

**Exploration of Domestic Water Management Practices and  
Paradigm Shift Using IoT Enabled AI System for Devising  
Water Conservation in Ingenious Homes**

**Thesis submitted in partial fulfilment of the  
Degree of Doctor of Philosophy in Resource Management**

**By**

**J. Sofia Jannet**

**(17PHRMP003)**

**Supervisor**

**Dr.M.R.Thilakam**

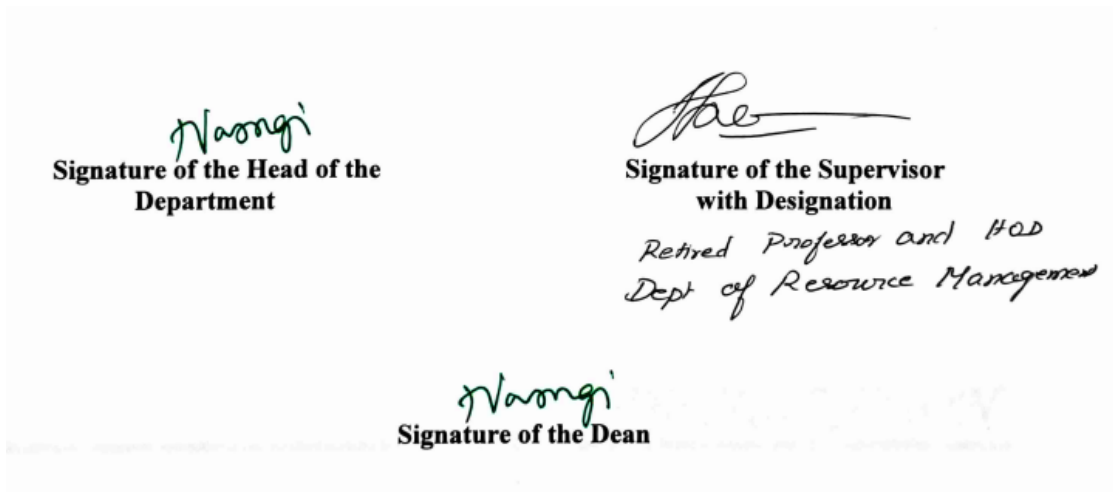
**Department of Resource Management**

**Avinashilingam Institute for Home Science and  
Higher Education for Women, Coimbatore – 641 043.**

**May 2023**

## CERTIFICATE FROM THE SUPERVISOR

I **Dr.M.R.Thilakam**, certify that the thesis entitled “**Exploration of Domestic Water Management Practices and Paradigm Shift using IoT Enabled AI System for Devising Water Conservation in Ingenious Homes**” submitted for the award of Doctor of Philosophy (Ph.D) by **J.Sofia Jannet** is the record of research work carried out by her during the period from July 2017 to March 2023 under my guidance and supervision, and that her work has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship, or other Titles in this Institute or any other University or Institution of Higher Learning.



The image shows three handwritten signatures in green ink. The first signature is on the left, above the text "Signature of the Head of the Department". The second signature is on the right, above the text "Signature of the Supervisor with Designation" and "Retired Professor and HOD Dept of Resource Management". The third signature is at the bottom center, above the text "Signature of the Dean".

*Naongi*  
Signature of the Head of the Department

*Naongi*  
Signature of the Supervisor with Designation  
Retired Professor and HOD  
Dept of Resource Management

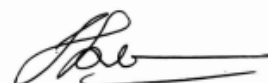
*Naongi*  
Signature of the Dean

## DECLARATION

I **J.Sofia Jannet**, declare that the thesis entitled “**Exploration of Domestic Water Management Practices and Paradigm Shift using IoT Enabled AI System for Devising Water Conservation in Ingenious Homes**” submitted by me for the award of **Doctor of Philosophy (Ph.D)** is the record of work carried out by me during the period from 2017 to 2023 under the guidance of **Dr.M.R.Thilakam** and has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship, Titles in this Institute or any other University or other similar Institution of Higher Learning.



**Signature of the Research Scholar  
(J.Sofia Jannet)**



**Signature of the Supervisor  
(Dr. M. R. Thilakam)**

## ACKNOWLEDGEMENT

I am grateful to **God Almighty** for the good health, well being, immense grace and blessings He has bestowed upon me over the course of this research.

I am eternally indebted to **Dr.T.S.Avinashilingam**, the Institute's Founder and First Chancellor, and **Dr.Rajammal P.Devadas**, Former Chancellor, for creating this haven of education and bestowing their divine favour upon me here at Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.

I record my thankfulness to **Padmashri Dr.P.R.Krishnakumar**, Former Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for facilitating the smooth conduct of the study.

I thank **Dr.S.P.Thyagarajan**, Chancellor of the Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for all the facilities that were made available to me to carry out this study.

My heartfelt thanks go out to **Dr.Premavathy Vijayan**, who served as the Vice-Chancellor of the Avinashilingam Institute for Home Science and Higher Education for Women in Coimbatore.

To the Vice-Chancellor, **Dr.V.Bharathi Harishankar**, of the Avinashilingam Institute for Home Science and Higher Education for Women in Coimbatore, I extend my most sincere gratitude for providing all the facilities that were necessary for the successful completion of this research project.

I express my thanks to the Registrar, **Dr.S.Kowsalya**, Avinashilingam Institute for Home Science and Higher Education for Women in Coimbatore, for providing all the support for the smooth conduct of the study.

I take this opportunity to extend my sincere gratitude to **Dr.N.Vasugi**, Dean, School of Home Science and Head (i/c) of the Department of Resource Management, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing untiring assistance and being a pillar of support at all times.

I am deeply grateful to **Dr.K.Manimozhi**, The Controller of Examinations, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her support and encouragement in the submission of this research work.

I express my gratitude to **Dr.G.P.Jeyanthi**, who served as the former Director of Research and Consultancy, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing me with guidance and recommendations during the duration of the course.

I offer my sincere gratitude to **Dr.V.Murugesan**, Former Dean of Research and Consultancy, and **Dr.P.Lalitha**, Director, Research and Development, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for helping me to ensure that the research was carried out in a timely and efficient manner.

I extend my sincere thanks to Former Head of the Department of Resource Management, **Dr.S.Visalakshi Rajeswari**, for all her assistance over the course of my studies.

Words cannot express my gratitude to my Supervisor **Dr.M.R.Thilakam**, Former Head, Department of Resource Management for her invaluable advice, unwavering support, and patience during this research work. Her immense knowledge and plentiful experience had encouraged me in all the time of my academic research and daily life. This study would not have been possible without her moral support, motivation, suggestions, and ideas. The door to reach her was always open whenever I ran into trouble or had a question about my research or writing. She consistently steered me in the right direction whenever she thought I needed it.

I record my warm thanks to **Dr.Chandra Sekaran**, Professor, Department of Soil Science, Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Subject Expert and Doctoral Committee member. He has been an incredible source of support and has given many insightful recommendations that have aided in the development of this research project.

The faculty members **Dr.R.Jeyagowri, Dr.B.Loganayaki, Dr.D.Sumathi, Mrs.P.Sakthidevi, Dr.V.Sarasvathy and Dr.Sheeba Gopalakrishnan.U,** Department of Resource Management, Avinashilingam Institute of Home Science and Higher Education for Women, Coimbatore, provided me with helpful information, encouragement, and well-wishes throughout my research period. I consider myself very fortunate to have had such leading lights around me.

I owe my special thanks to **Mr.Kanagaraj,** Assistant Engineer at Coimbatore City Corporation, Kuniyamuthur, Coimbatore, who assisted with all the required secondary data collection. My heartfelt thanks to **Mr.Ezhil,** Assistant Engineer, Coimbatore City Corporation, Kuniyamuthur, Coimbatore, who shared all his valuable inputs and ideologies of water management among the samples through an online platform.

I propose my gratitude to **Abitek Testing Laboratory,** Saibaba Colony, Coimbatore, for the prompt assistance they provided in the analysis of the water samples. I place on record my sincere thanks to **Mr.Vignesh Chockanathan,** Managing Director, Hailstone Technology, Coimbatore, for the quick assistance he provided in the development of the prototype.

I convey my sincere thankfulness to **Mr.Marudhaachalam,** Mugil Data Systems, who kindly assisted with the statistical analysis in this research work.

I extend my warm thanks to **Mr.M.Kalaivanan,** Director – Tamil Nadu Puppetry Art, Founder of Kalai Trust and Thendral Children Forum who wholeheartedly helped with the development of puppet pageant for the knowledge dissemination session.

I express my deepest gratitude to **Mr. Karunakaran** who volunteered his precious time to assist me in this thesis work.

I offer a special thanks to my **peers, Co-scholars,** and **other staff** of the Department for their support during the period of study.

I am extremely grateful for my family members, friends and relatives for their role in this research.

Without these invisible hands and hearts, this accomplishment would not have been possible.

In conclusion, I express my gratitude to each and every **homemaker** who had participated in this study for their unwavering cooperation.

## LIST OF TABLES

| <b>Table No.</b> | <b>Title</b>   | <b>Page No.</b> |
|------------------|--|-----------------|
| 1                | <b>Per Capita Demand of Water in Standard Indian Town and Domestic Consumption</b>                     | 28              |
| 2                | <b>Zone/Ward/Street-wise Selection of Samples</b>  | 55              |
| 3                | <b>Type of Containers Involved in Water Storage</b>  | 69              |
| 4                | <b>Learning Modules Developed for the Water Management Knowledge Dissemination Programme</b>           | 84              |
| 5. (a)           | <b>Personal Minutiae of the Homemakers – Educational Qualification and Employment Status</b>           | 93              |
| 5. (b)           | <b>Family Details and Income Category</b>  | 94              |
| 5. (c)           | <b>Housing Details of the Homemaker</b>  | 96              |
| 6                | <b>Specifics of Alternate Water Sources Available</b>  | 97              |
| 7                | <b>Association of Socio-demographic Variables with Awareness of Water Conservation</b>                 | 99              |
| 8                | <b>Households Using Water Conservation Tools</b>   | 102             |
| 9                | <b>Association between Socio-demographic Factors and Use of Water Conservation Tools</b>               | 104             |
| 10               | <b>Association between Selected Socio-demographic Variables and Understanding Rainwater Collection</b> | 108             |
| 11               | <b>Habitude of Saving Rainwater among Selected Homemakers</b>  | 110             |
| 12               | <b>Extravagance of Water Usage in Domestic Water-based Activities</b>                                  | 111             |
| 13               | <b>Quantified Daily Water Waste as per Data Collected</b>  | 112             |
| 14               | <b>ANOVA for Quantified Water Waste</b>  | 112             |
| 15               | <b>Frequency of Soft Water Supply During Seasonal and Non-Seasonal Variation</b>                       | 115             |

|           |   |                |
|-----------|---|----------------|
| <b>16</b> | <b>Quality and Quantity of Soft Water Supplied during Seasonal and Non-Seasonal Variation</b>                                       | <b>116</b>     |
| <b>17</b> | <b>Homemaker's Satisfaction with the Distributed Soft Water Quality and Quantity (During Summer)</b>                                | <b>118</b>     |
| <b>18</b> | <b>Homemaker's Satisfaction with the Distributed Soft Water Quality and Quantity (During Non-summer)</b>                            | <b>121</b>     |
| <b>19</b> | <b>Overall Satisfaction with the Distribution of Soft Water</b>   | <b>124</b>     |
| <b>20</b> | <b>Physical, Chemical and Biological Parameters of the Samples from Different Zones of the Selected City</b>                        | <b>128</b>     |
| <b>21</b> | <b>Type of Water Filtration Practiced by the Selected Homemakers</b>  | <b>131</b>     |
| <b>22</b> | <b>Analysis of Potable Water Quality after Common Purification Methods</b>  | <b>132</b>     |
| <b>23</b> | <b>Analysis of Physical Parameters of Stored Water at Different Intervals in Different Containers</b>                               | <b>136</b>     |
| <b>24</b> | <b>Repeated Measures ANOVA for the Physical Properties of Stored Water</b>  | <b>139</b>     |
| <b>25</b> | <b>Analysis of Chemical Parameters of Stored Water at Different Intervals in Different Containers</b>                               | <b>144-145</b> |
| <b>26</b> | <b>Repeated Measures ANOVA for the Chemical Properties of Stored Water</b>  | <b>147</b>     |
| <b>27</b> | <b>Analysis of Biological Parameters of Water Quality Stored in Different Containers</b>  | <b>149</b>     |
| <b>28</b> | <b>Descriptive Analysis of Water Usage</b>  | <b>151</b>     |
| <b>29</b> | <b>Difference in Water Consumption between Traditional Method and using Labor-saving Devices for Performing Selected Activities</b> | <b>152</b>     |
| <b>30</b> | <b>Difference in the Usage of Water between Paid Assistant and Homemaker</b>  | <b>153</b>     |
| <b>31</b> | <b>Homemaker's Responses before and after the Knowledge Dissemination Programme</b>   | <b>157-158</b> |
| <b>32</b> | <b>Comparison of Behavioural Attitude Scores before and after the Intervention Programme</b>  | <b>160</b>     |
| <b>33</b> | <b>Paired Sample t-Test</b>   | <b>161</b>     |

## LIST OF FIGURES

| <b>Figure No.</b> | <b>Title</b>   | <b>Page No.</b> |
|-------------------|--|-----------------|
| 1                 | Role of Children in Water Management Spotted in Niger  | 3               |
| 2                 | Per Capita Availability of Water   | 7               |
| 3                 | Blue and Green Water   | 19              |
| 4                 | Status of Fresh Water  | 22              |
| 5                 | Graphical Representation of Water Use and Needs Theory   | 26              |
| 6                 | Coimbatore Population  | 51              |
| 7                 | Coimbatore City Zones Map Showing – North, South, East, West and Central Zones                           | 52              |
| 8                 | Zone/Ward/Street-wise Multi-stage Framework of the Study Samples   | 53              |
| 9                 | Selected Wards from Each Zone of Coimbatore City   | 54              |
| 10                | Sample of the Water Testing Report   | 64              |
| 11                | Location Map – West Zone   | 65              |
| 12                | Waters' Qualitative Status Quo   | 68              |
| 13                | Design of Sample Selection –Monitoring and Assessing the Quality of Water Stored in Different Containers | 71              |
| 14                | Selection of Study Area  | 73              |
| 15                | Written Material - <i>Poster Developed</i>   | 79              |
| 16                | Invitation - Water Management Knowledge Dissemination Programme  | 80              |
| 17                | Phase I - Descriptive Study: Homemakers' Socio-demographic Characteristics                               | 87              |
| 18                | Phase II - Experimental Investigation: Water's Qualitative and Quantitative Status Quo                   | 88              |
| 19                | Phase III – Knowledge Germination and Dissemination  | 89              |
| 20                | Phase IV – Conceptualization of Design   | 90              |

|           |  |            |
|-----------|--|------------|
| <b>21</b> | <b>Basics of Water Conservation Techniques</b>   | <b>98</b>  |
| <b>22</b> | <b>Reasons for Not Saving Rainwater</b>  | <b>110</b> |
| <b>23</b> | <b>Division among City Zones – Number of Homemakers in Each Zone</b>                         | <b>113</b> |
| <b>25</b> | <b>Raise of Water Needs during Seasonal Periods (Summer)</b>                                 | <b>114</b> |
| <b>26</b> | <b>Reasons for Inadequacy of Water</b>   | <b>126</b> |
| <b>27</b> | <b>Total Dissolved Solids in Common Purification Methods</b>                                 | <b>133</b> |
| <b>28</b> | <b>Hardness of Water Analyzed in Common Purification Methods</b>                             | <b>134</b> |
| <b>29</b> | <b>Comparison of pH Values of Water Stored in Different Containers</b>                       | <b>138</b> |
| <b>30</b> | <b>Variations in Water EC Values Stored in Different Containers</b>                          | <b>140</b> |
| <b>31</b> | <b>Level of Water Hardness in Transition from Container to another Container</b>             | <b>142</b> |
| <b>32</b> | <b>Differentiation of Alkalinity in Water Stored in a Variety of Selected Containers</b>     | <b>143</b> |
| <b>33</b> | <b>Disparity of Iron Level in Water Saved in Chosen Containers</b>                           | <b>146</b> |
| <b>34</b> | <b>Water Wastage at Home Reported before and after the Knowledge Dissemination Programme</b> | <b>159</b> |
| <b>35</b> | <b>Habit of Saving Water Reported before and after the Knowledge Dissemination Programme</b> | <b>160</b> |
| <b>36</b> | <b>Block Diagram Representing the Thorough Architecture of the Invention</b>                 | <b>165</b> |
| <b>37</b> | <b>Alert through SMS</b>   | <b>170</b> |
| <b>38</b> | <b>Data Stored in Cloud</b>  | <b>170</b> |
| <b>39</b> | <b>Honor of the Invention Acknowledged – (Patent Published)</b>                              | <b>171</b> |

## LIST OF PLATES

| <b>Plate No.</b> | <b>Title</b>   | <b>Page No.</b> |
|------------------|--|-----------------|
| 1                | Researcher Conducting Household Interview  | 56              |
| 2                | Apt to Test - Water Samples  | 63              |
| 3                | Collected and Stored Water Samples   | 70              |
| 4                | Quantifying Used Water   | 74              |
| 5                | Created Whatsapp Group   | 83              |
| 6                | Conduct of the Programme   | 84              |
| 7                | Google form for the Pre and Post-evaluation Form                                     | 84              |
| 8                | Water Conservation Tools Identified in the Selected Households                       | 103             |
| 9                | Models of Rainwater Harvesting Observed  | 107             |
| 10               | Noted Colour Changes with Increased Turbidity  | 117             |
| 11               | Pitting in Aluminium Container/ Storage of Water in Aluminium Containers             | 137             |
| 12               | The Juxtaposition of the Two Scenarios - Water Usage by Paid Assistant and Homemaker | 154             |
| 13               | Components of the Mechanical Prototype - Jalaflex Espy (PATENT PUBLISHED)            | 164             |
| 14               | Welcome Message - IoT Based Water Management System                                  | 168             |
| 15               | Continuous Water Wastage Alert   | 168             |
| 16               | Day 2 Water Usage Data in Bathroom and Kitchen                                       | 168             |
| 17               | Day 3 Water Usage Data in Bathroom and Kitchen                                       | 168             |
| 18               | SMS Alert Sent Successfully  | 169             |
| 19               | Pls Resolve the Tap and Reset  | 169             |
| 20               | Emergency Situation Activated  | 169             |
| 21               | Water Excess Use Detected  | 169             |

## LIST OF BOXES

| <b>Box No.</b> | <b>Title</b>                                 | <b>Page No.</b> |
|----------------|--|-----------------|
| 1              | Our Earth, Air, Land and Water on Loan       | 1               |
| 2              | Water Quality – Perspective of World Bank    | 4               |
| 3              | Water Shortage – Reality                     | 5               |
| 4              | Water - Blue gold                            | 19              |
| 5              | Nectar of Immortality – The Rain             | 20              |
| 6              | Definition of Drinking Water by BIS          | 22              |
| 7              | History of Siruvani Water in Coimbatore City | 23              |
| 8              | Minimum Essential Water Need in a House      | 27              |
| 9              | SDG - Clean Water and Sanitation             | 29              |
| 10             | Definition of Pollution                      | 30              |
| 11             | Future Need of Water                         | 35              |

## LIST OF EXHIBITS

| <b>Exhibit No.</b> | <b>Title</b>  | <b>Page No.</b> |
|--------------------|---|-----------------|
| <b>1</b>           | <b>Drinking Water Contamination with Drainage Water</b>   | <b>9</b>        |
| <b>2</b>           | <b>Map showing the Location of the Study - Coimbatore</b>                                       | <b>50</b>       |
| <b>3</b>           | <b>Program Schedule – Water Management Knowledge Dissemination Programme</b>                    | <b>80</b>       |
| <b>4</b>           | <b>Written Material - <i>Brochure Developed</i></b>   | <b>81, 156</b>  |
| <b>5</b>           | <b>Interpersonal Means of Communication - <i>Developed Puppet Show (Copyright Material)</i></b> | <b>82</b>       |

## LIST OF APPENDICES

| <b>Appendix No.</b> | <b>Title</b>  | <b>Page No.</b> |
|---------------------|---|-----------------|
| <b>A</b>            | <b>(i). Interview Schedule - English</b>                      | <b>210</b>      |
|                     | <b>(ii). Interview Schedule - Tamil</b>                       | <b>220</b>      |
| <b>B</b>            | <b>Ethical Clearance Certificate</b>                          | <b>231</b>      |
| <b>C</b>            | <b>Indian Standards and WHO Guidelines for Drinking Water</b> | <b>232</b>      |
| <b>D</b>            | <b>Brochure</b>   | <b>233</b>      |
| <b>E</b>            | <b>Copyright Document</b>                                     | <b>239</b>      |
| <b>F</b>            | <b>Plagiarism Report</b>                                      | <b>240</b>      |
| <b>G</b>            | <b>Publications</b>   | <b>243</b>      |

## **LIST OF ABBREVIATIONS**

|               |  |
|---------------|--|
| <b>AC</b>     | <b>Alternating Current</b>                   |
| <b>AI</b>     | <b>Artificial Intelligence</b>               |
| <b>BCM</b>    | <b>Billion Cubic Metres</b>                  |
| <b>BIS</b>    | <b>Bureau of Indian Standards</b>            |
| <b>CCMC</b>   | <b>Coimbatore City Municipal Corporation</b> |
| <b>CD ROM</b> | <b>Compact Disc Read-Only Memory</b>         |
| <b>CFU</b>    | <b>Colony-forming Unit</b>                   |
| <b>DC</b>     | <b>Direct Current</b>                        |
| <b>DVD</b>    | <b>Digital Versatile Disc</b>                |
| <b>EC</b>     | <b>Electrical Conductivity</b>               |
| <b>EPA</b>    | <b>Environmental Protection Agency</b>       |
| <b>GPF</b>    | <b>Gallons Per Flush</b>                     |
| <b>GPRS</b>   | <b>General Packet Radio Services</b>         |
| <b>GSM</b>    | <b>Global System for Mobile</b>              |
| <b>ICSP</b>   | <b>In-Circuit Serial Programming</b>         |
| <b>IoT</b>    | <b>Internet of Things</b>                    |
| <b>IT</b>     | <b>Information Technology</b>                |
| <b>LCD</b>    | <b>Liquid Crystal Display</b>                |
| <b>LCPD</b>   | <b>Litres Per Capita per Day</b>             |
| <b>MCU</b>    | <b>Microcontroller Unit</b>                  |
| <b>ML/s</b>   | <b>Millilitres Per Second</b>                |
| <b>MLD</b>    | <b>Millions of Litres per Day</b>            |
| <b>MOUD</b>   | <b>Ministry of Urban Development</b>         |
| <b>NC</b>     | <b>Normally Closed</b>                       |
| <b>NO</b>     | <b>Normally Open</b>                         |

|                  |   |
|------------------|---|
| <b>NTU</b>       | <b>Nephelometric Turbidity Unit</b>                           |
| <b>PC</b>        | <b>Personal Computer</b>                                      |
| <b>RO</b>        | <b>Reverse Osmosis</b>  |
| <b>RWH</b>       | <b>Rainwater Harvesting</b>                                   |
| <b>SIM</b>       | <b>Subscriber Identity Module</b>                             |
| <b>SMS</b>       | <b>Short Message Service</b>                                  |
| <b>SODIS</b>     | <b>Solar Water Disinfection System</b>                        |
| <b>SOP</b>       | <b>Standard Operating Procedure</b>                           |
| <b>SPSS</b>      | <b>Statistical Package for the Social Sciences</b>            |
| <b>SWF India</b> | <b>Smart Water Future India</b>                               |
| <b>SWQM</b>      | <b>Smart Water Quality Monitoring</b>                         |
| <b>TCP/IP</b>    | <b>Transmission Control Protocol/ Internet Protocol</b>       |
| <b>TDS</b>       | <b>Total Dissolved Solids</b>                                 |
| <b>TWAD</b>      | <b>Tamil Nadu Water Supply and Drainage Board</b>             |
| <b>UGSS</b>      | <b>Under Ground Sewerage Scheme</b>                           |
| <b>ULB</b>       | <b>Urban Local Bodies</b>                                     |
| <b>ULBs</b>      | <b>Urban Local Bodies</b>                                     |
| <b>UN</b>        | <b>United Nations</b>   |
| <b>UNICEF</b>    | <b>United Nations International Children’s Emergency Fund</b> |
| <b>UN-SDG</b>    | <b>United Nation - Sustainable Development Goals</b>          |
| <b>USB</b>       | <b>Universal Serial Bus</b>                                   |
| <b>UV</b>        | <b>Ultra Violet</b>   |
| <b>WC</b>        | <b>Water Closet</b>   |
| <b>WHO</b>       | <b>World Health Organization</b>                              |