PERFORMANCE INDEX FOR PALM OIL MILL EFFLUENT MANAGEMENT

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ABSTRACT

The world is currently facing an energy crisis. This issue rises society concerns about the environment and energy and it urged the scientists and engineers to incorporate in sustainability process design or by retrofit of the existing or traditional process plant. There is much consideration needed to be considered environmental sustainability. Due to these issue, a systematic and structural sustainability evaluation tools are needed to help in the process of engineering design, analysis, improvement, retrofit and decision making. This research proposed a performance index for palm oil mill effluent management. Firstly, the assessment was performed with ratio normalization calculation method to measure and compare the current sustainability performance of a related palm oil mill. The feature has presented in more detail parameters to indicators for further extensive evaluation. Moreover, the weights of the parameters were determined by expert opinion survey. Based on the result evaluated, the poor performer indicators were determined, and suitable improvement method was proposed. The improvement method was chosen by comparing and evaluate various improvement methods that were suitable to enhance the weak perform indicator. This POME management model will benefit the company by assess sustainability performance of their industry and further improve it. This study is significant as it will bring an influential impact and improvement to the current palm oil industry in POME management.

ABSTRAK

Dunia sedang menghadapi krisis tenaga. Isu ini meningkatkan kebimbangan masyarakat tentang alam sekitar dan tenaga dan ia menggesa saintis dan jurutera untuk meningkatkan prestasi reka bentuk proses kemapanan atau dengan mengubahsuai loji proses sedia ada atau tradisional. Terdapat banyak pertimbangan yang perlu dipertimbangkan di dalam issue ini. Oleh demikian, alat penilaian kelestarian sistematik dan struktur diperlukan untuk membantu dalam proses reka bentuk kejuruteraan, analisis, penambahbaikan, retrofit dan membuat keputusan. Makalah ini membentangkan indeks kemampanan untuk proses sisa-sisa kilang kelapa sawit. Pertama, penilaian dilakukan dengan kaedah pengiraan nisbah normalisasi untuk mengukur dan membandingkan prestasi kemampanan semasa bagi kilang minyak sawit yang berkaitan. Aspek ini telah membahagikan kepada parameter yang lebih terperinci kepada petunjuk untuk penilaian lebih lanjut. Berdasarkan keputusan yang dinilai, indikator yang berpresrasi lemah telah ditentukan, dan kaedah penambahbaikan yang sesuai telah dicadangkan. Model kerangka sistematik ini akan memberi manfaat kepada syarikat dengan menilai prestasi kemampanan industri mereka dan terus memperbaikinya. Kajian ini adalah penting kerana ia akan membawa impak dan peningkatan yang berpengaruh kepada industri minyak sawit semasa.

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LIST OF ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
BBIS	-	Bioenergy Based Industrial Symbiosis
BOD	-	Biochemical oxygen demand
CAPEX	-	Capital Expenditure
COD	-	Chemical Oxygen Demand
CPO	-	Crude Palm Oil
DOE	-	Department of Environment
EFB	-	Empty Fruit Bunches
EHS	-	Environment, Health and Safety
EN	-	Environment
EP	-	Economic Performance
EPL	-	Economic Performance Lower
EPU	-	Economic Performance Upper
ESD	-	Engineering for Sustainable Development
ESD	-	Engineering for Sustainable Development
FLDA	-	Federal Land Development Authority
FFA	-	Free Fatty Acid
FFB	-	Fresh Fruit Bunches
FTA	-	Fault Tree Assessment

DP	-	Gross Domestic Product
GHG	-	Greenhouse Gases
GREENSCOPE	-	Gauging Reaction Effectiveness for the Environmental Sustainability of Chemistries with a Multi-Objective Process Evaluator
GRI	-	Global Reporting Initiative
GRI	-	Global Reporting Initiative
GRI	-	Global Reporting Initiative
HEN	-	Heat Exchanger Networks
HEN	-	Heat Exchanger Networks
IIM	-	Inoperability Input–output Model
ILUC	-	Indirect Land Use Change
IS	-	Industrial Symbiosis
ISO	-	International Organization for Standardization
LCA	-	Life-cycle Assessment
MINLP	-	Mixed Integer Nonlinear Programming
MPOB	-	Malaysian Palm Oil Board
NKEA	-	National Key Economic Area
OPEX	-	Operating Expense
PEI	-	Potential Environment Impact
PFD	-	Process Flow Diagram
POME	-	Palm Oil Mill Effluent
PTT	-	Proximity to Target
ROR	-	Rate of Return
RSPO	-	Roundtable on Sustainable Palm Oil

WAR	-	WAste Reduction
BOD	-	BOD_3 (Mg/L)
COD	-	COD (mg/L)
IIS	-	Index Indicator Score
MRE	-	Mixed Raw Effluent (ton/ton)
O&G	-	Oil and grease content (mg/L)
PC	-	Production cost (Rm/ton)
pH	-	Potential of Hydrogen
RNI	-	Ratio Normalization Indicator score
SUS	-	Suspended Solid (mg/L)
UOW	-	Use of fresh water (m^3/ton)

LIST OF SYMBOLS

$x^{M}{}_{ci}$	-	Mean of *x* Data for Compared Items *ci*
$x^{T}{}_{i}$	-	Target/Standard Value of *x* for Indicator *i*
$Mark_{c}$	-	Mark of the Related Class
$PAS_{m,p}$	-	Parameter Aggregation Score of Parameter *p* for Mill *m*
$PS_{m,p}$	-	Parameter Score of Parameter *p* for Mill *m*
$TI\ S_{m}$	-	Total Index Score of Mill *m*
$TIIS_{m,p}$	-	Total Indicator Index Score of Parameter *p* for Mill *m*
$TIMIS_{im}$	-	Total Improvement Methods Index Score for Related Improvement Method (*im)*
VS_{p}	-	Voted Score for a Parameter *p*
W_{p}	-	Weight for Parameter *p*
$IIS_{m,i}$	-	Indicator Index Score of Indicator *i* for Mill *m*
$Mark^{max}$	-	Maximum Mark of the Class
$N_{c,p}$	-	Voted Number of a Class *c* for a Parameter *p*
N^{max}	-	Maximum Voter Number
$N_{p,i}$	-	Number of Indicator *i* for Parameter *p*
EPS_{im}	-	Economy Parameters Score for related Improvement Method (*im)*
$RNI_{im,ci}$	-	Ratio Normalization Index of Compared Items *ci* for Related Improvement Method (*im)*
$RNI_{m,i}$	-	Ratio Normalization Index Indicator *i* for Mill *m*
x_{i}^{L}	-	Lower Limit of Indicator *i*
x_{i}^{U}	-	Upper Limit of Indicator *i*

x_i^{mid}	-	Midpoint of Indicator *i*
$x_{im,ci}$	-	*x* data of Compared Item (ci) for Related Improvement Method (*im)*
$x_{m,i}$	-	*x* data of Indicator *i* for Mill *m*
c	-	Class
im	-	Improvement Methods
i	-	Indicator
ep	-	Economy Parameters
m	-	Mill
N	-	Number
p	-	Parameter

CHAPTER 1

INTRODUCTION

1.1 Introduction

Palm oil is one of the vegetable oil, which acts as an important role in many commercial food industries. This chapter provides an overview of the current palm oil mill industry. This is followed by an introduction of the problem background, problem statement, research objectives and the scope of work for this study, which aims to develop new methodologies to assess current palm oil mill industry and palm oil mill effluent management.

1.2 Research Background

The primary product of palm oil mill is crude palm oil. There are 5 major steps in palm oil milling processes which are bunch reception, sterilisation, stripping, digestion and oil extraction (Gunstone *et al.,* 1987). The first process is bunch reception. Bunches are transported to the mills by trucks or cages on a narrow-gauge railway system or by road with a motor lorry or tractor trailer. After reception process, it is followed by sterilisation. The purpose of sterilisation is to the prevention of any further rise in FFA (Free Fatty Acid) due to enzyme action by inactivation of the lipolytic enzymes. Hence, this procedure also to loosen the fruit still attached to the bunch stalk, by providing sufficient heat to penetrate the points of attachment of the fruits to the spikelets to bring about hydrolysis at these points. Next process is the stripping processes. The object of stripping, sometimes called ‘threshing’, is to separate the sterilised fruits together with the associated calyx leaves from the sterilised bunch stalks. After the stripping process, it is followed by the digestion process. After the bunch has been stripped, the sterilised fruit must be reheated purpose to loosen the pericarp from the nuts and further prepared for the pressing process. The process is carried out in steam-heated vessels provided with stirring arms to be known as digester or kettles. Final step is an oil extraction process. Although many systems, both wet and dry, have been used over the years to extract the crude oil from the digested fruit mash, it is common practice nowadays to use screw presses, especially when general palm fruits must be processed (Othman *et al.,* 2010).

However, with huge development of this industry in country has the result of some negative impact from the effluents or by products. The impact under the fossil fuels category came from the production of the fertilizers used as well as diesel usage for transportation and harvesting in the nursery and plantation phases. Results show that there are several impact categories with significant impacts from crude palm oil production. These factors have resulted in, decrease in air quality and climate change. The impact categories of climate change and a decrease in air quality came from upstream activities and the palm oil mill effluent (POME) in the mill (Subramaniam *et al.,* 2010).

Sustainable development has been popularly defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Von Schirnding *et al.,* 2005). Recently, there are lots of studies of sustainability of palm oil mill process, but there still contain room for improvement in palm oil mill effluent (POME) assessment and treatment. The environmental sustainable assessment process still considered insufficient amount. Moreover, a sustainable assessment with the integration of the palm oil mill process is seen still has a large potential to grow and improve. The palm oil mill index approach is used in this research to measure sustainability practice in palm oil mill process.

1.3 Problem Statement

Malaysia with 19.67 million metric tons of total crude palm oil production, placed second after the Indonesia in worldwide crude palm oil production rank. This corresponds to 100.4 million metric tons of fresh fruit bunch processed per year (Malaysian Palm Oil Board, 2014). Nonetheless, with this huge amount of annual production, there is a bigger responsibility to ensure the sustainability of palm oil production to protect humans and conserve the environment, while achieving economic viability. Moreover, in the palm oil mills process, it produces a large amount of organic waste which commonly known as palm oil mill effluent (POME). In the palm oil milling process, the process produced large amounts of this organic waste. Data proposed from Thailand in the year 1993 shows that on a weight basis, such wastes amount to nearly 80% of inputs (Preasertsan *et al.*, 1996).

In palm oil mill process about 1.5 m^3 of water is needed to process 1 ton of fresh fruit bunch (FFB). From all the water user about half of this water amount ends up as waste (palm oil mill effluent (POME)). POME is an unwanted wastewater produced from the palm oil milling process. This wastewater is thick, brownish with a distinct offensive odour, and has a high organic matter content and highly pollution (Ahmad et al., 2009). The thick brownish raw POME in the viscous colloidal form is discharged at a temperature between 80°C and 90°C. If the untreated POME is discharged into watercourses, it certainly will cause considerable environmental problems due to its high biological oxygen demand (BOD) and high chemical oxygen demand (COD). This assessment tool will act as a guide to assess their mill. In addition, this type of assessment method has done by “Environmental Index for Palm Oil Mill” (Jamaludin *et al.*, 2016), which conducted a complete assessment including environmental assessment. However, the study used proximity to target method for the assessment. PTT is a good normalization formula, but it need more than one mill or sample data to do the calculation. A lone mill data will not be able to use the formula. Moreover, the study also did not consider of financial issue in the improvement section.

1.4 Research Objectives

The main objective of this research is to improve the POME management of palm oil mill. The research objectives are detailed as below:

1. To improve an existing framework and adopt in the context of POME management by using ratio normalization method to generate improvement method.

2. To evaluate palm oil mill effluent management in index score format in industry.

3. To construct weight values, which emphasize the importance of certain parameters and propose an improvement method with the consideration of the interactive relationship between POME index and economy feature.

1.5 Scope of Study

In orders to achieve the listed objectives, the scopes of study are stated below:

i. Reviewing of the current management procedure, practice and identifying the research gap on the assessment on palm oil mill effluent treatment process.

ii. Studying the parameters used to set the weighting index on each of the processes, and determine the weighting index on related environmental parameter.

iii. Performance database is structured based on environmental and palm oil mill effluent related features. All the indicators, criteria and regulations are limited in palm oil mill.

iv. Palm oil mill standard data collection is collected from previous study. Weight data is collected from IOI Pamol Kluang Palm Oil Mill.

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