

Water Science and Technology Library

Volume 90

Editor-in-Chief

Vijay P. Singh, Department of Biological and Agricultural Engineering & Zachry
Department of Civil and Environmental Engineering, Texas A&M University,
College Station, TX, USA

Editorial Board

R. Berndtsson, Lund University, Lund, Sweden

L. N. Rodrigues, Brasília, Brazil

Arup Kumar Sarma, Department of Civil Engineering, Indian Institute of
Technology Guwahati, Guwahati, Assam, India

M. M. Sherif, Department of Anatomy, UAE University, Al-Ain, United Arab
Emirates

B. Sivakumar, School of Civil and Environmental Engineering, The University of
New South Wales, Sydney, NSW, Australia

Q. Zhang, Faculty of Geographical Science, Beijing Normal University, Beijing,
China

The aim of the *Water Science and Technology Library* is to provide a forum for dissemination of the state-of-the-art of topics of current interest in the area of water science and technology. This is accomplished through publication of reference books and monographs, authored or edited. Occasionally also proceedings volumes are accepted for publication in the series. *Water Science and Technology Library* encompasses a wide range of topics dealing with science as well as socio-economic aspects of water, environment, and ecology. Both the water quantity and quality issues are relevant and are embraced by *Water Science and Technology Library*. The emphasis may be on either the scientific content, or techniques of solution, or both. There is increasing emphasis these days on processes and *Water Science and Technology Library* is committed to promoting this emphasis by publishing books emphasizing scientific discussions of physical, chemical, and/or biological aspects of water resources. Likewise, current or emerging solution techniques receive high priority. Interdisciplinary coverage is encouraged. Case studies contributing to our knowledge of water science and technology are also embraced by the series. Innovative ideas and novel techniques are of particular interest.

Comments or suggestions for future volumes are welcomed.

Vijay P. Singh, Department of Biological and Agricultural Engineering & Zachry Department of Civil Engineering, Texas A and M University, USA
Email: vsingh@tamu.edu

More information about this series at <http://www.springer.com/series/6689>

Agnieszka Stec

Sustainable Water Management in Buildings

Case Studies From Europe

 Springer

Agnieszka Stec
The Faculty of Civil and Environmental
Engineering and Architecture, Department
of Infrastructure and Water Management
Rzeszow University of Technology
Rzeszów, Poland

ISSN 0921-092X ISSN 1872-4663 (electronic)
Water Science and Technology Library
ISBN 978-3-030-35958-4 ISBN 978-3-030-35959-1 (eBook)
<https://doi.org/10.1007/978-3-030-35959-1>

© Springer Nature Switzerland AG 2020

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Water is a key resource of nature and it is indispensable for human health and life. Water resources determine the proper functioning of sectors such as agriculture, industry, tourism, transport, and energy. Many regions in the world, including Europe, are affected by the problem of limited water availability. Freshwater resources are particularly important as their quality and quantity are constantly decreasing. Climate changes, urbanization, and population growth are expected to increase water shortages in the future causing many serious adverse environmental changes threatening current and future generations. Therefore, it is important that the management of this resource is sustainable, which requires an integrated approach taking into account the environmental, economic, and social dimensions. The European Union Water Framework Directive rightly reminds us that “*water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.*”

Considering the above, the monograph presents some possibilities of saving fresh water by using alternative sources of water in residential buildings. The attention was drawn to rainwater and gray water, which are increasingly used around the world and are a valuable source of water, especially for non-potable uses. The main purpose of the book was to show that unconventional water systems not only reduce the consumption of tap water, but can also be financially profitable. Therefore, some analyses of Life Cycle Cost rainwater harvesting systems and graywater recycling systems located in selected European cities were carried out. These locations were characterized by different climatic conditions, different water consumption by residents, and different water purchase prices. This allowed determining the impact of these parameters on the profitability of using the tested systems.

Alternative sources of water in residential buildings, in spite of the development and implementation of appropriate ecological strategies, are used quite rarely in many European countries. This can be influenced by many factors, including the financial aspect, hygiene, and legal considerations. To find out the reason for this, a survey was conducted in selected European countries and its results are presented in this monograph. Such research is very important since the acceptance of society can be decisive in implementing unconventional solutions in construction.

The research outcomes presented in the monograph are not only scientific but also practical ones and can be a guide for potential investors in the decision-making process already at the investment planning stage. This book, therefore, can contribute to the growing interest in alternative water systems in housing, and thus to promote sustainable construction.

Rzeszów, Poland

Agnieszka Stec

Acknowledgements

The author would like to thank the reviewers, namely Prof. Ing. Zuzana Vranayová, Ph.D., Professor at the Department of Building Facilities at Faculty of Civil Engineering, Technical University in Košice and Prof. Ing. Štefan Stanko, Ph.D., Professor at the Department of Sanitary and Environmental Engineering at Faculty of Civil Engineering, Slovak University of Technology in Bratislava.

The author would like to thank also the publisher—Springer Nature for providing the opportunity for this publication.

Contents

1	Introduction	1
1.1	Background	1
1.2	The Purpose and the Scope of the Work	7
	References	7
2	Water Resources	13
	References	19
3	Demand for Water in the Building	21
	References	31
4	Alternative Water Resources	33
4.1	Rainwater Harvesting	33
4.1.1	The Characteristics of Rainwater	33
4.1.2	Technical Aspects of the Use of Rainwater	36
4.2	Graywater Recycling	46
4.2.1	The Characteristics of Gray water	46
4.2.2	Graywater Recycling Systems	48
	References	58
5	Research on the Effectiveness of Systems with Alternative Water Sources for Buildings Located in Selected European Countries	61
5.1	Simulation Model of the Rainwater Harvesting System	61
5.2	The Efficiency of Rainwater Harvesting System	69
5.3	The Impact of Rainfall on Volumetric Reliability—Dry Year and Wet Year	90
5.4	Model of Graywater Recycling System	94
	References	97

6	Research on the Financial Effectiveness of Alternative Water Supply Systems in European Countries	99
6.1	Life Cycle Cost Methodology	99
6.2	Variants of Sustainable Water Management in Buildings	103
6.3	Case Studies	104
6.4	Analysis Results	110
6.4.1	Results of Life Cycle Cost Analysis	110
6.4.2	The Impact of Life Span	117
6.5	Sensitivity Analysis	123
	References	129
7	The Impact of Rainwater Harvesting on a Drainage System and a Catchment	131
7.1	Study Area	132
7.2	Results of Hydrodynamic Simulations	135
	References	139
8	Awareness and Acceptance of the Public Regarding Alternative Water Sources	141
8.1	A Description of Research Methodology	142
8.2	Survey Results and Their Analysis	142
8.2.1	Research Group Analysis	142
8.2.2	Possibilities of Using Alternative Sources in a Building	145
	References	167
9	Summary and Final Conclusions	169

Abbreviations

BOD ₅	Biochemical oxygen demand
EEA	European Environment Agency
EU	European Union
EUR	Euro
EurEau	European Federation of National Associations of Water Services
GWHS	Graywater recycling system
IRR	Internal Rate of Return
LCC	Life Cycle Cost
MBR	Membrane bioreactor
NPV	Net Present Value
PB	Payback Period
RBC	Rotating biological reactor
RWHS	Rainwater harvesting system
SBR	Sequencing batch reactor
WFD	Water Framework Directive
WHO	World Health Organization
WWAP	World Water Assessment Programme
YAS	Yield-after-spillage algorithm
YBS	Yield-before-spillage algorithm