

World Water Resources

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Water Resources and Integrated Management of the United Arab Emirates

 Springer

World Water Resources

Volume 3

Series Editor

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This series aims to publish books, monographs and contributed volumes on water resources in the world, with particular focus per volume on water resources of a particular country or region. With the freshwater supplies becoming an increasingly important and scarce commodity, it is important to have under one cover up to date literature published on water resources and their management, e.g. lessons learnt or details from one river basin may be quite useful for other basins. Also, it is important that national and international river basins are managed, keeping each country's interest and environment in mind. The need for dialog is being heightened by climate change and global warming. It is hoped that the Series will make a contribution to this dialog. The volumes in the series ideally would follow a "Three Part" approach as outlined below: In the chapters in the first Part *Sources of Freshwater* would be covered, like water resources of river basins; water resources of lake basins, including surface water and under river flow; groundwater; desalination; and snow cover/ice caps. In the second Part the chapters would include topics like: *Water Use and Consumption*, e.g. irrigation, industrial, domestic, recreational etc. In the third Part in different chapters more miscellaneous items can be covered like impacts of anthropogenic effects on water resources; impact of global warming and climate change on water resources; river basin management; river compacts and treaties; lake basin management; national development and water resources management; peace and water resources; economics of water resources development; water resources and civilization; politics and water resources; water-energy-food nexus; water security and sustainability; large water resources projects; ancient water works; and challenges for the future. Authored and edited volumes are welcomed to the series. Editor or co-editors would solicit colleagues to write chapters that make up the edited book. For an edited book, it is anticipated that there would be about 12–15 chapters in a book of about 300 pages. Books in the Series could also be authored by one person or several co-authors without inviting others to prepare separate chapters. The volumes in the Series would tend to follow the "Three Part" approach as outlined above. Topics that are of current interest can be added as well.

Readership

Readers would be university researchers, governmental agencies, NGOs, research institutes, and industry. It is also envisaged that conservation groups and those interested in water resources management would find some of the books of great interest. Comments or suggestions for future volumes are welcomed.

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Water Resources and Integrated Management of the United Arab Emirates

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ISSN 2509-7385

ISSN 2509-7393 (electronic)

World Water Resources

ISBN 978-3-030-31683-9

ISBN 978-3-030-31684-6 (eBook)

<https://doi.org/10.1007/978-3-030-31684-6>

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The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

I dedicate this volume to my mentors and friends, Professor Christopher G. St. C. Kendall (USA) and late Professor Alan E.A.M. Nairn, for their role in shaping my scientific career. (ASA)

I dedicate this volume to the love of my life, my late wife, Dr. Nagda A. Obeid; may Allah rest her soul in peace. (ZER)

Foreword

I am very pleased to present this valuable book on the UAE water resources prepared by two distinguished scholars in the field of geology and hydrogeology, Prof. Abdulrahman Sultan Alsharhan and Prof. Zeinelabidin Elsayed Rizk.

The sustainable management of water resources is a common global challenge for all countries but particularly so in an arid desert country such as the UAE with very little renewable water resources. As noted in detail in the book, there is an increasing challenge for the country to ensure provision of water—the basis of our survival—against rapidly growing demands and the onset of climate change.

Researchers are aware of the challenges facing water resources in the UAE and are working with the federal and local government entities to help increase scientific understanding and find innovative solutions.

The book is comprehensive and is comprised of 28 chapters, describing conventional and nonconventional water resources in the UAE, diagnosing the challenges facing these resources, and describing ways and means of water conservation through technical solutions and social practices. The book also includes several case studies on the use of remote sensing, geographic information systems, isotope hydrology, and modeling techniques utilized in water resource assessment in the UAE. Finally, the book analyzes the issue of water governance and discusses the importance of balancing water resource management and meeting the increasing water demand.

This book is the first of its kind to be available in the UAE in the English language. It is a remarkable achievement and fills the knowledge gap in natural resource management in the Arab world and, particularly, in the UAE. It is a highly recommended read for students and scholars alike interested not only in water resource management but also in topics such as desertification and climate change.

I congratulate the authors for developing this outstanding book and encourage others to follow their footsteps in contributing to the advancement of science in the UAE and to protect our precious natural resources.

Minister of Climate Change and Environment,
Ministry of Climate Change and Environment
Dubai, United Arab Emirates

Thani Ahmed Al-Zeyoudi

Acknowledgments

The authors of this book would like to thank His Excellency (HE) Dr. Thani Ahmed Al Zeyoudi, Minister of Climate Change and Environment (MOCCAE), United Arab Emirates (UAE), for writing the foreword and for his kind and encouraging statements in introducing this book to the Arab and international readers. Without HE's support, this publication would not have been possible.

The authors would like to thank the Ministry of Climate Change and Environment (MOCCAE), Ministry of Energy (MoE), Federal Competitiveness and Statistics Authority (FCSA), National Center of Meteorology and Seismology (NCMS), Environment Agency-Abu Dhabi (EAD), Abu Dhabi Water and Electricity Authority (ADWEA), Dubai Electricity and Water Authority (DEWA), Sharjah Electricity and Water Authority (SEWA), and Federal Electricity and Water Authority (FEWA) for the information derived from their publications and websites, which were used in the preparation of this book.

The authors would like to thank Prof. Warren W. Wood, Michigan State University, East Lansing, Michigan, United States, for his kind revision of Chap. 24 on the application of national isotopes' techniques for water resource investigations in the UAE. The authors thank Dr. Redouane Choukrallah, International Center for Biosaline Agriculture (ICBA), for his kind revision of Chap. 14 on water desalination: environmental impacts and brine management.

Gratitude and appreciation are extended to the graduate students we have supervised and graduated from UAE University (UAEU) and Ajman University (AU), who now hold key positions in the ministries responsible for water resources, academic institutions, federal and local authorities, and public services. Their theses research and recent publications were used in this book.

The authors would like to thank their families who have stood by their side and supported them to go ahead with this publication which has taken much of their time and effort. Special thanks to Dr. Ayman Z. Rizk for his help in running the iThenticate and Turnitin programs licensed for Ajman University on the book manuscript and provision of the PDF files three times for each chapter.

The authors would like to thank the administrations and colleagues in their academic institutions for their continuous support and help.

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Abbreviations

AADC	Al Ain Distribution Company
AAS	Atomic Absorption Spectrophotometry
ACI	American Concrete Institute
ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
ADDC	Abu Dhabi Distribution Company
ADSSC	Abu Dhabi Sewerage Services Company
AED	United Arab Emirates dirham
ADWEA	Abu Dhabi Water and Electricity Authority
ADWEC	Abu Dhabi Water and Electricity Company
ADFCA	Abu Dhabi Food Control Agency
AMPD	Ajman Municipality and Planning Department
amsl	Above mean sea level
AOAD	Arab Organization for Agricultural Development
As	Arsenic
ASR	Aquifer Storage Recovery
AUST	Ajman University of Science and Technology
AW	Arab world
B	Boron
BOD	Biochemical oxygen demand
Br	Bromide
BSA	Bismuth sulfite agar
BWRO	Brackish water reverse osmosis
GCC	Gulf Cooperation Council
Cd	Cadmium
Cr	Chromium
Ca ²⁺	Calcium ion
Ca(HCO ₃) ₂	Calcium bicarbonate
CaSO ₄	Calcium sulfate
CaCO ₃	Calcium carbonate
¹⁴ C	Carbon 14

CEDARE	Center for Environment and Development for the Arab Region and Europe
CDM	Clean Development Mechanism
Cl ⁻	Chloride ion
CO ₂	Carbon dioxide
CCS	Carbon capture and storage
CO ₂ /m ³	Carbon dioxide per cubic meter
CFCl ₃	Trichlorofluoromethane
CFCs	Chlorofluorocarbons
Co	Cobalt
CH ₄	Methane
CPDPs	Cogeneration Power Desalination Plants
C _u	Uniformity coefficient
Cu	Copper
DC	Direct current
DEWA	Dubai Electricity and Water Authority
DM	Dubai Municipality
DP	Desalination plant
2D	Two-dimensional
3D	Three-dimensional
DLR	German Aerospace Center
DO	Dissolved oxygen
D _d	Drainage density
DS-1	DubaiSat
DST	Defined substrate technology
DEM	Digital elevation model
DWEA	Dubai Electricity and Water Authority
EAD	Environment Agency-Abu Dhabi
ECA	Eastern coastal area
ECCD	Energy and Climate Change Directorate
EDSA	Eastern drainage southern area
EGDC	Emirates Green Development Council
EMR	Eastern mountain ranges
ECC	Energy and climate change
EPA	Environmental Protection Agency
EPD	Environmental Protection Department
EPDA	Environment Protection and Development Authority
DRDAS	Earth Resources Data Analysis System
ESCWA	Economic and Social Commission for Western Asia
ESRI	Environmental Systems Research Institute
d ₅₀	Effective grain size
EC	Electric conductance
EDN	Effluent distribution network
EC	Electrical conductivity
ED	Electrodialysis

ERWDA	Environment Research and Wildlife Development Authority
ESCWA	Economic and Social Commission for Western Asia
ET	Evapotranspiration
F ⁻	Fluoride ion
FAO	Food and Agriculture Organization
Fe	Iron
FE	Finite element
F _s	Stream frequency
ET	Evapotranspiration
FCSA	Federal Competitiveness and Statistics Authority
FEA	Federal Environmental Agency
FEWA	Federal Electricity and Water Authority
EDTA	Ethylenediaminetetraacetic acid
FAO	Food and Agriculture Organization
FM	Fujairah Municipality
FWA	Federal Water Authority
GIS	Geographic information systems
GMWL	Global meteoric water line
GCMs	Global climate models
GP	Gravel plain
GPD	Gallon per day
GCC	Gulf Cooperation Council
GDP	Gross domestic product
GHGs	Greenhouse gases
GMWL	Global meteoric water line
COM	Cabinet of Ministers
GSM	General Secretariat of Municipalities
GSO	GCC Standardization Organization
GW	Global Water Intelligence
GWRA	General Water Resources Authority
GWRO	Groundwater reverse osmosis
² H	Deuterium
³ H	Tritium
H ₂ S	Hydrogen sulfide
HMS	Hydrologic Modeling Center
HGA	HydroGeoAnalyst
HCO ₃ ⁻	Bicarbonate ion
t _{1/2}	Half-life time
dh/dl	Hydraulic gradient
ICBA	International Center for Biosaline Agriculture
IAEA	International Atomic Energy Agency
ICP-AES	Inductively coupled plasma-atomic emission spectrometry
I _c	Infiltration capacity
IP	Induced polarization
IPCC	Intergovernmental Panel on Climate Change

IDA	International Desalination Association
IRENA	International Renewable Energy Agency
Ir	Infiltration rate
ISO	International Organization for Standardization
IWA	International Water Association
IWRM	Integrated water resources management
lpcpd	Liters per capita per day
IAEA	International Atomic Energy Agency
IWACO	International Workshop on Aliasing, Confinement and Ownership
JICA	Japan International Cooperation Agency
K	Hydraulic conductivity
K ⁺	Potassium ion
KCl	Potassium chloride
Km	Kilometer
kg	Kilogram
Ks	Hydraulic conductivity of the soil layer
LDAS	Land data assimilation systems
L/d	Liters per day
L/Sec	Liter per second
Pb	Lead
Li	Lithium
LMWL	Local meteoric water line
MMWL	Mediterranean meteoric water line
Ωm	Ohm meter
M	Meter
MAF	Ministry of Agriculture and Fisheries
Mn	Manganese
Mg ²⁺	Magnesium ion
μS/cm	Microsiemens per centimeter
Mn	Manganese
MAR	Managed aquifer recharge
MAF	Ministry of Agriculture and Fisheries
μg /L	Micrograms per liter
Mo	Molybdenum
MOE	Ministry of Energy
MOEW	Ministry of Environment and Water
MSF	Multistage flash
MOFA	Ministry of Foreign Affairs
(MOCCAE)	Ministry of Climate Change and Environment
mg/L	Milligram per liter
MCM	Million cubic meters
MENA	Middle East and North Africa
MEW	Ministry of Electricity and Water
MED	Multi-effect distillation
MMWL	Mediterranean meteoric water line

MPMR	Ministry of Petroleum and Mineral Resources
MSP	Methane serpentinized peridotites
MIST	Masdar Institute of Science and Technology
MIG	Million imperial gallons
MgCl ₂	Magnesium chloride
MWE	Ministry of Water and Electricity
Na ⁺	Sodium ion
NGOs	Nongovernmental organizations
NH ₃	Ammonia
NH ₄ ⁻	Ammonium
NO ₂ ⁻	Nitrite
NO ₃ ⁻	Nitrate
NO ₃ ⁻ -N	Nitrate-Nitrogen
¹⁵ N	Nitrogen-15 isotope
NaCl	Sodium chloride
N _e	Effective porosity
Ni	Nickel
NASA	National Aeronautics and Space Administration
NCMS	National Centre of Meteorology and Seismology
NF	Nanofiltration
NDC	National Drilling Company
N ₂ O	Nitrous oxide
NH ₄ Cl	Ammonium chloride
¹⁸ O	Oxygen 18
O ₃	Ozone
Pb	Lead
PET	Potential evapotranspiration
pH	Hydrogen ion concentration
PO ₃ ²⁻	Phosphate
ppb	Part per billion
ppm	Part per million
Ps	Water surplus
R	Groundwater recharge
RSB	Regulation and Supervision Bureau
²²⁶ Rd	Radium
²²² R	Radon
R _b	Bifurcation ratio
RO	Reverse osmosis
RS	Remote sensing
STP	Sewage treatment plant
Sc	Storage coefficient
SC	Specific capacity
Se	Selenium
SEPA	Sharjah Environment and Protected Areas Authority
Sr	Strontium

Sy	Specific yield
SPC	Sewage Projects Committee
SEWA	Sharjah Electricity and Water Authority
SPOT	Earth observation satellite (French: Satellite Pour l'Observation de la Terre)
SWRO	Seawater reverse osmosis
SWI	Saltwater intrusion
SWS	Schlumberger Water Services
SAR	Sodium adsorption ratio
S _y	Specific yield
SOS	Slow-release oxygen source
Sr	Strontium
Se	Selenium
S _c	Storage coefficient
F _s	Stream frequency
SO ₄ ²⁻	Sulfate ion
TDEM	Time-domain electromagnetic method
TDS	Total dissolved solids
TH	Total hardness
T	Transmissivity
TEM	Transient electromagnetics
TDEM	Transient-domain electromagnetics
TA	Total alkalinity
TH	Total hardness
TDS	Total dissolved solids
(TDIC)	Total dissolved inorganic carbon
TM	Thematic mapper
TPH	Total petroleum hydrocarbon
TRANSCO	Abu Dhabi Transmission & Despatch Company
TSS	Total suspended solids
TU	Tritium unit
UN	United Nations
UAE	United Arab Emirates
UAEU	United Arab Emirates University
UAQ	Umm Al Quwain
UAQM	Umm Al Quwain Municipality
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United States Geological Survey
UPC	Urban Planning Council
UTM	Universal Transverse Mercator
VES	Vertical electrical soundings
VRBA	Violet red bile agar
WDC	World Dam Commission
WDCA	Western Drainage Central Area

WDNA	Western Drainage Northern Area
WHO	World Health Organization
WMO	World Meteorological Organization
WWF	World Wide Fund
Zn	Zinc