Groundwater and its susceptibility to degradation:

A global assessment of the problem and options for management

UNEP

DFID Department for International Development

DGDC Belgian Development Cooperation

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

UNEP/DEWA
DFID

This publication was prepared on behalf of the United Nations Environment Programme's Division of Early Warning and Assessment (UNEP-DEWA) by the British Geological Survey (BGS), which is a component body of the UK Natural Environment Research Council. The principal BGS authors were Brian Adams (Chapter 3), Roger Calow (Chapter 8), John Chilton (Chapter 7), Ben Klinck (Chapter 6), Adrian Lawrence (Chapters 3, 4, 7 and 8) Brian Morris (Chapters 1, 2, 4, 5 and 6, project manager) and Nick Robins (Chapter 6).

ISBN: 92-807-2297-2

For bibliographic and reference purposes, this publication should be cited as Morris, B L, Lawrence, A R L, Chilton, P J C, Adams, B, Calow R C and Klinck, B A. (2003) Groundwater and its Susceptibility to Degradation: A Global Assessment of the Problem and Options for Management. Early Warning and Assessment Report Series, RS. 03-3. United Nations Environment Programme, Nairobi, Kenya.

Cover photographs clockwise from top:
1. Main, front cover: Groundwater's vital role in city water supply; surveillance of periurban wellfield supplying Bishkek (Kyrghyzstan)
2. Top, front cover: Leaking oil production well; potential pollution source on a vulnerable limestone aquifer (Barbados)
3. Middle, front cover: Solid waste disposal needs careful design and siting to minimize pollution risk (UK)
4. Bottom, front cover: Wellhead water quality monitoring; an important aspect of public water-supply surveillance (Bolivia)
5. Top, back cover: Community maintenance of handpump-equipped rural water supply boreholes (Tamil Nadu India)
6. Upper centre, back cover: Sampling a community borehole in a low-income urban neighbourhood (Bolivia)
7. Lower centre, back cover: Village handpump with well-designed protective plinth, soakaway and washing slab (Malawi)
8. Bottom, back cover: Low-income districts in many developing cities depend on nearby aquifers for low-cost water supply (Kenya)

To obtain copies of this publication, please contact:

UNEP

Division of Early Warning and Assessment
United Nations Environment Programme
P.O. Box 30552
Nairobi 00100
Kenya
Tel: (254 2) 62 41 05
Fax: (254 2) 62 42 69
E-mail: dewainfo@unep.org

Partner organisations in the production of this publication:

DFID

Department for International Development
No.1 Palace Street
London SW1E 5HE
United Kingdom

DGDC
Belgian Development Cooperation

Belgian Development Cooperation
Rue Marie-Terese 1B
1000 Brussels
Belgium

BGS 1835

British Geological Survey
Keyworth
Nottingham NG12 5GG
United Kingdom

CONTENTS

Figures

Tables

Plates

Text Boxes

ACKNOWLEDGEMENTS

We would like to thank UNEP-DEWA and the UK Department for International Development for supporting this publication, and especially Salif Diop and Patrick Mmayi at UNEP who were key motivators during its production.

In addition to the BGS staff acknowledged in the opening page John Bloomfield, Jeff Davies and David Kinniburgh and Magali Moreau contributed to this report. The authors' efforts were greatly enhanced by the skills of the drafting, editing and design team comprising Gill Tyson, Audrey Jackson, Amanda Hill, Brian Morris and Celia Kirby. Mike Price (Postgraduate Research Institute for Sedimentology of the University of Reading) undertook a perceptive and typically thorough technical review. At UNEP, Halifa Drammeh, David Smith, Beth Ingraham, Audrey Ringler and Matthew Fortnum were all instrumental in realising this project, as was Emmanuel Naah at UNESCO/International Hydrological Programme. Willi Struckmeier at the German Federal Institute for Geosciences and Natural Resources (BGR) kindly facilitated use of the latest version of the Groundwater Resources of the World map. Finally, the many examples used in this review were drawn from the work of groundwater professionals of many nationalities, especially from the developing world, a number of whom it has been the authors' privilege to work with. Their contributions to our understanding of this vital global water resource are gratefully acknowledged.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS*

BTEX	Benzene, toluene, ethylbenzene, xylene; aromatic compounds with health guideline limits
CEAQ	Comisión Estatal de Aguas de Querétaro (Mexico)
DDT	Dichlorodiphenyltrichloroethane, a pesticide once widely used to control insects in agriculture and insects that carry diseases such as malaria
DFID	United Kingdom Department for International Development
DNAPL	Dense non-aqueous phase liquid
DOC	Dissolved organic carbon, with values usually quoted in mg/l
ECE	United Nations Economic Commission for Europe
Eh	Oxidation potential, with values usually quoted in mV
FAO	Food and Agricultural Organisation of the United Nations
IPCC	Intergovernmental Panel on Climate Change
K	Hydraulic conductivity, with values usually quoted in m/d; a measure of the permeability of a rock
LNAPL	Light non-aqueous phase liquid
OECD	Organisation for Economic Cooperation and Development
PDAM Jakarta	Perusahaan Daerah Air Minum, Jakarta (Indonesia)
R	Recharge to groundwater, typically measured in mm/year
S	Storage coefficient or storativity; a dimensionless value which is the volume of water which an aquifer releases or takes into storage per unit surface area of aquifer per unit change in head
SAGUAPAC	Cooperativa de Servicios Públicos "Santa Cruz" Ltda.(Bolivia)
T	Transmissivity, the product of hydraulic conductivity and aquifer thickness, with values usually quoted in m^2/d
TOC	Total organic carbon, with values usually quoted in mg/l
UNEP-DEWA	United Nations Environment Programme, Division of Early Warning and Assessment
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFPA	United Nations Population Fund
US-EPA	United States Environmental Protection Agency
WHO	World Health Organisation

**Note: this glossary does not include abbreviations or acronyms in this publication that are described in nearby text*

FOREWORD

From Klaus Töpfer, United Nations Under Secretary–General and Executive Director of the United Nations Environment Programme (UNEP)

Recently UNEP produced its third UNEP Global Environment Outlook, GEO-3. GEO-3's multi-sectoral regional and global assessment of the state of the environment paid a special attention to the conditions of the world's water resources. The GEO-3 report identified a wide spectrum of existing and emerging water issues that need to be addressed if the world is to achieve sustainable development. Many of these issues were the subject of Governing Council decisions in 2001, prominent among them being decisions to promote regional and intergovernmental dialogue on water, strengthening the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), improving the strategic framework of global international waters assessment programme and facilitating regional co-operation on the transfer of environmentally-sound technology.

GEO3 draws attention to the fact that the availability and quality of fresh water is rapidly becoming one of the most critical environmental and developmental issues of the twenty-first century. By 2025, countries considered water stressed will host two-thirds of the world's population. Across the globe, groundwater is being depleted by the demands of megacities and agriculture, while fertiliser run-off and chemical pollution are threatening water quality and public health. In the developing world over 80 per cent of all diseases are attributable to unsafe water and poor sanitation; often rivers downstream from large cities are little more than open sewers.

The information provided in GEO-3 confirms that the transboundary nature of freshwater resources, lakes and underground aquifers, presents an opportunity for nations to work together to manage those resources for the benefit of all and that watershed boundaries do not reflect socio-political boundaries. Recent water assessments confirm that developing countries are continuing to withdraw groundwater for domestic, industrial and agricultural use at an increasingly alarming rate. The pollution of aquifers is also on the rise due to a variety of reasons.

To adequately cover groundwater degradation issues at a global level, there is a need to strengthen collaboration and co-ordination between institutions, their programmes and projects. The new GEMS Water Programme, for example, needs to build on its links with WHO, WMO and UNESCO, as well as collaborating institutions such as the British Geological Survey, UCC/DHI and IGRAC. More emphasis should be placed on capacity building and the harmonisation of assessment methods – particularly in developing countries.

Water is life and sound management of water resources is an integral component of the new paradigm for sustainable development – one that allows the steady improvement in living standards without destroying the fragile natural capital of river, marine and groundwater systems.

The establishment of a surveillance network for monitoring the extent and level of aquifer pollution remains one of the key components of effective global groundwater protection. Regional observatories of aquifer vulnerability and degradation could gain valuable knowledge through the comparison of water quality conditions, and the results would be a powerful public awareness tool. This would ultimately increase the chances of closing the gap between policy enactment and enforcement – so often a stumbling block to achieving sustainable water use.

From Martin Walshe, Senior Water Adviser,
UK Department for International Development (DFID)

The Millennium Development Goals (MDGs) were adopted by member countries of the UN in 2000 as a global consensus on objectives for addressing poverty. Water has a key role in strategies for achieving all of the MDGs, which include a target to reduce by half the proportion of people without access to a safe water supply and a commitment to ensure environmental sustainability.

The 2002 World Summit on Sustainable Development (WSSD) in Johannesburg made an important advance when it placed poverty eradication at the heart of efforts to achieve sustainable development. The Summit brought the development and environment movements together and committed the international community to a systematic effort both to reduce poverty and pursue sustainable development. A new target on sanitation and a commitment to have water resource plans for all countries in place by 2005 were made at WSSD. The importance of water and its fundamental contribution to sustainable development is now recognised, but the contribution of water to poverty reduction will only be realised if it is set in the broader context of social and economic development and environmental improvement.

The last 50 years have seen unprecedented development of groundwater resources. At a regional level groundwater is of huge importance in Africa, Asia and Central and South America. Nationally, countries from Palestine to Denmark are dependant on groundwater and examples of local reliance can be drawn from Mexico City to small villages in Ethiopia. An estimated 2 billion people worldwide rely on aquifers for a drinking water supply. In a rural context, groundwater provides the mainstay for agricultural irrigation and will be the key to providing additional resources for food security. In urban centres groundwater supplies are important as a source of relatively low cost and generally high quality municipal and private domestic water supply. However, concerns are growing over the sustainability of individual water sources and there is a growing need for management strategies that recognise the complex linkages that exist between groundwater supplies, urban land use and effluent disposal.

This production of this book has been partly funded by DFID through the Infrastructure and Urban Development Division water programme. It provides an overview of the susceptibility of groundwater to degradation caused by human activities, including both quantity and quality impacts, and examines the different issues affecting groundwater resources in rural and urban/industrial settings.

SUMMARY

This publication provides an overview of groundwater occurrence and of the main issues affecting its quantity and quality. We see how the resource is used in our cities, in industry and mining, in agriculture and rural water supply; how it sustains many of our wetlands; how in its own undramatic way groundwater has become an integral part of billions of people's lives. Numerous examples illustrate resource management issues and underline the need for active management rather than *ad hoc* development.

There are some key messages that those involved in planning and managing groundwater development need to note if the resource is to be used in a sustainable way:

Groundwater is a globally important, valuable and renewable resource

Its importance stems from its ability to act as a large reservoir of freshwater that provides "buffer storage" during periods of drought. Much groundwater is of good quality water because of natural purification processes, and its typically modest treatment requirements make it a valuable source of potable water which can be developed cheaply and easily, if necessary in a piecemeal fashion

Groundwater is under threat of degradation both by contamination and by inappropriate use

Despite its importance, groundwater is often misused, usually poorly understood and rarely well managed. The main threats to groundwater sustainability arise from the steady increase in demand for water (from rising population and per capita use, increasing need for irrigation etc) and from the increasing use and disposal of chemicals to the land surface

Groundwater needs to be carefully managed if its use is to be sustained for future generations

Management is required to avoid serious degradation and there needs to be increased awareness of groundwater at the planning stage, to ensure equity ("Fair play") for all stakeholders and most important of all to match water quality to end use (thereby maintaining the best quality for potable use).

Despite the threats from potentially polluting activities, groundwater is often surprisingly resilient, and water quality over large areas of the world remains good. In part this is because many aquifer systems possess a natural capacity to attenuate, and thereby mitigate the effects of pollution, especially of microbial contaminants. As it is impossible to completely avoid aquifer pollution, this capacity should not be underestimated, but instead taken advantage of to minimise the consequences to water supplies and to ecological uses of groundwater.

Although groundwater is not easily contaminated, once this occurs it is difficult to remediate, and in the developing world, such remediation may prove practically impossible. For that reason it is important to identify which aquifer systems and settings are most vulnerable to degradation because the replacement cost of a failing local aquifer will be high and its loss may stress other water resources looked to as substitutes. This can be especially important for urban water supply where, notwithstanding local pollution threats, globally the biggest challenge to groundwater quality is not from high-profile contaminants like arsenic or toxic industrial chemicals but salinisation.

A particular water management difficulty arises from the small scale and incremental nature of groundwater development because highly dispersed ownership/use needs imaginative regulatory and financial measures. In such cases there is often the problem that the generally high quality of much groundwater is not reflected in the value of the uses to which it is put. The longstanding conflict in peri-urban aquifers between groundwater for irrigation versus public water supply is a case in point.

A vital aid to good groundwater management is a well-conceived and properly supported monitoring and surveillance system. 'Out of sight, out of mind' is a poor philosophy for sustainable development. The general neglect of groundwater resources in terms of national planning, monitoring and surveillance will only be overcome once effective monitoring is regarded as an investment rather than merely a drain on resources. For this reason monitoring systems should be periodically reassessed to make sure that they remain capable of informing management decisions so as to afford early warning of degradation and provide valuable time to devise an effective strategy for sustainable management.