CARBON, NITROGEN AND PHOSPHORUS REMOVAL FROM DOMESTIC WASTEWATER BY ALTERNATING AEROBIC-ANOXIC PROCESS

NOORUL HUDAI BT ABDULLAH

A thesis submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JANUARY 2017
This thesis is dedicated to:

Special dedication to my late father, Abdullah Bin Abdul Rahman who taught me how to read and how to write. The person dreamed to see me one day high educated. He left the life but his dream still alive.

Special dedication to my beloved mother, mother-in-law and father-in-law, Che Meriam Binti Che Soh, Zainun Binti Awang and Abd Rahman Bin Mohamed, without them none of my success would be possible.

To my beloved husband Mohd Hilmi Bin Abd Rahman, he has been a source of motivation and strength during moment of discouragement and despair.

Thanks for advices, affections continued supports and supplications during my study

and lastly,

Special thanks to my beloved sisters, brothers and all my friends, who always together through thick and thin, guidance and encouragement to finish my study. May Allah SWT bless all of you with all prosperity, happiness, wisdom and good health in this world and the Hereafter.

Ammen Ya Rabbal Alam.
ACKNOWLEDGEMENT

The most important acknowledge is to our Lord Most Merciful Most Wise by whose mercy I was able to successful completion of this PhD study. His Mercy is such that unworthy slave like me is given the ability to work in His cause through which I remember Him SWT and be grateful towards all He has given me. Allah states in the Quran 'Then remember Me; I will remember you. Be grateful to Me, and do not ungrateful to Me' (al-Baqarah 2: 152), May Allah accept my humble work as an effort to remember and thank Him SWT. Ameen Ya Rabbal Alameen.

I would like to express my deep and sincere gratitude to my supervisor, Assoc. Prof. Dr. Mohamad Ali Fulazzaky and my co-supervisor Prof. Dr. Abdull Rahim Bin Mohd Yusoff for their patience, understanding, encouragement and personal guidance that I have been able to complete this study. I am grateful for all of the opportunities that they have provided me. This research would not have seen the light of day were it not for the help of many people and several organisations.

I wish to express my warm and sincere thanks to all staff in Centre for Environmental Sustainability & Water Security (IPASA) for allowing me to use their laboratory facilities. I would like also to express my appreciations to my colleagues in IPASA laboratory whose have taught me so much and help me to get through my work in the laboratory including Atikah, Hairul, Shakila, Maria, Amerreza, Mimi, Aziah, Hazwan and all students and staff in Environmental Laboratory Faculty of Civil Engineering, University Teknologi Malaysia. I wish to extend my warmest thanks to my collaborated, Indah Water Konsortium to allowing and helping me to collect the sample during this research and also the sponsorship from Ministry of Higher Education Malaysia (MyPhD) and the grant from University Teknologi Malaysia.
Excessive amount of nutrients (nitrogen and phosphorus) released from wastewater may lead to degradation of the receiving water and can induce adverse effects on human health and the environment. The use of coupled nitrification-denitrification can significantly remove major pollutants from domestic wastewater, however researchers only have limited understanding of the alternating aerobic-anoxic process in a single reactor and therefore needs to be verified. This study performed treatment using an alternating aerobic-anoxic (AAA) process in a single reactor to remove major pollutants from domestic wastewater i.e., carbon, nitrogen and phosphorus. Comparative analysis of the coupled nitrification-denitrification reactions was carried out to investigate different periods of nitrification-denitrification cycles and to analyse the effect of initial dissolved Fe/P molar ratio and pH on iron-hydroxide-phosphate precipitation. The results indicated that 3-h aerobic digestion and 3-h anoxic time was the best cycle to remove the pollutants where the removal efficiencies of COD and NH₄⁺ were verified as high as 97% and 87%, respectively, achieving the desired inorganic nitrogen concentration of less than 10 mgNL⁻¹ in the outflow to meet stringent effluent standards. The denitrification/ nitrification ratio of 2.1, indicates that denitrification occurs in the reactor faster than nitrification because it can prevail over nitrifying bacteria in competition for reaction kinetics. The AAA treatment process to remove soluble reactive and total phosphorus from domestic wastewater had a moderate efficiency. Two types of Fe₆(OH)₉PO₄ and Fe₅(OH)₆(PO₄)₃ precipitate may occur in different conditions of the AAA process. The results advance the understanding that proper AAA treatment effectively removes carbon, nitrogen and phosphorus pollution from domestic wastewater. The contribution of this study in removal of major pollutants from domestic wastewater will require future assessment in a prospective wastewater treatment facilities setting.
ABSTRAK

Nutrien berlebihan (nitrogen dan fosforus) yang dilepaskan dari air sisa boleh menurunkan kualiti dan boleh menyebabkan kesan buruk kepada kesihatan manusia dan alam sekitar. Penggunaan nitrifikasi-denitrifikasi boleh menyinsihkan bahan pencemar utama dari air sisa domestik, pemahaman penyelidik terhad dalam proses selang seli aerobik-anoksik dalam reaktor tunggal dan perlu disahkan. Kajian ini telah menjalankan proses selang seli aerobik-anoksik (AAA) dengan reaktor tunggal untuk menghapuskan bahan pencemar utama dari air sisa domestik seperti contoh karbon, nitrogen dan fosforus. Analisis perbandingan reaksi nitrifikasi-denitrifikasi telah dijalankan untuk menyiapkan perbezaan tempoh kitaran nitrifikasi-denitrifikasi dan menganalisis kesan awal nisbah molar Fe/P dan pH dalam mendakan ferum-hidroksil-fosfat. Keputusan menunjukkan kitaran 3-jam aerobik dan 3-jam anoksik adalah kitaran yang terbaik dalam menghapuskan bahan pencemar, di mana kecepatan penyingkiran bagi COD dan NH$_4^+$ adalah 97% dan 87%, mencapai kepekatan nitrogen inorganik yang dikehendaki kurang dari 10 mgNL$^{-1}$ dalam aliran keluar untuk memenuhi piawaian efluen yang ketat. Dengan nisbah denitrifikasi/ nitrifikasi ialah 2.1, ini menunjukkan bahawa denitrifikasi berlaku dalam reaktor cepat berbanding nitrifikasi kerana ia boleh mengatasi bakteria nitrifikasi dalam persaingan untuk tindak balas kinetik. Proses rawatan AAA untuk mengurangkan fosforus reaktif larut dan fosforus daripada air sisa domestik mempunyai kecekapan yang sederhana. Dua jenis mendakan Fe$_4$(OH)$_9$PO$_4$ dan Fe$_5$(OH)$_6$(PO$_4$)$_3$ boleh berlaku dalam keadaan proses AAA. Keputusan kajian rawatan AAA efektif untuk menyingkirkan karbon, nitrogen dan fosforus daripada air sisa domestik. Sumbangan kajian ini telah menyingkirkan karbon, nitrogen, fosforus daripada air sisa domestik dan memerlukan penilaian pada masa hadapan dalam rawatan fasiliti air sisa.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td>ii</td>
<td></td>
</tr>
<tr>
<td>DEDICATION</td>
<td>iii</td>
<td></td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iv</td>
<td></td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
<td></td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>vi</td>
<td></td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>vii</td>
<td></td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xi</td>
<td></td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xii</td>
<td></td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xvi</td>
<td></td>
</tr>
<tr>
<td>LIST OF SYMBOLS</td>
<td>xviii</td>
<td></td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xix</td>
<td></td>
</tr>
</tbody>
</table>

1 INTRODUCTION  
1.1 Introduction 1  
1.2 Problems statement 2  
1.3 Objectives of the study 3  
1.4 Scope of the study 4  
1.5 Research significances 5  
1.6 Organisation of the thesis 6  

2 LITERATURE REVIEW 7
2.1 Introduction  
2.2 Domestic wastewater  
  2.2.1 Characteristics of domestic wastewater  
  2.2.2 Major pollutants in domestic wastewater  
  2.2.3 Regulations  
2.3 Alternating Aerobic-Anoxic Treatment process  
  2.3.1 Alternating Aerobic-Anoxic process for carbon  
  and nitrogen removal  
  2.3.2 Alternating Aerobic-Anoxic process for  
  phosphorus removal  
2.4 Summary  

3 MATERIALS AND METHODS  
3.1 Introduction  
3.2 Stages of experimental run  
3.3 Domestic wastewater  
  3.3.1 Characterisation of the domestic wastewater  
3.4 Discontinuous aerobic-anoxic reactor  
  3.4.1 Stage of the experimental run  
  3.4.1.1 Aerobic digestion process  
  3.4.1.2 Alternating aerobic-anoxic treatment  
  processes  
  3.4.1.3 Precipitation of iron-hydroxy-phosphate of  
  added ferric iron  
3.5 Analytical methods  
3.6 Summary  

4 APPLICATION OF ALTERNATING AEROBIC-ANOXIC  
PROCESS FOR THE REMOVAL OF CARBON AND FOR  
THE SELECTION OF THE BEST CONDITION OF  
ANOXIC TIME-AEROBIC DIGESTION CYCLE  
4.1 Introduction  
4.2 Characteristics of domestic wastewater
4.3 Aerobic digestion process

4.4 Conditioning the Alternating Aerobic-Anoxic treatment process
   4.4.1 Ratio of denitrification to nitrification

4.5 Summary

5 APPLICATION OF ALTERNATING AEROBIC-ANOXIC PROCESS FOR THE REMOVAL OF INORGANIC NITROGEN POLLUTION
   5.1 Introduction
   5.2 Conditioning the experimental environments
   5.3 Experimental data validation
      5.3.1 The three different experimental environments
      5.3.2 The two different alternating aerobic-anoxic periods
   5.4 Summary

6 APPLICATION OF ALTERNATING AEROBIC-ANOXIC PROCESS FOR THE REMOVAL OF PHOSPHATE OF WITH ADDITIONAL OF FERRIC IRON
   6.1 Introduction
   6.2 Experimental data validation
      6.2.1 Biological phosphorus removal conditions
      6.2.2 Precipitation of iron-hydroxy-phosphate during water flows into the reactor
      6.2.3 Precipitation of iron-hydroxy-phosphate in the reactor
      6.2.3.1 Iron-hydroxy-phosphate accumulation in activated sludge
      6.2.3.2 Influences of Fe/P molar ratio and pH
   6.3 Summary
7 CONCLUSIONS AND RECOMMENDATIONS 80
7.1 Conclusions 80
7.2 Recommendations 81

REFERENCES 83
Appendices A - D 98-116
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Principal of concern in wastewater treatment (Tchobanoglous <em>et al.</em>, 2004; Henze &amp; Comeau, 2008)</td>
<td>11</td>
</tr>
<tr>
<td>2.2</td>
<td>Minimum national standards for secondary treatment (Tchobanoglous <em>et al.</em>, 2004)</td>
<td>14</td>
</tr>
<tr>
<td>2.3</td>
<td>The Urban Wastewater Treatment Directive (91/271/EEC) sets discharge limits for wastewater treatment plants. Values for total phosphorus and nitrogen only apply to discharges &gt; 10,000 population equivalents (PE) discharging to surface waters classed as sensitive (e.g. those subject to eutrophication) (Gray, 2004).</td>
<td>15</td>
</tr>
<tr>
<td>2.4</td>
<td>Acceptable conditions of sewage discharge of standard A and B (DOE, 2009)</td>
<td>16</td>
</tr>
<tr>
<td>3.1</td>
<td>Operating parameters of the AAA treatment process</td>
<td>30</td>
</tr>
<tr>
<td>3.2</td>
<td>The categories of alternating aerobic-anoxic treatment process (AD=Aerobic digestion process, AT=Anoxic time process)</td>
<td>33</td>
</tr>
<tr>
<td>3.3</td>
<td>The parameters and methods used for the experiments</td>
<td>33</td>
</tr>
<tr>
<td>4.1</td>
<td>Main characteristics of domestic wastewater from IWK treatment plant at Taman Impian Emas, Skudai, Johor.</td>
<td>39</td>
</tr>
<tr>
<td>4.2</td>
<td>Expected condition according to the SVI values (Spellman, 2013)</td>
<td>41</td>
</tr>
<tr>
<td>4.3</td>
<td>Three different condition of the AAA processes</td>
<td>48</td>
</tr>
<tr>
<td>5.1</td>
<td>Urban wastewater treatment directive 91/271/EEC</td>
<td>58</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Application of the Alternating Aerobic-Anoxic treatment process</td>
<td>8</td>
</tr>
<tr>
<td>3.1</td>
<td>Stage of experimental run</td>
<td>25</td>
</tr>
<tr>
<td>3.2</td>
<td>Operational frame work</td>
<td>26</td>
</tr>
<tr>
<td>3.3</td>
<td>Indah Water Konsortium treatment plant at Taman Impian Emas, Skudai, Johor Bahru, Malaysia</td>
<td>27</td>
</tr>
<tr>
<td>3.4</td>
<td>Schematic of Discontinous Aerobic Anoxic Reactor</td>
<td>29</td>
</tr>
<tr>
<td>4.1</td>
<td>Evolution of MLSS concentration in accordance with $t$ under the Aerobic Digestion conditions</td>
<td>41</td>
</tr>
<tr>
<td>4.2</td>
<td>Variation of the SVI value in accordance with $t$ under the Aerobic Digestion conditions</td>
<td>42</td>
</tr>
<tr>
<td>4.3</td>
<td>Linear regression analysis of plotting the organic loading rate versus the rate of organic removal.</td>
<td>42</td>
</tr>
<tr>
<td>4.4</td>
<td>Variation of SS concentration in accordance with $t$ under the Aerobic Digestion conditions</td>
<td>43</td>
</tr>
<tr>
<td>4.5</td>
<td>Variation of COD removal efficiency in accordance with $t$ under the Aerobic Digestion conditions</td>
<td>44</td>
</tr>
<tr>
<td>4.6</td>
<td>Variation of NH$_4^+$ removal efficiency in accordance with $t$ under the Aerobic Digestion conditions</td>
<td>44</td>
</tr>
<tr>
<td>4.7</td>
<td>Variation of TP removal efficiency in accordance with $t$ under the Aerobic Digestion conditions</td>
<td>45</td>
</tr>
</tbody>
</table>
4.8 Results of monitoring the inorganic nitrogen concentrations (i.e., blue for influent NH$_4^+$ concentration, red for effluent NH$_4^+$ concentration, and green for effluent NO$_3^-$ concentration) and the inorganic nitrogen pollutant removal efficiency (purple) for three different experimental conditions.

4.9 Cycles of nitrification-denitrification for the same Anoxic Time and Aerobic Digestion periods of: (a) 6-6 h, (b) 5-5 h, (c) 4-4 h, (d) 3-3 h, (e) 2-2 h, (f) 1-1 h and (g) 0.5-0.5 h (INP: inorganic nitrogen pollutant, NH$_4^+$ plus NO$_3^-$).

4.10 Cycles of nitrification-denitrification for the different Aerobic Digestion and Anoxic Time periods of: (a) 4-2 h, (b) 2-1 h, (c) 1-0.5 h, (d) 2-4 h, (e) 1-2 h and (f) 0.5-1 h (INP: inorganic nitrogen pollutant, NH$_4^+$ plus NO$_3^-$).

4.11 Performance of the Alternating Aerobic-Anoxic treatment process to remove COD and inorganic nitrogen concentrations.

4.12 Ratio of denitrification to nitrification in accordance with cycle of Anoxic Time and Aerobic Digestion period.

5.1 Results of monitoring the inorganic nitrogen concentrations (i.e., black for influent NH$_4^+$ concentration, red for effluent NH$_4^+$ concentration, and blue for the effluent NO$_3^-$ concentration) and the INP removal efficiency (green) for three different experimental conditions. Note that AD means aerobic digestion, AAA means alternating aerobic-anoxic process and AM means addition of methanol.

5.2 Linear regression analysis for the correlation between the organic loading rate and organic removal rate. The straight line has a slope of 0.8583 and intercepts at minus 0.0083 with $R^2=0.9614$. 

Note: This text is a natural language representation of the content in the provided image.
5.3 Results of monitoring the inorganic nitrogen concentrations at outlet of the reactor during the Alternating Aerobic-Anoxic processes (i.e., black for NH$_4^+$ concentration, red for NO$_3^-$ concentration, and green for NH$_4^+$ plus NO$_3^-$ concentrations) to run a single test for alternating aerobic (3 h) and anoxic (6 h) process. Note that AD means aerobic digestion and AT means anoxic time.

5.4 Results of monitoring the inorganic nitrogen concentrations at outlet of the reactor during the Alternating Aerobic-Anoxic processes (i.e., black for NH$_4^+$ concentration, red for NO$_3^-$ concentration, and green for NH$_4^+$ plus NO$_3^-$ concentrations) to run a single test for alternating aerobic (3 h) and anoxic (3 h) process. Note that AD means aerobic digestion and AT means anoxic time.

5.5 Variations of pH (black) and redox potential (red) pursuant to time for the alternating aerobic (3 h) and anoxic (6 h) process. Note that AD means aerobic digestion and AT means anoxic time.

6.1 Variations of DO, pH, redox potential and temperature

6.2 Variations of added ferric iron concentration and concentration of SRP removal

6.3 Variations of influent TP concentration, amount of TP accumulation and TP/MLSS ratio

6.4 Variations of Fe/P molar ratio and phosphorus removal efficiency

6.5 Variations of concentrations and phosphorus removal efficiency of SRP

6.6 Variations of concentrations and phosphorus removal efficiency of TP
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>Alternating aerobic-anoxic</td>
</tr>
<tr>
<td>AD</td>
<td>Aerobic digestion</td>
</tr>
<tr>
<td>AM</td>
<td>Addition of methanol</td>
</tr>
<tr>
<td>AT</td>
<td>Anoxic time</td>
</tr>
<tr>
<td>BOD</td>
<td>Biochemical oxygen demand</td>
</tr>
<tr>
<td>C</td>
<td>Carbonaceous</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical oxygen demand</td>
</tr>
<tr>
<td>DAAR</td>
<td>Discontinuous aerobic-anoxic reactor</td>
</tr>
<tr>
<td>D/N</td>
<td>Denitrification/Nitrification</td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved oxygen</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Environment</td>
</tr>
<tr>
<td>F/M</td>
<td>Food to microorganism</td>
</tr>
<tr>
<td>HRT</td>
<td>Hydraulic retention time</td>
</tr>
<tr>
<td>IHP</td>
<td>Iron-hydroxy-phosphate</td>
</tr>
<tr>
<td>INC</td>
<td>Inorganic nitrogen concentration</td>
</tr>
<tr>
<td>INP</td>
<td>Inorganic nitrogen pollution</td>
</tr>
<tr>
<td>IWK</td>
<td>Indah Water Konsortium</td>
</tr>
<tr>
<td>MLSS</td>
<td>Mixed liquor suspended solids</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogenous</td>
</tr>
<tr>
<td>N₂</td>
<td>Nitrogen gas</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>Ammonium</td>
</tr>
<tr>
<td>NO₂⁻</td>
<td>Nitrite</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>Nitrate</td>
</tr>
<tr>
<td>NTK</td>
<td>Nitrogen Total Kjeldahl</td>
</tr>
<tr>
<td>ORP</td>
<td>Oxidation reduction potential</td>
</tr>
<tr>
<td>P</td>
<td>Phosphorous</td>
</tr>
<tr>
<td>SRP</td>
<td>Soluble reactive phosphorus</td>
</tr>
<tr>
<td>SRT</td>
<td>Sludge retention time</td>
</tr>
<tr>
<td>SS</td>
<td>Suspended solids</td>
</tr>
<tr>
<td>SVI</td>
<td>Sludge volume index</td>
</tr>
<tr>
<td>WWTP</td>
<td>Wastewater treatment plant</td>
</tr>
</tbody>
</table>
LIST OF SYMBOLS

\[ t \] - Time (day)
\[ R^2 \] - Correlation coefficient (dimensionless)
## LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>List of Publications</td>
<td>98</td>
</tr>
<tr>
<td>B</td>
<td>Aerobic Digestion Process</td>
<td>99</td>
</tr>
<tr>
<td>C</td>
<td>Alternating Aerobic-Anoxic Treatment Process</td>
<td>106</td>
</tr>
<tr>
<td>D</td>
<td>The Physical and Chemical Characteristics and Typical Composition of Untreated Domestic Wastewater</td>
<td>115</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Introduction

Water as medium for waste transport would be easily contaminated by human activities. Many methods have been proposed to treat contaminated water to protect human health and the environment. In order to upgrade the existing wastewater treatment facilities, the typical advanced technologies have been proposed to remove many types of pollutant, effectively (Tchobanoglous et al., 2004). The development of wastewater treatment plant need to be considered leading economic indicators to having low operational and maintenance costs (Shammas et al., 2009; Lewandowski, 2015). Aerobic digestion (AD) has been known since 1950 as biological wastewater treatment process to remove organic compounds, colloids and suspended solids to avoid the excessive pollutants released into the receiving water (Shammas and Wang, 2007). Currently, the most popular wastewater treatment techniques include extended aeration, sequencing batch reactor and oxidation ditch. The use of activated sludge in biological treatment processes under aerobic, anoxic and anaerobic conditions can remove carbon, nitrogen and phosphorus due to the presence of microorganisms and air (Tsuneda et al., 2006; Fulazzaky, 2009; Romero et al., 2013).
Nitrification has two successive processes of converting NH$_4^+$ to NO$_2^-$ by *Nitrosomonas* bacteria and then NO$_2^-$ to NO$_3^-$ by *Nitrobacter* bacteria. Denitrification is the biological reduction of NO$_3^-$ to nitrogen gas (N$_2$) by facultative heterotrophic bacteria (Risgaard-Petersen et al., 2006). During denitrification, some chemoorganotrophs are capable of replacing O$_2$ with NO$_3^-$ as the terminal electron acceptor under certain conditions. The overall process of reduction of NO$_3^-$ to N$_2$ is carried out by a variety of bacteria such as *Alcaligenes*, *Achromobacter*, *Micrococcus* and *Pseudomonas* (Caldwell et al., 1979; Mara and Horan, 2003).

The removal of nutrients (nitrogen and phosphorus) has become the priority in treating domestic wastewater because of the excessive amount of these elements might affect human health and the receiving water body (Sedlak, 1991). The important things for improving the quality of water and living environment are to remove the major pollutants of carbon, nitrogen and phosphorus containing in domestic wastewater (Fulazzaky, 2009). This study used a laboratory scale alternating aerobic-anoxic reactor to remove carbon, nitrogen and phosphorus from domestic wastewater.

1.2 Problems statement

Effluent of domestic wastewater treatment plants contains high concentrations of nutrients that may lead to the degradation of the receiving water quality. The excessive of nutrients in aquatic ecosystems can induce adverse effects on human health and the environment (Camargo and Alonso, 2006). The immediate removal of contaminated wastewater from their sources, followed by treatment, reuse, or dispersal into the environment, is necessary to protect public health and the environment. There are several types of wastewater treatment plants to remove the pollutants from domestic wastewater for instance trickling filter, extended aeration,
sequencing batch reactor and oxidation ditch; however, these types of wastewater treatment plants are using more than one reactor to remove the pollutants. The design of secondary domestic wastewater treatment plants is usually based on the need to reduce carbon, nitrogen and phosphorus to limit pollution of the environment. Most domestic wastewater treated in wastewater treatment plants includes a variety of physical, chemical and biological treatment processes. Even though a better removal efficiency of suspended matter (SS), biochemical oxygen demand (BOD) or chemical oxygen demand (COD) can be achieved by many types of conventional biological wastewater treatment plants, simultaneous removal of nitrogen and phosphorus from a domestic wastewater need to be verified to meet a stringent effluent standard regulated by the law. In order to remove the three major pollutants (i.e., carbon, nitrogen and phosphorus), this study proposed the alternating aerobic-anoxic (AAA) using a single-sludge reactor to remove the pollutants from domestic wastewater. An understanding of AAA treatment process for removal efficiency is crucial to investigate, because of limited understanding of AAA treatment process in a single-sludge reactor.

1.3 Objectives of the study

The objectives of this study are as follows:

1) to have a configuration of pilot plant with a design that can be applied by using activated sludge to reduce carbon based on typical characteristics of domestic wastewater and to ensure the possibility of using the AAA conditions for the removal of nitrogen and phosphorus.

2) to assess the efficiencies of the AAA treatment process for nitrogen removal by comparing two different AAA time periods that drive the coupled nitrification-denitrification in single activated sludge.
3) to define the empirical formula for complex solids of iron-hydroxy-phosphate (IHP) precipitates caused by simultaneous precipitations of FePO$_4$ and Fe(OH)$_3$ in different experimental conditions and to assess the overall performance of the AAA process for the removal of phosphorus from domestic wastewater.

1.4 **Scope of the study**

The scopes of this study are:

1) to monitor BOD, COD, SS, NH$_4^+$, NO$_2^-$, NO$_3^-$, PO$_4^{3-}$, pH, DO, salinity and temperature to having an insight on the characteristic of raw domestic wastewater collected from Indah Water Konsotium (IWK) wastewater treatment plant at Taman Impian Emas, Skudai, Johor Bahru, Malaysia.

2) to perform the treatment of wastewater under the AD conditions until it reaches a stable rate of COD removal.

3) to conduct the experiments under the AAA treatment conditions with the different operations of same anoxic time (AT) – aerobic digestion (AD) period and different AT - AD period for the selection of the best AT - AD cycle.

4) to condition the best AT - AD cycle of AAA treatment system for assessing the possibility of using this new biotechnological treatment process in the future.
5) to verify the application of AAA treatment process for precipitation of IHP of added FeCl₃.

1.5 Research significances

The significances of this study are summarised below:

1) The use of AAA treatment process in a single reactor to remove carbon, nitrogen and phosphorus can be operated with low operating costs because it can reduce capital investment, energy consumption and human labour.

2) The conditioning of the AAA treatment system can have an insight on the application of this new biotechnological process in the future.

3) The precipitation of IHP can enhance the usability of AAA treatment process in removing three major pollution elements (carbon, nitrogen and phosphorus) of domestic wastewater.
1.6 Organisation of the thesis

Chapter 1 discusses background, problem statements, objectives, scope, and significant of the study. Chapter 2 reviews the related issues of carbon, nitrogen and phosphorus removed from domestic wastewater under aerobic, anoxic, anaerobic and alternating aerobic-anoxic conditions. Chapter 3 elaborates the materials and methods for the use of AAA treatment system to remove carbon, nitrogen and phosphorus from domestic wastewater. Chapter 4 discusses the applications of aerobic digester to remove organic matters and AAA treatment process for the selection of the best AT - AD cycle. Chapter 5 discusses the conditioning of the AAA treatment system to remove inorganic nitrogen pollution (INP) from domestic wastewater. Chapter 6 attempts to precipitate the IHP for enhancing the usability of the AAA treatment process. Chapter 7 concludes the recommendation of the research study.
REFERENCES


