

**IMPROVING THE PERFORMANCE OF UNIT
OPERATIONS OF WATER TREATMENT PLANTS
WHERE IRRIGATION TANKS ARE USED AS THE
SOURCE**

H. A. D. P. Hapuarachchi

(08/8047)



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Degree of Master of Science

Department of Civil Engineering

University of Moratuwa
Sri Lanka

December 2010

**IMPROVING THE PERFORMANCE OF UNIT
OPERATIONS OF WATER TREATMENT PLANTS
WHERE IRRIGATION TANKS ARE USED AS THE
SOURCE**

H. A. D. P. Hapuarachchi

(08/8047)



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Thesis submitted in partial fulfillment of the requirements for the degree Master of
Science

Department of Civil Engineering

University of Moratuwa
Sri Lanka

December 2010

Declaration of the Candidate & Supervisors

Declaration of the Candidate

“I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any University or other 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”

Signature

Date.....

Copyright Statement

‘I hereby grant the University of Moratuwa the right to archive and to make available my thesis in whole or part in the University Libraries in all forms of media, subject to the provisions of the current copyright act of Sri Lanka. I retain all proprietary rights, such as patent rights. I also retain the right to use in future works (such as articles or books) all or part of this thesis.

Signature

Date.....

Declaration of the Supervisors

“I have supervised and accepted this thesis for the award of the degree”

Supervisor 1 Name.....

Date.....

Signature.....

Supervisor 2 Name.....

Date.....

Signature.....

Acknowledgements

First of all I wish to acknowledge the University of Moratuwa for providing me the funds necessary to carry out this study under a Senate Research Committee Grant. I wish to express my sincere gratitude to Prof (Mrs.) N. Ratnayake and Dr. J.M.A. Manatunge, the supervisors for their valuable advice, suggestions and encouragement during my endeavor in fulfilling the requirements of Master of Science Degree

I offer my deep gratitude to the Dr. Pathmalal Manage, Senior Lecturer in the Faculty of Science, University of Sri Jayewardenepura for assisting me in carrying out experiments for the algal counts and Microcystin analyses.

I also wish to sincerely thank Prof. J.M.S.J. Bandara, Research Coordinator and Dr. M. Jayaweera, Senior Lecturer, Department of Civil Engineering, University of Moratuwa for their valuable suggestions and encouragement during the study.

I express my sincere gratitude to Mrs. Manjula Ranasinghe, Mrs. Nilanthi Gunathilake, Mr. L. Justin Silva, Ms Inoka Udayangani, Ms. Chamari Pushpika and Ms. Priyashani Cooray of the Environmental Engineering Laboratory of University of Moratuwa for the assistance in laboratory analysis.

I take this opportunity to offer my gratefulness to Eng. K. Vinodan and the staff of the ECTAD Water Supply Project at Ampara and the Staff of the Research and Training Division of the National Water Supply and Drainage Board at Ratmalana for assisting me to carry out this study.

I am very glad to make a special note of Mahaweli Authority of Sri Lanka, my employer for allowing me to take no-pay leave for carrying out this full time research study. I offer my deep gratitude to Eng. (Mrs.). P. Thalagala, Director - Project planning, Eng. H.H.P Premakumara, Director – River Basin Development and Reservoirs, Eng. S.W. Ediriweera, Head- Dam safety management centre and Mr. Anurudda, Environmental officer of the Mahaweli Authority of Sri Lanka for helping me to collect water quality data of other irrigation tanks in Sri Lanka.

I take this opportunity to offer my gratefulness to Prof. E.I.L. Silva, former Director of Institute of Fundamental Studies (IFS) and Mr. J.P. Padmasiri, Scientist of IFS, Hanthna, Kandy for assisting me to collect algal data of irrigation tanks in North Central Province.

I wish to thank Mr. A.S. Pathirathne and Mr. Udaya Warnajith of Haycarb PLC, Colombo 10 for their help by providing powdered activated carbon samples for my experiments.

Finally I dedicate my gratitude to my husband, Manjula and I am indebted to my parents, who provided me everything possible for me to achieve the success of this study.

Abstract

Worldwide, increasing demand for drinking water to cater to the increasing urban population has led to the use of lakes and reservoirs with unprotected catchments as sources of public water supplies. These water bodies receive drainage water containing large amount of nutrients, mostly from intensive agricultural practices, resulting in algal blooms, which have become a growing environmental problem. Conventional treatment used for surface water may not always produce satisfactory quality water in these situations. In addition, the increasing occurrence of toxins produced by cyanobacteria in such water bodies has become an important public health issue.

“Eastern Coastal Towns of Ampara District (ECTAD) Water Supply Project”, where the raw water source is an irrigation tank with high inflows of nutrients was used as a case study. Coagulation, flocculation, dissolved air floatation (DAF), rapid gravity filtration and disinfection are the unit operations that have been designed and constructed, while Pre-chlorination and Powdered Activated Carbon (PAC) adsorption are also currently used in this water treatment plant, which have been introduced to treat taste and odour problems encountered after commissioning the plant.

The case study was carried out to evaluate the efficacy of pre-chlorination, activated carbon adsorption, Dissolved Air Flotation, filtration and disinfection in removal of cyanotoxins, taste and odor causing dissolved organic substances and colour causing substances such as iron and manganese from the source water, in order to provide satisfactory potable water.

The samples were collected at the source, and the inlet and outlets of each unit operations. Samples were collected in the morning and afternoon to capture the diurnal variations in quality. It was decided to carry out four trials during two dry seasons and two wet seasons since the raw water quality reports showed that the quality was significantly varied seasonally.

It was found from this study that raw water in Konduwatuwana Tank has high cyanobacteria content and *Microcystis aeruginosa* is the predominant specie. Main findings of our study were that PAC was effective in removal of Microcystin as well as dissolved organic substances, but needs to be optimized by providing sufficient contact time, and pre-chlorination does not improve the performance. The results of this study were generalized using water quality data of irrigation tanks in Gal oya cascade system, several irrigation tanks in the Kala Oya Basin and another few selected irrigation tanks in the North Central Province (not in the Kala Oya Basin).

Table of Content

	Page No
Declaration of the Candidate & Supervisors	i
Acknowledgements	ii
Abstract	iii
Table of Content	iv
List of Tables	vii
List of Figures	viii
List of Abbreviations	xi
List of Appendices	xii
1. Introduction	1
1.1 General Description	1
1.2 Cyanobacteria and Cyanotoxins	3
1.2.1. Introduction about Cyanobacteria and Cyanotoxins	3
1.2.2. Microsystins	5
1.2.3. Cylindrospermopsin	7
1.3 ECTAD Water Supply Project	8
1.3.1. Background	8
1.3.2. Raw Water Source	9
1.3.3. Rapid Mixer	12
1.3.4. Flocculators	12
1.3.5. DAF Units	13
1.3.6. Rapid Sand Filter	14
2. Background Studies	14
3. Objective of the Research	23
3.1 Broad Objective	23
3.2 Specific objectives	23

4. Methodology	24
4.1 Methodology Flow Chart	24
4.2 Analysing raw water quality of Konduwatuwana Tank	25
4.2.1 Water quality parameters and methods used.	25
4.2.2 Analysing total iron, total manganese using AAS	26
4.2.3 Determination of COD	26
4.2.4 Measuring algae concentration	27
4.2.5 Detection of Microcystins using Immuno Strips	28
4.2.5.1 Requirements	28
4.2.5.2 The Microcystin Immuno Strip	28
4.2.5.3 Sample preparation and testing procedure	29
4.2.5.4 Interpretation of Results	30
4.3 Evaluation of performance of treatment operations	30
4.4 Taste and Odour Removal	31
4.5 Generalizing the Results	32
5. Results and Discussion	35
5.1 Raw water quality of Konduwatuwana Tank	35
5.1.1 Raw water pH	35
5.1.2 Turbidity	38
5.1.3 Total Iron Concentration	39
5.1.4 Total Manganese Concentration	41
5.1.5 Algal Concentration	42
5.1.6 Algal Toxin Concentration	46
5.1.7 Chemical Oxygen Demand	47
5.1.8 Total Organic Carbon Concentration	49
5.2 Treatment Operations	49
5.2.1 Mycrocystin Removal	49
5.2.2 Total Iron Removal	52
5.2.3 Total Manganese Removal	54
5.3 Taste and Odor Removal	57
5.4 Generalizing the Results	61
5.4.1 Generalizing the Results based on Dissolved Organic Substances	61
5.4.2 Generalizing the Results based on Total Iron Concentration	62

5.4.3 Generalizing the Results based on Total Manganese Concentration	63
5.4.4 Generalizing the Results based on Algal Concentration	65
6. Conclusions and Recommendations	71
6.1 Conclusions	71
6.2 Recommendations	72
References	74
Appendices A Detail of Types of PAC Used	77



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

List of Tables

	Page
Table 1.1: Categories of Cyanotoxins.	4
Table 1.2: The Catchment areas of Tanks	11
Table 1.3: Layer detail of RSF	14
Table 2.1: Algal Studies about Konduwatuwana Tank.	17
Table 4.1: Water quality parameters and methods used.	25
Table 4.2: Selected irrigation tanks and parameters for generalizing the results	33
Table 5.1: Algal species identified in Konduwatuwana tank	43
Table 5.2: Microcystin LR concentration in raw water of Konduwatuwana Tank	47
Table 5.3: The COD of the raw water during dry and wet seasons	48
Table 5.4: Microcystin identification test results for dry season 1 st trial	50
Table 5.5: Microcystin identification test results for dry season 2 nd trial	50
Table 5.6: 2-MIB and geosmin concentrations of Konduwatuwana tank water	57
Table 5.7: Percentage COD removal of various PACs	60
Table 5.8: Selected irrigation tanks for algal analyses and related WSSs	67



List of Figures

	Page
Figure 1.1: The chemical structure of MC-LR	5
Figure 1.2: A photograph of <i>Microcystis</i> bloom	5
Figure 1.3: The chemical structure of Cylindrospermopsin	6
Figure 1.4: A photograph <i>Cylindrospermopsis raciborskii</i> specie	6
Figure 1.5: Flow chart of unit operations	7
Figure 1.6: Konduwatuwana WTP intake	8
Figure 1.7: Raw water pipe line from intake to WTP	8
Figure 1.8: The sketch of the irrigation system	8
Figure 1.9: Land use types of catchment area of Konduwatuwana Tank	10
Figure 1.10: PACL is added to the rapid mixer	10
Figure 1.11: PAC is added to the rapid mixer	10
Figure 1.12: Flocculation tank with mechanical stierr	11
Figure 1.13: The baffles are placed end of the flocculation tank	11
Figure 1.14: The series of flocculation tanks	11
Figure 1.15: The water passes from each flocculation tank over a baffle to the DAF plant	11
Figure 1.16: DAF tank with scum collected surface	12
Figure 1.17: The series of DAF tanks	12
Figure 1.18: Empty filtration chamber	13
Figure 1.19: Filtration chamber with filtrate	13
Figure 2.1: Algae counts in Irrigation Tanks, Source: J. P. Padmasiri (Review of algal problems faced by NWSDB)	14
Figure 2.2: Algae counts in Irrigation Tanks, Source: Regional laboratory of Ampara	15
Figure 2.3: Algal species present in Konduwatuwana Tank according to Aapola's study (2007)	16
Figure 4.1: Methodology flow chart	22
Figure 4.2: The Sedgwick-Rafter counting cell	26
Figure 4.3: Immuno Strips	27
Figure 4.4: Results Interpretation with Immuno Strips	28
Figure 4.5: Operation Sequences	29

Figure 4.6: Allowing the raw water to absorb the organic matter using the shaker	30
Figure 5.1: Variation of pH in water samples in the study period.	32
Figure 5.2: Variation of raw water alkalinity	33
Figure 5.3: Changes in pH during a 24 hour period in waters of high and low alkalinities. (source: William et al., 1992)	34
Figure 5.4: Variation of raw water pH in Konduwatuwana tank in past years	34
Figure 5.5: Variation of turbidity in water samples in the study period	35
Figure 5.6: Variation of turbidity in Konduwatuwana tank in past years	36
Figure 5.7: Variation of total iron concentration in water samples in the study period	36
Figure 5.8: Variation of total iron concentration in Konduwatuwana tank in past years	37
Figure 5.9: Variation of total manganese concentration in water samples in the study period	38
Figure 5.10: Variation of total manganese concentration in Konduwatuwana tank in past years	38
Figure 5.11: Algal analysis results in raw water samples during the study period	39
Figure 5.12: Diurnal variation of <i>Microcystis aeruginosa</i> concentration with the depth	40
Figure 5.13: Diurnal variation of <i>Microcystis wesenbergi</i> concentration with the depth	40
Figure 5.14: Diurnal variation of <i>Cylindrospermopsis</i> concentration with the depth	40
Figure 5.15: <i>Myrcocystis</i> and <i>Cylindrospermopsis</i> in a sample	41
Figure 5.16: COD Variation of the Raw Water during Dry and Wet Weather	43
Figure 5.17: TOC Variation of the Raw Water during Wet Weather	44
Figure 5.18: Total Iron Variation along the Treatment Process – Wet Season Trial 1	46
Figure 5.19: Total Iron Variation along the Treatment Process – Dry Season Trial 1	47
Figure 5.20: Total Iron Variation along the Treatment Process – Dry Season Trial 2	47
Figure 5.21: Total Iron Variation along the Treatment Process – Wet Season Trial 2	48
Figure 5.22: Total Manganese Variation along the Treatment Process – Wet Season Trial 1	49
Figure 5.23: Total Manganese Variation along the Treatment Process – Dry Season Trial 1	49

Figure 5.24: Total Manganese Variation along the Treatment Process – Dry Season Trial 2	50
Figure 5.25: Total Manganese Variation along the Treatment Process – Wet Season Trial 2	50
Figure 5.26: Percentage COD removal of three different PACs for 60 minutes contact time	52
Figure 5.27: Percentage COD removal of three different PACs for 22 minutes contact time	54
Figure 5.28: COD measurements of irrigation tanks in the Kala Oya Basin (Source: Studies on the water quality of Kala Oya Basin, Final Report 2003 by River Basin Planning and Management Division of MASL)	55
Figure 5.29: Total iron measurements of different irrigation tanks in the cascade system. (Source: Water quality Report by Regional Laboratory Ampara)	55
Figure 5.30: Total iron measurements of different irrigation tanks in the Kala Oya Basin (Source: Studies on the water quality of Kala Oya Basin, Final Report 2003 by RBP&M Division of MASL)	56
Figure 5.31: Total manganese measurements of different irrigation tanks in the cascade system. (Source: Water quality Report by Regional Laboratory Ampara).	57
Figure 5.32: Total manganese measurements of different irrigation tanks in the Kala Oya Basin (Source: Studies on the water quality of Kala Oya Basin, Final Report 2003 by RBP&M Division of MASL)	57
Figure 5.33: Algal analysis results of Inginiyagala Tank	58
Figure 5.34: Algal analysis results of Himidurawa Tank	58
Figure 5.35: Algal analysis results of Weeragoda Tank	59
Figure 5.36: Algal analysis results of Thuruwila Tank	60
Figure 5.37: Algal analysis results of Nallachchiya Tank	60
Figure 5.38: Algal analysis results of selected nine irrigation tanks in NCP	62
Figure 6.1: Selection of treatment operations for water treatment plants where irrigation tanks are used as the source	65

List of Abbreviations

Abbreviation	Description
AAS	- Atomic Absorption Spectrophotometer
AC	- Activated Carbon
APHA	- American Public Health Association
COD	- Chemical Oxygen Demand
CYN	- Cyindrospermopsin
DAF	- Dissolved Air Flotation
DBP	- Disinfection by-products
ECTAD	- Eastern Coastal Towns of Ampara District
ELISA	- Enzyme Linked Immuno Sorbent Assay
FAS	- Ferrous Ammonium Sulphate
GAC	- Granular Activated Carbon
HPLC	- High Performance Liquid Chromatography
IFS	- Institute of Fundamental Studies
LB	- Left Bank
LD ₅₀	- Fifty percent Lethal Dosage
MASL	- Mahaweli Authority of Sri Lanka
MC-LR	- Microcystin Leucine Arginine
MIB	- methylisoborneol
NCP	- North Central Province
NWSDB	- National Water Supply and Drainage Board
PAC	- Powdered Activated Carbon
PACL	- Polyaluminium chloride
RB	- Right Bank
rpm	- revolutions per minutes
RSF	- Rapid Sand Filter
THM	- Trihalomethanes
UoM	- University of Moratuwa
WHO	- World Health Organization
WSS	- Water Supply Scheme
WTP	- Water Treatment Plant

List of Appendices

Appendices	Description	Page
Appendices – A	Details of types of PAC used	76



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk