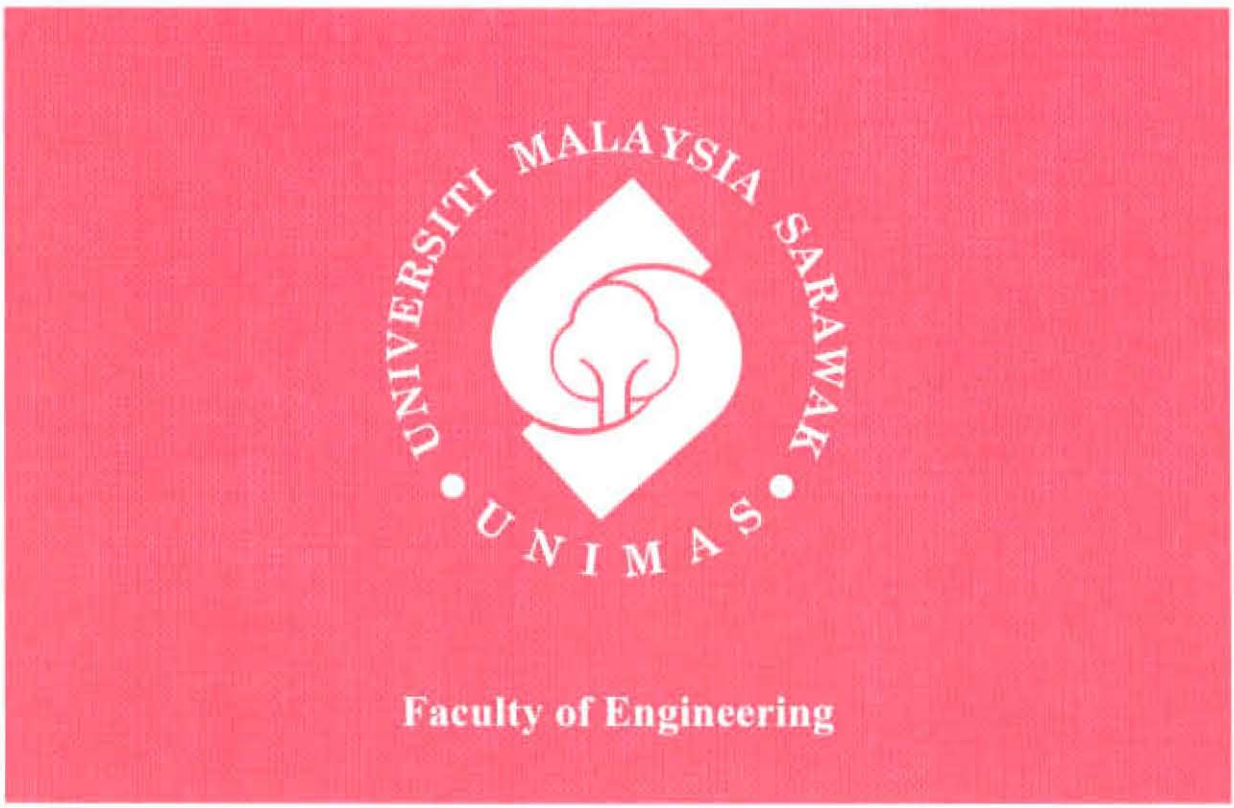

CHARACTERIZATION OF COD REMOVAL FROM PALM OIL MILL EFFLUENT (POME) WITH THE AID OF ANAEROBIC BIOREACTOR

EUGENE ANAK JACKSON JOY

Bachelor of Engineering with Honours
(Mechanical and Manufacturing Engineering)
2017

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ABSTRACT

This aim of this study is to evaluate the effects of hydraulic retention time (HRT) and solid retention time (SRT) on chemical oxygen demand (COD) removal from POME. POME can cause serious environmental damage if it is discharged untreated. This study will explore the potential of POME in anaerobic digestion in which bacteria convert organic compounds into biogas without oxygen at the same time remove contaminating compounds from the effluent. The current study is conducted using anaerobic bioreactor. HRT is operated at 6, 8 10, 12 and 15 days. Meanwhile, SRT is operated at 10, 15 and 20 days. The anaerobic bioreactor is operated for 30 days. Water sample are collected from the anaerobic reactor to test for its COD. The optimum HRT was at 12 days giving the COD removal rate and concentration of 40.4% and 30,400 mg/L respectively. The optimum SRT on COD removal from POME was at 20 days. The COD of effluent was 33,630 mg/L giving a removal rate of 34.1%. Anaerobic bioreactor has the potential to become an effective process to treat POME in which it can achieve satisfactory on COD removal. Treating POME anaerobically has proven to be successful because it is cost effective, capable to reduce damage to the environment, minimizes the amount of sludge produced and has the ability to recover renewable energy in the form of methane gas.

ABSTRAK

Kajian ini dijalankan untuk menilai kesan masa hidraulik pengekalan (HRT) dan masa tahanan pepejal (SRT) terhadap penyingkiran COD daripada POME. POME boleh menyebabkan kerosakan alam sekitar yang serius jika ia dilepaskan tanpa dirawat. Kajian ini akan meneroka potensi POME dalam pencernaan anaerobik di mana bakteria menukar sebatian organik kepada biogas tanpa oksigen dalam masa yang sama mengeluarkan sebatian yang mencemarkan dari efluen. Kajian ini dijalankan menggunakan bioreaktor anaerobik. HRT dikendalikan pada 6, 8 10, 12 dan 15 hari. Sementara itu, SRT beroperasi pada 10, 15 dan 20 hari. Bioreaktor anaerobic dikendalikan selama 30 hari. Sampel air telah dikumpul daripada reaktor untuk menguji COD tersebut. HRT optimum adalah 12 hari yang memberi penyingkiran COD dan kepekatan masing-masing sebanyak 40.4% dan 30,400 mg/L. SRT optimum pada COD penyingkiran daripada POME adalah pada 20 hari. COD efluen adalah 33.630 mg/L memberi kadar pembuangan 34.1%. Bioreaktor anaerobik mempunyai potensi untuk menjadi satu proses yang berkesan untuk merawat POME di mana ia boleh mencapai memuaskan di COD penyingkiran. Merawat POME secara anaerobik telah terbukti berjaya kerana ia adalah kos efektif, mampu untuk mengurangkan kerosakan kepada alam sekitar, mengurangkan jumlah enapcemar yang dihasilkan dan mempunyai keupayaan untuk memulihkan tenaga boleh diperbaharui dalam bentuk gas metana.

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LIST OF ABBREVIATIONS

BOD	-	Biochemical Oxygen Demand
COD	-	Chemical Oxygen Demand
HRT	-	Hydraulic Retention Time
SRT	-	Solid Retention Time
OLR	-	Organic Loading Rate
C/N	-	Carbon to Nitrogen Ratio
POME	-	Palm Oil Mill Effluent
GHG	-	Greenhouse Gas
FFB	-	Fresh Fruit Bunch
EFB	-	Empty Fruit Bunch
FFA	-	Free Fatty Acid
CPO	-	Crude Palm Oil

LIST OF EQUATIONS

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The palm oil industry is one of the major industries in Malaysia and it is growing rapidly to become a significant agriculture-based industry. Malaysia came in second behind Indonesia as the world's largest supplier of palm oil. Table 1.1 shows that the total productions of crude palm oil in 2015 and 2016 are 19,961,581 and 17,319,374 tonnes respectively (MPOB, 2015, 2016).

Table 1.1: Malaysian production of crude oil palm in 2015 and 2016 (MPOB, 2015, 2016).

Month	**2015 (tonnes)**	**2016 (tonnes)**
January	1,160,687	1,129,747
February	1,121,628	1,042,904
March	1,495,151	1,219,449
April	1,693,425	1,301,291
May	1,810,530	1,364,583
June	1,763,667	1,532,613
July	1,815,634	1,585,341
August	2,051,000	1,701,833
September	1,959,064	1,715,085
October	2,037,466	1,677,873
November	1,653,946	1,574,938
December	1,399,383	1,473,717
Total	19,961,581	17,319,374

In the year 2015, the area planted with oil palm reached 5.64 million hectares, an increase of 4.6% compared to 5.39 million hectares recorded in the year 2014. Sabah is still the largest oil palm planted state, with 27% of the total oil palm planted area, followed by Sarawak with 26%, while Peninsular Malaysia accounted for 47%. The palm oil industry provides a source of livelihood to rural families in government land schemes and private small holders, as well as employment opportunities to agricultural workers in estates (Wu, Mohammad, Jahim, & Anuar, 2010). Furthermore, Malaysia is responsible for 12% and 27% of the world's total production and exports of oils and fats (Madaki & Seng, 2013b). Malaysia is known as the major producers and exporters of palm oil and its products. Therefore, it is important to satisfy the world-wide need for oils and fats sustainability.

1.2 Characteristics and Properties of POME

Due to the expansion of palm oil industry, impacts towards the environment have always been the main concern to non-governmental organizations (NGOs). The negative impacts include deforestation, loss of biodiversity, indiscriminate burning, water pollution and serious greenhouse gases (GHG) emission. The most significant pollutant from palm oil mills is palm oil mill effluent, also known as POME. Palm oil mill effluent (POME) is a by-product of processed FFB to obtain crude palm oil (CPO) and other palm oil products. In the past, POME is seen as a waste in the palm oil industry. POME is often discharged into the waterways by palm oil mills. Although POME is biodegradable, it cannot be discharged directly from the mill without treating it first. This is because POME is acidic in nature and it contains residual oil which is not easily separated using the conventional gravity-based system. The oily mixture requires the presence of oxygen to be decomposed completely. This condition is known as high biochemical oxygen demand (BOD). Sometimes, raw POME can have a BOD which is 100 times higher than domestic sewage (Madaki & Seng, 2013a).

POME is composed of water soluble components of palm fruits as well as suspended cellulosic materials such as palm fibres, oil, grease, fats, cell walls, organelles, a variety of carbohydrates, a range of nitrogenous compounds, free organic acids and minor organic and mineral constituents. POME consists of 95 - 96% water, 4 - 5% total solids, 2 - 4% suspended solids and 0.6 - 0.7% oil and grease. It has been estimated that

the production of 1 tonne of crude oil palm generates about 2.5 - 3.5 m^3 of POME (Ahmad et al., 2015; Jefferson et al., 2016). The greenhouse gas such as methane and carbon dioxide are responsible for ozone depletion. Methane is generated during POME digestion which is not utilized and it escapes into the atmosphere.

The composition of POME depends largely on the season, raw material quality and the operations being conducted. When it is still fresh, POME is a thick brownish colloidal mixture of water, oil and fine suspended solids. This effluent has a high temperature in the range of 80 - 90ºC. It possesses high amounts of solids (40000 mg/L), very high Biochemical Oxygen Demand (BOD) (25000 mg/L), Chemical Oxygen Demand (COD) (51000 mg/L) and oil and grease (6000 mg/L). The typical characteristics of POME can be referred to Table 1.2. During the extraction process, no chemicals are added and hence, the effluent is non-toxic. Normally, the pH of POME is low due to the presence of organic acids in complex forms which are produced during fermentation process.

Table 1.2: Characteristics of POME (MPOB, 2012)

CHARACTERISTICS OF POME		
Parameter*	**Mean**	**Range**
pH	4.2	3.4 - 5.2
Biochemical Oxygen Demand (BOD)	25000	10250 - 43750
Chemical Oxygen Demand (COD)	51000	15000 - 100000
Total Solids	40000	11500 - 79000
Suspended Solids	18000	5000 - 54000
Volatile Solids	34000	9000 - 72000
Oil and Grease	6000	130 - 18000
Ammoniacal Nitrogen	35	4 - 80
Total Nitrogen	750	180 - 1400
*Units in mg/L except pH		

1.3 Impact of POME

When POME is discharged into the waterways, it will cause the water to turn brown, smelly and slimy. Untreated POME in the water cause water depletion and aquatic pollution. Aquatic organisms and their habitats are hugely affected. Microorganisms living in the water will consume dissolved oxygen at a faster rate compared to the rate of oxygen can dissolve in the water. As a result, fish and other marine organisms will perish

due to depletion of oxygen. Besides that, long-term exposure to harmful pollutants result in fish to become susceptible to disease-producing bacteria and viruses. Bioaccumulation occurs when big fish feeds on smaller fish which is already contaminated. When birds or other mammals eat the polluted aquatic organism, the contamination is accumulated. Since we are at the top of the food chain, we will end up with these contaminants in our body. Human health will definitely be affected. Hence, it can lead to kidney failure and other chronic disease. This is due to the contaminants which have spread throughout the food chain.

1.4 Treatment of POME

The purpose of this study represents the potential strategies to reduce the environmental impacts caused by POME at the same time characterize COD removal. Anaerobic digestion is a method which will be used for the treatment of POME. The milling process of palm oil produces wastewater known as POME which has high COD. The discharge of POME to the environment is undesirable and most palm oil mills are challenged to acquire the use of anaerobic treatment process of POME. The reduction and removal of COD from POME in palm oil mills can reduce the impact to environment. In this study, an anaerobic bioreactor is used to aid with COD removal.

1.5 Problem Statement

Various anaerobic methods are being used to treat POME. This is because the palm oil industry understood the benefits of POME which can contribute in terms of energy production, cleaner water and supply of organic fertilizer. Although, new methods and technologies have been developed to find approachable solutions for POME management, yet palm oil mills are still struggling to meet up with more stringent limits of effluent discharge allowed by Department of Environment (DOE) Malaysia (Madaki & Seng, 2013a). Conventional ponding system and open digesting tanks were not environmental friendly due to the release of biogas into the atmosphere. Besides, these methods required longer retention time and extensive land area (Choi et al., 2013; Loh et al., 2013; Wu et al., 2010; Zhang et al., 2008). The expanded granular sludge bed (EGSB) reactor displayed better performance in treating POME and are gaining popularity because of its higher loading rates (Wang et al., 2015).

The use of environmentally sound biotechnologies can change the status of POME from waste to resource. Treating POME not only focuses on the capturing of methane. Even clean water and organic fertilizers can be recovered from POME. By adopting an international trend of promoting pollution prevention through cleaner production, which is based on reduction, replacement, reuse, recovery and recycling (5R) policy (Wu, Mohammad, Jahim, & Anuar, 2009), POME has the potential to become a valuable resource in the future.

1.6 Research Question

How to characterize COD removal from POME with the aid of anaerobic bioreactor under the effects hydraulic retention time (HRT) and solid retention time (SRT)? This research is designed to answer this question.

1.7 Objective of Research

The broad objective of this study is to characterize COD removal from POME with the aid of anaerobic bioreactor. For achieving the goal of this study, the broad objective is divided into the following specific objectives:

a) To evaluate the effect of hydraulic retention time (HRT) on COD removal.
b) To determine the effect of solid retention time (SRT) on COD removal.

1.8 Scope of Study for Achieving Research Goals

This study is about the characterization of COD removal from POME with the aid of anaerobic bioreactor. Characterization of COD removal is based on the effects of HRT and SRT. The scope of study is divided into three stages:

i. Evaluate the effect of hydraulic retention time (HRT)
   a) The related information is gathered through literature review.
   b) Instrumentation to measure HRT are gathered.
   c) Data collection and calculation from the anaerobic bioreactor for analysis of HRT.

ii. Determine the effect of solid retention time (SRT)

a) The related information is gathered through literature review.
b) Instrumentation to measure SRT are gathered.
c) Data collection and calculation from the anaerobic bioreactor for analysis of SRT.

1.9 Novelty of Research

This research is conducted to contribute to COD removal from POME. High values of COD from POME is known to be harmful to the environment when it is discharge without any treatment. Besides, this research will explore the potential of POME in anaerobic digestion in which bacteria convert organic compounds into biogas without oxygen at the same time remove contaminating compounds from the effluent. Therefore, this work will positively add new knowledge to the current technology for POME treatment.

1.10 Framework of Research

The framework of this research is shown in Figure 1.1.

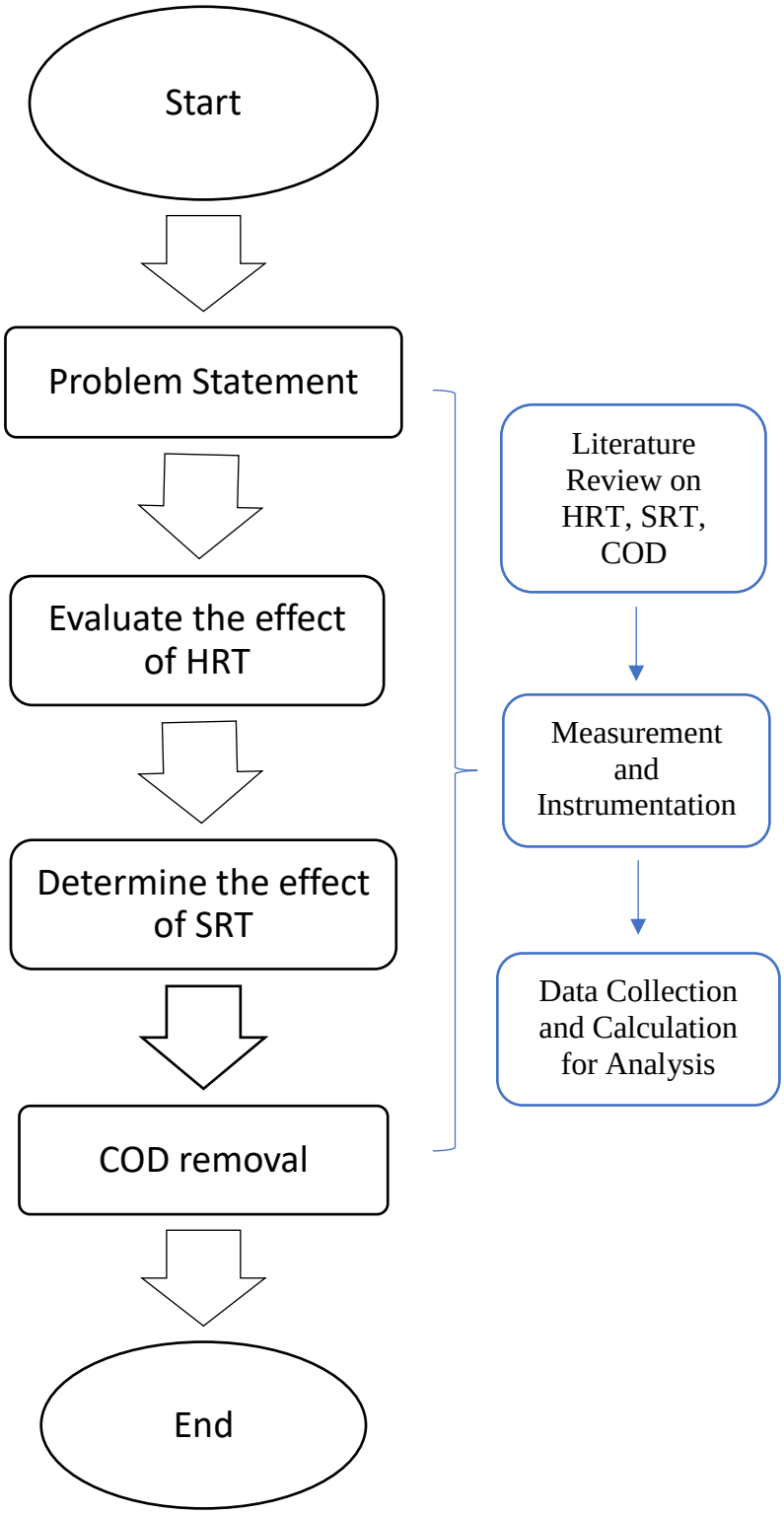

Figure 1.1: Framework of Research

1.11 Structure of Report

The structure for this report is shown in Figure 1.2.

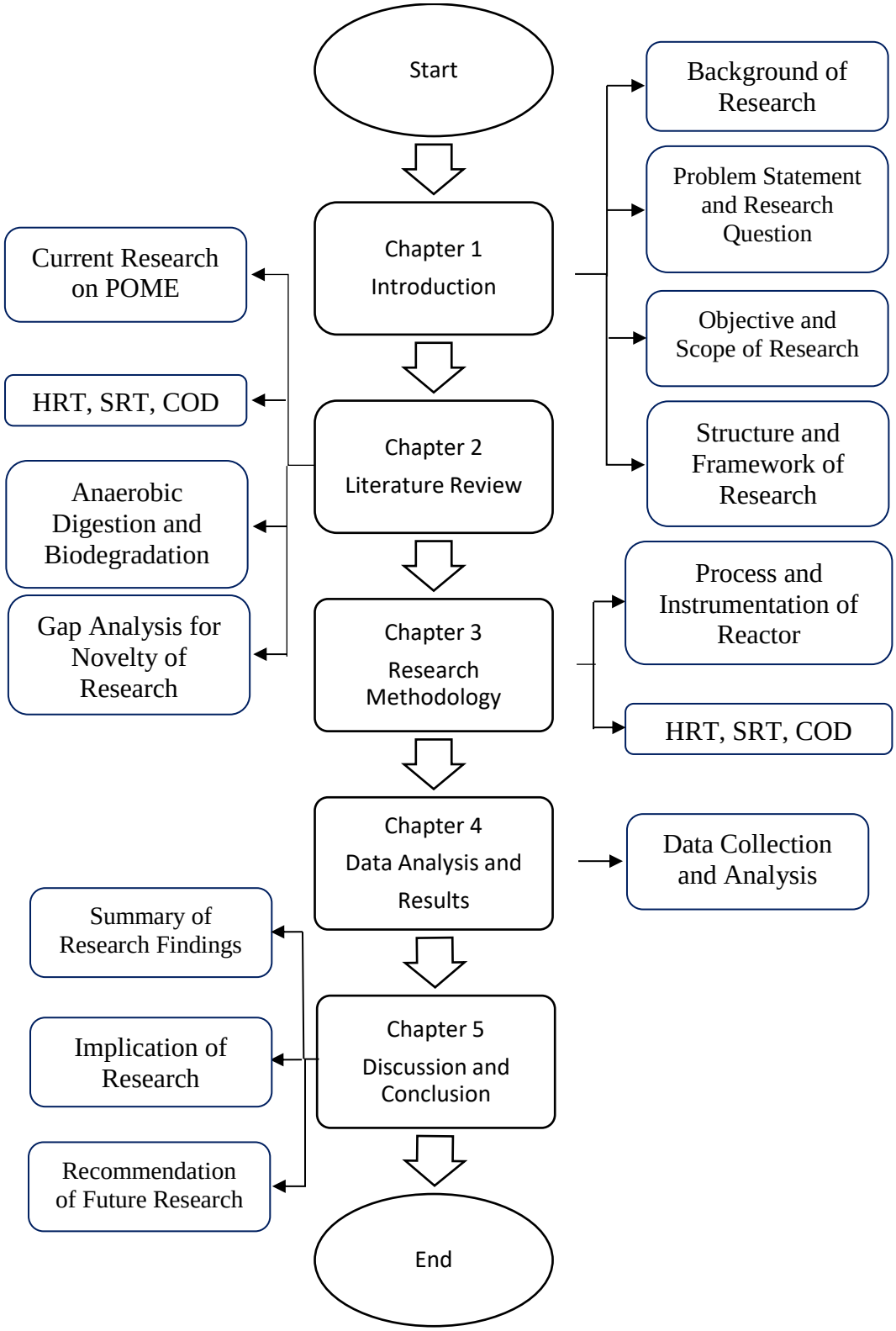

Figure 1.2: Structure of Report