

CONTENTS

Acknowledgements	i
Executive summary	iii
List of tables	xii
List of figures	xv
Abbreviations	xviii

Chapter 1 Introduction 1-5

1.1	General	1
1.2	Introduction	1
1.3	Motivation for the present study	3
1.4	Objectives of the study	4
1.5	Organization of the thesis	4

Chapter 2 Literature Review 6-40

2.1	General	6
2.2	Definitions related to water quality	6
2.2.1	Quality of the aquatic environment	6
2.2.2	Pollution of the aquatic environment	7
2.3	Water use and water quality	7
2.3.1	Factors affecting water quality	7
2.4	Water Quality Assessment	9
2.4.1	Objectives of water quality assessment	10
2.5	Water Quality Monitoring	11
2.6	Policies and Regulations for Water Quality Management in India	21
2.7	Water Quality Management in India	24
2.8	Assessing Water Quality: Review of literature	24
2.8.1	Water Quality Index	24
2.8.2	Review of significant Water Quality Indices	25
2.8.3	Other Water Quality Indices	29
2.8.4	Critical appraisal of earlier studies for water quality assessment for Indian rivers and scope of work	31
2.9	Assessing Urbanization: Review of literature	32

2.10	Impact of Urbanization on Water quality	34
2.10.1	Population Impacts on Water Quality	34
2.10.2	Impacts of Erosion and Sedimentation	34
2.10.3	Impacts of Urban runoff	35
2.10.4	Impacts of Industrial waste water discharges	35
2.11	Assessing impact of urbanization on water quality: Review of literature	35
2.12	Scope of work with reference to the studies reported in the literature	39

Chapter 3 Development of Water Quality - Urbanization 41-72

Regression (WQURM) model

3.1	Introduction	41
3.2	Methodology	41
3.2.1	Water Quality Index model	43
3.2.1.1	Introduction	43
3.2.1.2	Selection of parameters for water quality index model formulation	43
3.2.1.2.1	Sewage and municipal wastewater	43
3.2.1.2.2	Urban run-off	43
3.2.1.2.3	Agricultural activities	44
3.2.1.3	Input parameters for the Water Quality Index model	44
3.2.1.4	Effect of water quality parameters on water quality	45
3.2.1.4.1	Effect of pH	45
3.2.1.4.2	Effect of Dissolved oxygen	45
3.2.1.4.3	Effect of biological oxygen demand	45
3.2.1.4.4	Effect of total dissolved solids/electrical conductivity	46
3.2.1.4.5	Effect of Nitrate Nitrogen	46
3.2.1.4.6	Effect of micro-organisms	47
3.2.1.5	Development of a rating scale to obtain the rating value (Vr) for each parameter	47
3.2.1.5.1	pH	48
3.2.1.5.2	Dissolved oxygen (DO)	48

	3.2.1.5.3	Biochemical oxygen demand (BOD)	48
	3.2.1.5.4	Total coliform	49
	3.2.1.5.5	Nitrate nitrogen	49
	3.2.1.5.6	Electrical conductivity	49
	3.2.1.6	Estimating the Weighing factor of each indicator parameter (W_i)	50
	3.2.1.6.1	Weightage of each parameter	50
	3.2.1.6.2	Derivation of the weightage of each parameter	51
	3.2.1.6.3	Weighing factor of each parameter	52
	3.2.1.7	Development of the sub-index value ($W_i \times V_r$) for each water quality parameter	52
	3.2.1.8	Development of Water Quality Index (WQI)	53
3.2.2		Urbanization Index Model	53
	3.2.2.1	Urbanization	53
	3.2.2.2	Selection of parameters for Urbanization Index model	54
	3.2.2.2.1	Demographic aspect	55
	3.2.2.2.2	Economic development aspect	56
	3.2.2.2.3	Spatial aspect	56
	3.2.2.2.4	Infrastructural development aspect	57
	3.2.2.3	Development of urbanization scale for each of the urbanization parameter	57
	3.2.2.3.1	Population size	58
	3.2.2.3.2	Population density	58
	3.2.2.3.3	Number of industries	59
	3.2.2.3.4	Built- up area	59
	3.2.2.3.5	Roofing types	59
	3.2.2.3.6	Electricity Facilities	59
	3.2.2.3.7	Educational Facilities	60
	3.2.2.3.8	Health Services	60
	3.2.2.3.9	Assets	60
	3.2.2.4	Urbanization Score of a district	64
	3.2.2.5	Urbanization Index of a district	65
	3.2.2.6	Urbanization Index of Catchment of Station	65

3.2.2.7	Development of Classes of Urbanization in this study	69
3.2.3	Water Quality- Urbanization Regression model (WQURM)	70
Chapter 4 Application of the model		73-95
4.1	Introduction	73
4.2	Description of Sabarmati river basin	73
4.2.1	Overview of basin	73
4.2.1.1	Topography	74
4.2.1.2	Climate	75
4.2.1.3	Rainfall	76
4.2.1.4	Temperature	76
4.2.2	Sabarmati river and its tributaries	76
4.2.3	Land use/land cover	78
4.2.4	Hydrological units	80
4.2.4.1	Sub-basins	80
4.2.4.2	Watersheds	80
4.2.5	Pace of Urbanisation and Increase in Urban Water Use	83
4.2.6	Industries in Sabarmati river basin	83
4.2.7	Sabarmati river pollution status	83
4.3	Data base for Sabarmati river basin	84
4.3.1	Details of stations selected on Sabarmati river and its tributaries	84
4.3.2	Data base for Water Quality	86
4.3.3	Data base For Urbanization level of districts in Sabarmati river basin	92
4.4	System for application	94
Chapter 5 Results and Discussions		96-127
5.1	Introduction	96
5.2	Water Quality Index model	96
5.2.1	Results of Water Quality Index model	96
5.2.2	Observations on Water quality of Sabarmati river	98
5.2.3	Seasonal variation of Water quality Index for the stations on Sabarmati river	103

5.3	Urbanization Index model	106
5.3.1	Results of Urbanization Index model	106
5.3.2	Urbanization index of the catchment of the stations	109
5.3.2.1	Urbanization Index for catchment area of Station S_3	110
5.3.2.2	Urbanization Index for the catchment area of station S_5 and S_2	111
5.3.2.3	Urbanization Index for the catchment area of Stations S_1 and S_4	113
5.4	Results of Urbanization Index in Sabarmati river basin	118
5.5	Results of Water Quality Index and Urbanization Index in Sabarmati river basin	118
5.6	Correlation between Water quality and Urbanization	119
5.7	Water Quality - Urbanization Regression model (WQURM)	121
5.8	Observed versus predicted plot for the Water Quality - Urbanization Regression Model	125
5.9	Summary of the Results	126
Chapter 6 Validation of models		128-164
6.1	Introduction	128
6.2	Validation of Water quality index model	128
6.2.1	Derivation of weightage of each parameter by Experts opinion (Delphi technique)	128
6.2.2	Water Quality Index (WQI) of the five stations by Delphi technique	129
6.3	Validation of water quality index model developed in the study by comparison with Delphi technique	131
6.4	Validation of Urbanization Index model	131
6.5	Validation of Water Quality - Urbanization Regression model (WQURM)	133
6.5.1	The Mahi river basin	133
6.5.2	Data base for Water Quality at Mahi River Basin	137
6.5.3	Data base for Urbanization level of districts on Mahi river basin	141
6.5.4	Water Quality Index of Stations on Mahi River	143

6.5.5	Urbanization Index of districts located on Mahi river basin	143
6.5.6	Computation of the urbanization index of the catchment of the stations on Mahi river	145
6.5.6.1	Urbanization Index for catchment area of Station M ₁	146
6.5.6.2	Urbanization Index for catchment area of Station M ₂ , M ₃ and M ₄	147
6.5.7	Results of Water Quality Index and Urbanization Index of the stations on Mahi river	159
6.5.8	Water Quality- Urbanization Regression model (WQURM) validation on Mahi river	159
6.6	Framing hypothesis and adopting the test of statistical significance of the WQURM model applied on Sabarmati river	163
Chapter 7 Conclusions		165-169
7.1	General	165
7.2	Conclusions	165
7.3	Research Contributions	165
7.4	Scope of future work	169
References		170-182
Appendix		183-224
	Appendix I EC Drinking Water Standards	183
	Appendix II EC bathing water standards	184
	Appendix III Designated Best Use Classification of Surface water (CPCB Standards)	184
	Appendix IV IS 10500 Drinking Water Specification (Second revision)	185
	Appendix V WHO Guidelines for drinking water quality WHO, Geneva, 1984	185
	Appendix VI Distribution of Population, Decadal Growth Rate and Population Density for Gujarat	187
	Appendix VII Population data base for Rajasthan (districtwise), Census of India, 2011	188

Appendix VIII Population Density data for Rajasthan (districtwise), Census of India	189
Appendix IX Data of Households with main source of lighting for Gujarat (districtwise), Census of India, 2011	191
Appendix X Data of Households with main source of lighting for Rajasthan (districtwise), Census of India, 2011	196
Appendix XI Census Houses By Predominant Material Of Roof data for Gujarat, Census of India, 2011	202
Appendix XII Census Houses By Predominant Material Of Roof data for Rajasthan, Census of India, 2011	205
Appendix XIII Assets data base for Gujarat (districtwise), Census of India,2011	210
Appendix XIV Assets data base for Rajasthan (districtwise), Census of India,2011	215
List of papers from the present research	225-226