

**SIMULATION OF WATER DISTRIBUTION NETWORK
WITH AN INTERMITTENT WATER SUPPLY AND
ANALYSING AVAILABILITY OF RESIDUAL
CHLORINE**

Kankanam Pathirana Chamindi Chathurika

198483D

Master of Science in Environmental Engineering and Management

Department of Civil Engineering

Faculty of Engineering

University of Moratuwa

Sri Lanka

August 2024

**SIMULATION OF WATER DISTRIBUTION NETWORK
WITH AN INTERMITTENT WATER SUPPLY AND
ANALYSING AVAILABILITY OF RESIDUAL
CHLORINE**

Kankanam Pathirana Chamindi Chathurika

198483D

Thesis/Dissertation submitted in partial fulfilment of the requirements for the degree

Master of Science in Environmental Engineering and Management

Department of Civil Engineering

Faculty of Engineering

University of Moratuwa

Sri Lanka

August 2024

DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date: 02/08/2024

K.P.C Chaturika

The above candidate has carried out research for the PhD/MPhil/Masters thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Eng. Primal Jinadasa

Signature of the Supervisor:

Date:

Name of Supervisor: Professor. Manatunge J.M.A

Signature of the Supervisor:

Date:

ACKNOWLEDGEMENT

Initially, I would like to extend my deepest appreciation to Professor Jagath Manathunge, of the Environmental Engineering Division of the Department of Civil Engineering, University of Moratuwa. His invaluable support and guidance throughout the research project as the supervisor and the Masters Degree Programme as a lecturer have greatly improved my knowledge and skills.

Secondly, I extend my sincere gratitude to Eng. Primal Jinadasa, Deputy General Manager (Planning & Design) of the National Water Supply & Drainage Board, for his unwavering support, guidance, and expertise throughout the completion of this research endeavour. His continuous encouragement served as a vital source of motivation to successfully conduct this research.

Furthermore, I would like to express my gratitude towards my employer, the National Water Supply & Drainage Board, and its staff for their exceptional support and provision of resources, which were instrumental to successfully complete this study.

I am also profoundly grateful to my family and friends for their unwavering support and encouragement throughout this study.

ABSTRACT

The intermittent nature of water supply in certain regions presents challenges in maintaining water quality and ensuring the appropriate level of disinfection. To address this issue, a simulation approach is utilized to model the dynamics of water flow, chlorine decay, and demand patterns within the distribution network. In modelling of intermittent water supply schemes (IWSSs) it is essential to consider partial/no flow condition and high water demand during initial filling stage to fill consumer storage tanks. The modified pressure dependent analysis was used to model the WDN. Through the development of a comprehensive simulation model, this study present variation of residual chlorine level within an IWS. By considering factors such as water demand variations, network topology, availability of storage facilities, the proposed simulation model provides a systematic framework for hydraulic modelling of an intermittent water supply systems. Modelling was carried out using the Bentley WaterGEMS software with the aid of ArcGIS platform and Ahangama water supply scheme in Sri Lanka where, intermittent water supply provided in alternate days used as the area for implementing the proposed methodology. The findings of this study are expected to contribute to the enhancement of water quality and quantity management practices in intermittent supply contexts, ultimately leading to improved public health outcomes and sustainable water distribution network operations.

Keywords: water distribution networks, chlorine injection, intermittent water supply, water quality management, WaterGEMS

TABLE OF CONTENTS

DECLARATION	i
ACKNOWLEDGEMENT	ii
ABSTRACT	iii
LIST OF FIGURES	vii
LIST OF TABLES	ix
ABBREVIATIONS	x
1 INTRODUCTION	1
1.1 Background and Rationale	1
1.2 Statement of the Problem	3
1.3 Scope and Significance of the Study	4
1.3.1 Scope of the Study	4
1.3.2 Significance of the Study	4
1.4 Organisation of Chapters	5
2 LITERATURE REVIEW	6
2.1 Overview of Intermittent Water Supply Networks	6
2.2 Modelling of intermittent water distribution networks.	8
2.3 Water Quality in intermittent water distribution networks	10
2.3.1 Residual Chlorine within WDN	12
3 METHODOLOGY	14
3.1 Research Design and Approach	14
3.2 Proposed Methodology	14
3.3 Description of the Study Area	16
3.3.1 Location of the Study Area	16
3.3.2 Distribution Network	18
3.3.3 Materials and Tools Used	19
3.4 Data Collection	19

3.4.1	Primary Data	19
3.4.2	Secondary Data	20
3.5	Development of Hydraulic Model	21
3.5.1	Model Building	21
3.5.2	Assigning Elevation Data	21
3.5.3	Assign the pipe parameters	23
3.5.4	Assign Consumer data to the system	23
3.5.5	Assign demands based on PDF technique	26
3.6	Computation of Model	29
3.7	Validation and Verification of the Proposed Methodology	30
3.7.1	Selection of Locations	30
3.7.2	Statistical Analysis	31
3.8	Analysis of Water Quality	32
3.9	Validation of RCL Availability	34
4	RESULTS AND DISCUSSION	35
4.1	Data Collection Results	35
4.2	Primary Data Collection Results	35
4.2.1	Inflow to the system	35
4.3	Results of the Computed Model	37
4.4	Calibration of Model	38
4.5	Validation of the Model	38
4.6	Water Quality Analysis	42
4.7	Limitations and Challenges	44
4.7.1	Data Availability and Usability	44
4.7.2	Model Performance and Assessment of Results	44
4.7.3	Limited Validation to a Single Case Study	44
5	CONCLUSION	45

6	REFERENCES	47
7	APPENDICES	50

LIST OF FIGURES

Figure 2.1: Average Hours of water supply (www.ib-net.org)	6
Figure 2.2: Flow chart for PDA analysis during partial flow condition (Mohan, 2020)	9
Figure 2.3: Behaviour of Chlorine within a WDN (Chlorine residual testing fact sheet, CDC SWS Project, 2008)	12
Figure 3.1: Proposed methodology for the case study	15
Figure 3.2: Study Area - Ahangama WSS	16
Figure 3.3: Schematic Diagram of Hapugala WTP	17
Figure 3.4: Water Distribution from Halloluwagoda Ground Reservoir	17
Figure 3.5: Water Distribution Network	18
Figure 3.6: Contour Map creation for assign elevation	22
Figure 3.7: Application of T-Rex Function	22
Figure 3.8: Customer Locations within Ahangama WSS	24
Figure 3.9: Assigning Consumer Data to WaterGEMS software	25
Figure 3.10: Demand Patterns Assigned	27
Figure 3.11: Initially assigned consumer nodes	28
Figure 3.12: Initially Demand Assigned Customer meter Table	29
Figure 3.13: Installed Locations of Pressure Loggers	31
Figure 3.14: Assigning RCL parameters to the reservoir	32
Figure 3.15: Assign RCL parameters.	33
Figure 4.1: Average Hourly Flow Results from consumer demand patterns.	36
Figure 4.2: Comparison of hourly Pressure Variation in Node 1054	38
Figure 4.3: Comparison of hourly Pressure Variation in Node 1086	39
Figure 4.4: Comparison of hourly Pressure Variation in Node 1054	39
Figure 4.5: Comparison of hourly Pressure Variation in Node 2204	40
Figure 4.6: Comparison of hourly Pressure Variation in Node 995	40
Figure 4.7: Comparison of hourly Pressure Variation in Node 2251	41
Figure 4.8: Observed pressure data vs simulated pressure data in Node 1352	41
Figure 4.9: Modelled data of RCL availability during 10p.m of the water interrupted day	42

Figure 4.10: RCL Availability at the furthest away point from the Halloluwagoda Reservoir 43

Figure 4.11: Modelled data of RCL availability during 10p.m of a continuous water supply system 43

LIST OF TABLES

Table 2.1: Global occurrence of IWSS (Kumpel, Intermittent water supply: prevalence, practice, and microbial water quality, 2016)	7
Table 3.1: Pipe Details of Ahangama Water Distribution Network	18
Table 3.2: Roughness Coefficients (C) ideal values for pipelines	23
Table 3.3: Correlation Coefficient values and their interpretations	32
Table 3.4: Values used for analyse the chlorine decay	33
Table 4.1: Flow Discharged to the system.	36
Table 4.2: Correlation coefficient values of each location	42
Table 7.1: Pressuure variation of J-2251	53
Table 7.2 : Pressuure variation of J-995	54

ABBREVIATIONS

ADD	Average Daily Demand
AHF	Average Hourly Flow
AHFR	Average Hourly Flow Rate
CWS	Continuous Water Supply
DEM	Digital Elevation Model
DI	Ductile Iron
dia.	Diameter
EPS	Extended Period Simulation
GIS	Geographic Information Systems
GR	Ground Reservoir
HDPE	High Density Polyethylene
HPC	Heterotrophic Plate Count
IWS	Intermittent Water Supply
IWSS	Intermittent Water Supply System
MSL	Mean Sea Level
N	North
NRW	Non-Revenue Water
NWSDB	National Water Supply & Drainage Board
PDNA	Pressure Deficient Network Algorithm
PVC	Polyvinyl Chloride

RCL	Residual Chlorine Level
WDN	Water Distribution Network
WSS	Water Supply Scheme
WTP	Water Treatment Plant