CHAPTER 12

Monitoring and assessment

In order to support the attainment of safety in recreational water environments, the responsible management authorities should establish a programme for evaluating existing hazards and monitoring the area for any changes that may occur. Threats to human health may include natural hazards, such as surf, rip currents or aquatic organisms or may have a man-made aspect, such as discharges of wastewater. Comprehensive review of the recreational area and monitoring for any changes enables a responsive strategy to protect public health be implemented.

To provide practical guidance concerning the design and implementation of monitoring programmes for recreational water use areas, WHO developed a book *Bathing Water Monitoring* (Bartram & Rees, 2000). The structure is based upon a framework "Code of Good Practice (COGP) for Recreational Water Monitoring," which is presented in this chapter. The Code was developed through an extensive process of consultation and within the context of cooperation between WHO and the European Commission. The application of the Code under specific circumstances is described in greater detail in the book.

This framework COGP constitutes a series of statements of principle or objectives that, if adhered to, would lead to the design and implementation of a credible monitoring programme. It applies in principle to the monitoring of all waters used for recreational activities that involve repeated or continuous direct contact with a water body. In many circumstances, there are different approaches or methods that can be applied to achieve the objectives stated in the Code. While equally valid in isolation of one another, the adoption of diverse approaches within a single programme may mean that results are not comparable between different locations or enforcement programmes.

The framework COGP provides a linkage to the various health effects associated with recreational waters and incrementally builds up the component parts of a successful programme—key health issues, monitoring and assessment strategies, and principal management considerations.

12.1 Design and implementation of monitoring programmes

12.1.1 Design of monitoring programmes

1. The objective(s) of a monitoring programme or study should be identified formally before the design of the programme and stated prior to data gathering. Ideally objectives would be based on assessment of the frequency and

severity of different adverse health outcomes, with the subsequent monitoring programme designed around those with the greatest public health benefit.

2. Objectives should be described in a manner that can be related to the scientific validity of the results obtained. The required quality of any data should be derived from the statement of objectives and stated at the outset.
3. Where data (such as results from water quality analyses) are to be compared between laboratories or between sites, all available measures to ensure comparability of results should be implemented:
   - A quality assurance programme based on internal controls and external controls (interlaboratory comparisons) is essential.
   - Criteria should be developed for dealing with participating laboratories consistently failing to comply with minimum analytical quality. These should be stated prior to data collection.
4. In designing and implementing monitoring programmes, all interested parties (legislators, nongovernmental organizations, local communities, laboratories, etc.) should be consulted. Every attempt should be made to address all relevant disciplines and involve relevant expertise.
5. The scope of any monitoring programme or study should be defined. This would normally take the form of definition of criteria for inclusion/exclusion of recreational water use areas and preparation of an inventory of recreational water use areas.
6. The catalogue of basic characteristics of all recreational water use areas should be prepared and updated periodically (generally annually)—and also in response to specific incidents—in a standardized format. It should include as a minimum the extent and nature of recreational activities that take place at the recreational water use area and the types of hazards to human health that may be present or encountered. Unless specifically excluded, the list of potential hazards to human health would normally include drowning and injury-related hazards, known or anticipated dangerous aquatic organisms, microbial quality of water and cyanobacteria or harmful algae. Monitoring programmes frequently also address aesthetic aspects and amenity parameters because of their importance to health and well-being.
7. Programme or study design should take account of information derived from the inventory of recreational water use areas and catalogue of basic characteristics, which may require refinement of programme objectives.
8. The logistical planning of any monitoring programme or study should take account of socioeconomic, technical/scientific and institutional capacities, staffing, equipment availability, consumable demands, travel and safety requirements and sample numbers, without compromising achievement of the objectives or scientific validity of the programme or study.
9. The hierarchy of authority, responsibility and actions within a programme or study should be defined. All persons taking part in the programme or study should be aware of their roles and inter-relationships.

10. Staff should be adequately trained and qualified, including with regard to health and safety aspects.
11. Monitoring programmes should include appropriate quality assurance (QA), which does not infringe on health and safety and which covers the integrity of all observation, interview, field sampling and water quality analyses as well as data input, analysis and reporting.
12. A QA Officer should be appointed who reports directly to senior management. The QA Officer should regularly audit all aspects of the operation with special regard to procedures, traceability of the data and reporting.
13. Essential elements of QA programmes include:
    — The writing and implementation of a Quality Manual and Standard Operating Procedures (SOPs). All SOPs should be regularly overhauled and updated as necessary and any deficiencies reported and appropriate remedial action taken.
    — SOPs should include maintenance and updating of inventories and catalogues; methodologies for all major equipment; all sampling and analytical procedures; sample receipt, screening and storage; and reporting.
14. Where samples are taken for laboratory analysis they should be registered on arrival at the laboratory. The applied laboratory procedures should conform to the SOPs defined at the laboratory. Where possible, all analytical procedures should follow defined protocols (e.g., International Organization for Standardization or American Public Health Association protocols). All equipment should be calibrated regularly and the operational procedures submitted to quality control staff in order to guarantee traceability of the data.
15. Laboratory accreditation can form a valuable part of activities relating to analytical quality, e.g., through pursuit of requirements for ISO/IEC 17025.
16. The programme should be evaluated periodically and whenever the general situation or any particular influence is changed. Commitment to support such evaluations should be built into the monitoring programme's design and authorization.

12.1.2 Data collection

17. Collection of data and information should utilize the most effective combination of methods of investigation, including:
    — observation;
    — historical review of deaths, injuries and accidents (including details on lifeguard positioning, number of rescues effected, preventive actions and attendance figures);
    — water quality sampling and analysis;
    — interview of appropriate persons; and
    — review of published and unpublished literature.
18. Frequency and timing of analytical sampling and selection of sampling sites should reflect recreational water area types, use types and density of use, as

well as temporal and spatial variations in the recreational water use area, which may arise from seasonality, tidal cycles, rainfall and discharge and abstraction patterns.

19. Analytical sampling should provide a data set amenable to statistical analysis.

12.1.3 Data handling

20. Data handling and interpretation of results should be done objectively, without personal or political interference.
21. The need for transformation of raw data, before analysis, to meet the conditions for statistical analysis should be agreed upon with a statistical expert before commencing analysis. In addition, procedures should be defined for handling censored data (such as 'less than' and 'greater than' data).
22. Data handlers and collectors should agree on a common format for recording results of analyses and surveys and should be aware of the ultimate size of the data matrix. The preferred approach is to use a database or spreadsheet that allows automatic logical verifications (i.e., only allows entries for certain date and numeric ranges). Forms and survey instruments should be compatible with this format. Likewise, data handlers should agree on a format for the output of results with those responsible for interpreting and presenting the data. Data entry should be double checked to ensure accuracy.
23. Procedures for dealing with inconsistencies such as omissions in records, indeterminate results (e.g., indecipherable characters, results outside the limits of the analytical methods) and obvious errors should be agreed upon in advance of data collection. On receipt from the data collectors, record forms should be examined and the agreed procedure followed. Discrepancies should be referred immediately to the data collector for correction or amendment. Where correction is not possible, resampling is generally the preferred option (with due regard for prevailing conditions); estimates may be preferable to leaving gaps in the record. Such estimates, however, must be recorded as such and the methodology of the estimate outlined.
24. Ideally, arrangements should be made to store data in more than one location and format, to avoid the hazards of loss and obsolescence. At all locations, data should be backed up regularly. Data should be transcribed accurately, handled appropriately and analysed to prevent errors and bias in the reporting.
25. The statistical methodologies should be reviewed by a statistical expert and comments taken into account in finalization.
26. Data should be handled and stored in such a way to ensure that the results are available in the future for further study and for assessing temporal trends.

12.1.4 Data interpretation

27. Data should be interpreted and assessed by experts with relevant recommendations for management actions prior to submission to decision-makers. Interpretations should always refer to the objectives and should also

propose improvements, including simplifications, in the data gathering activities, identifying future research needs and guidelines for environmental planning.

28. Interpretation of results should take account of all available sources of information, including those derived from inventory, catalogue of basic characteristics, sanitary and hazard inspection, water quality sampling and analysis, and interview, including historical records of these.

12.1.5 Reporting

29. The findings should be discussed with the appropriate local, regional and/or national authorities and others involved in management (including integrated water resource management), such as the industrial development and/or national planning boards.
30. Results should be reported to all concerned parties, including the public, legislators and planners. Any information relating to quality of recreational water use areas should be clear, should be concise and should integrate safety, microbial and aesthetic aspects.
31. In issuing information to concerned parties (the public, regulators, non-governmental organizations, legislators, etc.), it is essential that their requirements are kept in mind.
32. Where specific or extreme events that may threaten public health occur, the competent public health authority should be informed and recommendations should be made to the water user population about the risks of dangerous water conditions or poor water quality (see chapter 13).
33. Reports addressing the quality of recreational water use areas should be accompanied by reference to local and visitor perceptions of the aesthetic quality and risks to human health and safety (see chapter 9).
34. The deleterious impacts of human health hazards and aesthetic pollution and control measures to avoid or reduce such impacts should be introduced into environmental health education programmes in both formal and informal educational establishments.
35. The usefulness of the information obtained from monitoring is limited unless a supportive administrative and legal framework (together with an institutional and financial commitment to appropriate follow-up action) exists at local, regional and international levels.

12.2 Aspects relevant to specific hazards

The following items apply in addition to the general guidance given above in relation to specific hazards. As noted in chapter 1 (Figure 1.2), in order to maximise public health gains management authorities should prioritize according to the hazards having the most serious outcomes. Thus, generally speaking, drowning prevention measures would be prioritized over general beach cleaning. The reader should also refer to the relevant chapters in this volume.

12.2.1 Drowning and injury hazards

1. The catalogue of basic characteristics should include, wherever relevant, hazards such as beach slopes, tides, flows and currents, actual user groups, nearby hazardous areas such as cliffs, shallow waters dangerous for diving, weirs and other such hazards as identified from local knowledge and records of health effects.
2. Information regarding measures to prevent or ameliorate hazard exposure or outcomes, including, for example, lifeguard provision, staff training, signs, emergency telephone numbers, access to first aid, medical facilities, fencing, warning systems for adverse conditions and emergency routes, should be included in the catalogue of basic characteristics.
3. Monitoring and assessment programmes should address those hazards and preventive measures, described in 1) and 2), that are subject to change.
4. When assessing the significance of hazards, account should be taken of the severity and likelihood of adverse health outcomes, together with the extent of exposure.

12.2.2 Microbial water quality assessment and sanitary inspection

5. Sanitary inspection should be undertaken as a necessary adjunct to microbial water quality analysis to identify all real and potential sources of microbial contamination. It should assess their impact on the quality of the recreational water use area and water user health. During inspection, the temporal and spatial influences of pollution on water quality should receive full consideration.
6. An exhaustive sanitary inspection should be carried out immediately prior to the principal bathing season. Inspections of specific conditions should be conducted in conjunction with routine sampling during the bathing season. Pertinent information should be recorded on standardized checklists and used to update the catalogue of basic characteristics. If a problem is identified, it may be necessary to collect supplementary samples or information to characterize the problem.
7. Visual faecal pollution or sewage odour should be considered a definite sign of elevated microbial pollution, and necessary steps should be taken to prevent health risks to bathers.
8. SOPs for sanitary inspections, water sampling (including depth) and analyses should be well described to ensure uniform assessments.
9. Sample point location and distance between each should reflect local conditions (overall water quality, recreational usage, predicted sources of faecal pollution, temporal and spatial variations due to tidal cycles, rainfall, currents, onshore winds and point or non-point discharges) and may vary widely between sites.
10. Sterile sample containers should be used for microbiological samples. Scrupulous care should be taken to avoid accidental contamination during handling

and sampling collection. Every sample should be clearly identified with time of collection, date and location.

11. A sampling depth relevant for the exposure of concern should be selected and adhered to consistently in order to allow comparison between locations.
12. Samples should be kept in the dark and maintained as cool as possible within a chilled insulated container and delivered to the laboratory promptly after collection. Samples should be analysed as soon as possible and preferably within 8 h of collection. Sample storage is recommended not to exceed 24 h at 5 °C.
13. Additional information should be collected at the time of sampling, including water temperature, weather conditions, water transparency, presence of faecal material, abnormal discoloration of the water, floating debris, cyanobacterial or algal blooms, flocks of seabirds and any other unusual factors. All information should be recorded on standardized checklists.
14. Local and national conditions should be taken into account when selecting appropriate microbial indicators.
15. The influence of specific events such as rain on the recreational water use areas, especially in relation to the duration of the peak contamination period, should be established and prior agreed procedures implemented.
16. Extreme events such as epidemics and engineering and natural disasters may require additional measures to ensure there is no additional risk associated with recreational water use areas.
17. The procedures to be used for transformation of raw data to meet the statistical requirements should be agreed upon with the statistical expert prior to analysis. The most usual need is to transform bacterial counts to logarithms and to convert their approximately lognormal frequency distribution to normality.
18. When unexpectedly high microbiological results are obtained, resampling should be undertaken to help determine whether this was due to sporadic events or persistent contamination. In the latter case, the source of pollution should be established and appropriate action taken.

12.2.3 Cyanobacteria and algae

19. Monitoring of recreational water use areas should be sufficient to identify risk of blooms, taking into account actual or potential accumulation of toxic cyanobacteria and algae.
20. Sampling points should be located to represent different water masses (stratified waters, waters coming from river mouths, etc.) in the investigation area and the sources of nutrients (discharges, upwellings, etc.). Possible transport mechanisms of toxic phytoplankton should be considered, wind induced accumulations of scum should be identified and sampling schemes should be arranged accordingly.
21. In areas of high risk, sampling for algae should be carried out at least weekly. During development of blooms, sampling should be intensified to daily.

22. Monitoring of toxicity (using bioassays, chemical or immunological procedures) is justified only where reason exists to suspect that hazards to human health may be significant. In such cases, long-term information on phytoplankton populations (toxic, harmful and others) should be collected where appropriate.
23. Analyses of toxins should be undertaken only where standard, replicable and reliable analyses can be performed.
24. Where conditions are such that monitoring is considered essential, temperature, salinity (in marine coastal areas), dissolved oxygen, transparency, presence of surface water stratification, phytoplankton biomass (chlorophyll), surface current circulation (transport of algae) and meteorological patterns such as seasonal rainfall, storms and special wind regimes should be considered.

12.2.4 Other biological, physical and chemical hazards

25. Monitoring for other locally important hazards is justified only where reason exists to suspect that hazards to human health may be significant. Such occurrence may be highly localized.
26. Only where standard, replicable and reliable analyses may be undertaken for known parameters should such analyses be undertaken.
27. Approaches to the assessment of the significance of locally important hazards will depend on the type of hazard and should take account of their magnitude and frequency, severity and occurrence of health effects, and other local factors.

12.2.5 Aesthetic aspects

28. Selection of aesthetic pollution parameters for monitoring should take into account local conditions and should consider parameters such as surface accumulation of tar, scums, odours, plastic, macroscopic algae or macrophytes (stranded on the beach and/or accumulated in the water) or cyanobacterial and algal scums, dead animals, sewage-related debris and medical waste.
29. Assessment of aesthetic pollution indicators should take into account the perception and requirements of the local and any visiting populations in reference to specific polluting items as well as the feasibility of their monitoring.

12.3 Progressive implementation of monitoring and assessment

To protect health it is necessary to develop monitoring orientated towards hazards to human health in response to public health priority. This will normally mean that several aspects (beach safety, pollution control, etc.) will be developed in parallel. There are different levels of monitoring (as there are with management, see chapter 13), although each level deals with each of the major hazard groups (as outlined in Table 12.1). Typically, monitoring proceeds through local activities in isolation

TABLE 12.1. LEVELS OF MONITORING IN RELATION TO RESOURCE REQUIREMENTS[a]

Level	Basic information /visit rate	Accident hazards	Microbiological parameters	Cyanobacteria and algae	Other
Local (no national organization)	Local action comparable to basic level, in some locations only.	Local action comparable to basic level, in some locations only.	Local action comparable to basic level, in some locations only.	Local action comparable to basic level, in some locations only.	Local action comparable to basic level, in some locations only.
Basic (no access to equipment or staff resources at national level; limited local resources)	At least one pre-season visit; creation of a catalogue of basic characteristics; all recreational waters registered, but more–used and higher–risk beaches inspected and monitored.	Annual inspection for identification of any hazards and interventions (e.g., signs, warning systems).	Inspection for faecal pollution or sewage odour; delimitation of high risk areas; initial screening of microbial indicator parameters for primary classification; internal quality control at laboratories; at least one sample a month once the recreational water is classified.	Inspection for scum, type and transparency.	Register of local special problems.
Intermediate (limited access to resources both local and national level)	Comprehensive cataloguing and timetabling of visits; additional visits during peak seasons (e.g., monthly); greater proportion of recreational waters monitored.	Periodic verification of interventions during bathing season; central capacity for incident investigation.	Identification and cataloguing of potential sources of contamination; all recreational waters at primary classification; monthly sampling; additional sampling and investigation of unexpected peak values; reclassification scheme initiated; investigation of rain effects and design of preventive measures; internal quality control at laboratories; occasional inter-laboratory comparison studies.	Phosphate analysis (freshwater) Chlorophyll a (freshwater) where bloom events probable.	Check on local information availability; active warning and management response.
Full (no significant resource limitations)	Additional visits during peak seasons (e.g., fortnightly or weekly); complete cataloguing, including updating for each recreational area; all beaches with significant use monitored.	Central register of recorded incidents; decentralised capacity and procedure for incident investigation.	Additional microbiological parameters if necessary; possible reclassification investigated where indicated; internal and external quality controls regularly operated; convergence among participating laboratories.	Toxicity detection and toxin analysis capacity if necessary (not routine); remote sensing methods where relevant.	Chemical monitoring (for appropriate parameters).

[a] adapted from Bartram & Rees, 2000.

of any national or regional framework through basic, intermediate to full scale monitoring.

Extensive guidance on the development of practical and effective monitoring programmes for the safety of recreational water environments is presented in Bartram & Rees (2000).

12.4 References

Bartram J, Rees G, ed. (2000) *Monitoring bathing waters: a practical guide to the design and implementation of assessments and monitoring programmes*. London, E & FN Spon. Published on behalf of the World Health Organization, Commission of the European Communities and US Environmental Protection Agency.

ISO/IEC 17025 (1999*) General requirements for the competence of testing and calibration laboratories*. International Organization for Standardization, Geneva, Switzerland.