U N E P / D E W A / R S . 0 3 - 3











British Geological Survey Groundwater and its Susceptibility to Degradation

A global assessment of the problem and options for management

Groundwater and its susceptibility to degradation:

A global assessment of the problem and options for management







Belgian Development Cooperation

GD

British Geological Survey

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)

Copyright © 2003, United Nations Environment Programme, Department for International Development and the Natural Environment Research Council (NERC) except the image 'The Groundwater Resources of the World' (© BGR Hannover 2003) and all other diagrams and photos 1-7 (© NERC 2003 All rights reserved) and photo 8 (© UNEP 2003).

This report may be reproduced in whole or in part and in any form for educational or non-profit purposes without special permission from the copyright holders, provided that acknowledgement of the source is made. UNEP, DFID and BGS would appreciate receiving a copy of any material that uses this publication as a source. No use of this publication may be made for resale or for any other commercial purpose whatsoever without prior permission in writing from the United Nations Environment Programme, the Department for International Development and the British Geological Survey (on behalf of the Natural Environment Research Council).

To obtain copies of this publication, please contact:



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:



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



British Geological Survey Keyworth Nottingham NG12 5GG United Kingdom



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

Disclaimer

This publication is a review drawn from many sources and it is intended that the material be used for general guidance only. The views expressed are those of the authors and do not necessarily represent the views or policies of UNEP, DFID or any of their affiliated organisations. The designation of geographical entities in this report and the presentation of the material do not imply any expressions of any opinion whatsoever on the part of UNEP concerning legal status of any country, territory, city or area or its authority, or concerning the delimitation of its frontiers or boundaries. Mention of a commercial company or product in this report does not imply endorsement by UNEP. The use of information from this publication concerning proprietary products for publicity or advertising purposes is not permitted. Trademark names and symbols are used in an editorial fashion with no intention of infingement of trademark or copyright laws. We regret any errors or omissions that may unwittingly have been made.

CONTENTS

1	Introduction	1
	The world's hidden water resource	1
	Setting the scene	1
	Types of groundwater degradation problems	5
	Global water issues that affect groundwater	5
	Global water challenges and the role of groundwater	7
	Scope of this book	8
2	Hydrogeological environments	9
	Importance of different aquifer properties	10
	Hydrogeological settings	12
3	Groundwater exploitation: using aquifers in a sustainable way	19
	The conundrum of safe yield and sustainable use	20
	Negative impacts of over-exploitation	22
	Assessing probability of adverse impacts from high abstraction	25
	Risk of groundwater degradation due to over-abstraction and options to mitigate its impact	28
	Impact of groundwater level depletion on society	30
4	Fundamentals of pollution	33
	Sources of pollution	33
	Attenuation of contaminants in the subsurface	35
	Pollution risk and aquifer vulnerability	42
	Subsurface contaminant load	44
	Groundwater pollution risk assessment	46
5	Urbanisation processes and effects of our growing cities on groundwater	49
	Conflicts in use of the urban subsurface	49
	Pattern and stage in evolution of a city underlain by a shallow aquifer	51
	Urbanisation processes that affect groundwater	53
	Implications of urban processes for city water resources	58
6	Impact of industry and mining	67
	Industry	67
	Mining	77
7	Protecting rural groundwater quality	85
	Role of groundwater in rural areas	85
	Salinisation problems	87
	Problems from fertilisers	91
	Problems from pesticides	94
	Other issues affecting rural aquifers	98
8	Perspectives on groundwater management	105
	The measured approach to groundwater management	105
	Coping strategies and indirect ways of managing groundwater resource	109
	Monitoring considerations	115
9	Bibliography	120

Figures	-	
Figure 1	Fetimated extent of aroundwater used for drinking water in Asia and Central and South America	age Nos
Figure 2	Cities in Africa that are dependent on groundwater	2
Figure 3	Global trends in water use	5
Figure 4	Localised groundwater flow systems in minor aquifers	12
Figure 5	Patterns of water-level decline in an aquifer under different recharge conditions	22
Figure 6	Typical impact of excessive abstraction on coastal and lowland aquifer system	29
Figure 7	Major human activities and how they have intensified through time	33
Figure 8	Factors affecting microbe survival and half-life	37
Figure 9	Pathogen diameters compared with aguifer matrix apertures	37
Figure 10	Subsurface distribution of aromatic low-density and halogenated high-density hydrocarbons following a major	
F ' 44	surface spillage	39
Figure 11	Schematic representation of double porosity aquifer	43
Figure 12	Conceptual scheme of groundwater pollution risk	43
Figure 13	Examples of urban groundwater vulnerability maps	44
Figure 14	The vicious circle: lack of resources ~ knowledge ~ planning	48
Figure 15	Facels of degradation of a groundwater system underlying a city	50
Figure 17	Stages in the evolution of a water initiastructure in a city overlying a productive aquiter	51
Figure 17	Evolution of water supply and waste disposal in a typical city undertain by a shallow aquiter	5Z
Figure 10	Rates of circulation in water supply mains in urbanisation	54
Figure 19	Main pathways of mining contamination to a human recentor	70
Figure 20	Consumption of nitrogen fertiliser 19/6 to 1989	01
Figure 22	Pathways for pollution of aroundwater supplies by on-site sanitation	00
Figure 22	Partie of responses a groundwater agency might adopt when dealing with a groundwater problem	107
Figure 24	Different dimensions of sustainability when considering social and political feasibility of water reform	1107
Figure 25	Contrasting views on the prioritisation of water management policies in Middle Eastern and North African countries	110
Figure 26	Schematic illustration of an aquifer which crosses an international boundary	117
Figure 27	Northern Africa: an important region of internationally shared aquifers	117
Tables		
Table 1	Population of megacities dependent on groundwater	2
Table 2	Estimated percentage of drinking water supply obtained from groundwater	3
Table 3	Selected national statistics on agricultural irrigation and groundwater use	3
Table 4	Industrial water use in the world's most industrialized and least industrialised countries	4
Table 5	Characteristics of the principal hydrogeological environments	13
Table 6	Impact of excessive groundwater abstraction	21
Table 7	Susceptibility of different hydrogeological settings to adverse side effects during excessive abstraction	26
Table 8	Factors affecting the susceptibility of aquifers to adverse side effects from excessive abstraction	26
Table 9	Some categories of substances with reported endocrine-disrupting properties	34
Table 10	Processes promoting contaminant attenuation in groundwater systems	35
Table 11	Hydrogeological settings and their associated groundwater pollution vulnerability	42
Table 12	Definition of aquifer vulnerability classes	43
Table 13	Summary of activities that could potentially generate a subsurface contaminant load	45
Table 14	Benefits and costs of using the urban subsurface	49
Table 15	Impact of urban processes on infiltration to groundwater	53
Table 16	Impact on groundwater quality from various sources of urban aquifer recharge	58
Table 17	Transport characteristics of the common urban contaminants/contamination indicators	59
Table 18	Potential groundwater contaminants from common industrial operations	67
Table 19	Relative importance of different contaminant groups for typical industrial and other activities generating a waste load	86 b
Table 20	Frequently encountered organic contaminants in groundwater in England and Wales	69
Table 21	Attenuation processes in the aquifer unsaturated and saturated zone for various contaminant groups following a	
	point source spill	70
Table 22	Common sources of groundwater pollution from industry	71
Table 23	Hazard teatures of principal industrial and other contaminants posing a threat to underlying groundwater	73
Table 24	Assessing now soon effects of problem contaminant group are likely to affect the user/user group	/6

Table 25 Groundwater problems arising from mining activities 77 Table 26 Examples of defensive mine planning measures (based on hydrogeological and geochemical principles) applicable at different stages in the life-cycle of a mine 78 Table 27 Hydrogeological settings and dependent populations in sub-Saharan Africa 85 87

Table 28 Areas under irrigation that are affected by salinity in selected countries

GROUNDWATER AND ITS SUSCEPTIBILITY TO DEGRADATION

		Page Nos
Table 29	Summary of pesticide use and occurrences in groundwater	95
Table 30	Examples of improved sanitary protection measures for different groundwater sources	100
Table 31	Examples of localised pathway factors for different groundwater sources	101
Table 32	Examples of waste-water irrigation approaches	102
Table 33	Example of groundwater action checklist for problems affecting groundwater resources of a region	108
Plates		14
Plate 1	Groundwater resources of the world	14
Text Box	(es	
Box 1	Extract from Agenda 21	1
Box 2	What is 'climate change'?	6
BOX 3	Impact of global warning	/
Box 5	How groundwater moves	9 11
Box 6	Aquifers under stress	19
Box 7	Effects of pumping groundwater for public supply on nearby river flows—a UK example	20
Box 8	Over-exploitation of the Mehsana alluvial aguifer in India	22
Box 9	Subsidence in different aquifer systems	23
Box 10	Lack of subsidence control in the free market: Jakarta, Indonesia and Bangkok, Thailand	24
Box 11	An example of groundwater over exploitation from Inner Mongolia	25
Box 12	Examples of the impact of heavy abstraction on urban public supply borehole productivity	27
Box 13	Pollution and contamination	33
Box 14	Assessing risk to drinking water supply from on-site sanitation; designing separation distance using a pathogen	
D 45	attenuation criterion	36
BOX 15	Secondary water quality changes	38
BOX 10 Box 17	Secondary water quality changes in urban aquifers	40 41
Box 18	Vulnerability of urban aquifers: assessment examples from developing cities in Bangladesh and Kyrghyzstan	41
Box 10	Patterns of urban groundwater: rising water levels	55
Box 20	Patterns of urban groundwater: falling water levels	56
Box 21	Patterns of urban groundwater: groundwater rebound	57
Box 22	Composition of urban waste waters	60
Box 23	Groundwater contamination by pathogens: a case study from Mérida, Mexico	61
Box 24	Contaminant attenuation at work: effects on urban aquifers in Thailand and Bolivia	62
Box 25A	The engine driving water quality change: deep penetration of urban recharge in Santa Cruz	63
Box 25B	Primary and secondary water quality effects on deep groundwater in Santa Cruz	64
Box 26	Urban water supply from basement aquifers; experience from Uganda	65
Box 27	Solid waste disposal in Chiang Mai, Thailand	72
BOX 28	Pesticides in solid waste disposal site; Helpston, England	72
BOX 29 Rox 20	Halogenaled solvenis: the UK experience	77
Box 30	Groundwater pollution due to leather industries: examples from India and Mexico	74
Box 32	'No basta decir Adios' (It's not enough to say goodbye)	73
Box 33	The development of acid mine drainage (AMD) from pyrite	80
Box 34	Consequences of mine water rebound: Wheal Jane tin mine, England	81
Box 35	Contamination of potable groundwater supplies by tin mining; Ron Phibun, Thailand	82
Box 36	Example of effects of coal mining on aquifer properties: Selby coalfield, England	83
Box 37	Salinisation and waterlogging problems in the Indus valley, Pakistan	89
Box 38	Other salinisation threats to groundwater	90
Box 39	Influence of agriculture on groundwater quality in the Canary Islands	92
Box 40	Nitrate leaching below intensively cultivated soils: two examples from Sri Lanka	93
Box 41	Influence of climate on groundwater nitrate	94
BOX 42	Risk of leaching of pesticides and their derivatives from tropical agricultural soils: examples from Barbados, Sri Lanka and India	97
Box 43	Waste-water re-use for agricultural irrigation in León-Guanajuato, Central Mexico	103
Box 44	Wetlands vs irrigation: groundwater management conflicts in central Spain	106
Box 45	Realpolitik	109
Box 46	Strong economies have diverse options: the case of Israel	113
Box 47	Urban groundwater pollution monitoring and early warning network: an innovative example from West Africa	116
Box 48	Data collection to help protect the poorest communities: an African perspective	118

iii

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 CEAQ	Benzene, toluene, ethylbenzene, xylene; aromatic compounds with health guideline limits Comisión Estatal de Aguas de Querétaro (Mexico)
וסס	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
К	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)
т	Transmissivity the product of hydraulic conductivity and aquifar thickness, with values usually

预览已结束, 完整报告链接和二维码如下:



https://www.yunbaogao.cn/report/index/report?reportId=5 11843