

# **Suitability of Wastewater for Irrigation in Saudi Arabia: Analysis of Public Perceptions and Quantitative Microbial Risk Assessment**

Thesis submitted for the degree of Doctor of Philosophy

by

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## Contents

<b>Table of Contents</b>	<b>i-iv</b>
<b>List of Figures</b>	<b>v-vii</b>
<b>List of Tables</b>	<b>viii-x</b>
<b>Abbreviations and Acronyms</b>	<b>xi-xii</b>
<b>Abstract</b>	<b>xiii-xiv</b>
<b>Introduction</b>	<b>1-27</b>
<b>Review of Literature</b>	<b>28-79</b>
<b>Methodology</b>	<b>80-134</b>
<b>Quantitative Microbial Risk Assessment</b>	<b>135-162</b>
<b>Perceived Risk Assessment</b>	<b>163-237</b>
<b>Discussion</b>	<b>238-275</b>
<b>Summary and Recommendations</b>	<b>276-294</b>
<b>References</b>	<b>295-346</b>
<b>Appendices</b>	<b>347-388</b>

## Table of Contents

<b>Chapter 1 Introduction</b>		<b>1-27</b>
1.1	Global Situation of Water Resources	2
1.2	Saudi Arabia: Key Factors Affecting Water	3
1.2.1	Topography and Climatic Conditions	3
1.2.2	Domestic Water Consumption	8
1.2.3	Agriculture in Saudi Arabia	8
1.3	Conventional and Non-Conventional Water Resources in Saudi Arabia	10
1.3.1	Surface Water	10
1.3.2	Ground Water	11
1.3.3	Desalinated Water	11
1.3.4	Wastewater	12
1.4	Water shortfall in Saudi Arabia	12
1.5	Government Policies about Water	13
1.6	Integrated Water Resources Management in Saudi Arabia	18
1.7	Rationale for the Study	21
1.8	Research Objectives and Key Activities	23
1.9	Structure of the Thesis	25
<b>Chapter 2 Review of Literature</b>		<b>28-79</b>
2.1	Wastewater Utilisation: A Historical Perspective	28
2.2	Evolution of Knowledge and Legislation related to Microbial Risks associated with Wastewater	34
2.3	Research Methodologies for Microbial Risk Assessment	40
2.4	Empirical Research related to Wastewater Usage and Hazards	43
2.4.1	Evidence from Epidemiological Studies	43
2.4.2	Evidence from Microbial Analyses	47
2.4.3	Evidence from Quantitative Microbial Risk Assessments [QMRA]	58
2.4.4	Evidence from Review Articles	59
2.5	Public Perceptions about Wastewater Reuse	65
2.5.1	Public Perceptions in United States of America	65

2.5.2	Public Perceptions in Europe and Australia	67
2.5.3	Public Perceptions in Asian Countries	68
2.5.4	Public Perceptions in the Middle East	69
2.5.5	Public Perceptions in African Nations	71
2.5.6	Use of Wastewater from Islamic Perspective	73
2.5.7	Ways to Increase Public Acceptance	74
2.6	Conclusions	77
<b>Chapter 3 Methodology</b>		<b>80-134</b>
3.1	Site Selection	82
3.1.1	Al-Hassa Region	82
3.1.2	Tabouk Region	85
3.2	Scientific Risk Assessment	87
3.2.1	Design Approach to QMRA	87
3.2.2	Field Work related to QMRA	91
3.2.3	Laboratory Procedures related to QMRA	99
3.2.4	QMRA Data Analysis	104
3.3	Public Perceptions about Wastewater Usage in Agriculture	106
3.4	Statistical Data Analyses	127
3.4.1	Descriptive Statistical Analyses	128
3.4.2	Inferential Statistical Analyses	129
3.4.3	Reliability Analysis	131
3.4.4	Validity Analysis	132
3.5	Summary and Conclusions	133
<b>Chapter 4 Quantitative Microbial Risk Assessment</b>		<b>135-162</b>
4.1	Assessment of Water Quality at Al-Hassa	135
4.2	Effect of Physicochemical Parameters on <i>E. coli</i> Concentrations	143
4.3	Comparative Efficiency of Wastewater Treatment Plants at Al-Hassa and Tabouk	149
4.4	Batch Experiment: <i>E. coli</i> Regrowth under Laboratory Conditions	150
4.5	Risks associated with Consumption of Vegetables produced through Unrestricted Wastewater Irrigation [Al-Hassa]	152

<b>Chapter 5 Perceived Risk Assessment</b>		<b>163-237</b>
5.1	Farmers' Perceptions	163
5.1.1	Descriptive Analyses	163
5.1.2	Perceptions about Wastewater	172
5.1.3	Inferential Statistical Analyses	182
5.1.4	Reliability and Validity Analyses	192
5.2	Consumers' Perceptions	201
5.2.1	Descriptive Analyses	201
5.2.2	Perceptions about Wastewater	206
5.2.3	Inferential Statistical Analyses	214
5.2.4	Reliability and Validity Analyses	233
<b>Chapter 6 Discussion</b>		<b>238-275</b>
6.1	Scientific Risk Assessment	239
6.1.1	Water Quality in Different Sources	239
6.1.2	Physicochemical Properties of Irrigation Water	241
6.1.3	Effect of Location and Season on Microbial Concentrations	243
6.1.4	Efficiency of Treatment Plants	245
6.1.5	Reasons for Fluctuations in E. coli Concentrations	245
6.2	Public Risk Perceptions	248
6.2.1	Respondents' Profiles	248
6.2.2	Farm Types and Farming Practices	249
6.2.3	Perceptions about Wastewater	250
6.2.4	Conjoint Choices of Farmers and Consumers	261
6.2.5	Simulations of Farmers and Consumers' Willingness to Pay	265
6.3	Study Limitations	269
6.4	Conclusions	271
<b>Chapter 7 Summary and Recommendations</b>		<b>276-294</b>
7.1	Scientific Risk Assessment	277
7.2	Public Risk Perceptions and Acceptance of Wastewater Usage	280
7.3	Contributions to Knowledge	284
7.4	Recommendations	285
7.5	Future Research Directions	290
<b>References</b>		<b>295-346</b>

<b>Appendices</b>		<b>347-388</b>
<b>Appendix 1</b>	Guide for Focus Group Discussions	347
<b>Appendix 2</b>	Questionnaire for Farmers' Survey	351
<b>Appendix 3</b>	Questionnaire for Consumers' Survey	369
<b>Appendix 4</b>	Dataset for QMRA	388

## List of Figures

1.1	Water Scarcity Projections to 2050	2
1.2	Water Stress Countries and Water Scare Regions	3
1.3	Geographical location of Kingdom of Saudi Arabia	4
1.4	Study Objectives	25
2.1	Historical Developments in Wastewater Usage	32
2.2	Wastewater Use: Typologies and Risks	33
2.3	Wastewater Usages around the World	33
2.4	The Integrated Nature of Stockholm Framework	38
2.5	Microbial Risk Assessment Methodologies and Guidelines	43
2.6	Acceptance of Wastewater reuse: Factors at National and Personal levels	76
3.1	Phases of Study Design, Data Collection and Analysis	81
3.2	Geographical Locations of the Study Regions	83
3.3	Sources of Irrigation water in Al-Hassa Region	85
3.4	Land use for Agricultural Production in Tabouk	86
3.5	Wastewater Treatment Facilities in Tabouk and Al-Hassa	88
3.6	Phase I-Sampling from different sources in Al-Hassa	93
3.7	Phase II-Sampling from main and sub-main Canals	93
3.8	Sampling points from Main and Sub-main Canals	94
3.9	Measuring Physiochemical Properties of Irrigation Water	95
3.10	Phase III-Sampling from Treatment Plants	95
3.11	Hypothetical Re-growth of <i>E. coli</i> in Irrigation System of Al-Hassa	97
3.12	Sources of Contamination in Drainage Water	98
3.13	Phase IV-Experimental Set up	99
3.14	Key Steps in Membrane Filtration Method	103
3.15	Key Steps in Modified Bailenger Method	103
3.16	Data Collection for Public Perceptions Survey	108
3.17	Choice Modelling for Consumers' Conjoint Analysis	123
3.18	Data Collection in Al-Hassa	126
3.19	Statistical Data Analysis: Choice of Methodologies	134

4.1	Constitution of Irrigation Water at Source [Al-Hassa]	136
4.2	Mean <i>E. coli</i> concentrations in water from various sources	137
4.3	Trends in <i>E. coli</i> Concentrations in the Irrigation Canals	140
4.4	Growth of <i>E. coli</i> under Laboratory Conditions	151
5.1	Farmers' Profile: Age, Education and Number of children per Households	164
5.2	Major Sources of Information for Farmers	166
5.3	Irrigated Farm Area in Al-Hassa and Tabouk	167
5.4	Irrigation Sources at Al-Hassa and Related Information	170
5.5	Comparisons of Irrigation Methods and Systems	171
5.6	Perceptions about the Reasons, Risks and Permissibility of Wastewater Irrigation	173
5.7	Acceptability of various uses of wastewater	176
5.8	Perceptions of Risks according to Crops and Exposure	178
5.9	Satisfactions with Quantity and Quality of Irrigation Water	181
5.10	Farmer's Perceptions- Selection of factors [Scree Plot]	200
5.11	Farmers' Perceptions - Components' Plot in Rotated Space	200
5.12	Consumers' Profile based on Gender, Age, Education, No. of Children and Monthly Income	203
5.13	Key Sources of Information about Methods of Agricultural Production (%)	203
5.14	Purchasing Habits by Type of Market and Frequency of Purchase	205
5.15	Effect of Stage of Production on the Quality of Vegetables	206
5.16	Consumer's Perceptions about the Reasons, Risks and Permissibility of Wastewater Irrigation	207
5.17	Consumer's Acceptability of Uses of Wastewater	210
5.18	Consumers' Perceptions of Health Risks from Crops irrigated with Wastewater	211
5.19	Consumers' Perceptions about Effectiveness of Public Health and Safety Rules and Responsibilities	213
5.20	Consumer's Perceptions- Selection of factors [Scree Plot]	236
5.21	Consumers' Perceptions - Components' Plot in Rotated Space	236
6.1	Factors affecting <i>E. coli</i> Concentrations in Irrigation System	248
6.2	Permissibility of Wastewater Blended Irrigation under Varying International Guidelines and Risk Perceptions from Public	274



7.1	Comparisons of Physicochemical Properties and Microbial Concentrations in Al-Hassa Irrigation Water with International Guidelines and Standards	279
7.2	Comparisons of Public Acceptance levels in Al-Hassa and Tabouk with International Communities	283
7.3	Proposed Strategic Policy Actions and Future Research related to Wastewater in Saudi Arabia	294

## List of Tables

1.1	Climatic Indicators of Saudi Arabia [1980 to 2009]	6
1.2	Water Requirements of Major Crops grown in North-western Saudi Arabia	9
1.3	Major Crop Yields in Saudi Arabia	10
1.4	Sources of Water Demand and Supply in Saudi Arabia	14
2.1	Hazards associated with Wastewater use in Agriculture	37
2.2	Epidemiological Evidence of Microbial Hazards related to Wastewater Usage	45
2.3	Evidence of Microbial Hazards related to Wastewater Usage through Microbial Analysis	50
2.4	Evidence of Microbial Hazards related to Wastewater Usage through QMRA and MC Simulations	60
3.1	Summary of Sampling Activities in various Phases	100
3.2	Key Inputs for QMRA-MC Simulations	107
3.3	Learning derived through the Focus Group Discussions	112
3.4	Extraction of major themes and Likert Scale ratings used in the Farmers' Questionnaire	118
3.5	Extraction of major themes and Likert Scale ratings used in the Consumers' Questionnaire	121
4.1	Helminth eggs counts (egg/l) in various water sources	138
4.2	Helminth eggs counts (egg/l) in Irrigation Canals	139
4.3	Differences in Mean <i>E. coli</i> Concentrations [Main Canal]	142
4.4	Differences in Mean <i>E. coli</i> Concentrations [Sub-canal]	142
4.5	Physicochemical Parameters* and <i>E. coli</i> Concentration in Main canal F1 [Mean and SD**]	145
4.6	Physicochemical Parameters* and <i>E. coli</i> Concentration in Sub-canal F1.1 [Mean and SD**]	146
4.7	<b>Correlations Analysis: <i>E. coli</i> and Physicochemical Parameters [Summer]</b>	148
4.8	<b>Correlations Analysis: <i>E. coli</i> and Physicochemical Parameters [Winter]</b>	148
4.9	Wastewater Quality and Efficiency of Treatment Plants	150

4.10	Tolerable Additional Burden of Disease for Reference Pathogens	153
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4.11	<b>Median and 95 percentile <i>Ascaris</i> infection risks from unrestricted irrigation [sampling points where <i>Ascaris</i> eggs were recovered]</b>	<b>153</b>
4.12	Median and 95-percentile infection risks from the consumption of 74.8 g/day of tomato irrigated with main canal water	157
4.13	Median and 95-percentile infection risks from the consumption of 74.8 g/day of tomato irrigated with sub-canal water	158
4.14	Median and 95-percentile infection risks from the consumption of 21.4 g/day of cucumber irrigated with main canal water	159
4.15	Median and 95-percentile infection risks from the consumption of 21.4 g/day of cucumber irrigated with sub-canal water	160
4.16	Median and 95-percentile infection risks from the consumption of 5.7 g/ 3 to 5 days per week of okra irrigated with main canal water	161
4.17	Median and 95-percentile infection risks from the consumption of 5.7 g/ 3 to 5 days per week of okra irrigated with sub-canal water	162
5.1	Farmers' Preferences for Irrigation Source and Tariff and Product Yield and Quality	183
5.2	Differences in the Mean Rankings of Farmers' agreement to the Reasons for Wastewater Usage [Likert scale 1 to 5; 5 = highest agreement]	187
5.3	Differences in the Mean Rankings of Farmers' Acceptability of Wastewater Uses [Likert scale 1 to 5; 5 = highest acceptability]	188
5.4	Differences in the Mean Rankings of Farmers' Risk Perceptions from Crops irrigated with Wastewater [Likert scale 1 to 6; 6 represented the extreme risk]	190
5.5	Differences in the mean rankings of Farmers' Risk Perceptions from variable Exposure Levels with Wastewater [Likert scale 1 to 7; 7 represented the extreme risk]	191
5.6	Correlation Analysis: Farmers' Agreement to Reasons for Wastewater Usage [Al-Hassa n = 300; Tabouk n=: 193]	193
5.7	Correlation Analysis: Farmers' Perceptions about various	194

	Uses of Wastewater [Al-Hassa, n = 300]	
5.8	Correlation Analysis: Farmers' Perceptions about various Uses of Wastewater [Tabouk, n = 193]	195
5.9	Correlation Analysis: Farmers' Risk Perceptions from Wastewater Irrigated Crops [Al-Hassa n = 300; Tabouk n=: 193]	196
5.10	Correlation Analysis: Farmer's Risk Perceptions from Wastewater Exposure [Al-Hassa n = 300; Tabouk n=: 193]	196
5.11	Cronbach's Alpha values for Farmer's Reponses	197
5.12	Farmers' Perceptions-Rotated Factor Analysis Solution	199
5.13	Consumer' Preferences for buying Vegetables	216
5.14	Conjoint Models: Relative Importance of Irrigation, Origin, Price and Risks in Consumers' Preference for Vegetable Products	217
5.15	Ideal Products based on Consumer's Preferred Attributes	218
5.16	Differences in the Mean Rankings of Consumers' Agreement to the Reasons for Wastewater Usage [Likert scale 1 to 5; 5 = highest agreement]	221
5.17	Differences in the Mean Rankings of Consumers' Acceptability of Wastewater Uses [Likert scale 1 to 5; 5 = highest acceptability]	222
5.18	Differences in the Mean Rankings of Consumers' Risk Perceptions from Crops irrigated with Wastewater [Likert scale 1 to 6; 6 represented the extreme risk]	224
5.19	Differences in the Mean Consumers' Perceptions about Effectiveness of authorities/regulation and Safety Responsibilities at Personal and Public levels [Likert scale 1 to 7; 7 represented the extreme agreement]	225
5.20	Correlation Analysis: Consumers' Agreement to Reason for Wastewater Usage [Al-Hassa n = 200; Tabouk n=: 177]	228
5.21	Correlation Analysis: Consumers' Perceptions about various Uses of Wastewater [Al-Hassa, n = 200]	229
5.22	Correlation Analysis: Consumers' Perceptions about various Uses of Wastewater [Tabouk, n = 177]	230
5.23	Consumers' Risk Perceptions from Wastewater Irrigated Crops [Al-Hassa n = 200; Tabouk n=: 177]	231

5.24	Correlation Analysis: Consumers' Perceptions about the Effectiveness of authorities/regulations and Safety Responsibilities at Personal and Public levels [Al-Hassa n = 200; Tabouk n=: 177]	232
5.25	Cronbach's Alpha values for Consumers' Reponses	234
5.26	Consumers' Perceptions-Rotated Factor Analysis Solution	235
6.1	Simulated Scenarios of Farmers and Consumer' Willingness to Pay for Wastewater	266
6.2	Conjoint Simulations of Farmers' Preferences	268
6.3	Conjoint Simulations of Consumer's Preferences	268

## Abbreviations and Acronyms

ANOVA	Analysis of variance
AT	Air Temperature
AWWA	American Water Works Association
CDSI	Central Department of Statistics and Information
cfu	colony forming units
CLIS	Council of Leading Islamic Scholars
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DALYs	Disability Adjusted Life Years
DO	Dissolved Oxygen
ds/m	deciSiemens/m
<i>E. coli</i>	<i>Escherichia coli</i>
EC	Electrical Conductivity
EPA	Environmental Protection Agency
FAO	Food and Agriculture organisation
FGDs	Focus Group Discussions
ha	hectares
HIDA	Irrigation and Drainage Association
IMF	International Monetary Fund

Km	Kilometre
Km <sup>2</sup>	Square kilometre
KSA	Kingdome of Saudi Arabia
l/c/d	Litre per capita per day
m <sup>3</sup>	Cubic metre
MAW	Ministry of Agriculture and Water
MENA	Middle East and North Africa
MEP	Ministry of Economy and Planning
mg/l	milligram per litre
ml	millilitre
MOA	Ministry of Agriculture
MOWE	Ministry of Water and Electricity
MPN	Most Probable Number
ppm	parts per million
QMRA	Quantitative Microbial Risk Assessment
QMRA-MC	Quantitative Microbial Risk Analysis—Monte Carlo
RC	Residual Chlorine
RIRA	Recycled water Irrigation Risk Analysis
SA	Saudi Arabia
SD	Standard Deviation
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
TURB	Turbidity
UN	United Nations
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Emergency Fund
UNPD	United Nations Population Division
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation

WT	Water temperature
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# **Suitability of Wastewater for Irrigation in Saudi Arabia: Analysis of Public Perceptions and Quantitative Microbial Risk Assessment**

## **Abstract**

Wastewater reuse for irrigated practice is an alternative solution in which food production can be improved especially in the arid-region where freshwater resources are often limited. However; the potential public health risk associated with wastewater reuse remain a major concern, as well as public perceptions towards wastewater. This research was conducted in two main agricultural cities within the Saudi Arabia, namely Al-Hassa having experience of unrestricted irrigation project and Tabouk where wastewater reuse project has not been developed. The study aimed at quantifying microbial risks through standard QMRA methodology as well as assessing the perceived risks from public and their acceptability of wastewater uses. Using *helminth* eggs and *Escherichia coli* as indicators, QMRA results showed that the microbial concentrations exceeded the levels permissible under Saudi standards yet based on QMRA-MC simulations, vegetables produced with unrestricted irrigation of wastewater were safe for human consumption after washing and traditional treatment with lemon and vinegar in line with WHO 2006 guidelines. The public perceptions based on Likert scale ratings of 493 farmers and 377 consumers showed that familiarity with wastewater reuse reduced the level of concerns leading to greater acceptability of proposed uses. The degree of acceptability moved on a

continuum with high approval for outdoor applications on one end and high rejection of uses involving personal contact and hygiene. A set of policy recommendations aimed at increasing the use of wastewater in Saudi Arabia has been put forward emphasizing the need to progress on short to medium and long-term activities concurrently through coordination between key players and stakeholders.

**Keywords:** Wastewater reuse, Irrigation, Public attitude, risk assessment, wastewater quality, Microbial aspects.