed below in the context of the analysis and interpretation of the data generated during surveillance activities.

Quality

The target for water quality should be compliance with national standards, which should in turn be based on the health criteria given in Volume 1. Water quality is assessed by means of sanitary inspections and appropriate analytical measurements, discussed in detail in sections 5.3 and 5.4, respectively.

Quantity

Estimates of the volume of water needed for health purposes vary widely. It is assumed here that daily per capita consumption of drinking-water is approxi-
mately 2 litres, although this figure varies from country to country. However, this does not take into account the water needed for personal and domestic hygiene, which are also important for the maintenance and improvement of public health. In rural areas, daily consumption for these purposes varies widely; in urban areas, with piped supplies to house connections, it may exceed 100 litres per capita per day.

Measurements of the volume of water collected or supplied for domestic purposes may be used as a basic hygiene indicator. Some authorities use a guideline value of 50 litres per capita per day, but this is based on the assumption that personal washing and laundry are carried out in the home; where this is not the case, lower figures may be acceptable.

In the analysis of bulk figures related to water entering piped distribution systems, it should be borne in mind that:

- The figures will be averages, and consumption in different households may vary widely, e.g. with socioeconomic status.
- Leakages may make a significant contribution to apparent consumption.
- Even a single dwelling using piped water for irrigation or for commercial purposes may significantly influence the apparent consumption for a community water supply.
- The flow of water entering the distribution system during the day does not necessarily represent the sustained input during 24 hours, and overflows may be significant at certain times.

### Coverage

From the public health standpoint, the percentage of the population provided with drinking-water—the coverage—is the most important single indicator of the overall success of a water-supply programme. From the point of view of the water-supply agency, coverage is expressed as the percentage of the total population served; it may be subdivided into the population served by domestic connections, by public standposts, and by point sources such as wells and springs.

However, the surveillance agency has a responsibility for the public health aspects of water supply to the entire population. It is therefore essential that the agency undertake wider surveys of the various means by which drinking-water is provided to the population, the estimated population served by each means of supply, and the relative health risk associated with each of them. This information should be formally reported to the national planning authorities and used to guide water-supply programmes and funding strategies.

### Cost

Cost may be an important factor influencing access to water, and is especially important in periurban areas where water is purchased from vendors. Where such
water is the only water available for personal and domestic hygiene purposes, the adverse effects of high costs on public health are proportionally greater. In these circumstances it is quite common for the amount paid by individual families for water to be sufficient, if combined, to finance the construction or expansion of a piped water supply adequate to satisfy public health needs. Information on the cost per family is therefore important for national and regional planning purposes.

Cost is also important in community water supplies where the local capacity to finance operation and maintenance is limited, especially if inappropriate technology has been employed. Where the surveillance agency identifies problems of this type, it is vital that the national and regional planning structures are informed, so that the situation will not be repeated and adequate support for operation and maintenance is provided.

Cost recovery is essential if a water supply is to be sustainable; it requires a rational charging structure. Charges must be collected and used for the purpose intended. Consumers are reluctant to pay for a poor-quality service, and this may compound the problem. Various forms of cost recovery are used, including metering, flat rates for domestic use, and charges related to the size or value of properties. Metering is often favoured, but may meet resistance from consumers; it can be costly in both installation and subsequent reading and charging.

**Continuity**

Analysis of data on continuity of supply requires the consideration of two components—daily and seasonal continuity. Continuity can be classified as follows:

- year-round services from a reliable source with no interruption of flow at the tap;
- year-round service with daily variation, of which the most common causes are:
  - restricted pumping regimes in pumped systems, whether planned or due to power failure;
  - peak demand exceeding the flow capacity of the conduction line or the capacity of the reservoir;
- seasonal service variation resulting from source fluctuation, which typically has three causes:
  - natural variation in source volume during the year
  - volume limitation because of competition with other uses such as irrigation
  - periods of high turbidity when the source water may be untreatable;
- compounded daily and annual discontinuity.

This classification reflects broad categories of continuity, which are likely to affect hygiene in different ways. Thus daily discontinuity results in low supply
pressure and a consequent risk of in-pipe recontamination, which is potentially hazardous in the case of unchlorinated community water supplies. Other consequences include reduced availability and lower volume use, which adversely affect washing habits. Household water storage may be necessary, and this may lead to an increase in the risk of contamination during such storage and associated handling. Seasonal discontinuity often forces users to obtain water from inferior and distant sources. As a consequence, in addition to the obvious reduction in quality and quantity, time is lost in making regular collections.

5.2.2 Hygiene practices

Some of the information generated by surveillance will be of interest in connection with hygiene education (see Chapter 7). Four types of information that are useful in this regard can be readily obtained:

- **Areas where hygiene education is most needed**—these may be where water is of poor quality, or where continuity is poor with the result that household storage becomes necessary.
- **The facilities available for hygiene education**—the existence of a school, community organizations, health post, or other community centre may serve to facilitate the work of hygiene educators.
- **Information on behaviour**—this can easily be collected by simple observation; observation of household water storage practices, for example, may show that water is stored in open or closed containers and is withdrawn by scooping it out by hand, by means of any available container or a container reserved for the purpose, or by means of a tap or syphon.
- **Information on the preferred means of communication**—this should cover radio and television, and the stations received, with a view to their use for educational programmes.

5.3 Assessment of the sanitary situation

Sanitary inspection forms (see Annex 2) are needed to collect information regarding specific points of risk to the water supply. This information may be used in various ways to facilitate the improvement of community water supplies. Key questions include:

- How can the data be expressed in terms of relative risk in order to compare a number of systems, including those of highest priority, and identify simple remedial measures that can be undertaken at local level?
- How many false positives, i.e. falsely identified risk points, can be tolerated without invalidating the system? In other words, is the system robust?
- How can a scoring system be developed which is sufficiently discriminatory to identify systems requiring urgent attention without overwhelming the workforce with the sheer amount of remedial action required? (There is, for
Table 5.1 Examples of sanitary inspection risk scores

<table>
<thead>
<tr>
<th>Risk score</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No observed risk</td>
</tr>
<tr>
<td>1–3</td>
<td>Low risk</td>
</tr>
<tr>
<td>4–6</td>
<td>Intermediate risk</td>
</tr>
<tr>
<td>7–10</td>
<td>High risk</td>
</tr>
</tbody>
</table>

* The term “risk” as used here indicates potential danger to human health from a water source or supply. In Volumes 1 and 2, “risk” has a more precise quantitative connotation.

For each type of water source the proportion or percentage of points recorded as positive for risk during the sanitary inspection gives a sanitary risk score. These scores can then be arbitrarily associated with different levels of relative risk (see Table 5.1).

The scores associated with various levels of risk should be selected in the light of local circumstances. Because the objective is to produce a classification that facilitates remedial action, it is important to ensure that the proportion of supplies or point sources falling into each category is reasonably balanced. In the early stages of implementation a narrow range of scores in the “high-risk” category may be advisable in order to avoid overloading the workforce.

It is a relatively simple matter to grade point-source systems where there are typically only 10 points for inspection, but more complicated to grade community water-supply systems which sometimes include a number of sources, treatment plants, and reservoirs, plus a distribution system. In the latter case it is particularly important to rely not only on numerical comparisons obtained by analysis of sanitary inspection data but also on an understanding of the overall functioning of the water supply. This highlights the importance of adequate training related to the water-supply practices in the locality or region concerned.

5.4 Microbiological water quality

As with sanitary inspection, data on microbiological water quality may usefully be divided into a number of categories; the levels of contamination associated with each category should be selected in the light of local circumstances. A typical example, little advantage in a strategy that classifies 80% of systems as being at “very high risk” unless massive resources are available for remedial action.

- How can the most important source(s) of pollution be identified among the number of potential sources that may have been noted?
- How can recurrent problems be identified which should be remedied by changes in strategy at national level rather than by repeated local remedial action?

For each type of water source the proportion or percentage of points recorded as positive for risk during the sanitary inspection gives a sanitary risk score. These scores can then be arbitrarily associated with different levels of relative risk (see Table 5.1).

The scores associated with various levels of risk should be selected in the light of local circumstances. Because the objective is to produce a classification that facilitates remedial action, it is important to ensure that the proportion of supplies or point sources falling into each category is reasonably balanced. In the early stages of implementation a narrow range of scores in the “high-risk” category may be advisable in order to avoid overloading the workforce.

It is a relatively simple matter to grade point-source systems where there are typically only 10 points for inspection, but more complicated to grade community water-supply systems which sometimes include a number of sources, treatment plants, and reservoirs, plus a distribution system. In the latter case it is particularly important to rely not only on numerical comparisons obtained by analysis of sanitary inspection data but also on an understanding of the overall functioning of the water supply. This highlights the importance of adequate training related to the water-supply practices in the locality or region concerned.
classification scheme is presented in Table 5.2, based on increasing orders of magnitude of faecal contamination.

Where community water supplies are unchlorinated, they will inevitably contain large numbers of total coliform bacteria, which may be of limited sanitary significance. It is therefore recommended that the bacteriological classification scheme should be based on thermotolerant (faecal) coliform bacteria or *E. coli*.

Grouping of point sources into categories of the type shown in Table 5.2 is generally straightforward. Occasionally, however, where a number of samples are taken each year, the levels of faecal contamination may vary widely between successive samples. The reasons for this are often obvious and may be related to seasonal influences such as rainfall.

However, where piped small-community water supplies are being analysed and samples are taken at various points in the system, water quality may differ in different parts of the system at any one time. Again, the reasons for this may become obvious during the sanitary inspection or—if these differences are the result of cross-contamination or contamination caused by leaks in pipework—after resampling.

It is common to use 95% compliance criteria when assessing the results of microbiological analysis. This procedure is appropriate only where adequate numbers of samples are analysed for statistical purposes and is not generally applicable to small-community water supplies.

### 5.5 Risk assessment

For the purposes of risk analysis, the results of *E. coli* counts and sanitary inspection are combined.

Examination of the faecal grading together with the sanitary inspection risk scores for a large number of facilities should make it possible to assess relative priorities both for local remedial action and for regional planning purposes. In general, the classification schemes shown in Tables 5.1 and 5.2 facilitate such risk analysis when combined as illustrated in Fig. 5.1. Nevertheless, it may be necessary to test various classifications to find the combination most useful for local conditions.

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**Table 5.2 Example of classification and colour-code scheme for thermotolerant (faecal) coliforms or *E. coli* in water supplies**

<table>
<thead>
<tr>
<th>Count per 100 ml</th>
<th>Category and colour code</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>A (blue)</td>
<td>In conformity with WHO guidelines</td>
</tr>
<tr>
<td>1–10</td>
<td>B (green)</td>
<td>Low risk</td>
</tr>
<tr>
<td>10–100</td>
<td>C (yellow)</td>
<td>Intermediate risk</td>
</tr>
<tr>
<td>100–1000</td>
<td>D (orange)</td>
<td>High risk</td>
</tr>
<tr>
<td>&gt;1000</td>
<td>E (red)</td>
<td>Very high risk</td>
</tr>
</tbody>
</table>
Figure 5.2 illustrates the use of risk analysis in practice. It is clear that there is a general tendency for the results to be distributed in a band running from the top right to the bottom left of the table. This is to be expected since a greater risk of contamination is likely to be associated with the occurrence of a greater degree of contamination. Nevertheless, a high sanitary risk score associated with low-level faecal contamination still requires urgent action, as does a low sanitary risk.
score associated with high-level faecal contamination. It can be seen that the priority rating of such systems is high.

It is worth emphasizing that the analysis is representative of only one moment in time, whereas the inspection takes account of the previous history of the installation and future points of risk. It is this that makes the combined analysis useful—and particularly important when surveillance staff are dependent on a single bacteriological analysis or a number of analyses undertaken on a single date.

5.6 Presentation of information

Information must be presented in a form that is intelligible and useful to the recipients. The means of presenting the results obtained by monitoring community water supplies merits particular attention as there are several target audiences, each with different information needs and different perceptions and understanding of water-supply issues.

5.6.1 Target audiences

In general, the target audiences are likely to include local system operators, community members or their representatives with limited knowledge of matters such as water quality. For this group, it is recommended that data should be interpreted in the light of national standards or goals rather than presented only in “raw” form. Reporting to the community should generally take place as soon as possible after monitoring is completed. Where remedial actions are shown by sanitary inspection to be necessary, these should be noted. If possible, information should be provided about remedial actions that are possible at local level and those that require external assistance. Sources of information and/or advice for the former and sources of support for the latter may be noted. Where appropriate, the report may also be sent to agencies who would be responsible for providing the external assistance. The possibility of using a pictorial form which may also serve as the sanitary inspection form has been noted earlier (see section 3.3.2), examples are given in Annex 2. In general, presenting data in an easily understandable form, e.g. pictorially or by means of colour coding, is more likely to result in action by personnel at the local level.

Where a situation merits action at the individual or household level (e.g. when the severity of contamination indicates the need for household treatment), information should be disseminated not only to the community but also to the individuals and/or households concerned. “Multipliers” such as schools, clubs, and community meetings may be used for this purpose.

Regional planners and engineers whose responsibilities or areas of influence cover a number of supplies form another important target audience. This group often includes external agencies—both bilateral and multilateral aid agencies and NGOs—as well as national authorities.
The information required by this group is very different from that needed by the community, and consists essentially of data useful for regional planning purposes. Most information will therefore be presented in an annual report, although more frequent reporting of high-priority actions may be required. Typically, an annual report will outline the overall quality of the water-supply service in the region and identify the systems in most urgent need of attention from a public health viewpoint. Priorities can be rated as described in section 5.5. It may also sometimes be possible to indicate the nature and extent of the work required, e.g. “replace storage tank damaged by subsidence”, or “increase coverage, currently 45% of a total population of 1850”.

The timing of the delivery of these reports is vital and should be such as to enable them to be used in the preparation of annual work plans and budgets. An example of the form that such a regional annual report may take is shown in Annex 11.

National planners, a third likely target audience, will use surveillance information for large-scale planning purposes. Information intended for this group should highlight geographical priorities and major national problems. Reporting methodology should be standardized nationally to allow reasonable comparisons to be made between regions. National reports typically resemble regional reports both in presentation and timing; an example is shown in Annex 11. In general, information at this level should be presented in a highly digested form suitable for a nontechnical audience.

5.6.2 Simple data presentation

Experience has shown that data presented in an appropriate, generally highly simplified, form is both educative and easy for nontechnical groups, and especially local and planning staff, to understand. Material should therefore be prepared with this in mind.

At local level, a simple classification of the performance of facilities, for instance by colour coding of the type shown in Table 5.2, tends to generate competition among communities and system operators and motivation for operation and maintenance. Experience has shown that improvement is effected without substantial external inputs, probably through more effective use of the available technical facilities. For monitoring purposes, classifications of this nature facilitate the comparison of results and thus the assessment of improvement or deterioration.

In planning at both regional and national levels, the principal uses of surveillance information include policy- and strategy-making, the estimation of resource requirements and water-resource planning, and the identification of priorities for investment. The method of data presentation should facilitate comparison of water supply (in terms of quality, quantity, coverage, cost, and continuity) in different regions, the recognition of long-term trends in these parameters at
regional and national level, and the pinpointing of recurrent problems that require policy changes if they are to be overcome. The quantitative nature of the data generated should make it possible to estimate the resource requirements for trained staff for surveillance at various levels, the operational requirements for surveillance, and the investment in operation and maintenance required in water-supply improvement and expansion. Estimation of the total water-resource requirements for drinking purposes facilitates intersectoral coordination and large-scale water resource planning.

5.7 Use of surveillance findings

5.7.1 Use of data at local level

At the local level, it is especially important to ensure close collaboration between the surveillance and supply agencies. Data generated by surveillance—e.g. on quality and quantity—should be shared between these agencies to maximize their usefulness. Similarly, field staff responsible for sanitary inspection should be in close communication with the staff of the supplier (whether private, municipal, or community organization) responsible for operation and maintenance.

The information reported by the surveillance agency to the supplier at local level should therefore be both detailed and appropriate to the user (e.g. the water-supply operator). However, especially with regard to water-quality data, interpretation in the context of national legislation is essential. Furthermore, some analysis of long-term trends with respect to quality, quantity, continuity, coverage, and cost, and an overall analysis of service quality, e.g. on an annual basis, facilitates the work of both agencies in ensuring adequate resources for the water-supply sector.

5.7.2 Regional use of data

Strategies for regional prioritization are typically of a medium-term nature and have specific data requirements. While the management of information at national level is aimed at highlighting common or recurrent problems, the objective at regional level is to assign a degree of priority to individual interventions and to prioritize remedial actions accordingly.

It is therefore important to derive a relative measure of health risk and thus establish the priority for remedial action. While the data cannot be used on their own to determine which systems should be given immediate attention (which would also require the analysis of economic and sociocultural factors), they provide an extremely important tool for determining regional priorities. It should be a declared objective to ensure that remedial action is carried out each year on a predetermined proportion of the systems classified as high-risk.

At regional level, it is also important to monitor the improvement (or deterioration) both of individual supplies and of the supplies as a whole. In this
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context, simple measures, such as the mean sanitary inspection score of all systems, the proportion of systems with given degrees of faecal contamination, the mean continuity or quantity of water supplied per capita per day, and the mean tariff for domestic consumption, should be calculated yearly and changes monitored.

In many countries, a high proportion of small-community water-supply systems fail to meet quality standards. However, it should be recognized that to condemn a large number of supplies is not particularly useful and may actually be counterproductive. In such circumstances it is important that realistic goals for progressive improvement are agreed with the suppliers and subsequently implemented. At no time should the surveillance agency give up its authority to demand compliance with standards; equally, however, it should recognize that the supplier should be allowed a reasonable period in which to effect improvements in the supply. Where compliance with standards is impossible (because of insuperable technical difficulties or extreme budget limitations) or would be counterproductive (because it would divert resources from other improvements of greater public health importance), the surveillance agency may elect to postpone action until the situation improves.

5.7.3 Use of data for national planning

At national level, priorities should be set and disseminated by means of an annual report with recommendations. The circulation list for this report should include all surveillance and supply agencies, the national planning authorities, and agencies involved in coordination within the water-supply sector, e.g. government ministries responsible for local government, natural resources, health, and finance, and external support agencies. Information exchange with the national planning authorities may provide a basis for a mutually supportive relationship between the surveillance and supply agencies.

To promote prioritization of remedial measures at national level, it is most important that information flow to the national centre is efficient, that all information generated is received, and that the national centre has the means with which to undertake the analysis of this information.

Setting priorities at national level is by its very nature a long-term process and there is often therefore little urgent need for data. Provided that specific information on individual water supplies is available from the regional centres rapidly on request, it is not necessary for the national centre to receive frequent updates for its database; periodic updates may be adequate.