

**ASSESSMENT OF DRINKING WATER QUALITY AND  
AVAILABILITY THROUGH RAINWATER HARVESTING  
IN AN ARID REGION**

*By*

**Avadhesh Kumar Singh Bhadauria**

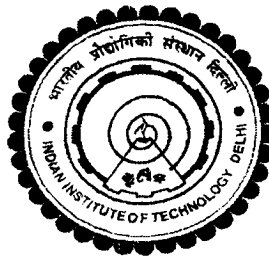
Centre for Rural Development and Technology

*Submitted*

*In fulfillment of the requirements  
for the award of the degree of*

**DOCTOR OF PHILOSOPHY**

*to the*

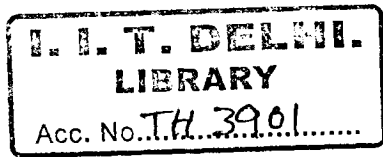


**INDIAN INSTITUTE OF TECHNOLOGY, DELHI**

New Delhi-110016, INDIA

September-2008

account of drinking water; Rainwater harvesting.



TH  
E28.1.037  
BHA-A



*Dedicated*

*To*

*My Parents,*

*Lord Mahakaleshwar,*

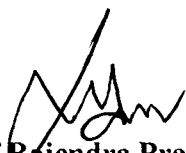
*Wife Dr. (Smt.) Aruna,*

*Children Miss. Esha, and Master Shubham.*

## CERTIFICATE

This is to certify the thesis entitled “**Assessment of drinking water quality and availability through rainwater harvesting in an arid region**” being submitted by Mr. Avadhesh Kumar Singh Bhadauria to the Indian Institute of Technology, Delhi, India, for the award of the degree of “**DOCTOR OF PHILOSOPHY**”, is a record of original bonafide research work carried out by him. Mr. Avadhesh Kumar Singh Bhadauria has worked under our guidance and supervision.

To the best of our knowledge, the thesis has reached the requisite standard. The material contained in this thesis has not been submitted, in part or in full to any other University or Institute for the award of any degree or diploma.



**Prof. Rajendra Prasad**

Professor

C.R.D.T.

I. I. T. Delhi.



**Dr. V.K. Vijay**

Assoc. Professor

C.R.D.T.

I.I.T. Delhi.



**Prof. A.K. Gosain**

Professor

Dept. of Civil Engg.

I.I.T. Delhi.

## ACKNOWLEDGEMENTS

It is great pleasure and privilege to express my deep sense of gratitude and profound indebtedness to my supervisors, Prof. Rajendra Prasad former head, Dr. V.K. Vijay Associate Professor and Prof. A.K. Gosain for their valuable guidance and constant encouragement throughout the period, which culminated in successful completion of my research work.

I wish to extend my sincere thanks to all faculty members and specially Prof. Santosh Satya former head, Dr S.N. Naik Associate Professor, Dr A.K. Kesari Associate Professor and Prof. P.L. Dhar Head C.R.D.T. for their support and encouragement.

I am thankful to Directorate of Technical Education, Government of Goa, and All India Council for Technical Education, Government of India and Principal Prof. S.N. Lal (retired), Prof. D.P. Roy of Goa Engineering College, Farmagudi for sponsoring me under Quality Improvement Programme for Ph.D.

My special word of thanks to Dr. V.P.S. Sorayan, Dr. Jagpal Singh (retired faculties), Prof. S.G. Deshmukh then Q.I.P. Coordinator, Prof. R. Chattopadhyay then Associate Q.I.P. Coordinator, Dr. S. Hegade and Dr. B. R. Chahar of Indian Institute of Technology Delhi for their guidance and help.

I wish to thank Prof. Mukesh Khare, Mr Raje Singh for permitting me to conduct water testing experiments and also to provide help in Environmental Engineering Laboratory.

I also wish to thank Shri Anupam Mishra of Gandhi Peace Foundation New Delhi for suggesting about the site selection of arid region.

I am thankful to Dr. P.S.Sankhala Superintending Chemist Public Health Engineering Department Jodhpur, Er. Rooparam Meena Superintending Engineer Public Health Engineering Department Jaisalmer, Er. R.K. Vishnoi Executive Engineer Public Health Engineering Department Jodhpur, Er. Ganga Singh Rathore Assistant Engineer and Er. Anil Mathur Junior Engineer in Public Health Engineering Department Jaisalmer, Smt. Archana Mathur Senior Chemist in Public Health Engineering Department Water testing Laboratory Jodhpur, Mr. Sohanlal Senior Chemist, Mr. Anup Gautam and Jogaram Laboratory Assistant in Public Health Engineering Department Water testing Laboratory Jaisalmer, Mr. Gautam Laboratory Asst. of M.B.M.Engg. College Jodhpur for their unconditional support and their co-operation during my experimental work.

The acknowledgement shall remain incomplete unless I thank my friends and fellow research scholars Mr. Ajay, Mr. Sharad, Mr. Sandeep, Mr. Mahender, Mr. Pradeep, Mr. Ranveer, Mr. Udaybhaskar, Mr. Suresh, Mr. Bullu Pradhan, Mr. Parag, Mr. Shyam Sunder, Mr. Nirmal Kumar, Mr. Prashant and all research scholars for their help and encouragement during this study at I.I.T. Delhi.

I am also thankful to the Principal, H.O.D and my colleagues of Government Engineering College Goa for their help and encouragement.

Last but not least, I would like to record a word of thanks to my wife Dr. (Smt.) Aruna and children Miss Esha and Master Shubham for their unrelenting support and their sacrifice without which it would not have been possible for me to complete my thesis, also my deep and hearty thanks to my parents for their constant encouragements throughout my study period.

  
A.K.S. Bhadauria

## ABSTRACT

Water is the basic need of human beings. An important role of any welfare state is to supply safe and potable water to its rural and urban masses. An assessment of drinking water supply and availability in the rural arid region of Rajasthan state is made in this study. A case study of Chacha village in arid region of Rajasthan state was undertaken. The study was conducted to evaluate the present status of rain water harvesting structures, in terms of water quality, quantity and cost analysis etc. In situ details were collected through field investigations in a selected village. The study area in the arid region is a backward village of western Rajasthan state which represents the complexities of drinking water supply systems. In spite of scanty rainfall, a large number of traditional rainwater harvesting structures exist in this region. Average rainfall of this study area is 197.6 mm. The people collect rainwater with their traditional skills and use it for drinking and other purposes for the rest of the year. Rainwater quality for the study area was examined for a long period of time to check the quality aspect of water under arid climatic conditions. Studies on tap water quality through rural water supply programme were undertaken over a period of one year for this village. Views of common man, public representatives and government officials related to water supply schemes were collected through questionnaire. Cost comparison of rainwater harvesting structures with piped water supply schemes was also carried out and reported in this thesis. The modern technology based tap water supply are not covering the whole population and proved to be costlier, energy consuming, unreliable and not fully safe especially in context of arid region. Traditional structures of *Tanka* provided good quality of water for drinking. Therefore amalgamating traditional water harvesting with modern systems can play a

major role in meeting the drinking water demand of the area in environment friendly way. Average demand of drinking water per capita per day was estimated as 2.65 litres in the village taking a sample of eight human beings in a year of study. It was found that maximum drinking water demand was 3.51 litres per day in the month of May and minimum was 2.10 litres per day in the month of December and February. Tap water supply is not sufficient to selected rural region especially in summer months of April to July and hence 10469755 litres of water scarcity was observed in year 2004 as per the total domestic and cattle water requirements. Traditional water harvesting structures like *Tankas* and rooftop water harvesting structures can play vital role for fulfilling water requirement. Water available by tanker water supply was not completely safe as per drinking water standards. Average 270 numbers of people (year 2002 - 2004 average) were seriously affected by water borne diseases by the use of tanker supplied water during the summer months. Interestingly, the most affected persons were below 6 year age group children and above 45 year aged persons with average percentage of 47 % and 22 % respectively (year 2002 to 2004). It has been observed that no harmful changes in water quality were found during storage of rainwater in traditional systems like *Tanka* RWHS and rooftop RWHS. During the storage for a long time of nine months, water quality changed to slightly alkaline. Calcium hardness, total hardness, chloride, pH, total dissolve solids and alkalinity increased but remained under safe limits hence water remained safe and uncontaminated. This phenomenon also indicates the use of construction material in traditional rainwater harvesting structure i.e. *Tanka* and roof top rainwater harvesting structures, which have an effect on the quality of rainwater during storage for the long time. These construction materials (i.e. locally available stone and

lime concrete) are also not creating any harmful effect on the stored water for almost a year. Tap water quality analysis for a year long study reports excess fluoride (1.50 mg/l to 2.60 mg/l), which may cause fluorosis disease in near future in villagers. There is a need to control the fluoride content in piped water supply. This emphasizes that where water is contaminated by excess fluoride, the traditional system of rainwater harvesting could be a better alternative for drinking water supply. Water supply systems in this area are completely free from arsenic problems.

It is found that traditional systems like *Tanka* seems to be sustainable and it should be preserved and encouraged for use. This is demonstrated that traditional rainwater harvesting structures like *Tankas* are found to be more suitable for supply of drinking water needs of rural population in scattered arid region of Rajasthan state. In the current context of severe scarcity experienced for drinking water in arid region, the traditional systems of rainwater harvesting is worth extending to other regions for achieving sustainable water supply in rural arid region of India. Rural masses are fulfilling their water needs through rainwater harvesting in *Tankas* and rooftop water harvesting structures, etc. The study reveals that the present rainwater harvesting structures are also in a position to cater the needs of rural masses for approx. 3 - 6 months and from rainwater harvesting and rest of the needs can be met with supplementing the water by piped water supply from the nearest water sources, thus ensuring the potable water round the year. However, there is need for necessary financial aid from government for meeting the initial cost and educating the masses for its upkeep of these units. Thus rural structures are proving to be good source of potable water at reasonable cost.

# CONTENTS

	Page No.
Certificate	i
Acknowledgement	ii
Abstract	iv
List of Contents	vii
List of Figures	xiii
List of Tables	xxiii
List of Photographs	xxv
<b>CHAPTER 1: INTRODUCTION</b>	1-6
1.1 Background	1
1.2 Scope of the study	3
1.3 Objectives of the study	5
1.4 Organization of thesis	5
<b>CHAPTER 2: LITERATURE REVIEW</b>	7-29
2.1 Introduction	7
2.2 Traditional methods of rainwater harvesting for drinking water	7
2.3 Rain water quality for drinking purposes	9
2.4 Quantity of drinking water for human beings	15
2.5 Water borne diseases in human beings	17
2.6 Sustainability of drinking water for human beings	21

2.7	Rrainwater situation in India	24
2.8	Summary	29

### **CHAPTER 3: TRADITIONAL WATER SUPPLY SYSTEMS OF**

	<b>ARID REGIONS</b>	30-37
3.1	Introduction	30
3.2	Baories	31
3.3	Jhalaras	31
3.4	Johad	31
3.5	Khadins	32
3.6	Kuis (Beris)	32
3.7	Kunds	33
3.8	Lakes (Samand)	33
3.9	Nadi	34
3.10	Paar	34
3.11	Roof water harvesting (RWH)	35
3.12	Tanka	35
3.13	Talabs	36
3.14	Wells (Kua)	36
3.15	Conclusion	37

### **CHAPTER 4: DESCRIPTION OF THE STUDY AREA**

4.1	General description	38
-----	---------------------	----

4.2	Site selection	40
4.3	About study area	40
4.4	Physiography	43
4.5	Hydrometeorology	43
4.5.1	Temperature	44
4.5.2	Wind	46
4.5.3	Relative humidity	48
4.5.4	Cloudiness	50
4.5.5	Rainfall	50
4.6	Geology and Soil	53
4.7	Socio-economic Profile	54
 <b>CHAPTER 5: METHODOLOGY</b>		 56-63
5.1	Introduction	56
5.2	Methodology	56
5.2.1	Performance Indicators	58
5.2.2	Primary data	58
5.2.3	Secondary data	59
5.3	Testing methods	60
5.4	Construction of interview schedule	61
5.5	Field data measurement	61
5.6	Performance analysis	62

<b>CHAPTER 6: RESULT AND DISCUSSIONS</b>	64-104
6.1 Introduction	64
6.2 Analysis of drinking water demand forecasting	
Graph	64
6.3 Water supply and water demand observations and	
water demand and supply graph	65
6.3.1 Analysis of drinking water demand	66
6.4 Water quality characteristics presentation from different sources	67
6.4.1 Presentation and analysis results of tap water	
(Piped water supply)	69
6.4.2 Presentation and analysis of Tanka RWHS water quality results	75
6.4.3 Presentation and analysis of Rooftop RWHS water quality results	80
6.4.4 Presentation and analysis of Tanker supplied water quality results	86
6.5 Average drinking water demand of human beings	90
6.5.1 Analysis of drinking water demand	90
6.6 Quantity of water in roof top rain water harvesting and Tanka	
rain water harvesting a village of arid region	91
6.7 Water borne diseases analysis	94
6.7.1 Presentation and analysis of results	95

## **CHAPTER 7: SOCIAL RELEVANCE OF RAIN WATER**

### **HARVESTING** 105-142

7.1 Introduction	105
------------------	-----

7.2	Methodology adopted	105
	7.2.1 Procedure adopted	105
7.3	Opinion and awareness survey	108
	7.3.1 Presentation of Category A General public results	108
	7.3.2 Presentation of Category B: Public representatives and government officials results	121
7.4	Analysis of test results	129
7.5	Summary	139
7.6	Critical interpretation	142

## **CHAPTER 8: COMPARISON OF DIFFERENT WATER SUPPLY**

	<b>SCHEME</b>	143-157
8.1	Introduction	143
8.2	Tanka water supply	143
	8.2.1 Design of Tanka and catchment's	144
	8.2.2 Annual cost analysis for Tanka water	145
8.3	Annual cost analysis of underground tank for roof top Rain water harvesting	148
8.4	Annual cost analysis of Piped water supply	149
8.5	Cost analysis of water supply by tanker	152
8.6	Sensitivity analysis of drinking water supply sources	154
8.6	Cost comparisons and results discussion	157

## **CHAPTER 9: SUMMARY, CONCLUSIONS AND SCOPE FOR**

<b>FURTHER WORK</b>	158-164
9.1 Summary	158
9.2 Conclusions	162
9.3 Suggestions	163
9.4 Scope for future study	164
<b>PUBLICATIONS</b>	165
<b>REFERENCES</b>	167
<b>APPENDICES</b>	
Appendix I	175
Appendix II	192
Appendix III	269
Appendix IV	270
Appendix V	272
<b>BIO-DATA</b>	276