Drinking-water source deterioration: an urgent problem Part 2

by Teun Bastemeyer and Michael D. Lee

In Part 2 of this article the authors discuss the causes of the deterioration of small and large water resources, and suggest some future action.

A SYSTEMATIC framework was devised to show the linkages beween water sources, their catchment area, the activities of the user communities and other non-user communites, and any external natural factors. It is useful to break down a review of these linkages by size of water source. Small water sources are generally used by smaller communities, and are affected most closely by the community themselves. Large water sources usually support a mix of large and small communities at different locations, and their problems have a wide range of both direct and indirect causes.

Small local water sources

The major problems affecting small local water sources and their dependant village communities are summarized in Table 1.

It is clear that user communities contribute greatly to many of the problems affecting their water sources, both directly by the depletion and contamination of the water, and indirectly through effects on the yield and quality of surface and sub-surface runoff from the catchment area.[1] There are five main categories of impacts:

- micro-biological contamination;
- chemical pollution;
- yield reduction from failing supply systems;
- yield reduction from competing demands; and
- yield reduction from land-use change.

A few examples of these five problem areas provide a useful perspective on the difficulties facing small communities.

Small local water sources can be inadvertently contaminated by the people who use them if they are not protected properly.

Micro-biological contamination The results of sanitary inspection and quality monitoring in a pilot water surveillance study in Yogyarkarta, Java, demonstrated that 65 to 85 per cent of public water facilities, mostly dug wells and rainwater tanks, became faecally contaminated because of poor site protection and the unhygienic management of the facility.

In the Rukwa region of Tanzania, for example, water sources were contaminated with faeces during the rainy season because of a lack of effective sanitation and a failure to protect open water sources. Rainwater runoff containing sediment and faecal material was draining into the wells and springs. The villagers were in the habit of taking baths and washing clothes next to the water source, and animals were allowed to drink freely at drinking-water sites meant for people.

Serious contamination of groundwater can also occur as a result of poor community sanitation facilities around a source and in a catchment area. Where soils are permeable or bedrock is cracked, contaminated water can travel rapidly through a source and into a water supply system. In a village 50km north of Gaborone, Botswana, a tracer (i.e. a traceable substance such as a dye) injected into a pit latrine was detected in a water supply borehole 25m away after only 235 minutes, showing how pathogenic bacteria can travel directly from sanitation facilities into water supplies. Bacteriological tests at the borehole put the level of faecal coliforms at 10 per 100ml.

Chemical pollution The chemical pollution of small water sources results from nitrate build-up in sanitation systems, the unsafe disposal of toxic substances, and the poor handling of community waste. The siting of pit latrines too close to wells can lead to long-term nitrate contamination. In Botswana, excessive nitrate levels were measured in up to 10 per cent of one study's groundwater samples. The contamination of groundwater with nitrates is a significant problem because it is a gradual process with cumulative effects that are hard to remedy. In Andhra Pradesh, nitrate contamination of groundwater by infiltration from septic tanks has become a major environmental problem. High concentrations of nitrates in drinking-water can cause methaemoglobinaemia in infants, and can produce carcinogenic nitrosomines in the stomach, leading to stomach carcinomas. In Tirupati, 59 out of 139 wells surveyed had nitrate levels in excess of the national permissible standards for drinking-water of 50mg/litre. Farmers in South-east Asia have been seen washing out pesticide and fertilizer residues in irrigation channels or streams used for drinking by others downstream.

Yield reduction from failing supply systems The poor functioning of drinking-water supply systems results in increased water losses and poor reliability. Ineffective planning and construction, inadequate operation and maintenance, and vandalism are all contributory factors. Handpumps that break down result in a loss of water supply, forcing communities to use traditional sources or else to break into the well head and expose the well water to contamination from ropes and buckets. This was observed in Shinyanga, Tanzania, where one study found that 57 per cent of communities with wells damaged by vandalism used local water holes, and 27 per cent broke open the well manhole.

Table 1. Environmental factors affecting local water sources

Source problem	*Unacceptable quality*	*Insufficient yield*
Nature of the problem	Contamination Taste/odour Physical appearance Chemical pollution High turbidity	Rainfall fluctuations Reduced water levels Depletion
Environmental factors	Pit latrine seepage Septic tank overflow Inadequate design Animals around source Open defaecation Human waste disposal Washing and bathing Accumulated organic waste Waste disposal in catchment Wastewater disposal near source Cutting trees Environmental degradation	Increased demand Water losses Inadequate design Wastage Vandalism Industrial demand Irrigation Deforestation Burning grass and shrubs in catchment Overgrazing Expanding agriculture
Solutions	Physical protection of wells (slabs, drainage) Improved sanitation Emptying of tanks or pits Better maintenance and repair Improved hygiene Organized waste disposal Catchment protection Drainage Wastewater treatment	Community control Repair Water use rules Improved designs Improved agricultural practices Alternative energy sources

Yield reduction from competing demands The use of small sources for other community needs affects the reliability and quality of service. In India, the use of mechanized pumps for irrigation has led to the lowering of local groundwater reserves below the level of dug and step wells. Rainwater harvesting systems in Africa often run dry before the beginning of the next rains because the stored water is used for non-drinking-water purposes. Competing demands often cause social conflict between users.

Yield reduction from land-use change Small sources often have small catchment areas, and the activities of local communities may quickly create water source problems. Land-use changes from settlement, construction, agricultural development, firewood collection, and grazing can all radically alter the amount and timing of surface water and groundwater flows and the quality of the water. Villages in the mountain catchments of the Cherrapunji river in India have been deforested by firewood collectors, which has resulted in massive monsoon runoff and the drying up of the streams and springs that the villagers had used for their summer water supply. Land use changes in many upland regions result in increased river, stream, and spring turbidity, and the clogging and deterioration of the slow sand filter water purification systems on which communities rely for safe drinking supplies.

Large water sources

With the increase in scale of larger, regional water sources, goes an increased range of factors that result in the deterioration of water quantity, quality, or reliability. A few user communities are joined by others who are less dependent on this one source alone. The catchment area also contains many other groups with diverse land-use activities and competitive claims on the source for irrigation, power generation, or industry.

The major factors identified as having serious impacts on water source quantity, quality, and reliability are summarized in Table 2. They are grouped into five broad categories based on their quantity and quality impacts:

- the exploitation of groundwater beyond sustainable yields;
- seasonal changes in river flow and quality, and groundwater recharge resulting from land-use change;
- the pollution of surface and subsurface sources by industrial discharges;
- pollution by agricultural chemicals; and
- pollution by sewage waste.

Exploitation of groundwater beyond sustainable yields Groundwater depletion is a global problem, and it leads to decreasing yields, the abandonment of wells, salinization, and land subsidence. It also causes severe problems to the sustainability of village-level operation and maintenance (VLOM) handpump programmes. The development and promotion of low-cost technology options for community-based water supply can be rendered ineffective by a general lowering of the water table.[2] Depletion occurs mainly because of uncontrolled private drilling and pumping from boreholes, and as a result of ineffective groundwater management legislation and monitoring. Extraction rates that exceed groundwater recharge rates, both for drinking-water and for the competing needs of agriculture and industry, will lead to a rapid lowering of the groundwater levels. Pumping becomes more difficult and more expensive, and the quality of service diminishes.

Table 2. Environmental factors affecting regional water sources

Source problem	*Poor quality*	*Unreliable yield*
Nature of the problem	Chemical pollution Organic (faecal) pollution Intrusion of salt water High turbidity	Destructive floods Falling groundwater table Seasonal fluctuations
Environmental factors	Industrial waste and wastewater disposal Use of pesticides and fertilizers Sewage discharge Over-extraction of groundwater Land-use changes	Land-use changes Erosion Urbanization Dams Insufficient recharge of aquifer
Solutions	Recycling of waste Creation of economic incentives Enforcement of waste control Technological improvements Improved maintenance of treatment plants Awareness raising Training Treatment plants Water resource management Better source siting	Land-use planning Reforestation Soil conservation Wastewater re-use Artificial recharge Erosion control

In many cases, the only solution is to invest in the deeper drilled wells with mechanized pumping systems that have proved expensive and difficult for communities to sustain. In the Yemen, groundwater levels fell by 20m in the 1970s on the Sana'a Plain as a result of the uncontrolled sinking of over 10 000 wells. Yields have fallen and the cost of accessing groundwater has increased dramatically. Near Bangkok, groundwater withdrawal has led to severe subsidence and saline intrusion along the coast at a rate of between 100 and 200m per year, and chloride concentrations in municipal wells have risen fivefold up to around 1250mg/litre.

Seasonal changes in river flow and quality and groundwater recharge from land-use change Deforestation and erosion continues to occur at a rapid rate in developing countries, as growing populations expand into forests and up hillsides in search of farmland and firewood, and commercial agriculture and industry clear and mine large tracts of land. Runoff and soil loss exacerbates winter flooding, reducing baseflows and the recharge of local and regional aquifers. The higher turbidity levels of runoff water from catchment erosion has significantly reduced the capacities of the reservoirs behind small drinking-water dams in Ghana, for example. Seasonal flooding in Bangladesh has been exacerbated by deforestation in the Indian Himalayas, resulting in the damage of water supply systems and the pollution of sources by contaminated floodwater.

Pollution of surface and sub-surface sources by industrial discharges Rapid industrial growth in many developing countries has led to tremendous increases in the amount and type of industrial pollutants discharged into water sources such as rivers and lakes. Many examples have been documented in India over the last ten years, as environmental awareness of the linkages between industry and water quality have grown. One study documented the effects of distillery waste discharge on the Neeva River in Andhra Pradesh. There, the colour, odour, and taste, let alone the chemical characteristics, make the river water unfit for domestic use.

Many of these problems are felt by small riverside communities living downstream of the large urban areas through which the river passes. Coffee and sugar factories in Kenya have historically poured their waste into waterways. At Kanpur, on the River Ganges, 45 tanneries and 10 textile mills discharge effluent into the river, rendering it unfit for human consumption and ritual bathing. (Consumption of river water, and bathing in the river, persist nevertheless among small communities downstream.) The discharge of hydrocarbons into aquifers from sub-surface storage tanks is also a growing problem in the South, particularly in Latin America, which relies heavily on groundwater for urban and peri-urban water supplies.

Pollution by agricultural chemicals Point and non-point pollution from agricultural chemicals expands as agriculture, particularly if irrigated, becomes more intensive and technical. Many of these chemicals leach or wash out from the rapidly expanding irrigated farmland into surface and groundwater. On a smaller scale, local farmers increasingly use, store, and dispose of such chemicals close to their water sources. In Chaing Mai province, Thailand, rural villagers commonly took drinking-water from irrigation canals downstream from where pesticides were regularly used. Pesticides are also used to control waterborne diseases such as malaria, bilharzia, and onchocerciasis. The effects of pesticide intake on the people who drink water from these treated sources have received little attention.

Shallow drinking-water wells in Sri Lanka are placed next to paddy fields, where fertilizers and pesticides are applied. In Juba, Sudan, boreholes exhibited high DDT concentrations close to villages in which 23 per cent of households used pesticides down their latrines to control fly problems. Although little direct documentation exists, WHO expects that the spraying of insecticides onto water sources will have a significant health effect on downstream users.

Pollution by sewage waste The purposeful discharge of raw sewage into the nation's rivers and lakes is a common occurrence in developing countries, just as it is in the industrialized world. In Europe, many countries rely on the diluting effect of large rivers and the ocean to dispose of effluent. The biological oxygen demand, total suspended solids, nitrates, and the pathogenic bacteria contents of raw and partially treated sewage flows are all serious concerns for downstream communities who use the source for drinking, fishing, or recreation. Only a few of the larger developing country communities have primary or secondary treatment facilities for human waste. Communities downstream of Bogota, Colombia, must contend with enormous concentrations of faecal coliforms in the Rio Bogota water on which they depend. A similar story can be told about the River

Ganges in India. Elsewhere in India, the disposal of sewage sludge on land causes high faecal coliform and hardness levels in shallow groundwater.

Future actions

There is a definite need to address more systematically this range of problems and their underlying causes. A lack of detailed data on problems at national, regional, and local levels appears to be the main reason why few developing countries have formulated overall policies concerning environmental protection and the management of water sources. While there is no shortage of reports detailing the problems, they are often descriptive rather than quantitative, and do not offer a systematic and workable set of solutions. Information is dispersed and not easily available to policymakers and decision-makers or to individual development project managers.

Nevertheless, for the majority of problems identified, solutions do exist. With small water sources where local, direct linkages are recognized between causes and effects, solutions may be fairly simple and local. With larger sources, where a range of user and non-user communities are negatively influencing the quantity, quality, and reliability of drinking-water supplies through actions at the source and in its catchment, the solutions are more complex. They can involve institutional and legal initiatives such as the drafting of laws, the establishment of a national environmental body, and the formation of a monitoring and regulatory programme.

Examples of specific solutions to source problems include improvements in sanitation at a household and collective level, the physical protection of water supply systems, soil and water conservation, reforestation, the containment and treatment of industrial waste, the artificial recharge of groundwater, and the more controlled use of agricultural chemicals. On the larger scale, there is increased attention on the partnership between communities and government authorities to manage and protect water resources. Legislation and regulation must be accompanied by a will to co-operate, and this can be fostered by information exchange, awareness raising, and the setting of mutual priorities. At a local level, communities must be active in bringing problems to the attention of agencies and, equally, agencies are responsible for assessing the wider significance of local, regional, national, and international causes and their effects, and for acting to prevent them. Reconciling conflicts of interest is clearly the responsibility of governments, who must foster and support community efforts to manage and protect their own and others' drinking-water sources.

Elements that are essential to the protection of drinking-water sources appear to be land-use planning and control measures, pollution source control regulations, water source selection and supply siting procedures, and community management of developed sources. There is little experience so far of countries developing effective integrated programmes to co-ordinate these measures. Individual projects, such as those financed by the World Bank, are now attempting this by conducting environmental impact assessments that analyse the impacts of, and the factors affecting, a drinking-water supply project. But while assessments may often identify causes and effects of significance for the long-term sustainability of the systems, they may not actually be able to prevent or protect against many of these factors because of the lack of a suitable control framework at the regional and national level. Existing environmental legislation and water laws mostly concern large river basins and focus on territorial or navigation issues, or major water rights allocations, rather than the quality and reliability of small and intermediate drinking-water sources. The enforcement of the laws that do exist is hampered by a lack of awareness of the vast range of environmental problems, and the costs and benefits associated with more effective prevention, protection, and management.

Benefits of protection It is critical that the benefits of environmental protection, which universally outweigh the costs of remedial actions when viewed in the medium and long term, be quantified and communicated to decision-makers as a basis for a managed and sustainable approach to development. Currently, all parties give higher priority to the meeting of short-term needs. As an encouragement to national authorities, more independent and detailed collections and analyses of environmental data by NGOs are required in order to set standards, provide workable guidelines, and promote water source protection at all levels in developing countries.

Special concerns Two major areas that require considerable attention are the development and application of low-cost techniques for waste management, and the more effective control and use of toxic chemicals. Low-cost technologies for waste water treatment and the management and control of industrial waste could be applied for the growing range of industries active in developing countries. Some technologies are already in existence, whereas others must be developed. It is important that the international community identify and promote existing appropriate techniques, identify areas for which initiatives are required, promote research in these areas, and develop adequate maintenance and monitoring programmes for these and for those already in existence.

Little detailed information is available for developing countries on the effects of the pesticides and other agricultural and industrial chemicals that are routinely discharged into water sources. The monitoring of these substances, and of their concentration and distribution, is not widespread, except in some of the major river-basins and international waterways. Many new substances are created by industrial chemists each year, and little information about the products' toxicology, particularly in drinking-water and the aquatic environment in general, is available. An increasing array of chemicals is being imported into developing countries and used in many planned and unplanned ways. Many countries do not have a functioning registry of toxic imports nor mechanisms for tracking their movement and use. Substances banned in the industrialized countries who develop them are sometimes dumped on the developing world market. This will require the attention of both national and international agencies in the coming years.

There is much work to be done in the area of the protection of drinking-water sources. The solutions to the environmental problems affecting source quality, quantity, and reliability are both expensive and technically and socially complex. Though awareness of the need to protect sources and prevent problems is increasing, experience in this area is still limited, and few countries have as yet developed effective policies or widespread grassroots movements to address the issues. ●

References

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diary

25-9 October 1992. **Water Malaysia '92, Kuala Lumpur, Malaysia.** The 8th Regional Conference and Exhibition of the Asia-Pacific Group (ASPAC) of the International Water Supply Association (IWSA). The conference programme will cover source development, water-quality control and monitoring, water treatment, distribution and management. More information from: *The Secretary, Organizing Committee, Water Malaysia '92, c/o Office of Director of Water Supplies, Public Works Department, Jalan Sultan Salahuddin, 50582 Kuala Lumpur, Malaysia. Fax: +60 3 2931557.*

1-5 November 1992. **International Conference on Water-Related National Disasters and their Environmental Impacts, Bangkok, Thailand.** Contact: *Prof. A. Das Gupta, AIT, GPO Box 2754, Bangkok 10501, Thailand.*

10-12 November 1992. **International Water and Effluent Treatment Exhibition '92, Birmingham, UK.** Annual show for the water industry. Details from: *Paul Tweedale, Exhibition Sales Manager, Turret Group plc, Turret House, 171 High Street, Rickmansworth, Herts WD3 1SN, UK. Fax: +44 923 771297.*

1-5 December 1992. **WATERTECH Indonesia, Jakarta, Indonesia.** Being held as part of the 2nd International Exhibition and Conference on Equipment and Systems for Pollution Control and Environmental Improvement. Details from: *Matthew Meredith, Overseas Exhibition Services Ltd., 11 Manchester Square, London W1M 5AB, UK. Fax: +44 71 486 8773.*

1-6 August 1993. **International Conference on Rainwater Catchment Systems, Nairobi, Kenya.** The 1993 conference will focus on the sustainability of rainwater systems projects, rainwater harvesting projects, participation in community development efforts and the key role of women in project development; plus applications of city water systems. Interested participants are invited to submit abstracts to the following address before December 1992: *John Mbugua, PO Box 56, Nakuru, Kenya. Fax: +254 2 716255/37 44379.*

30 August-12 September 1993. **15th International Congress on Irrigation and Drainage, New Delhi, India.** Contact: *Secretary-General, International Commission on Irrigation and Drainage, 48 Nyaya Marg, Chanakyapuri, New Delhi 110021, India.*

6-10 September 1993. **19th WEDC Conference, Accra, Ghana.** Papers are invited from interested participants on: water and sanitation, including community projects and innovative techniques; the environment; development, including income generation and small-scale irrigation. Offers must reach the co-organizers by 31 December 1992. Write to: *John Pickford, WEDC, Loughborough University of Technology, Loughborough, Leics LE11 3TU, UK. Fax: +44 509 211079.*

7-10 September 1993. **Making the Most of Resources: The second meeting of the Water Supply and Sanitation Collaborative Council, Rabat, Morocco.** The reports of the Working Groups on the seven main issues identified at the last meeting in Oslo in 1991 will be discussed by professionals from developing countries and external support agencies. More details from: *Ranjith Wirasinha, Executive Secretary, WSS Collaborative Council, c/o World Health Organization, Avenue Appia 20, CH-1211 Geneva 27, Switzerland. Fax: +44 41-22-791-3685.*

20-3 September 1993. **First Southern Africa Water and Wastewater Conference, Johannesburg, South Africa.** Aims to enable Southern African nations to share their knowledge, experience and technology to evolve the most cost-effective means of finding, treating, storing, conserving and recycling water. More information from: *Tracey Nolan, First Southern Africa Water and Wastewater Conference, 212 Molyneux Road, Liverpool L6 6AW, UK. Fax: +44 51 260 4097.*

8-11 November 1993. **International Conference on Environmentally Sound Water Resources Utilization, Bangkok, Thailand.** The objective is to bring together scientists and engineers to discuss and exchange their knowledge and experience in assessing and forecasting water-resources availability and use. Likely participants should contact: *Professor Tawatchai Tingsanchali, Division of Water Resources Engineering, Asian Institute of Technology, Bangkok 10501, Thailand. Fax: +66 2 5162126.*

1-3 February 1994. **International Conference on Groundwater — Drought, Pollution and Management, Brighton, UK.** Aims to provide an international forum for water-resources experts to discuss the issues of sustainability. The three broad themes are: quantity constraints, quality constraints and management solutions. The Organizing Committee are now inviting abstracts of papers which must reach them by 1 February 1993. All enquiries should be addressed to: *Jacqueline Watts, HR Wallingford Ltd., Howbery Park, Wallingford, Oxon OX10 8BA, UK. Fax: +44 491 32233.*