rainy season and then to subsequently increase in shallow groundwater in Kampala, Uganda (Barrett *et al*., 1999b; ARGOSS, 2002). Isotopic nitrogen ratios have demonstrated promise in distinguishing between various sources of nitrogen inputs, thereby providing a useful tool for assessing sources of nitrate pollution (Rivers *et al*., 1996; Barrett *et al*., 1999a). Ammonia may be indicative of very recent sewage contamination of shallow groundwater, but is likely to be rapidly oxidized to nitrate under typical conditions in shallow, unconfined aquifers.

A promising marker of sewage is 1-aminopropanone, which is present in human urine and which is not produced significantly by other natural processes. Caffeine may be a non-adsorbed, conservative indicator of sewage inputs, but it not be readily detectable in groundwater (Stroud, 2001). Other potential chemical indicators of sewage contamination in groundwater include trace metals, faecal sterols (e.g. coprostanol), sodium dodecyl sulphate and sodium tripolyphosphate (Ashbolt *et al*., 2001; Barrett *et al*., 1999a)

10.5 CHECKLIST

NOTE ▶ *The following checklist outlines information needed for characterizing sanitation practices in the drinking-water catchment area. It supports hazard analysis in the context of developing a Water Safety Plan (Chapter 16). It is neither complete nor designed as a template for direct use but needs to be specially adapted for local conditions. The analysis of the potential of groundwater pollution from human activity requires combining the checklist below with information about socioeconomic conditions (Chapter 7), aquifer pollution vulnerability (Chapter 8) and other specific polluting activities in the catchment area (Chapters 9 and 11-13).*

Is on-site sanitation practised in the drinking-water catchment area?

- ✓ Compile inventory on coverage with different types of on-site and/or off-site sanitation systems (including change over time)
- ✓ Assess size and proportion of population using on-site sanitation
- ✓ Estimate quantity of excreta disposed and loadings of pathogens, nitrate and other chemicals
- ✓ Evaluate adequacy of design, construction, condition and maintenance of on-site systems in relation to aquifer vulnerability and physical conditions in the catchment area (e.g. water table, soil, hydrogeology): consider checklist for Chapter 8
- ✓ Analyse population awareness regarding the need for protecting their groundwater sources through adequate design, construction, and maintenance of on-site systems

- ✓ For trench or pit latrines: assess siting in relation to groundwater levels, vulnerability to flooding, routines for excrement removal and inspection of liner integrity (and access of potential disease vectors such as insects and rodents for differentiation between them and drinking-water as cause of disease)
- ✓ For septic tank systems: assess siting both of tanks and drainage fields in relation to groundwater levels, vulnerability to flooding, adequacy of routines of sludge removal, tank inspection
- ✓ For contained or cartage systems: assess adequacy of collection, transportation and disposal practices in relation to groundwater sources
- ✓ For composting latrines or central systems: assess efficacy of the composting process as well as siting in relation to groundwater levels, vulnerability and to flooding
- ✓ …

Are centralized sewage treatment facilities located in the drinking-water catchment area?

- ✓ Check structure of services (e.g. percentage of population and areas of the settlement connected to storm water sewers, foul sewers and/or combined systems), and estimate wastewater volume per capita
- ✓ Evaluate adequacy of design, construction, condition and maintenance of treatment and sewage systems in relation to aquifer vulnerability and physical conditions in the in the drinking-water catchment area: consider checklist for Chapter 8
- ✓ Assess siting of treatment facilities in relation to groundwater, integrity of containment, susceptibility of facilities to flooding
- ✓ Assess practices for re-use of treated wastewater irrigation, aquifer recharge, fish ponds or other purposes
- ✓ Assess practices of human excreta or sludge re-use and/or disposal, e.g. land application: consider checklist for Chapter 9
- ✓ Evaluate the potential for contamination of sewage (and sludge arising from its treatment) with industrial chemicals, particularly persistent and toxic substances from an inventory of commercial activities in the catchment of the facility and licenses for connection to the system: consider checklist for Chapter 11
- ✓ In some settings, conduct microbiological analyses of raw sewage and effluent to assess treatment performance for pathogen elimination
- ✓ In some settings, particularly with reuse of effluent or sludge, conduct chemical analyses of concentrations of substances that potentially could contaminate groundwater in effluents and/or sludge
- ✓ …

Are there sewers in the drinking-water catchment area that may leak into groundwater?

Note: In many settings, assessing the risk of groundwater contamination from leaky sewers may be effectively combined with assessing the risk of direct ingress of sewage leaking out of sewers into the central drinking-water distribution system.

- ✓ Check depth of sewers in relation to groundwater table (for assessing likelihood of exfiltration and infiltration)
- ✓ Compile registered information on design, material and age of the sewer system
- ✓ Check whether regular sewer inspections are carried out (e.g. visual or close-circuit television)
- ✓ Compile inventory of licensed industrial and commercial discharges into the sewer system
- ✓ Compile inventory of medical care facilities connected to the system
- ✓ Compile information on land use and historic waste deposits that may indicate unregistered connections to the sewerage system or potential infiltration through leaks
- ✓ Compile information from laboratory analyses of groundwater samples taken in the vicinity of sewers (marker species, e.g. stable nitrogen isotopes, multi-component analyses in relation to known sewage constituents)
- ✓ Check for indication of leaks from budgets of wastewater flow streams and groundwater flow models
- ✓ …

Are hazardous events likely to increase groundwater pollution potential?

- ✓ Evaluate whether and how storm water events would enhance transport of pollutants to the aquifer
- ✓ Evaluate which spills and accidents are likely to cause groundwater pollution
- ✓ …

Is drinking-water abstracted in proximity to sanitation facilities?

- ✓ Assess distance between sanitation facilities and drinking-water abstraction
- ✓ Check adequacy of wellhead protection measures, wellhead construction and maintenance as well as sanitary seals used (see Chapter 18) to prevent ingress of contaminants from excreta disposal practices
- ✓ …

Are groundwater quality data available to indicate pollution from sanitation?

- ✓ Compile historic data from the area of interest, e.g. from local or regional surveys, research projects or previous monitoring programmes
- ✓ Check need and options for implementation of new or expanded monitoring programmes likely to detect contamination from sanitation
- ✓ …

What regulatory framework exists for sanitation?

- ✓ Compile information on national, regional, local or catchment area specific legislation, regulations, recommendations or common codes of good practices on siting, construction, operation and maintenance of sanitation facilities
- ✓ Check whether the regulatory framework adequately addresses environmental and specifically groundwater protection
- ✓ Identify gaps and weaknesses known which may encourage specific pollution problems
- ✓ …

Documentation and visualization of information on sanitation practices.

- ✓ Compile summarizing report and consolidate information from checklist points above
- ✓ Compile summary of types and amounts of wastewater and sludges generated, and of disease agents which are potentially hazardous if they leach into the aquifer
- ✓ Map locations of settlements and inventory sanitation facilities (use GIS if possible)
- ✓ …

10.6 REFERENCES

Aigner, C.M, Armstrong, R.J. and Butler, D. (1998) *Dry Weather Flow in Sewers*, CIRIA Report 177, London.

ARGOSS (2001) *Guidelines for Assessing the Risk to Groundwater From On-site Sanitation*. BGS Commissioned Report CR/01/42, BGS, Wallingford.

ARGOSS (2002) *Assessing Risk to Groundwater From On-site Sanitation: Scientific review and case studies*. BGS Commissioned Report CR/02/079N, BGS, Wallingford.

Ashbolt, N.J., Grabow, W. and Snozzi, M. (2001) Indicators of microbial water quality. In *Water Quality: Guidelines, standards and health – assessment of risk and risk management for water-related infectious disease*, (eds. L. Fewtrell and J. Bartram), pp. 289-315, IWA, London.