

## ACKNOWLEDGMENTS

I would like to sincerely thank USFilter for providing the funding for my research. I am extremely grateful to Dr. John Novak for providing me the opportunity of working under his guidance. During my stay at Virginia Tech I had a chance to learn from his varied experience. I gracefully acknowledge his able guidance, help, periodic review of my work, valuable suggestions and the time and energy devoted by him. I would also like to thank the time and support of my committee members. I am also thankful to Dr. Mohammad Abu Orf for periodically reviewing my work and providing insightful suggestions. I am thankful to Cytec Industries for providing the anionic polymer for this study.

I am also thankful to Chul Park for his invaluable guidance during the initial stages of my research. I would also like to thank Julie Petruska and Betty Wingate for their assistance. My most sincere appreciation for Jody Smiley who helped me in carrying out my experiments and for providing help whenever approached. I would also like to thank the many friends and acquaintances that I had a chance to interact and learn from during my master's study.

Finally I would like to thank my parents and my brother for providing me the opportunity to pursue higher education. I cherish and value their constant love, support and encouragement.

## TABLE OF CONTENTS

ABSTRACT.....	ii
ACKNOWLEDGMENTS.....	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
<b>CHAPTER I</b>	
INTRODUCTION.....	1
<b>CHAPTER II</b>	
LITERATURE REVIEW.....	5
THE FLOCCULATION PROCESS.....	6
FACTORS AFFECTING DEWATERING.....	7
Role of Biopolymers.....	7
Role of Cations.....	9
Role of Iron and Aluminum.....	10
Zeta Potential.....	11
Hyrdophobicity.....	12
THERMOPHILIC DIGESTION.....	13
Research Related to ATAD.....	14
REFERENCES.....	15
<b>CHAPTER III</b>	
Sequential Polymer Dosing for Effective Dewatering of ATAD Sludges.....	21
ABSTRACT.....	22
INTRODUCTION.....	23
METHODS AND MATERIALS.....	25
RESULTS AND DISCUSSIONS.....	26
CONCLUSIONS.....	34
REFERENCES.....	34

## CHAPTER IV

### The Effect of Biopolymers on the Dewatering Characteristics of ATAD

Sludges.....	49
ABSTRACT.....	50
INTRODUCTION.....	49
METHODS AND MATERIALS.....	52
RESULTS AND DISCUSSIONS.....	54
CONCLUSIONS.....	62
REFERENCES.....	63
Engineering Significance.....	78
Vita.....	79

## LIST OF TABLES

### CHAPTER III

Table 1. Dewatering Rates for the four ATAD plants.....	44
Table 2. Optimum conditioning using different chemical coagulants for sludge from different stages of treatment (Ephrata).....	45
Table 3. Minimum CST for Sludge from Holding Tank Following Conditioning and Dose required.....	46
Table 4. Changes in Zeta Potential ( $\zeta$ ) and pH across the ATAD system for the various plants.....	47
Table 5. Phosphorus concentrations across the ATAD systems.....	48

### CHAPTER IV

Table 1. Dewatering Rates (CST) for the Four ATAD plants.....	74
Table 2a. Polysaccharide concentration in solution for Cranberry, College Station and Ephrata.....	75
Table 2b. Protein concentration in solution for Cranberry, College Station and Ephrata .....	75
Table 3. Monovalent to Divalent (M/D) Cation ratio for the sludge from various treatment plants.....	76
Table 4. Solution Protein and Polysaccharide Distribution For Unconditioned and Conditioned ATAD Sludges.....	77

## LIST OF FIGURES

### CHAPTER III

Figure 1. Dewatering using Ferric Chloride (Sludge from Cranberry, PA).....	37
Figure 2. Variation in Zeta Potential for the sludge from Holding Tank of Ephrata dosed with Ferric Chloride.....	38
Figure 3. Changes in selected cations across the ATAD systems for the four treatment plants.....	39
Figure 4. Calcium and Magnesium concentration in solution after dosing with iron (Ephrata).....	40
Figure 5. Conditioning of the sludge from the holding tank at Titusville using iron and anionic polymer.....	41
Figure 6. Conditioning of the sludge from holding tank using iron and anionic polymer for College Station.....	42
Figure 7. Conditioning of sludge from holding tank using cationic and anionic polymer for Ephrata.....	43

### CHAPTER IV

Figure 1a. Protein concentration in solution Across the ATAD System in different size fractions (Titusville).....	66
Figure 1b. Polysaccharide concentration in solution Across the ATAD System in different size fractions (Titusville).....	66
Figure 2a. Iron and Aluminum concentration in the sludge in the first ATAD Digester for the different plants.....	67
Figure 2b. Soluble iron and aluminum concentrations in the first ATAD Digester for three plants.....	67
Figure 3. Variation in biopolymer with the total iron concentration .....	68
Figure 4. Changes in Cation Concentration in Solution Across the ATAD system (Titusville).....	69
Figure 5. Dewatering as measured by CST and M/D ratio.....	70
Figure 6. Effect of M/D ratio on solution biopolymer concentration.....	71

Figure 7 Protein in conditioned and unconditioned sludge for Ephrata and Titusville  
..... 72  
Figure 8a. Optimum iron dose vs Colloidal Biopolymer (Ephrata)..... 73  
Figure 8b. Optimum polymer dose vs Colloidal Biopolymer (Ephrata)..... 73