

BIOELIMINATION MECHANISMS OF AQUEOUS WASTE COMPOUNDS THROUGH VASCULAR PLANTS

by
H. S. BHATIA

Thesis Submitted in fulfilment of the
requirements for the award of the degree of
DOCTOR OF PHILOSOPHY



**DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
July, 1985**

TO THE MEMORY OF
MY INSPIRING & LOVING FATHER
WHO LEFT FOR HEAVENLY ABODE
WHILE I WAS PURSUING THIS STUDY

C E R T I F I C A T E

This is to certify that the thesis entitled "Bioelimination Mechanisms of Aqueous Waste Compounds through Vascular Plants" submitted by Mr. H.S. Bhatia to the Indian Institute of Technology, Delhi, for the award of Degree of DOCTOR OF PHILCSOPHY is a record of the bonafide research work carried out by him.

Mr. H.S. Bhatia has worked under my guidance for the submission of this thesis, which to my knowledge has reached the requisite standard.

The thesis or any part thereof, has not been submitted to any other University or Institution for the award of any degree or diploma.



(DR. P.K. JAIN)
Assistant Professor
Department of Civil Engineering
Indian Institute of Technology, Delhi

ABSTRACT

Waste disposal problems have been the focus of attention particularly with increase in population and industrialisation. The primary goal of waste treatment management hence is to develop an effective, low energy, low cost systems. The present work is aimed in such direction only. Vascular plant such as water hyacinth has assumed importance once it was discovered that it can be used for such treatments. The growth of water hyacinth (*Eichhornia Crassipes*) under N limiting conditions can be worked out based on certain mathematical models. In this study the various kinetic constants required to predict its growth rate, growth potential, area required for minimum standing crop, harvesting frequencies etc. have been worked out to predict optimum growth for its best usage in terms of nutrient removal under varying temperature conditions. The practical application of these constants has been illustrated by selecting a particular pond receiving 100 million litres of waste water annually. Curves have been plotted to allow immediate prediction and design of such growths and their subsequent harvestings. Water hyacinths are considered quite capable of not only solving the eutrophication problem by controlling the algal mass

but at the same time removing the much desired load at an improved efficiency. However, to make such system fully reliable under various conditions and to finally develop a well designed system the various bioelimination mechanisms have to be fully understood. Accordingly multistage cascading system, multicell hyacinth algal system and natural eco systems have been devised to understand such mechanisms. These studies provide significant informations as illustrated through scores of observations recorded in each of these systems. The conclusions drawn could be a thorough base for developing proper design criteria for such low cost but reliable treatment technology. An attempt has also been made to mathematically correlate some important parameters so that they can be used in a generalised way while designing such low energy systems.

ACKNOWLEDGEMENTS

The author expresses his deep sense of gratitude to his Supervisor, Dr. P.K. Jain, B.S.E. (Mich), M.S.E. San. Engr. (Mich.), Ph.D. (Lond.), MIE, M.A.S.C.E. M.Chl., EpS. (U.S.A.), Department of Civil Engineering, Indian Institute of Technology, New Delhi for his immense help and valuable guidance extended throughout the course of this study.

The author is extremely grateful to the Head of the Department, Professor (Dr.) T. Ramamurthy and Professor (Dr.) Subhash Chander, but for their constant encouragement and help, this work would not have been completed.

The author is highly indebted to Professor R.C. Singh of the Civil Engineering Department, Indian Institute of Technology, Delhi who was always willing to help in any matter or discussions concerning the research work.

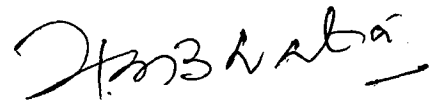
The author feels very happy to place on record his sincere thanks to the authorities of the Flood Wing of Delhi Administration, the Principal, Delhi College of Engineering and the Head of the Civil Engineering Department, for sponsoring the author under the Quality Improvement

Programme with all facilities to carry out his work and also to all the laboratory staff of Environmental Engineering Section of Civil Engineering Department of Indian Institute of Technology, New Delhi, for extending liberal help and cooperation during the progress of this work.

The author's thanks are due to all his co-research especially to Mrs. S. Jindal who helped from time to time through the exchange of ideas during the progress of this work.

The author wishes to express his heartfelt thanks to Professor (Dr.) A.F.S.A. Aowl of the Civil Engineering Department, Delhi College of Engineering for his constant help, guidance and encouragement during the course of the present work.

The author especially thanks his wife, Mrs. Jasbir Bhatia for the encouragement, cooperation and patience shown during the period of study.



(H.S. BHATIA)

CONTENTS		Page No.
	CERTIFICATE	1
	ABSTRACT	2
	ACKNOWLEDGEMENTS	4
	CONTENTS	6
	NOTATION	12
	LIST OF FIGURES	15
	LIST OF TABLES	18
CHAPTER I	INTRODUCTION	21
	1.1 General	22
	1.2 Past studies/Literature review	31
	1.3 Productivity studies	41
	1.4 Growthrate	43
	1.5 Objective & scope of the present work	45
CHAPTER II	WATER HYACINTH (E.CRASSIPES) SYSTEMATICS	47
	2.1 General	48
	2.2 Distribution	51
	2.3 Morphology	57
	2.4 Anatomy	60
	2.5 Phenology	64
	2.6 Vegetative Propagation	66
	2.7 Evapotranspiration	70
	2.8 Photosynthesis	71

2.9	Dry matter production	72
2.10	Community structure	72
2.11	Nitrogen fixation	73
2.12	Effect of light and temperature	74
2.13	Effect of Nutrient	76
2.14	Effect of pH	76
CHAPTER III CONVENTIONAL VERSUS AQUATIC SYSTEMS		85
3.1	Wastewater characteristics and treatment	86
3.2	Wastewater treatment (Conventional/advanced)	87
3.3	Contaminant removal mechanism	89
3.4	Impact of local environmental conditions	92
3.5	System reliability and Design of Aquatic units	92
3.6	Resource recovery	94
3.7	Assessment of Aquatic systems	95
CHAPTER IV GENERALITY OF GROWTH		113
4.1	Preliminary analysis	114
4.2	Experimental set-up details	115
4.3	Procedure of Experimentation	116
4.4	Effect of growth and growth versus treatabilities	119
4.5	Specific conclusions	120

CHAPTER V	GROWTH KINETICS	135
	5.1 General	136
	5.2 Parameteric Computations	138
	5.3 Growth models/Analytical Computations	140
	5.4 Applications	144
CHAPTER VI	DEVELOPMENT OF LABORATORY MODELS	151
	6.1 Detailed Analysis I	152
	6.2 Details of Multistage cascading system	152
	6.3 Basic components of multistage cascading system	153
	6.4 Component description	154
	6.5 Removal Mechanism	158
	6.6 Feasibility studies/levels of treatment	159
CHAPTER VII	DETAILED ANALYSIS II	176
	7.1 Detailed Analysis II	177
	7.2 Development of multicell hyacinth - algal system	178
	7.3 Details of Multicell hyacinth - algal system	180
	7.4 Component description	181
	7.5 Treatment mechanism/Influence of additional factors	184
	7.6 Multiphasic treatability studies	186
	7.7 Rates of uptake and uptake mechanisms, plants and their collections	188

7.8	Oxygen uptake/Plant respiration	189
7.9	Variations in important parameter in different cells of multicell vascular reactor	190
CHAPTER VIII DETAILED ANALYSIS III		205
8.1	Justification of replacing algae by water hyacinth in a waste water lagoon	206
8.2	Development of natural eco system	210
8.3	Analysis and sampling methods	213
8.4	Details of natural eco systems	214
8.5	Development of design parameters and establishment of mathematical correlations	219
CHAPTER IX BIOELIMINATION MECHANISMS/REMOVAL/ UPTAKE MECHANISMS		228
9.1	Removal Mechanisms	232
9.2	Reliability on the alkalinity system	235
9.3	Nutrient Removals	237
9.4	Oxygen Economy	246
9.5	Factors affecting oxygen economy	246
9.6	Measurement of primary productivity	247
9.7	BOD uptake and its seasonal variations	251
9.8	Suspended solid consumption	253
9.9	Uptake variations in individual cell of the multicell hyacinth algal system	254

CHAPTER X	DISCUSSIONS/ANALYSIS OF RESULTS/ APPLICATIONS	261
10.1	Characteristics of Vascular (Hyacinth) systems/Brief outline of present study	262
10.2	Plant growth	266
10.3	Conventional/Aquatic system with particular reference to hyacinth system	268
10.4	Removal mechanisms	269
10.5	Assessment/system reliability	270
10.6	Resource recovery	271
10.7	Growth kinetics	272
10.8	Generality of growth	274
10.9	Detailed Analysis I	277
10.10	Detailed Analysis II	278
10.11	Detailed Analysis III	282
10.12	Biodegradation mechanisms	284
CHAPTER XI	SUMMARY AND CONCLUSIONS	287
11.1	to Summary	288
11.4		
11.5	Conclusions	298
11.6	Development of Design parameters for vascular treatment systems	304
11.7	Important design parameters of raw heterogeneous aqueous waste vascular treatment system	309
11.8	Development of Mathematical correlations	311
11.9	Suggestions for Further work	311(a)

CHAPTER XII	REFERENCES	313
Appendix I	Important Tables and other relevant information	333
Appendix II	Papers published/communicated	339
Appendix III	Photographs related to the research work	341