WASTEWATER REUSE POTENTIAL IN SANA'A BASIN

By

Abdullah Mohammed Ali Derhem

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Irrigation and Hydraulics Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2016

WASTEWATER REUSE POTENTIAL IN SANA'A BASIN

By
Abdullah Mohammed Ali Derhem

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Irrigation and Hydraulics Engineering

Under the Supervision of

Prof. Dr. Abdallah Sadik Bazaraa

.....

Professor of Irrigation and Drainage
Irrigation and Hydraulics Department
Faculty of Engineering, Cairo University

Dr. Mohamed Hamdy Nour

.....

Associate Professor
Irrigation and Hydraulics Department
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2016

WASTEWATER REUSE POTENTIAL IN SANA'A BASIN

By
Abdullah Mohammed Ali Derhem

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Irrigation and Hydraulics Engineering

Approved by the
Examining Committee

_____
Prof. Dr. Abdallah Sadik Bazaraa, Thesis Main Advisor

_____
Dr. Mohamed Hamdy Nour, Member

_____
Prof. Dr. Mohamed Mohamed Salama, Internal Examiner

_____
Prof. Dr. Tarek Ismail Sabry, External Examiner
(Prof of Sanitary & Environmental Engineering, Faculty of Engineering, Ain Shams University)

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2016

Engineer's Name: Abdullah Mohammed Ali Derhem
Date of Birth: 1/1/1983
Nationality: Yemeni
E-mail: alanamyabdullah@gmail.com
Phone: 00201122773041
Address: 39 Noor-Alsabah, Faisal, Giza, Egypt

Registration Date: 1/3/2013
Awarding Date: 2016
Degree: Master of Science
Department: Irrigation and Hydraulics Engineering

Supervisors:

Prof.Dr. Abdallah Sadik Bazaraa
Dr. Mohamed Hamdy Nour

Examiners:

Prof. Dr. Tarek Ismail Sabry (External examiner)
(Prof of Sanitary & Environmental Engineering, Faculty of Engineering, Ain Shams University)
Prof. Dr. Mohamed Mohamed Salama (Internal examiner)
Porf. Dr. Abdallah Sadik Bazaraa (Thesis main advisor)
Dr. Mohamed Hamdy Nour (Member)

Title of Thesis:

Wastewater Reuse Potential in Sana'a Basin

Key Words:

Sana'a Basin; Wastewater Reuse; GIS; Hydraulic Analysis; Economic Analysis

Summary:

Reuse of wastewater in agriculture is considered one of the most recommended alternatives for alleviation of water shortage in Sana'a Basin, Yemen. The results showed that the reuse of wastewater can cover up to 30% of the agriculture demand, and can increase the period of usable groundwater resources from 20 years to 35 years. However, the results of economic analysis for different scenarios of reuse under the proposed cropping pattern showed that it is feasible under gravity conveyance, while the economic return is not attractive under pressurized systems. Government support to implement the reuse options is required for environmental protection and social welfare.

Acknowledgments

In this at the beginning and the end, all praise and thanks to Allah for giving me the patience and perseverance to successfully accomplish my MSc program.

I would like to express my special thanks to my supervisors; Prof. Dr. Abdallah Sadik Bazaraa, and Dr. Mohamed Hamdy Nour for their generous support, their encouragement, patience, and their invaluable guidance during all phases of this research. I feel the need to thank them from the bottom of my heart for giving me the opportunity to be here and pursue my dream. I will always look up to them with the deepest appreciation.

I would like to thank Prof. Dr. Mohamed Mohamed Salama and Prof. Dr. Tarek Ismail Sabry for their great effort in review and valuable comments.

I wish express my profound gratitude to Dr. Sharfeldeen Ahmad, and Dr. Fadhl Alnozaily for their support and encouragement.

I would like to thank NWRA-SB especially Mr. Saleh AL-Dabi (the head manager), for supporting me with data, and help which is the starting point for my research. Also, I would like to express my deep appreciation to all my friends for their advice and help.

My sincere thanks also go to all the professors of the Irrigation and Hydraulic Engineering Department at Cairo University for all the knowledge I gained in my graduate courses.

I will be forever grateful to my parents, my wife and my sons for their continuous support and encouragement that helped me to overcome difficulties during my whole life, my study and my research.

Table of Contents

List of Tables

List of Figures

Nomenclature

BOD	Biological oxygen demand (mg/l)
CLIMWAT	Climatic database to be used in calculation of crop water requirements, irrigation supply and irrigation scheduling for various crops for a range of climatological stations worldwide.
COD	Chemical oxygen demand
EIA	Environmental impact assessment
EPA	US Environmental Protection Agency
FC	Fecal Coliform
TSS	Total Suspended Solids
USAID	U.S. Agency for International Development
WASP	Water Quality Analysis and Simulation Program
WWTP	Wastewater Treatment plant
GIS	Geographic Information System
DPPR	(The third Socio-Economic) Development Plan for Poverty Reduction
ETa	Actual Evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
JICA	Japan International Cooperation Agency
MAI	Ministry of Agriculture and Irrigation
MWE	Ministry of Water and Environment
NWRA	National Water Resources Authority
NWRA-SB	National Water Resources Authority Sana'a Branch
NWSA	National Water and Sanitation Authority
SBWMP	Sana'a Basin Water Management Project
SWSLC	Sana'a Water Supply and Sanitation Local Corporation
WEC	Sana'a University Water and Environment Centre
WHO	World Health Organization
U.S. EPA	United State Environmental Protection Agency