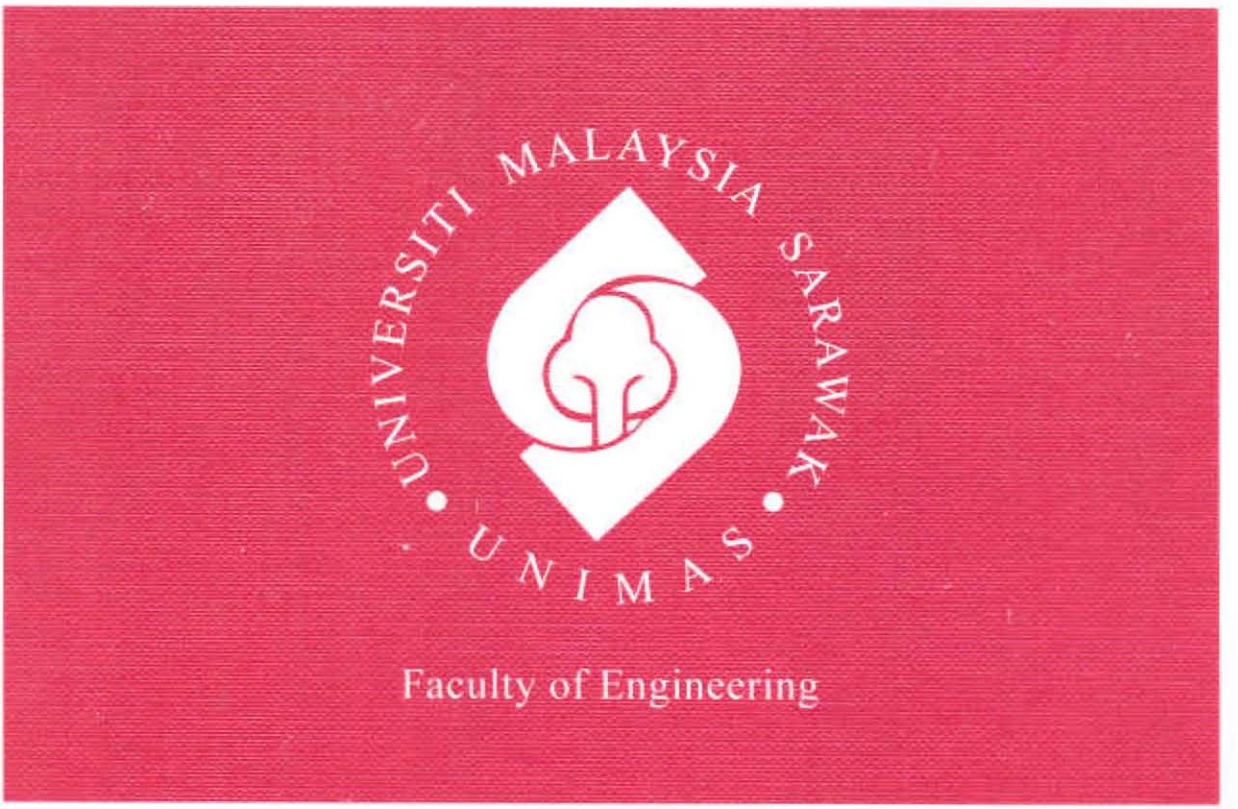


Environmental Management For Energy Industry: Application of ISO 14001 EMS and QUAL2K Modeling System

Georgie Wong Abdullah

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Environmental Management For Energy Industry: Application of ISO 14001 EMS and QUAL2K Modeling System

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DECLARATION

I, Georgie Wong Abdullah (15010111) from Faculty of Engineering UNIMAS hereby declare that the work Environmental Management For Energy Industry: Application of ISO 14001 EMS and QUAL2K Modeling System, is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

_____

Georgie Wong Abdullah (15010111)

Date:

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ABSTRACT

Environment management has been widely applied by policy makers and relevant authorities particularly in industry sector. The objectives of this research are to investigate and determine the environmental and operational performances of a coal-fired power plant in Sarawak, and to determine and recommend the impacts of landfill effluent discharge on water quality of Batang Kemena and the siting (selection of location) of Maskat Landfill's effluent discharge point, respectively. The parameters are air quality, generating efficiency, power availability and reliability for the first case study. The environmental parameters are the air quality parameters which include total suspended particulate, particulate matters up to 10 μm in size and sulfur oxides. Thermal Efficiency and Equivalent Availability Factor were selected as parameters for generating efficiency and availability. For reliability, the parameters are Equivalent Unplanned Outage Factor and Equivalent Planned Outage Factor. Overall findings show that better performance was recorded on environmental aspect, suggesting more focuses were put on regulatory concerns to ensure high environmental compliances. This case study also demonstrates some relevant evidences toward treating operational improvement as equally significant and beneficial efforts for economic gain and environmental enhancement. The second case study includes physico-chemical as well as heavy metals parameters such as DO, BOD_5, uBOD (represented as fast-BOD in QUAL2K), NH_3-N, NO_3-N, total suspended solids (TSS), lead (Pb), arsenic (As), cadmium (Cd), mercury (Hg) and nickel (Ni). The spatial modeling results illustrated the landfill leachate discharge would not significantly deteriorate the water quality of both Sg. Besai and Btg. Kemena during normal operations either under normal or low flow conditions (Scenarios 1 and 2). However, leakages or untreated and sudden release of

leachate (Scenario 3 and Scenario 4) would certainly result in serious contamination of these rivers as the concentrations of water quality parameters would degrade to Class III-V. This case study suggests Sg. Sesalak as the immediate stream to receive the leachate before it is subsequently channeled to Btg. Kemena. It makes recommendations in the effort to have a more implementable measures for managing Btg. Kemena river system. This work also defines a coordinating structure in aligning key roles and responsibilities of relevant stakeholders involving in environmental management of energy industrial in Sarawak.

Keywords: Environment management, energy industrial, ISO 14001, environmental performance, operational performance, water quality modeling

Pengurusan Alam Sekitar Untuk Industri Tenaga: Penggunaan ISO 14001 EMS dan Sistem Pemodelan QUAL2K

ABSTRAK

Penggunaan alam sekitar telah diaplikasikan secara meluas oleh penggubal polisi serta pihak berkuasa yang berkenaan khasnya dalam sektor industri. Objektif kajian ini adalah untuk menentukan prestasi alam sekitar dan operasi sebuah loji kuasa arang batu di Sarawak, dan untuk menentukan impaks pelepasan larut resapan daripada tapak perawatan sisa Maskat. Kajian kes yang pertama melibatkan parameter-parameter untuk kualiti udara, kecekapan penjanaan, ketersediaan kuasa dan keandalan. Parameter alam sekitar adalah termasuk jumlah zarah terampai, zarah terampai sehingga 10 μm dan sulfur oksida. Kecekapan Haba dan Equivalent Availability Factor dipilih sebagai parameter untuk kecekapan penjanaan, ketersediaan kuasa. Untuk keandalan, parameter yng digunakan adalah Equivalent Unplanned Outage Factor dan Equivalent Planned Outage Factor. Keputusan keseluruhan menunjukkan prestasi alam sekitar yang lebih baik, dan ini mencerminkan lebih fokus diberikan untuk memastikan pematuhan tinggi dalam peraturan alam sekitar. Kajian ini juga memaparkan bukti yang relevan bagi menunjukkan pentingnya peningkatkan operasi sebagai usaha kepentingan bersama ekonomi dan alam sekitar. Kajian kes yang kedua merangkumi fiziko-kimia serta logam berat seperti DO, BOD_5, uBOD (diwakilkan sebagai fast-BOD dalam QUAL2K), NH_3-N, NO_3-N, total suspended solids (TSS), lead (Pb), arsenic (As), cadmium (Cd), mercury (Hg) dan nickel (Ni). Keputusan pemodelan menunjukkan larutan resapan tidak menjejaskan kualiti air Sg. Besai dan Btg. Kemena di bawah operasi normal dan di bawah kadar

pengaliran larutan resapan yang rendah (Scenario 1 dan 2). Namun, tumpahan atau pelepasan larutan resapan secara tiba-tiba (Scenario 3 dan Scenario 4) akan membawa kepada pencemaran serius kepada sungai-sungai tersebut sehingga penurunan kualiti air ke tahap Class III-V. Kerja ini mencadangkan agar Sg. Sesalak dijadikan sebagai penerima larutan resapan sebelum ia dialirkan ke Btg. Kemena. Kerja ini memberi beberapa cadangan sebagai usaha untuk mewujudkan tindakan-tindakan yang lebih dapat dilaksanakan untuk pengurusan sistem sungai Btg. Kemena. Kerja ini juga menerangkan struktur koordinasi dalam penyelarasan peranan serta tanggungjawab pihak berkepentingan yang terlibat dalam pengurusan alam sekitar dalam sektor tenaga di Sarawak.

Kata kunci: *Pengurusan alam sekitar, industri tenaga, ISO 14001, prestasi alam sekitar, prestasi operasi, pemodelan kualiti air*

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LIST OF ABBREVIATIONS

ARM	Agricultural Runoff Model
As	Arsenic
AVG	Allgemeinverf¨ugbaresGew¨asserg¨ute
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BOD_5	Biological oxygen demand
CBOD	Carbonaceous biochemical oxygen demand
Cd	Cadmium
COD	Chemical oxygen demand
CORMIX	Cornell Mixing-Zone
CSTR	Continuously-stirred-tank-reactor
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DYRESM-WQ	Dynamic reservoir water quality model
EAF	Equivalent Availability Factor
ECOM-si	Estuarine, coastal and ocean model
EDH	Equivalent Derated Hours
EFDC	Environmental Fluid Dynamics Code
EMS	Environmental Management System
EPOF	Equivalent Planned Outage Factor
EUOF	Equivalent Unplanned Outage Factor
HEC-RAS	Hydrological Engineering Centre – River Analysis System

Hg	Mercury
HSPF	Hydrological Simulation Program–FORTRAN
IEEE	Institute of Electrical and Electronics Engineers
IFC	International Finance Corporation
ISO	International Organization for Standardization
ISO	International Organization for Standardization
ISO	International Organization for Standardization
IWMS	Integrated Wastes Management System
MLD	Million liter per day
NDEMS	National Database on Environmental Management Systems
NH_3-N	Ammoniacal nitrogen
Ni	Nickel
NO_3-N	Nitrate nitrogen
NPS	Non Point Source model
NWQS	National Water Quality Standards
Pb	Lead
POM	Princeton ocean model
QUASAR	Quality Simulation Along River Systems
SAMM	Skim Akreditasi Makmal Malaysia
SCORE	Sarawak Corridor of Renewable Energy
SE	Standard error
SIP	Samalaju Industrial Park
SMEs	Small and Medium-size Enterprises
SWAT	Soil and Water Assessment Tool

SWMM	Stormwater Management Model
TMDLs	Total maximum daily loads
TN	Total nitrogen
TOC	Total organic carbon
ToR	Terms of Reference
TP	Total phosphorus
TSP	Total Suspended Particulate
TSS	Total suspended solids
UBOD	Ultimate biochemical oxygen demand
USEPA	United States Environmental Protection Agency
VBA	Visual Basic for Applications
WASP	Water Quality Analysis Simulation Program
WQI	Water quality index
WSSD	World Summit on Sustainable Development
XOCs	Xenobiotic organic compounds

CHAPTER 1

INTRODUCTION

1.1 Introduction

Since the 1972 Stockholm Conference on the Environment and the 1992 Earth Summit, the environment continues to remain high on the international agenda. After the World Summit on Sustainable Development (WSSD) in 2002, positive progress has been made which has resulted in the establishment of a variety of environmental management mechanisms formulated to address specific environmental issues (Ejdyset *et al.*, 2016).

In Malaysia, the government has always been desirous and aware of the need to achieve sustainability in development since the implementation of the Malaysia Plans in the 1960s. To achieve sustainable development, environmental protection and development must go hand-in-hand. Thus, Parliament enacted the law, namely the Environmental Quality Act (EQA) in 1974, to provide the regulatory framework for environmental management.

At present, most states in Malaysia have started to diversify and transform its economy from agricultural and manufacturing based economies into industrialization. In the context of Sarawak, since independence about half century ago, Sarawak has progressed from a primarily rural agriculture based economy to a modern, progressive industrialised country. Industrialisation has intensified over the last decade and this rapid

developments and structural changes of the State's economy have brought in their wake many environmental problems which must be addressed satisfactorily.

1.2 Problem Statement and Research Hypothesis

Currently, Sarawak is implementing a long-term economic perspective plan which covers a period of 15 years from 2016 until 2030. In this plan, energy industry has been identified as the most focused industry to power Sarawak towards industrialized economic structure, where the energy intensive heavy industry is located. Significant changes in the Sarawak's environment resulting from accelerated development require changes in environmental management framework to protect and enhance the environmental quality.

There are 2 main issues experiencing in environmental management with regard to energy industry in Sarawak. The first issue is to have a more self-regulating environmental management system (EMS). Given the complexity and diverse scope of environmental issues in energy industry, the hard enforcement approach of government regulations has been experienced as having some limitations which include inflexible against realities on the ground; reactive rather than proactive initiatives; heavy-handed; cost-ineffective etc. In this regard, the government is promoting a more self-regulating approach in environmental management system (EMS) in order to expedite paradigm shift with respect to environmental management and sustainability.

The ISO 14001 is a systematic approach, taken proactively to effectively integrate environmental considerations into an organization's daily operation and management

culture, enhance a company's performance and ensure that an organization is effectively managing its environmental risks (Alberti et al., 2000; Nicholas and Smith, 2005). Realizing that there will be wide range of benefits offered by the ISO 14001 EMS, the Sarawak government is proposing ISO 14001 as the regulating mechanism to ensure environmental sustainability of the industry.

Many researches have conducted studies and written literatures on ISO 14001 EMS implementation and improved environmental performance, compliance of legislations, increase of corporate image and etc; however, there are very limited studies to justify the effectiveness of ISO 14001 EMS in energy related industry, particularly in Sarawak.

To get a better understanding on the overall performances as highlighted from the above paragraph, a research on the effectiveness of ISO 14001 in energy related industry that are currently adopting ISO 14001 EMS is deemed necessary and appropriate.

The hypotheses of this research: there are positive implications attributed to the implementation of ISO 14001 EMS; and there are compliances to the environmental regulations as well as satisfactory operational performances.

The second issue of environmental management faced by the energy industry in Sarawak is to have a water quality modeling system for better management of industrial effluent discharge. Water quality models try to simulate changes in the concentration of pollutants as they move through the environment in water bodies Thus, there are needs to apply water quality modeling in order to determine sources of pollution, to allocate pollutant loads, and to predict the effectiveness of actions taken to meet water quality standards. The model is crucial to predict water quality impacts in a relatively simple

manner compared with the complexities of actual water systems. This will also help to address limitations and uncertainties inherent in measuring the attainment of water quality and facilitate in water quality management.

Through extensive literature works, it was found that application of water quality modeling has substantial ability and performance for modeling river water quality, however, currently there is no such research on the application of this model for industrial effluent discharge in Sarawak. It could be due to the lacking of an institution or expertise for water modeling system.

Considering the need for more systematic manner in water catchment management, a study on the water quality modeling system is required as it can serve as one of the ideal approaches for effective management of industrial effluent discharge in Sarawak.

The hypotheses of this research: development of water quality modeling for modeling effluent discharge of industrial wastes, by applying the existing modeling tool; and prediction of the potential polluted segment of a river system by the effluent discharge through simulation of the interactions between multiple chemical and biological parameters and river water system.

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1.3 Objectives and Specific Aims

The primary objectives of this research are 1) to investigate and determine the environmental and operational performances of a coal-fired power plant in Sarawak currently implementing ISO 14001 EMS; and 2) to determine and recommend the impacts of landfill effluent discharge on water quality of Batang Kemena and the siting (selection of location) of Maskat Landfill's effluent discharge point, respectively.

The specific aims of this research are as follows:

I) Environmental and operational performances

a) To evaluate the operational and environmental performances of a coal power plant in Sarawak;
b) To monitor the power plant's past few years' trends of performances by comparing the data with the available standards;
c) To recommend some relevant approaches and strategies which could improve the implementation of ISO 14001 EMS for continual improvement in the plant.

II) Impacts of Effluent Discharge on Labang Water Treatment Plant

a) To set up a water quality modeling QUAL2K applicable for modeling industrial effluent discharge;
b) To model the water quality of the potential polluted segments by applying different modeling scenarios; and
c) To make recommendations on the siting (selection of location) of discharge point of the industrial effluent in order to minimise adverse impacts to the nearby community.

1.4 Scope of the Research

The scope of the first research is to conduct EMS literatures review as to assess effectiveness of ISO 14001 as an EMS in the Sejingkat Coal Power Plant. Air quality is chosen as environmental indicator for evaluation of environmental performance. The air quality data ranging from January 2013 to June 2015 will be utilized in this research. For operational performance, data from 2010 to 2013 of the relevant performance parameters in accordance with performance standards developed by the Institute of Electrical and Electronics Engineers (IEEE) are used.

All data will then be statistical analysed and compared with the Recommended Malaysian Air Quality Guidelines and the Environmental Quality (Clean Air) Regulations, 2014 to determine the compliance status. Some air quality treatment technologies will be suggested to further improve the treatment effieciency with the attempt to improving the air quality.

For the second research, research work is to apply QUAL2K water quality modeling system for building a model for modeling industrial effluent discharge and its implication to the water quality of Batang Kemena and its main tributaries. There will be two separate water quality models developed for Sg. Besai discharge and Btg. Kemena discharge. In addition, the potential polluted segment (from effluent discharge of Maskat waste treatment facility) of Batang Kemena to Labang raw water intake point will also be covered in the modeling work. There are four (4) modeling scenarios designed based on various effluent discharge rate and river water flow conditions. This is to provide a representation of various river conditions against pollution input of effluent discharge.

1.5 Significance of the Research

This research will create the awareness of the importance of EMS implementation in energy industry in order to increase the environmental performance and legislative compliance. Besides, this research will make relevant recommendations on areas for improvements and how these improvements could contribute to better implementation of the EMS. As a result, the researcher is hopeful that such findings will contribute to a better environmental condition of Sarawak; such as decreased environmental pollution, and thus contribute to a higher reputation and corporate image.

This research also helps in assessing the potential of QUAL2K model for predicting the water quality along the studied rivers. The water quality model developed in this study can serve as a scientific and reliable operational tool for water quality management policies. Probably the most significant contribution of this research is to provide reliable and useful information that are essential for policy makers and authorities in Sarawak in making more accurate and sustainable decisions before any irreversible action is taken. This is crucial for a sustainable environment as well as the State's economic and social well being.

1.6 Organisation of the Thesis

This thesis is organized in five associated chapters. Chapter 2 focuses on the literature review related to the case studies and their basic principals. Review on literature in relation to the current research works are presented and further discussed by referencing to previous works relevant to the case studies.

Chapter 3 discusses the methodology and experimental setup applied in this research work. This includes descriptions on how the ISO 14001 EMS is applied to improve the environmental and operation performance for the studied power plant as one of the main energy industrial sectors in Sarawak. Descriptions on how the water quality model is applied to model concentrations of effluent discharge for different scenarios of discharge based on the different flow conditions are also included in the chapter.

Chapter 4 presents the results obtained from the experiments and visualization of the results in graphs and table forms. In addition, analysis and discussion for each of the experiments are made based on the obtained results. Uncertainties and limitations in the results are also discussed, in tandem with the suggestion for improvements to address the shortcomings.

Chapter 5 outlines conclusion of the current research work with some recommendations highlighted for future research works.

CHAPTER 2

LITERATURE REVIEW

2.1 Performance Monitoring on Sejingkat Coal Power Plant

In recent years, more and more international and local industry players have adopted various types of EMSs for monitoring of performances that commercial, industrial and service operations have on the operational and environment (ISO, 2001).

The use of EMSs is becoming more common, particularly among larger companies (Ambec & Lanoie, 2008) as they are aware that the EMSs can provide various benefits that can be tapped in the long run of the business. This includes improving their operational and environmental performances, enhancing compliance with the environmental rules and regulations as well as increasing plants' operational efficiency (Ilnitch *et al.*, 1998).

Around the globe, ISO 14001 is the most widely used standard for EMSs (Singh *et al.*, 2015; Montiel & Husted, 2009). There are more than 100 countries around the world recognizing the ISO 14001 as an international standard (Puvanasvaran *et al.*, 2012). The ISO 14001 standard, which is specifically focusing on EMS, is part of the ISO 14000 family and represents the core set of standards used by organizations for designing and implementing an effective EMS (ISO, 2009). Recently, ISO 14001 has undergone its second revision i.e. ISO 14001:2015, which focusing on the needs and expectations of interested parties associated with the organization. In this aspect, identification of risks associated with threats and opportunities as well as significant issues in the environment and compliance obligations is required. The 14001:2015 has been written based on Annex

SL, a new high level structure to simplify integration of various ISO-based management systems. The ISO 14001 acts both as an internal management tool and as a way of demonstrating a company's environmental commitment to its customers and clients. It also provides guidelines for the establishment or improvement of an EMS. Besides continual improvement as the main principle of ISO 14001, the ISO 14001:2015 outlines some major changes which include structural change and substantive changes such as increased accountability of leadership; life cycle approach; rethinking impact; risks and opportunities; pro-active reporting and strengthened compliance (ISO, 2015). Among other key benefits of ISO 14001 EMS include reduced cost of waste management; savings in consumption of energy and materials; increased compliance with applicable laws and regulations and other environmentally oriented requirements, lower distribution costs; improved corporate image among regulators, customers and the public; and continually improvement on the above (Tarí *et al.*, 2012; Mohammed, 2000; Epstain and Roy, 1997).

2.1.1 Environmental Management System (EMS)

Environmental Management System (EMS) refers to the management of an organization's environmental programs in a comprehensive, systematic, planned and documented manner. It includes the organizational structure, planning and resources for developing, implementing and maintaining policy for environmental protection (Ilnitch *et al.*, 1998). On the same note, EMS is a system and database which integrates procedures and processes for training of personnel, monitoring, summarizing, and reporting of

specialized environmental performance information to internal and external stakeholders of a firm.

In recent years, more and more international and local industry players have adopted various types of EMSs for identifying and managing the impacts that commercial, industrial and service operations have on the environment (ISO, 2001). The use of EMSs is becoming more common, particularly among larger companies, realizing that there will be wide range of benefits that can be tapped in the long run of the business. These include improving their environmental performance as well as moving beyond compliance with the environmental rules and regulations.

In its most significant role, an EMS is working on principle to identifying the environmental issues that are generated by the work activities of an industrial and how these issues bring implications to the relevant stakeholders. An EMS helps set priorities for action and it educates and promotes each and every employee to continually look for ways to lessen those impacts and to protect the environment. In general, successful EMS can enhance efficiency and lower costs, reduce use of resources and waste. Besides, it helps to ensure compliance with regulatory requirements, encourage employee involvement in environmental performance and improve relations with customers.

Therefore, an EMS helps the industry players to be self-regulating and thus, ensuring continual improvement which results in minimizing environmental impacts associated with a facility's activities while helping to ensure compliance with environmental regulations. The most widely recognized model for an EMS is based on the

International Organization for Standardization (ISO) 14001 standard. This standard, which is applicable to organizations of all types and sizes, is according to the Plan-Do-Check-Act (PDCA) structure as outlined by Bessant *et al.* (2000). This involves a five-step process which addresses each of the following key elements of the ISO Standard.

Figure 2.1 shows the PDCA structure of first developing an environmental policy, planning the EMS, and then implementing it. The process also includes checking the system and acting on it. The model is continuous because an EMS is a process of continual improvement in which an organization is constantly reviewing and revising the system. This is a model which can be adopted by various industrial in SCORE, ranging from manufacturing facilities to service industries and to government agencies.

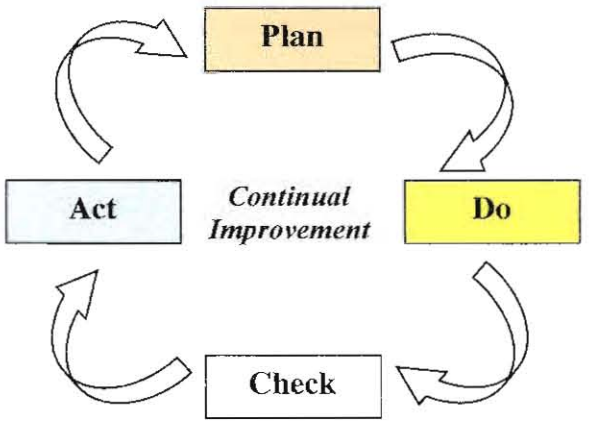


Figure 2.1: EMS model based on PDCA structure

Each element of PDCA structure which shall be included in the EMS documentation (Mindtools, 2015) is as described in Figure 2.2.



Figure 2.2: Elements of PDCA Structure

The elements of the PDCA structure as outlined above can be summarized into few key elements of an EMS as shown in Figure 2.3. Details of each key element of the EMS as explained by Nancy (2004) are as explained in Table 2.1.

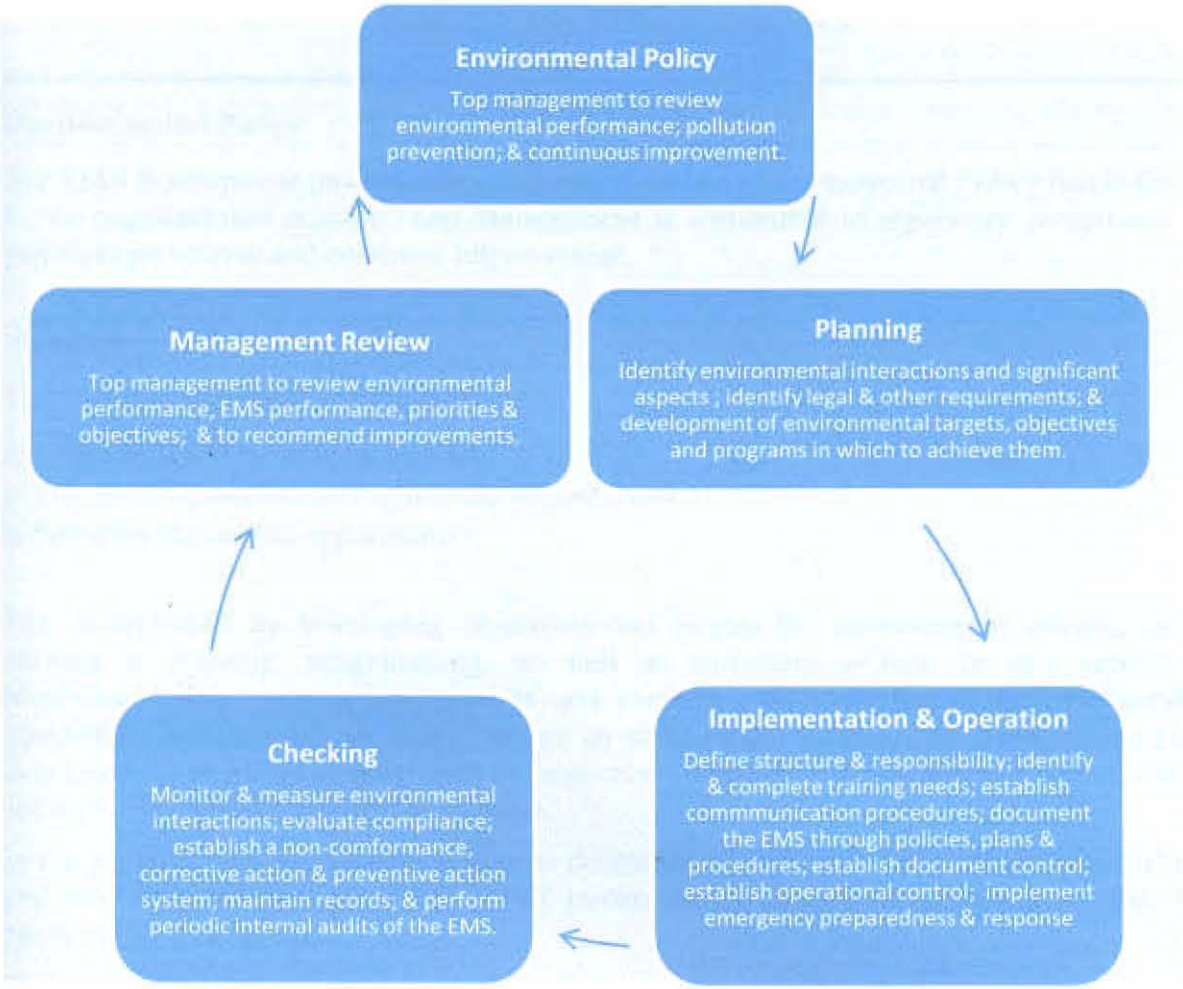


Figure 2.3: Key elements of an effective EMS

Table 2.1: Key elements of an EMS

Environmental Policy
The EMS development process starts with establishing an Environmental Policy that is tied to the organization's mission. Top Management is committed to regulatory compliance, pollution prevention and continual improvement.
Planning
The planning step consists of identifying:- a. Regulatory and other requirements; b. Processes, resources, and significant impacts; and c. Pollution prevention opportunities; This is followed by developing objectives and targets for improvement efforts; and creating a planning, programming, as well as budgeting system. In this process, identification of environmental aspects and impacts and reviewing of environmental compliance requirements are crucial before an environmental management system can be developed. In addition, material such as inspection checklists and procedures to assess and manage legal compliance shall be in place. In the planning step, organisations have to determine whether they have the internal skills and resources to develop an ISO 14001 environmental management system or should outsource its development. If the decision is to go for outsourcing, it is necessary to obtain several proposals and ensure that the Environmental Consultant has EMS experience and qualifications.
Implementation
The implementation step consists of:- a. Defining the structure, responsibilities, and programs; b. Implementing training; c. Creating the EMS documentation (including document control and record keeping); d. Communicating the EMS to personnel; e. Developing and implementing standard operating procedures [SOPs]; and f. Developing and implementing emergency preparedness and response procedures
Checking and Corrective
The checking and corrective action step includes:- a. Monitoring and measuring (e.g., internal assessments), b. Problem and cause identification, c. Corrective and preventative action implementation, and d. An EMS Review.

Table 2.1 continued

Management Review
In the management review step, upper management reviews the EMS, including the results of internal assessments. Modifications to the EMS are made, as necessary, to ensure compliance. The management review is designed to ensure continual improvement of the EMS, taking into account the results of checking and corrective actions.

2.1.1.1 The ISO 14001 EMS

International Organization for Standardization (ISO) 14000 is a family of standards related to environmental management and is based on a voluntary approach to environmental regulation. As described by ISO (2002), the ISO 14000 family addresses various aspects of environmental management as shown in Table 2.2. The ISO 14000 provides practical tools for companies and organizations looking to identify and control their environmental impact and constantly improve their environmental performance.

Table 2.2: The ISO 14000 family and their respective environmental management aspects.

Series Standard of the ISO 14000	**Environmental Management Aspects**
ISO 14001	Environmental management systems - Requirements with guidance for use.
ISO 14004	Environmental management systems - General guidelines on principles, systems and support techniques.
ISO 14006	Environmental management systems - Guidelines for incorporating ecodesign.
ISO 14015	Environmental assessment of sites and organizations.
ISO 14020	Environmental labels and declarations.

Table 2.2 continued

ISO 14030	Post-production environmental assessment.
ISO 14031	Environmental performance evaluation - Guidelines.
ISO 14040 series (14040 to 14049)	Life Cycle Assessment (LCA) which discusses pre-production planning and environment goal setting.
ISO 14064	Guidelines and requirements for water footprint assessments of products, processes, and organizations. Includes only air and soil emissions that impact water quality in the assessment.

An EMS is defined by ISO as: "part of the overall management system, which includes organizational structure, planning activities, responsibilities, practices, procedures, processes, and resources for developing, implementing, achieving, and maintaining the environmental policy" (Federal Facilities Council Report, 1999). The ISO 14001 standard, which is specifically focusing on EMS, is part of the ISO 14000 family and represents the core set of standards used by organizations for designing and implementing an effective EMS (ISO, 2009). The ISO 14001 acts both as an internal management tool and as a way of demonstrating a company's environmental commitment to its customers and clients. It also provides guidelines for the establishment or improvement of an EMS.

At present, it is not a mandatory requirement for Malaysian firms to implement ISO 14001. Adoption of ISO 14001 is mainly based on voluntary basis. Statistics show that there were 2,284 valid ISO 14001 certifications issued to various firms in 2014, considerably increases from 1,673 in 2010. This demonstrates positive growth (up 36%)

based on the trends observed over the last five years (ISO Survey, 2014) which also includes energy sector.

2.1.1.2 Benefits from ISO 14001 EMS Implementation

Literature studies indicate that in most cases, an effectively designed EMS coupled with the efficient implementation, can lead to improved environmental or business performance (Singh *et al.*, 2015). Several projects and numerous case studies of successful EMS practices in small and medium-size enterprises support the proposition that EMS significantly helps a company to improve its environmental performance. *The Manual for Implementing EMS in SME*, issued by the International Finance Corporation (IFC) outlines case studies from small and medium-size business facilities, that experiencing actual benefits by implementing the EMSs (Whitehouse *et al.*, 2005).

World Bank (1998) reported that case studies to assess the effectiveness of EMS were also been undertaken in Mexico with the objective to provide small and medium-size enterprises (SMEs) with technical assistance in implementing EMSs. The work which was initiated under the Guadalajara Environmental Management Pilot Project (GEMP), was financed by the World Bank and coordinated by the Mexico's Ministry of Environment and Natural Resources. A number of 11 large companies in Guadalajara, Mexico, were involved in the study. The case studies concluded that there were over 80 percent of the participating companies had been experiencing reduction on their industrial discharges or emissions, in just within three months of completing the formal EMS training. Statistical analysis also recorded that improvements on the work environment (~70%) and economic

performance (>50%). Furthermore, the project revealed that nearly 50% improvements recorded in various aspects of operation such as materials and energy efficiency, waste handling as well as legal compliance.

The National Database on Environmental Management Systems, NDEMS (2003) reported that the same study was conducted between 1997 and 2002 in North America (United States), by the University of North Carolina and the Environmental Law Institute. Over a five-year period, the study examined environmental performance data at 83 facilities. These facilities were various in business scales such as major manufacturers and electric utilities; auto parts suppliers; electroplaters; military bases and municipal water treatment plants. The main finding of the study concluded that in most of the participating facilities, an EMS plays a more significant role in ensuring regulatory compliance, compared to the other implications such as operating and management efficiencies.

There are numerous studies perceive benefits of accreditation to the ISO 14001 EMS. Campos *et al.* (2015) conducted a study on the ISO 14001 certified companies in South Brazil to determine the relevancy of environmental performance indicators in the application of ISO 14001. Based on multiple correspondences and the cluster analysis, the study showed that indicators of environmental performance are more applicable particularly in the industrial pulp and paper/furniture/wood and textile sectors. In contrast, companies from the services sector do not use such indicators. The results from cluster analysis also demonstrated that this is mainly due to the fact that legal and other requirements on environmental aspects are given more priority by the companies' management in maintaining their ISO 14001 certification.

Guerrero-Baena *et al.* (2015) employing a multicriteria method in order to evaluate the priority level of ISO 14001, focusing on a group of Spanish olive oil firms. Data derived from the study indicate that firms with ISO 14001 certification can give positive impacts on enhancement of environmental awareness among the employees.

Nguyen & Hens (2015) conducted a study to examine the influence of ISO 14001 certification in the cement industry in Vietnam. The findings concluded that both operational and environmental performances have showed significant differences between the certified and non-certified plants. In addition, significant improvement on environmental awareness was also recorded in the certified plants.

2.1.1.3 Summary

The success of the ISO 14001 implementation is very much related to the reasons of implementing the EMS. The reasons may vary (Campos, 2012) based on external to internal factors (Gavronski *et al.*, 2008; Potoski & Prakash, 2004; Govindarajulu & Daily, 2004; Nakamura *et al.*, 2001). In general, most of the previous studies reported that implementation of ISO 14001 standard manages to give positive implications on the organization's overall performance (Campos *et al.*, 2015; Campos, 2012; Tarí *et al.*, 2012; Lopez-Gamero *et al.*, 2010; Link & Naveh, 2006; Melnyk *et al.*, 2003; Lesourd & Schilizzi, 2001; Porter & Van Der Linde, 1995). Among the factors contribute to adoption of ISO 14001 are insistence from top management; perceived commercial benefits, marketing advantages, organizational culture and so on and so forth (Puvanasvaran *et al.*, 2010).

Studies on ISO 14001 in energy related sectors have been reported, however the studies mainly focusing on the environmental performance rather than both environmental and operational performances. For instance, Testa *et al.* (2014) conducted environmental performance study on 229 energy intensive plants in Italy and concluded that there was emission reduction of carbonic anhydride, suggesting that an EMS has significant impacts on environmental performance in energy industries. In Malaysia, a study on EMS in 3 power plants with ISO 14001 certified suggested that the EMS may be applied as cohesive elements to minimize impact on the environment (Jamaluddin, 2006). Inclusion of operational performance in this study can help to present a more representative effectiveness of ISO 14001.

2.2 Development of Water Quality Modeling for Sg. Besai and Btg. Kemena Discharge

The consistent and rapid growth of various development activities of industry, agricultural, domestic and industry wastes are mainly end up in landfill despite other modes of disposal such as incineration, composting, grinding and discharge to sewer, compaction, hog feeding, milling, reduction, anaerobic digestion etcs. This trend not only happens in Malaysia but also in other countries throughout the world (Aziz *et al.*, 2010; Tatsi & Zouboulis, 2002; Tchobanoglous *et al.*, 1993). This could be due to the landfill disposal method has relatively lower degree of complexity and more importantly, it is more economical in term of capital and operating costs. However, effluent discharge of the landfill in the form of leachate has become a great concern due to its significant level of

pollutants and thus, becomes one of the greatest environment concern (Kulikowska & Klimiuk, 2008).

2.2.1 Effluent Discharge of Landfill

Leachate is formed when a liquid, particularly from precipitation that entering and passing through a landfill and carrying along organic, inorganic, heavy matter, colloid, pathogen and other polluted matters during this percolation process (Salem *et al.*, 2008; Tatsi & Zouboulis, 2002). As a result of the process, leachate contains highly contaminated and hazardous substances. If left without treatment it will end up mixing with the surface and groundwater. Even though natural watercourse is having capability to dilute any contaminant, however, its dilution and carrying capabilities in taking in high load of leachate over long period of time are limited. Thus, treatment of leachate is crucial to prevent or minimize hazards to public health or safety and ensure protection and preservation of the environment. Knowledge of the quantity and composition of leachates is necessary when designing treatment facilities and is important in determining raw leachate pollution effect on the environment.

2.2.2 Leachate Characteristics

Leachate contains many substances and it can be considered as highly concentrated complex effluents which may contain mineral and organic compounds (humic substances,

fatty acids, aromatic compounds), heavy metals and many other hazardous chemicals. In general, leachate is characterized by high values of chemical oyxygen demand (COD), pH, ammonia nitrogen and heavy metals, as well as strong color and bad odor. Leachate quality is highly variable depends on various factors such as solid waste composition; age of refuse; operation of landfill; climate; hydrogeological conditions in vicinity of the landfill site; chemical and biological activities; moisture content; temperature; pH; degree of stabilization of landfill chemical and biological activities; and seasonal weather variations may affect the composition of leachate (Iaconi *et al.*, 2006; Park *et al.*, 2001; McBean *et al.*, 1995; Malina & Pohland, 1996; Westlake, 1995; McArdle *et al.*, 1988; Johansen & Carlson, 1976).

The breakdown and basic compositions of leachate is as shown in Table 2.3. As described by Ehrig (1983), landfill leachate can be classified in four main groups:

1. Dissolved organic matters

   Quantified as Chemical Oxygen Demand (COD), Total organic carbon (TOC), volatile fatty acids (that accumulate during the acid phase of the waste stabilization).

2. Inorganic macrocomponents

   Include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), ammonium (NH_4^{+}), iron (Fe^{2+}), manganese (Mn^{2+}), chloride (Cl^{-}), sulfate (SO_4^{2-}) and hydrogen carbonate (HCO_3^{-}).

3. Heavy metals

Include cadmium (Cd^{2+}), chromium (Cr^{3+}), copper (Cu^{2+}), lead (Pb^{2+}), nickel (Ni^{2+}) and zinc (Zn^{2+}).

4. Xenobiotic organic compounds (XOCs)

Originated from household or industrial chemicals and present in relatively low concentrations. (usually less than 1 mg/L of individual compounds). These compounds include among others a variety of aromatic hydrocarbons, phenols, chlorinated aliphatics, pesticides, and plastizers.

Other compounds that may be found in very low concentrations in leachate include borate, sulfide, arsenate, selenate, barium, lithium, mercury, and cobalt.

Table 2.3: Compositions of landfill leachate.

Parameter	**Range (mg/L)**
pH	4.5-9
Spec. Cond. ($\mu S\ cm^{-1}$)	2500-35000
Total Solids	2000-60000
Organic Matter	
Total Organic Carbon (TOC)	30-29000
Biological Oxygen Demand (BOD_5)	20-57000
Chemical Oxygen Demand (COD)	140-152000
BOD_5/COD (ratio)	0.02-0.30
Organic nitrogen	14-2500

Table 2.3 continued

Inorganic Macrocomponents	
Total phosphorous	0.1-23
Chloride	150-4500
Sulphate	8-7750
Hydrogen bicarbonate	610-7320
Sodium	70-7700
Potassium	50-3700
Ammonium-N	50-2200
Calcium	10-7200
Magnesium	30-15000
Iron	3-5500
Manganese	0.03-1400
Silica	4-70
Heavy Metals	
Arsenic	0.01-1
Cadmium	0.0001-0.4
Chromium	0.02-1.5
Cobalt	0.005-1.5
Copper	0.005-10
Lead	0.001-5
Mercury	).00005-0.16
Nickel	0.015-3
Zinc	0.03-1000

(Owen & Manning, 1997; Robinson, 1995; Chu *et al.*, 1994; Andreottola & Cannas, 1992; Karstensen, 1989; NaturvArdsverket, 1989; Lu *et al.*, 1985; Ehrig, 1983; Robinson & Maris, 1979; Garland & Mosher, 1975).

Changes in the compositions or quality of landfill leachates with the landfill age have been extensively studied. In general, young landfill leachates (the acid-phase landfill, <5 years) contain large amounts of biodegradable organic matter in the form of dissolved

organic carbon (DOC) which has concentration up to 20,000 mg/L. More than 95% of the DOC consists of volatile fatty acids, and as little as 1.3% of high molecular weight compounds. In a matured landfill (the methanogenic-phase landfill), the organic fraction in the leachate becomes dominated by refractory (non-biodegradable or humic-like) compounds. It was reported that 32% of the 2100 mg/L DOC consists of high molecular weight compounds (Wang *et al.*, 2003; Welander *et al.*, 1997; Harsem, 1983).

Study also showed that the concentration of the organic substances and the ratio of BOD to COD are generally higher during the active stage of decomposition. The ratio was gradually reduced to less than 0.1 when the decomposition of leachate has been stabilized (Diamadopoulos, 1994). Other significant substances with high concentration are ammonia nitrogen and dissolved solids such as chloride, sulfate, and sodium. On the other hand, heavy metals such as copper, iron, zinc, lead, manganese have relatively lower concentration. The influence of landfill age on temporal changes in leachate composition is depicted in Table 2.4.

Table 2.4: Leachate compositions versus landfill age (Renou *et al.*, 2008).

Parameter	**Young**	**Intermediate**	**Old**
	(<5 years)	(5-10 years)	(>10 years)
pH	6.5	6.5–7.5	>7.5
COD (mg/L)	>10,000	4,000–10,000	<4,000
BOD_5/COD	>0.3	0.1–0.3	<0.1
Organic compounds	80% volatile fat acids (VFA)	5–30% VFA + humic and fulvic acids	Humic and fulvic acids
Heavy metals	Low–medium	Low	Low
Biodegradability	Important	Medium	Low

2.2.3 Environmental Impacts of Landfill Leachate

The increasing urbanization of the world population has produced significant quantity of wastes which eventually will turn into a more contaminated landfill leachate. Landfill leachate has become one of the most highlighted environmental issues as it threatens human health when migrating from the landfill and contaminates the surrounding lands and water (Saeed *et al.*, 2009).

The major potential environmental impacts related to landfill leachate are pollution of groundwater and surface water as these are the sources of drinking water for human being. United States Environmental Protection Agency (USEPA) has reported that approximately 75 percent of the landfills in the USA are polluting groundwater (USEPA, 2004). Besides, the cases of water polluted by landfill leachate have also been found globally, especially in European countries, Australia and China. The risk of such pollution is probably due to the factor where most landfills were built without engineered liners and leachate collection systems in the past. Landfill leachate which is mainly constituent of large amount of organic matters, ammonia nitrogen, heavy metals and inorganic salts, is a great threat to the surrounding soil, groundwater and even surface water (Hassan & Ramadan, 2005). This problem is intensified when industrial wastes are involved as these wastes are resistant to biological or chemical degradation and, thus, are expected to persist in their original form for many years, perhaps even for centuries.

Some of the changes in water quality posed by the leachate release to surface water are oxygen depletion in part of the surface waterbody, changes in the stream bottom fauna and flora and ammonia toxicity. On the other hand, a release of leachate to the

groundwater may present several risks to human health and the environment. Once leachate is formed and is released to the groundwater environment, it will migrate downward through the unsaturated zone until it eventually reaches the saturated zone. Leachate then will follow the hydraulic gradient of the groundwater system, rendering an aquifer unusable for drinking-water purposes and other uses. Leachate impacts to groundwater may also present a danger to the environment and to aquatic species if the leachate-contaminated groundwater plume discharges to wetlands or streams.

Landfill leachate may present long-term threats to groundwater and also surface waters that are hydrologically connected. Even after a landfill site is closed, production of landfill leachate will keep on going for another 30-50 years and this poses great threat to the surrounding soil, groundwater and even surface water (Renou *et al.*, 2008; Robinson, 2005). This happens as leachate contains high concentrations of organic matter, ammonia-nitrogen, heavy metals (e.g. copper, iron, zinc, lead, manganese etc.), chlorinated organic and inorganic salts (e.g. chloride, sulfate, sodium etc.).

Improper management of landfill leachate will lead to significant negative effects on environment which include deterioration of the environment quality and a depletion of our global natural resources With the growth of population and development of the industry, the landfill leachate problem becomes increasingly serious. It is considered as a global problem (Periathamby *et al.*, 2009, Agumuthu *et al.*, 2007) and has been becoming a serious concern to all governments worldwide.

2.2.4 Water Quality Modeling

In recent years, water pollution control and water quality management strategies are gaining prominence in developed as well as developing countries in the wake of global environmental scenarios such as resource depletion, climate shifts, population pressure and, last but not least, increased public awareness. In spite of all the efforts taken by the research community and governmental agencies, water quality is deteriorating in many areas around the world.

From the development's perspective, water plays one of the significant roles. Most users of water depend on adequate levels of water quality. As populations and economies grow, more pollutants are generated and when these levels are not met, these water users will suffer negative implications. As many of these pollutants are waterborne, and hence can end up in surface and groundwater bodies and incur increased risks of health damage or loss. Conflicts among various users of water are increasingly over issues involving water quality as well as water quantity. This leads to the major efforts and costs involved in water management are devoted to water quality protection and management. Thus, more stringent regulations are mandatory for maintaining the water quality for sustainable utilisation. In this connection, water quality management is a critical component of overall integrated water resources management.

Ambient-based water quality prediction and management involves prediction on what pollutant loadings and their quantities will occur in the future, especially for both point source and non-point sources. Thus, there are needs to apply water quality modeling

in order to determine sources of pollution, to allocate pollutant loads, and to predict the effectiveness of actions taken to meet water quality standards. The model is crucial to help managers to predict water quality impacts in a relatively simple manner compared with the complexities of actual water systems. This will also help to address limitations and uncertainties inherent in measuring the attainment of water quality and facilitate in water quality management.

Water quality models try to simulate changes in the concentration of pollutants as they move through the environment in different water bodies, as the fate of pollutants is the resultant of interactions between mass transfer and kinetic processes. A pollutant concentration entering the environment may increase or decrease due to a wide variety of mechanisms. All these changes are the subject of water quality modeling. As the natural systems are highly complicated and dynamic, thus modeling is a continuous process of developing models in times, which more and more adequate to describe the real process. The water quality models represent a system of equations, relationships and observed data, created for description of the natural system, for demonstration and checking its behavior under different conditions in time. The focus here is the purpose, types, structure and application of the water quality models.

Successful water quality modelling requires the specification of an appropriate model structure and process formulation. Both must be related to the compartment structure of running water ecosystems including their longitudinal, vertical, and lateral zonation patterns. Furthermore, the temporal variability of abiotic boundary conditions may be important and must be incorporated by an appropriate choice of model parameters.

The key elements for creation the suitable water quality models are related with the good knowledge about a change in state of a system, presented with the difference in properties between the final and the beginning state. It is not possible to assess water quality without evaluation of the water quantity. That is why the water quality modeling includes as a main part the water quantity modeling (determination of flow characteristic), which gives the answer how water movement affects the concentration of the dissolved and suspended constrains.

2.2.4.1 Classification of Water Quality Models

The models applied in most of the studies are generally mathematical. A mathematical model is an equation, or a set of equations, that relates input parameters and variables to quantified outputs, based on specific assumptions and simplifications of the real system being modeled. Mathematical models can be described by many different criteria. Chapra & Reckhow (1983) provided the following descriptions of the descriptive terms for models that are used in this manual.

2.2.4.1.1 Empirical or mechanistic

An empirical model is developed primarily from an analysis of data. Empirical models are based more on fitting a set of data and less on theoretical principles. Mechanistic models, on the other hand, are intended to be mathematical descriptions of

theoretical principles. It should be emphasized that any good model has both empirical and mechanistic features, but it is possible to classify most models according to a stronger basis in either empiricism or theory.

2.2.4.1.2 Simulation or optimization

Simulation models are designed to describe the functioning of a system. The simulation models describe all models representing water quality changes in some mathematical form including all types of mechanistic models in which the processes are deterministically represented, and also statistical models.

The optimization models are a group of mathematical techniques used to obtain the least costly solution to some allocation situation. Optimization models are used to find a solution that is best (minimum or maximum) in some sense (often subject to constraints, such as cost or environmental quality). Many of the models nowadays have been adapted to provide interface between the user and the model by a computer program, formatted for simulation purposes.

Incorporation of appropriate methods in an optimization models is necessary for planning and forecasting in a way that is beneficial and applicable to water resource management.

2.2.4.1.3 Static or dynamic

Static or dynamic refer to the presence or absence of a time-dependency. Static or steady-state models describe behavior that is constant over time and is thus time-independent. Dynamic models describe behavior that varies with time and thus is time-dependent.

Static water resources include surface waters which are measured in cubic capacity of water in river bed or lake and ground waters. The resources also include groundwaters, measuring in total cubic capacity of water in pores.

Dynamic water resources include outgoing water amount from integrated water management unit in a temporal unit. The concept of dynamic water resources is primarily use for quantitative characterisation of surface water resources, as well as varying groundwater resources in the earth crust.

Dynamic water resources divisible in two parts, namely own water resources which spring up from precipitation and springs on the studied water management unit and troughflow water resources which are the roughly horizontal flow of water through soil or regolith (loose layer of rocky material overlying bedrock), or surface inflow from other water management units.

2.2.4.1.4 Lumped parameter or distributed parameter

Lumped or distributed parametera refer to the presence or absence of a space-dependency. Lumped-parameter models are zero-dimensional in space; they are based on an assumption of uniform conditions throughout the system modeled. A zero-dimensional model, for instance, is the continuously-stirred-tank-reactor (CSTR) that is used to estimate the concentration of a pollutant as a function of time. In contrast, distributed-parameter models, are developed to describe systems with variable conditions in one or more spatial dimension. On the other hand, a distributed parameter model, for instance, would be one that is used to describe the oxygen profile in a stratified lake.

Distributed parameter models are categorized further according to how they represent the real world in terms of spatial resolution. One-dimensional models are considered to be the most simple. They simulate either the vertical or longitudinal behavior of a water body. Two-dimensional models simulate the longitudinal and either transverse behavior or depth of a water body. Three-dimensional models are the most complex. They attempt to simulate the behavior of a whole system by taking into account all types of water movement. The decision of what type of model to use is usually limited by the amount of data available and the objective of the modelling study. A model is not a feasible water quality tool unless the appropriate data are available.

2.2.4.1.5 Deterministic or stochastic

Deterministic models use expected values (i.e. no real data) for all parameters and variables and yield predictions that are also expected values. Stochastic models incorporate variability, and possibly error, in probability density functions for selected parameters and/or variables. This results in a probability density function for the prediction.

Deterministic models are limited in that they provide the user with only a single set of output values for each proposed management alternative, when in fact the output values would be more accurately represented by a distribution in probability. In the past, an attempt has been made to satisfy these needs by applying sensitivity analysis. Selected parameters were varied and repetitious deterministic simulations performed, thus providing the user with a range of results for a range of parameter values.

Stochastic modeling provides a more practical and theoretically approach to assessing uncertainties. Stochastic models treat selected variables as random variables having distributions in probability and provide a theoretically sound framework for propagation of input uncertainty into uncertainty of results. Outputs from stochastic models provide both a range and likelihood of occurrence through calculations of means and variances associated with output values.

2.2.4.1.6 Cross-sectional or longitudinal

Cross-sectional models describe behavior among cases (e. g., a cross section of the lakes), in contrast to longitudinal models, which describe behavior for a single case over time. As a rule, cross-sectional models are more often empirical, whereas longitudinal models may be either empirical or mechanistic.

In constructing the water quality model, the river is assumed as a linear system in which transversal and vertical transport processes are considered as instantaneously completed ones. In other words, it means that the contaminant discharged into the stream from any external source is being instantaneously mixed with an elementary certain volume of water body.Therefore, the level of contamination of the stream by the pollutant at any point, along the longitudinal profile, is represented by the cross-sectionally averaged concentration of that substance.

A large amount of accurate cross-section data is indispensable for predicting changes in water quality. However, the measured cross-section data are usually sparse in the transverse direction at each cross-section as well as in the longitudinal direction along the waterway channel.

2.2.4.2 Process of Water Quality Modeling

The process of model building is an iterative process, which starts with expression of a working hypothesis, typically based on a priori knowledge about the system in the form of mathematical model. Typical processes involve in model building include:

- Formulation of objectives;
- Review of theoretical background;
- Formulation of the model;
- Creation of a model structure;
- Formulation of equations;
- Formulation of methods of solution;
- Selection of a computer code;
- Calibration of the model;
- Validation of the model;
- Statistical assessment of paired observations and simulations; and
- Sensitivity analysis, and visualization of results in graphs, tables and ArcView shapes.

Basic equations for water quality modeling, which are the modeling fundamental are:

- Conservation equations, which describe the conservation of momentum, water mass, heat energy, and constituent mass; and
- Equation for continuity of water.

The used solution techniques for solving the basic equations are analytical solution and numerical solution in dependence of the type of the system equations. All simulations are subject to uncertainty having in mind that the hydraulic and transport parameters and boundary conditions are never known in sufficient details as well as the existing distributions of the pollutants. Uncertainty in the results may be classified as associated with model input parameters and with numerical and conceptual difficulties in modeling pollutant transport.

The available water quality models are many different types in dependence of the level of input and output information, the complexity of the modeling events, the modeling water body, used mathematical methods, the type of the basic equations, the aim of the modeling, the structure of the modeling system, the scale of interest and others. Basically they are divided into simulation and optimization models.

The simulation models describe all models, represented water quality changes in some mathematical form in which the processes are deterministically represented and also statistical models while the optimization models are a group of mathematical techniques used to obtain the least costly solution to some allocation situation.

The simulation models by the type of model are divided into mechanistic, empirical, deterministic and stochastic models. The common tendency is the models to be more fundamental and less empirical. From the practical view the water quality management models will have empirical character in future.

Types of water quality models in dependence of the simulated water body are:

- Models of water quality in rivers;
- Models of water quality in estuaries;
- Models of water quality in reservoirs and lakes;
- Models of water quality in ground waters: and
- Models of water quality in run off.

Types of water quality models by function of pollutants:

- for estimation of non-point source pollution of stream flow from watershed and for estimation of point source (in stream) pollution.

Usually these two models work together, included in one common decision making system for evaluation of the water quality in every reach of the river, taking into account the self-purification capability of the stream flow and all physical, chemical and biological processes simulations.

2.2.4.3 Common Models in Water Quality Analysis

There are few common models used in water quality analysis and these models' background and applications are described below.

2.2.4.3.1 One-dimensional models

One-dimensional models are most commonly used in rivers, but can also be used in special cases in estuaries and lakes with large length-to-width ratios. One of the most common and widely used of this model is QUAL2E/2K: Enhanced stream water quality model.

The QUAL2E/2K series of models has a long history in stream water quality modeling. It was primarily developed by the U.S. Environmental Protection Agency (USEPA) in the early 1970s. Since, it has gained a broad user base, including applications outside the U.S. in Europe, Asia, and South and Central America. The Enhanced Stream Water Quality Model (QUAL2E/2K) is applicable to well mixed, dendritic streams. It simulates the major reactions of nutrient cycles, algal production, benthic and carbonaceous demand, atmospheric reaeration and their effects on the dissolved oxygen balance. It can predict up to 15 water quality constituent concentrations.

It is intended as a water quality planning tool for developing total maximum daily loads (TMDLs) and can also be used in conjunction with field sampling for identifying the magnitude and quality characteristics of nonpoint sources. By operating the model dynamically, the user can study diurnal dissolved oxygen variations and algal growth. However, the effects of dynamic forcing functions, such as headwater flows or point source loads, cannot be modeled with QUAL2E/2K. QUAL2E/2K-u is an enhancement allowing users to perform three types of uncertainty analyses: sensitivity analysis, first-order error analysis, and Monte Carlo simulation.

The model only simulates steady-state stream flow and contaminant loading conditions; the reference to dynamic modeling above refers only to water quality forcing functions of climatologic variables (air temperature, solar radiation, among others). The transport scheme in the model is the implicit backward-difference finite difference method.

2.2.4.3.2 Two- and Three-Dimensional Models

Two- and three-dimensional models are typically used in reservoirs, lakes, and estuaries. They are almost exclusively finite element, finite volume, or finite difference. As large water bodies are generally stratified, they must simulate buoyancy effects of which the hydrodynamic and transport equations are coupled. Some of the common models include CORMIX: Cornell Mixing-Zone Model, WASP: Water Quality Analysis Simulation Program, POM: Princeton ocean model and ECOM-si: Estuarine, coastal and ocean model.

The water parameters applied in two- and three-dimensional models include biochemical oxygen demand and dissolved oxygen dynamics, nutrients and eutrophication, bacterial contamination, and organic chemical and heavy metal contamination. In this model, environmental properties and chemical concentrations are modeled as spatially constant within segments. Segment volumes and type (surface water, subsurface water, surface benthic, subsurface benthic) must be specified, along with hydraulic coefficients for riverine networks.

CHAPTER 3

METHODOLOGY

3.1 Performance Monitoring of Sejingkat Coal Power Plant

This work offers a study to monitor the performance records of an ISO 14001 certified coal power plant, namely the Sejingkat Coal Power Plant in Sarawak, Malaysia. The power plant was certified with the ISO 14001:2004 certification on 1st April 2012 with the scope of supply under *Provision of Generation and Sales of Electricity*. The power plant was selected as the plant has been implementing ISO 14001 EMS for at least three years, serving as the primary criteria to justify its representativeness for the case study. Furthermore, the power plant plays significant role as one of the energy producers in the development of SCORE. In addition to that, this work has considered other criteria based on the study recommended by Ruth (2001). This includes the industry shall have substantial environmental and operational data in order to have more representative interpretations on the overall findings.

This study is based on data analysis by taking advantage of the current operational and environmental data whereby data collection was carried out from various sources which include the plant's operation records; log sheet for maintenance works; manufacturer information; environmental database as well as its environmental monitoring reports. All data were statistically analyzed to obtain output results in numerical values in graph and table forms. Although it would be ideal to use data before the ISO 14001 implementation, this study only used those available data after ISO 14001 for two reasons.

First, it is impossible to obtain data before ISO 14001 implementation as the data were not credible due to inconsistency in methodologies and experimental design. Second, the data were not organized for official reporting and official published purposes. Figure 3.1 is the flow chart summarizing the methodology.

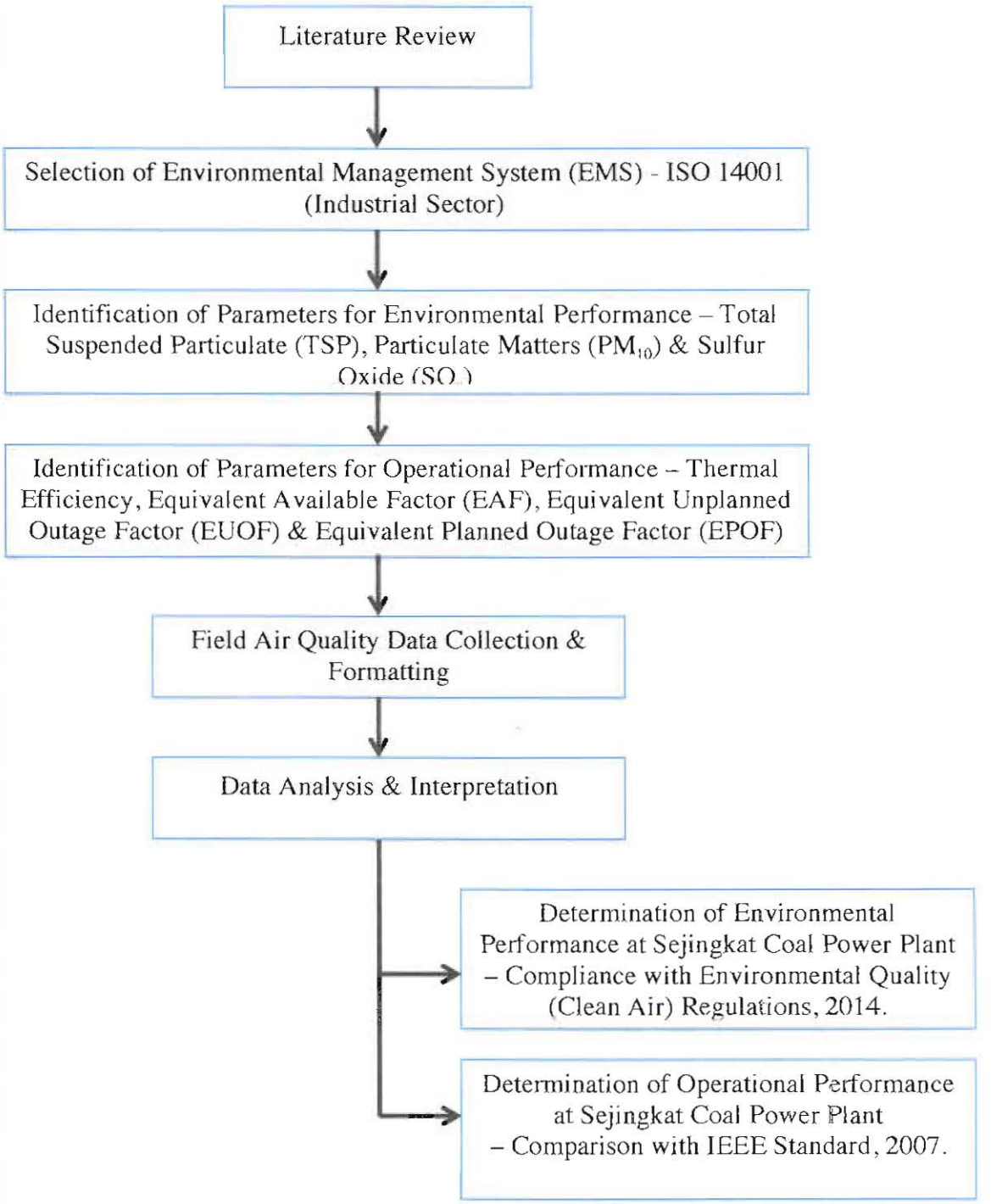


Figure 3.1: Summary of methodology for performance monitoring.

3.1.1 Analyses of Environmental Performance

Air quality was chosen as the environmental parameters as it is the main concern during the operation of the coal power plant. The air quality data ranging from January 2013 to June 2015 were utilized in this case study. The relevant air quality parameters included in this study are Total Suspended Particulates (TSP), Particulate Matters up to 10 μm in size (PM_{10}) and Sulfur Oxide (SO_x). Monthly average values of the air quality data were compared with the Recommended Malaysian Air Quality Guidelines and the Environmental Quality (Clean Air) Regulations, 2014 to determine the compliance status on the air quality. The findings are presented in graph form and relevant recommendations were made to improve the existing environmental performance.

3.1.2 Analyses of Operational Performance

In the attempt to make assessment on the plant's operating performance, Thermal Efficiency, Equivalent Availability Factor (EAF), Equivalent Unplanned Outage Factor (EUOF) and Equivalent Planned Outage Factor (EPOF) were identified as the performance parameters in accordance with performance standards developed by the Institute of Electrical and Electronics Engineers (IEEE). To substantial this, the performance standards were also approved by the American National Standards Institute standard. It provides interpretation of electric generating unit performance data and standardizes terminology and indexes for reporting electric generating unit reliability, availability, and productivity performance measures (IEEE Standard, 2007).

Monthly average values of thermal efficiency, EAF, EUOF and EPOF from the 4 generating units were calculated from January 2010 to August 2013. Mean and standard deviation of the values were determined for the calculation of standard error. The output results were presented in numerical values in table and graph in the form of error bars. Efficiency comparison of these parameters with other coal power plants was performed for benchmarking performance efficiency. Recommendations to achieve performance improvements were made based on the review of some relevant case studies carried out in other countries' coal power plants.

3.1.2.1 Thermal Efficiency

Thermal efficiency expresses the efficiency of conversion from fuel energy input to electrical energy output. Thermal efficiency monitoring was carried out on four steam generating units in the plant and the calculation of thermal efficiency which is based on heat rate of the generating units was derived as follows:

$$\textit{Thermal Efficiency (\%)} = (100)(3412) / \textit{Heat Rate} \qquad (3.1)$$

whereas, Heat Rate (Btu/kWh) = F / E;

F = heat energy input supplied by fuel to the power plant for a period (BTU);

E = energy output from the power plant in a period (kWh).

The equivalent BTU content of a single kWh of electricity is 3,412 BTU

3.1.2.2 Equivalent Availability Factor (EAF)

The availability factor of a power plant is the amount of time that it is able to produce electricity over a certain period, divided by the amount of the time in the period. The EAF measures the percentage of time that a generation unit is available to generate electricity if called upon in the marketplace. This parameter is considered very effective and has become increasingly popular in the measurement of power plant's performance (GE power systems, 2000). It takes into account the lost capacity effects as equivalent unavailable hours. The calculation of EAF is based on formula as shown as following:

$$\text{Equivalent Availability Factor, EAF} = \frac{\text{AH} - \text{EDH}}{\text{PH}} \times 100\% \qquad (3.2)$$

whereas

AH = Sum of all hours when the unit is available less the sum of all Planned Outage hours and Unplanned Outage Hours

EDH = Equivalent Derated Hours = $\frac{\text{DC} - \text{DO}}{\text{DC}} \times DH$

DO = The unit output during the Derated hours

DC = The unit Declared Capacity

DH = Sum of all hours when any portion of the Dependable Capacity of the unit is not available, but excluding Forced Outage hours and Scheduled Outage hours

PH = Period Hours

3.1.2.3 Equivalent Unplanned Outage Factor (EUOF)

The Unplanned Outage Rate is a measure of the plant's generating unit availability. The Equivalent Unplanned Outage Factor (EUOF) is the percent of scheduled operating time that a unit is out of service due to unexpected problems or failures and cannot reach full capability due to forced component or equipment failures. The calculation of EUOF is based on formula as follows:

Equivalent Unplanned Outage Factor
= (Unplanned Outage Hours / Period Hours) × 100% (3.3)

3.1.2.4 Equivalent Planned Outage Factor (EPOF)

The Planned Outage Rate is defined as measure of a planned ahead outage which leads to unit's unavailability. The outage has to be agreed and acknowledged by the load dispatch center to ensure proper grid mitigation activities are carried out accordingly. The calculation of Equivalent Planned Outage Factor (EPOF) is based on the percent of time during a specific period that a unit is out of service due to either planned or maintenance outages and the formula is as follows:

Equivalent Planned Outage Factor
= (Planned Outage Hours / Period Hours) × 100% (3.4)

3.2 Development of Water Quality Modeling for Sg. Besai and Btg. Kemena Discharge

This study outlines the potential environmental impacts caused by the proposed Maskat Landfill during operation stage. The potential impacts identified are based upon the outcome of the assessment and modeling works on surface river water quality. The assessment and projection of the impacts were carried out by taking consideration into the nature (i.e Maskat Landfill) and the size of the proposed Project as well as its surrounding environment. Figure 3.2 is the flow chart summarizing the methodology.

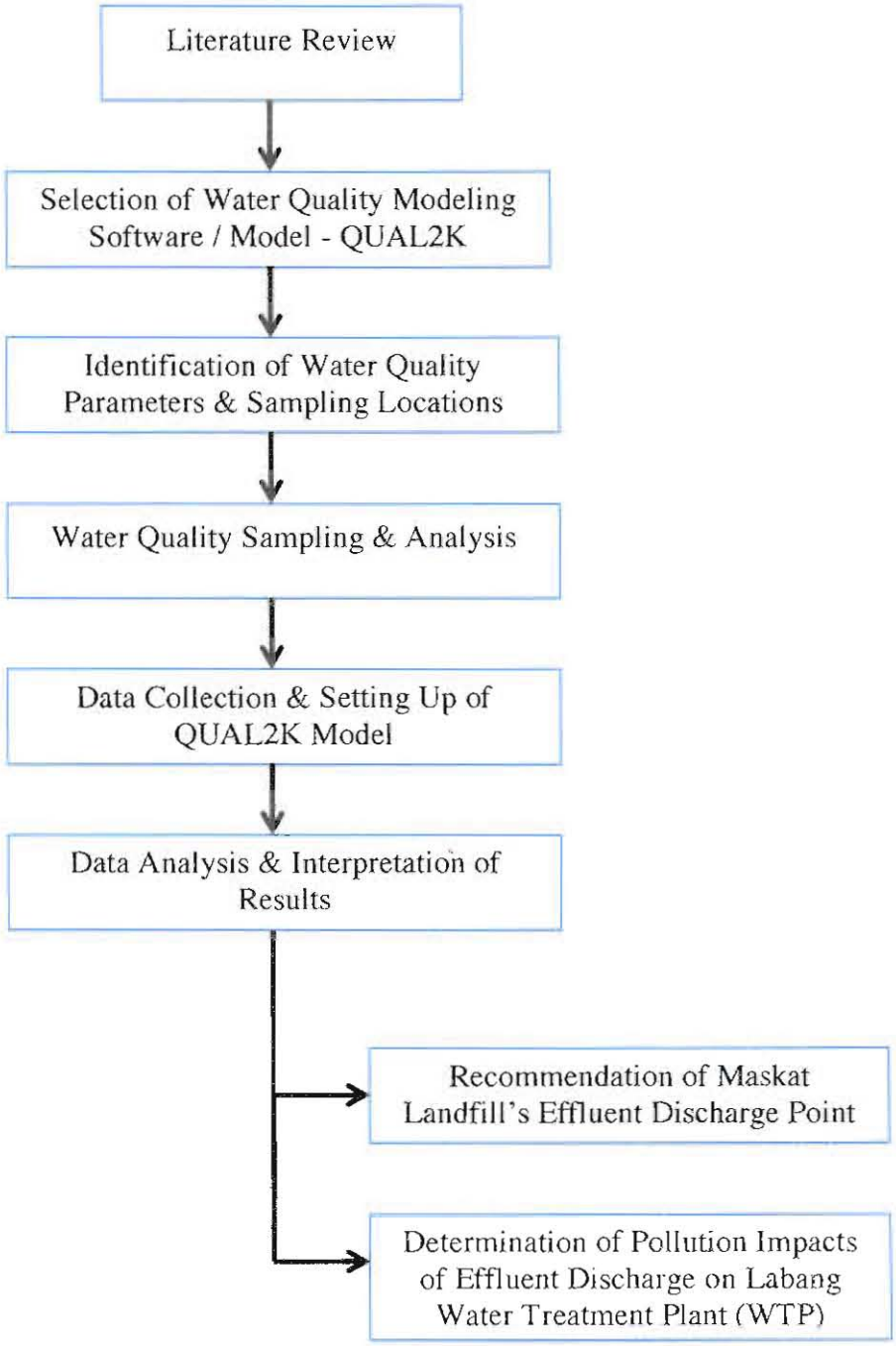


Figure 3.2: Summary of methodology for river water quality modeling.

3.2.1 River Water Sampling

A total of twelve (12) stations were identified throughout Sg. Besai and Btg. Kemena as shown in Figure 3.3. Baseline water quality sampling and surface water quality sampling were conducted from 6 June 2013 to 7 June 2013 and 30 July 2013 to 2 August 2013, respectively.

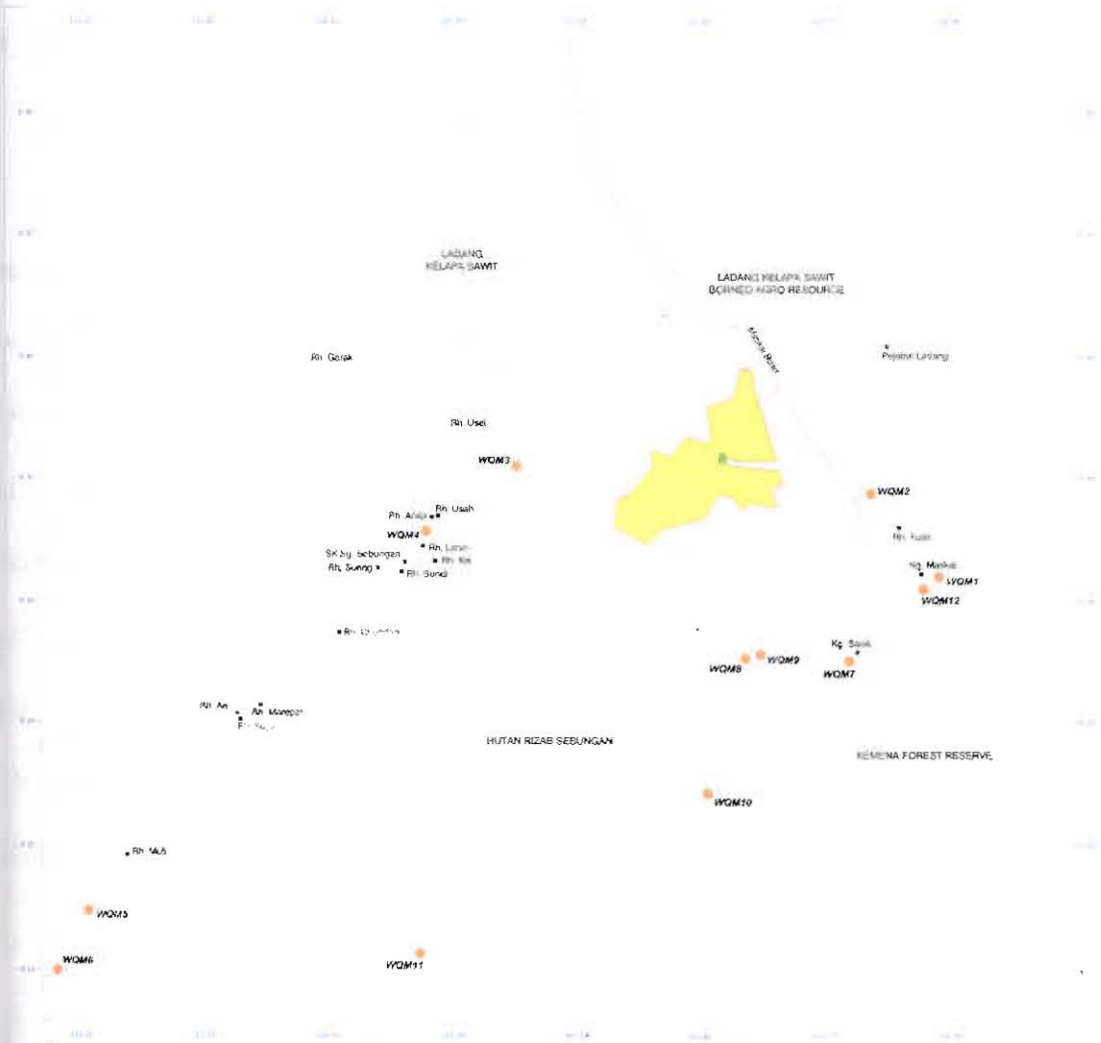


Figure 3.3: Water Quality Sampling Stations (WQM1 – WQM12).

All water samples were tested for parameters coherent to the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009, as well as for NO_3-N. In-situ measurements including temperature, DO, salinity, conductivity and pH were also made, in addition to hydraulic measurements of width, depth, velocity and discharge. All samples were sent to an Skim Akreditasi Makmal Malaysia (SAMM) accredited laboratory for testing.

3.2.2 Simulation Equation of QUAL2K Model

There were two separate water quality models developed for Sg. Besai discharge and Btg. Kemena discharge, respectively, to assess the impacts of leachate discharges. The water quality model used was QUAL2K, which was developed by the USEPA. The QUAL2K model has widely been applied for waste load allocations, discharge-permit allocations, and other pollution evaluations. QUAL2K is applicable to well-mixed dendritic streams where the major transport mechanisms of advection and dispersion are only significant along the longitudinal axis of flow for a stream. Streamflow and input of waste loads are considered to be constant i.e. in steady state during the simulation period. The model can also be used to study the assimilative capacities of receiving streams and to identify non-point waste loads (Brown & Barnwell, 1987).

A river is represented in the QUAL2K model as a linked group of streams and tributary reaches that consist of headwaters (the beginning of a stream reach) and sequential strings of completely mixed reactors, which are referred to as computational elements. Within each reach, all the computational elements have the same average depth,

stream slope, channel cross-section, and biological/chemical rate constants.

The QUAL2K model calculates a flow and mass balance for each computational element. The forcing function used for estimating transport is the stream discharge, which is assumed to be constant. Stream velocity, cross-sectional area, and depth are computed from stream flow. The QUAL2K model performs dissolved oxygen balance by including major source and sink terms in the mass balance equation. The nitrogen cycle is composed of four compartments: organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. The phosphorus cycle consists of dissolved phosphorus and organic phosphorus. Ultimate cBOD is modelled as a first order degradation process. The major source of dissolved oxygen is algal photosynthesis and atmospheric reaeration.

To develop a representative model for the Sg. Besai and Btg. Kemena sub-basin, ambient river water quality data and hydraulic characteristics were measured on-site, albeit not throughout the entire basin. A model building process will be carried out along the research work. This includes formulation of the model; creation of a model structure; formulation of equations; formulation of methods of solution; selection of a computer code; calibration of the model; validation of the model; statistical assessment of paired observations and simulations; sensitivity analysis, and visualization of results in graphs. These exercises are necessary to ensure that the model could be calibrated as accurately as possible as well as enabling a baseline representation of the current water quality conditions.

The general QUAL2K model assumptions and limitations that shall apply to this study include:-

- Streams are well mixed and generally homogenous with an evenly distributed concentration pattern, vertically and laterally. This is coherent to 1-dimensional water quality modeling.
- Flow characteristics in QUAL2K were simulated on a steady flow basis, with data collected from field surveys as well as authenticated/recognized literature values.

QUAL2K's most fundamental unit is the element as shown in Figure 3.2. A steady-state flow balance is implemented for each model element as below:

$$Qi \quad Qi \quad 1 \quad Qin,i \quad Qout,i \tag{3.5}$$

where

Qi = outflow from element i into the downstream element $i + 1$ [m^3/d],

Qi–1 = inflow from the upstream element i – 1 [m^3/d],

Qin,i is the total inflow into the element from point and nonpoint sources [m^3/d],

$Qout,i$ is the total outflow from the element due to point and nonpoint withdrawals [m^3/d].

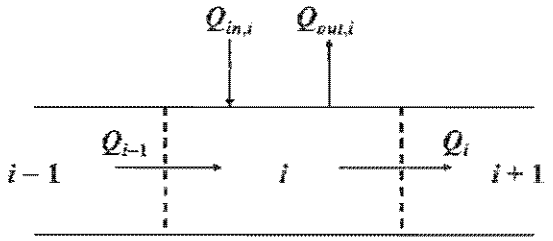


Figure 3.2: Element of QUAL2K's most fundamental unit

Thus, the downstream outflow is simply the difference between inflow and source gains minus withdrawal losses. The total inflow from sources is computed as:

$$Q_{in,i} = \sum_{j=1}^{psi} Q_{ps,i,j} + \sum_{j=1}^{npsi} Q_{nps,i,j} \tag{3.6}$$

where

Qps,i,j is the jth point source inflow to element i [m^3/d],

psi = the total number of point sources to element i,

$Qnps,i,j$ is the jth non-point source inflow to element i [m^3/d], and

$npsi$ = the total number of non-point source inflows to element i.

The total outflow from withdrawals is computed as:

$$Q_{out,i} = \sum_{j=1}^{pai} Q_{pa,i,j} + \sum_{j=1}^{npai} Q_{npa,i,j} \tag{3.7}$$

where

Qpa,i,j is the jth point withdrawal outflow from element i [m^3/d],

pai = the total number of point withdrawals from element i,

$Qnpa,i,j$ is the jth non-point withdrawal outflow from element i [m^3/d], and

$npai$ = the total number of non-point withdrawal flows from element i.

3.2.3 River Water Quality Parameters

Water quality parameters that were simulated included DO, BOD_5, uBOD (represented as fast-BOD in QUAL2K), NH_3-N, NO_3-N, total suspended solids (TSS), lead (Pb), arsenic (As), cadmium (Cd), mercury (Hg) and nickel (Ni). The model uses ultimate cBOD, so the 5-day measurement was extrapolated to acquire this value. By default, a decay rate k, of 0.23 was assumed for the ambient stream conditions. It should be noted that, besides practical considerations in terms of time and cost, there might be other benefits from using the 5-day measurement with extrapolation, rather that performing a longer-term cBOD. Although extrapolation does introduce some level of error, the 5-day value has the advantage that it would tend to minimize possible nitrification effects, which, even when inhibited, can begin to be exerted over longer time frames (Chapra, 2007).

In utilizing steady state water quality models QUAL2K, low flow analyses is important to provide a conservative representation of sensitive river conditions (with regards to pollution input). Unfortunately, due to unavailability of primary data (both rainfall and flow gauging stations) and lack of hydrological analysis, the low-flow conditions will have to be approximated. This is done by arbitrarily reducing the flow by 50%. At the very least, this will give some indications of the extent of the impact, in the event the riverine flow rate becomes lower than what was gauged. The modeling scenarios were designed based on various scenarios as described as follows:

SCENARIO 1 : Treated Effluent Discharge, Normal Flow

SCENARIO 2 : Treated Effluent Discharge, Low Flow

SCENARIO 3 : Raw Leachate Discharge, Low Flow

SCENARIO 4 : Raw Leachate Discharge, Low Flow, Shock Loading

*Normal flow: Current water quality conditions, baseline scenario.

*Low flow: Same as normal flow, except: 50% in-stream flow reduction.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Performances Monitoring of Sejingkat Coal Power Plant

4.1.1 Analyses of Environmental Performance

As shown in Figure 4.1 - Figure 4.3, the monitoring results from January 2013 to June 2015 show that in general, the levels of TSP, PM_{10} and SO_x are well within the prescribed Recommended Malaysian Air Quality Guidelines of 260 $\mu g/m^3$ (for TSP), 150 $\mu g/m^3$ (for PM_{10}) and 0.00035 g/Nm^3 (for SO_x) (DOE, 2003). The average concentrations for TSP, PM_{10} and SO_x are below the standard limits and have shown high compliance with the locally enforced Environmental Quality (Clean Air) Regulations, 2014. There were trace amount of TSP, PM_{10} and SO_x detected and the levels are within the safe limits as stipulated by the standards and is expected to exert a localized effect confined to the area within the Plant boundary. The collected data demonstrate that the plant has been maintaining a reasonably good thermal environmental performance over the years.

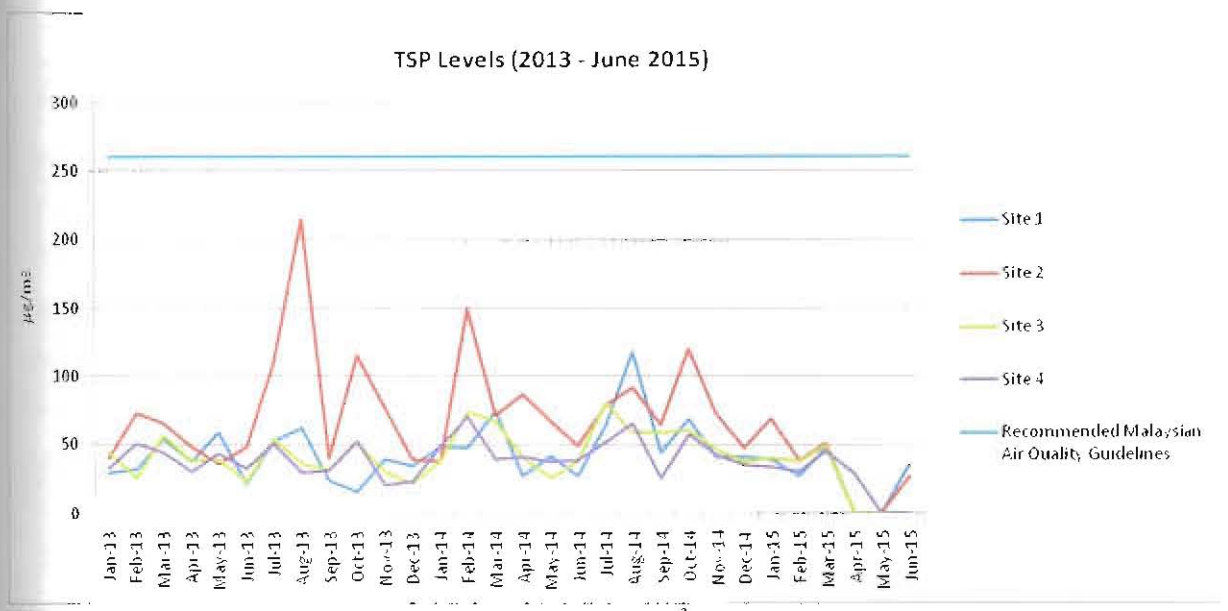


Figure 4.1: Average monthly readings of TSP ($\mu g/m^3$) from January 2013 to June 2015 at Sejingkat Coal Power Plant.

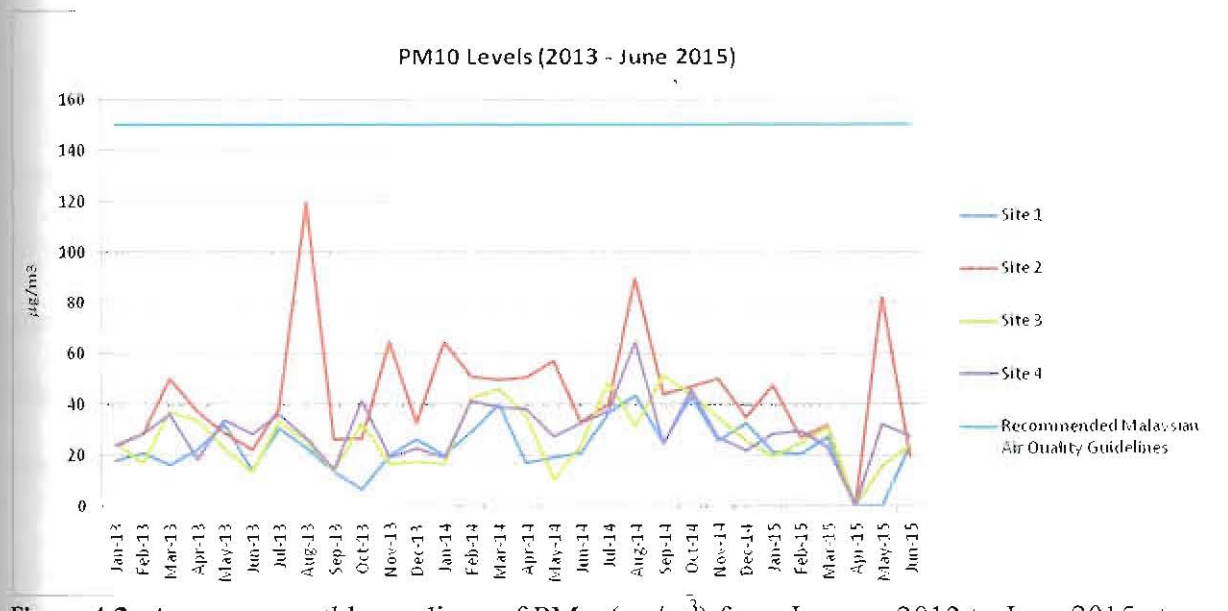


Figure 4.2: Average monthly readings of PM_{10} ($\mu g/m^3$) from January 2013 to June 2015 at Sejingkat Coal Power Plant.

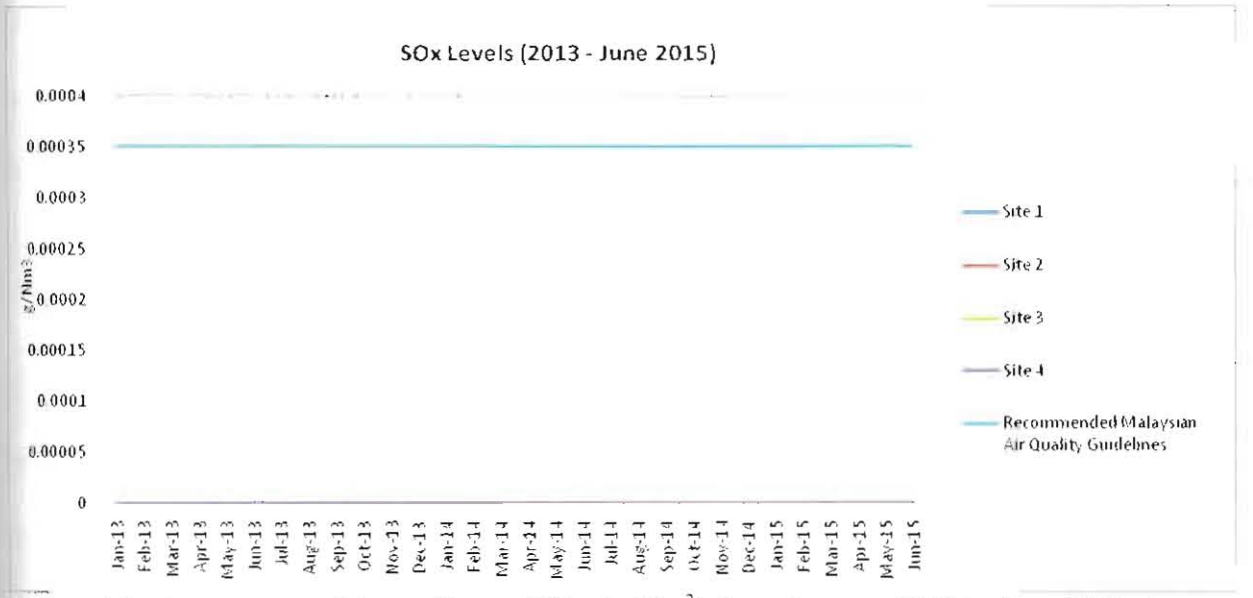


Figure 4.3: Average monthly readings of SO_x (g/Nm^3) from January 2013 to June 2015 at Sejingkat Coal Power Plant.

Note that the SO_x levels are very insignificant the values of which are well below 0.00005 g/Nm^3.

In addition, it is observed that there is no increased risk for the identified receptors. These findings mainly due to the effectiveness of the treatment facility, i.e. application of the electrostatic precipitator to filter the ash (residual from coal combustion), besides the sound maintenance practices. These trends are expected to be consistent should the plant strictly follows all the procedures and operating requirements as stipulated in the ISO 14001 EMS.

Inclusion of NO_x, i.e. NO and NO_2, as air quality parameter is necessary as it will best represent the overall air emission performance of the generating units (Eurelectric, 1997; EHP, 2015). Global emissions of NO_x from coal-fired power generation can bring certain level of impacts to the environment through acid rain, forest damage etc. which may pose direct and indirect damage to human health. There are also increasingly stringent international and national NO_x emission standards adopted in many countries (Nalbandian,

2009). This justifies the necessity to include monitoring of NO_x emissions from the plant as it is a significant air quality parameter which is measureable, quantifiable, controllable and also enforceable by the regulating agencies.

To further improve the emission of air pollutants, the plant may consider to adopt some of the available clean coal programs to reduce concentration of air pollutants released into the air. For instance, control of SO_2 by scrubbing with limestone slurry in a flue gas desulphurization; removal of PM by fabric filters, and reduction of emission of air pollutant (SO_2, NO_x, PM) by the existing proven flue gas treatment technologies. To minimize the emission of NO_x from the flue gases of coal burners, low-NO_x combustion technology which is operating based on the principle of staged combustion in burners could be a cost effective option. In addition, the use of catalysts that break apart the NO_x also could help to reduce NO_x formation by converting NO_x into non-polluting gases.

4.1.2 Analyses of Operational Performance

The results of the operational performance are as shown in Table 4.1. The averaged yearly readings of thermal efficiency from April 2012 to June 2015 are ranging from 30.79% to 31.00%, with the overall averaged reading of 30.86% recorded throughout the study. EAF of 89.60-90.68% were recorded with the overall averaged reading of 89.94%. The averaged readings of 1.70-2.86% and 4.11-7.51% were recorded on EUOF and EPOF, with the overall averaged reading of 2.09% for EUOF and 6.45% for EPOF.

Table 4.1: Average yearly readings of operational performance.

Year	Thermal Efficiency (%)	Equivalent Availability Factor (%)	Equivalent Unplanned Outage Factor (%)	Equivalent Planned Outage Factor (%)
Apr -Dec 2012	31.00	90.51	1.70	6.68
Jan-Dec 2013	30.79	89.49	1.93	6.40
Jan-Dec 2014	30.81	89.60	2.15	7.51
Jan-Jun 2015	30.90	90.68	2.86	4.11
Average	30.86	89.94	2.09	6.45

4.1.2.1 Thermal Efficiency

The findings show that all the 4 units of steam turbine generators were operating in high degree of inconsistency as shown in Figure 4.4. However, the error bars showed that, based on the 95% confidence interval, most of the error bars did overlap and this explains the difference between all of the thermal efficiency results may not be statistically significant.

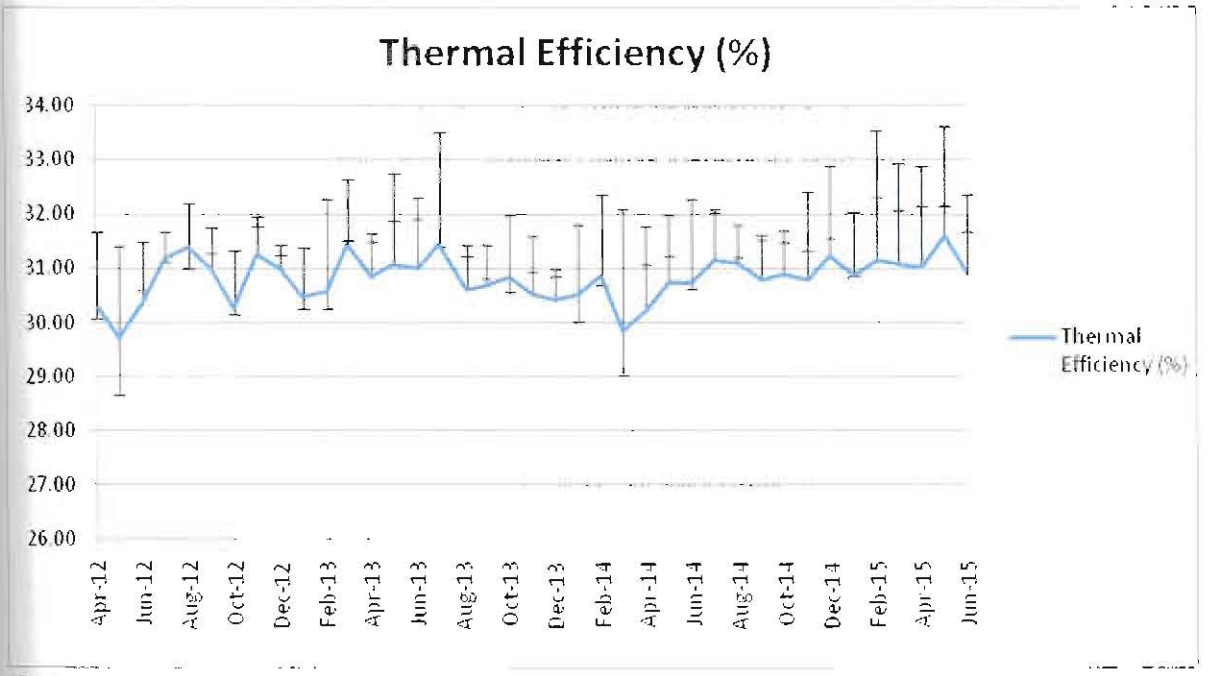


Figure 4.4: Average monthly readings of Thermal Efficiency (April 2012 to June 2015) at Sejingkat Coal Power Plant.

Table 4.2 shows Unit no.1 and 2 recorded the averaged thermal efficiency of 28.06% for the lowest reading to 30.80% for the highest readings. The same experienced by Unit no.3 & 4 whereby averaged thermal efficiency of 29.15% for the lowest reading to 33.21% for the highest readings were recorded. This inconsistency may due to the aging factor of the plant since its first commencement about 20 years ago. The aging of the plant will lose its efficiency attributed to mechanical wear of components which resulting in heat losses.

Table 4.2: Thermal efficiency data from April 2012 to December 2015.

Month-Year	Thermal Efficiency (%)			
	Unit #1	Unit #2	Unit #3	Unit #4
Apr-12	30.519	30.460	31.816	31.792
May-12	30.791	30.607	31.388	31.579
Jun-12	30.172	29.663	31.828	31.465
Jul-12	30.571	30.736	31.272	31.006
Aug-12	30.464	30.553	31.038	31.028
Sep-12	30.572	30.552	31.951	31.837
Oct-12	30.029	30.748	31.010	31.662
Nov-12	30.245	30.482	31.912	31.958
Dec-12	30.561	30.789	31.656	31.325
Jan-13	30.718	30.488	31.495	31.406
Feb-13	30.726	30.795	32.258	32.600
Mar-13	29.790	30.461	31.824	31.461
Apr-13	29.283	30.650	31.505	31.598
May-13	29.325	30.725	32.968	32.991
Jun-13	29.095	29.833	32.278	32.040
Jul-13	29.064	29.321	32.163	31.005
Aug-13	29.628	30.145	31.093	31.997
Sep-13	30.298	30.576	31.353	31.723
Oct-13	29.847	29.364	30.752	30.521
Nov-13	29.264	29.459	31.522	30.550
Dec-13	29.914	29.846	31.348	30.859
Jan-14	29.898	30.299	29.217	29.149
Feb-14	29.226	29.215	30.948	30.761
Mar-14	30.641	30.310	32.328	32.217
Apr-14	28.747	29.331	31.812	32.330
May-14	30.256	30.496		32.580
Jun-14	30.686	30.623	32.512	32.405
Jul-14	30.138	29.840	32.181	32.307
Aug-14	30.489	30.126	31.372	31.224
Sep-14	29.597	30.105	31.851	31.750
Oct-14	29.844	29.973	31.688	31.654
Nov-14	29.988	29.914	32.566	32.798
Dec-14	29.266	29.380	31.795	31.820
Jan-15	30.803	30.638	32.111	32.235
Feb-15	28.659	28.059	32.236	33.212
Mar-15	28.515	29.267	32.483	32.336
Apr-15	28.337	29.372	32.400	32.553

Table 4.2 continued

May-15	29.402	29.114	32.628	32.300
Jun-15	30.114	29.564	32.350	32.848
Average	29.88	30.05	31.76	31.77
Overall Average		**30.86**		
Min	28.34	28.06	29.22	29.15
Max	30.80	30.80	32.97	33.21

	Unit No. 1	Unit No. 2	Unit No. 3	Unit No. 4
Overall averaged reading (%)	29.88	30.05	31.76	31.77
Optimum design thermal efficiency (%)	32.44	32.44	33.75	33.75
Variance	-2.56	-2.39	-1.99	-1.98

* Averaged of optimum design thermal efficiency for all 4 generating units = 33.10%

Comparison with the optimum design thermal efficiency (see Table 4.2) recorded that Unit no.1 and Unit no.2 were operating averagely lowered by 2.56% and 2.39%. On the same note, Unit no.3 and Unit no.4 were operating averagely lowered by 1.99% and 1.98%. The findings from thermal efficiency monitoring recorded the overall average efficiency of 30.86% over the past three years. The plant may consider to set new target by increasing thermal efficiency for all generating units for at least 1% by the year 2018. This is in consideration of the averaged optimum design thermal efficiency of 33.10% and the global's average efficiency of coal-fired generation of 33% HHV (higher heating value) basis (Ecofys, 2014). Department of Energy and National Energy Technology Laboratory (NETL) has put forth a vision for overall improvement of thermal efficiency of the U.S. fleet of coal-fired power plants from 32.5% to 36% by 2020 (NETL, 2010). Similarly, Borsani (2012) reported an improvement of 0.7% of boiler efficiency in Suralaya power

plant, Indonesia. This in return gives a 0.8% reduction in fuel consumption for the power plant equipped with two boilers with 400 MW capacity. In Germany, a coal-fired subcritical plant owned by EnBW experienced efficiency increase of 1% after it was retrofit under efficiency improvement program in 2010 (Stamatelopoulos *et. al.*, 2011).

This can be implemented through a change in the fundamental energy supply structure which may include heating value of the coal raw material, type of broiler system, emission control equipment etc., which if attained may further benefit the plant as every percentage of efficiency improvement could enable the plant to generate the same amount of electricity from consuming less coal fuel and decrease emissions. Eventually, the improvement will lead to sustainable reductions in greenhouse gases and other polluting emissions, saving of fuel materials' cost, and enhancement of the plant's corporate image.

In addition, some efforts for efficiency improvements may include operation management; process and maintenance improvements; refurbishment of key functional equipment; upgrading of the existing facilities; adoption of new technology and positive behavioral change of staff. To address this, creation of a task force of operational efficiency is necessary to review the plant's current efficiency performance and formulate some realistic and workable action plans leading to continual improvement of the plant.

4.1.2.2 Equivalent Availability Factor (EAF)

The trend of EAF is as shown in Figure 4.5. The plant has recorded the average values of 72.56% to 98.70% of EAF from April 2012 to June 2015 (see Table 4.3). Comparing the EAF ranges of 84.42%-93.74% for the North American coal power plants (Richwine, 2006), amoderate performance in term of availability was achieved by the plant. This suggests that all of the steam turbine generator systems were operating in moderate performance credibility, considering the formula for EAF calculation has included both planned and unplanned hours as an unavailable hour, whereby any derating output of the generators was calculated and treated or penalized as unavailable factors. These results are mainly due to the operation control of the plant which was highly depended on external resources, maintenance and supportability performances.

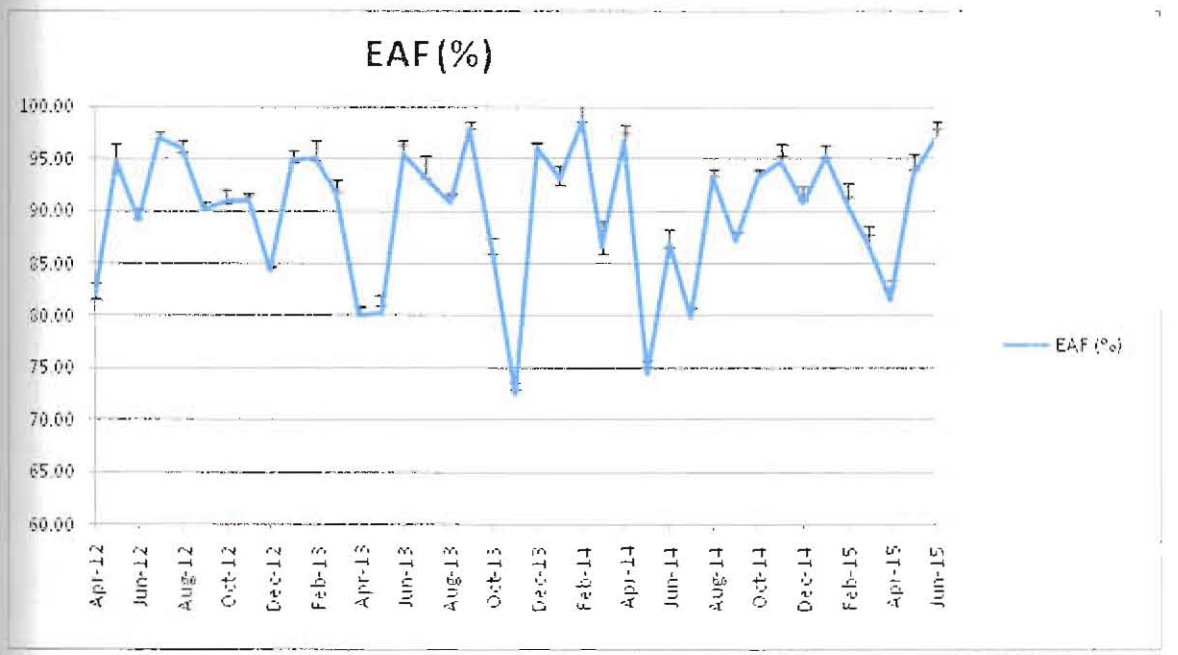


Figure 4.5: Average monthly readings of Equivalent Availability Factor (EAF) (%) (April 2012 to June 2015) at Sejingkat Coal Power Plant.

Table 4.3: EAF data from April 2012 to December 2015.

Month-Year	Equivalent Availability Factor (%) **Monthly average reading**
Apr-12	81.85
May-12	94.65
Jun-12	89.07
Jul-12	97.04
Aug-12	95.99
Sep-12	90.02
Oct-12	90.85
Nov-12	90.89
Dec-12	84.28
Jan-13	94.82
Feb-13	95.06
Mar-13	91.74
Apr-13	80.10
May-13	80.23
Jun-13	95.41
Jul-13	93.15
Aug-13	90.82
Sep-13	97.73
Oct-13	86.17
Nov-13	72.56
Dec-13	96.06
Jan-14	92.96
Feb-14	98.70
Mar-14	86.71
Apr-14	96.59
May-14	74.50
Jun-14	86.72
Jul-14	79.91
Aug-14	93.24
Sep-14	87.17
Oct-14	93.21
Nov-14	94.75
Dec-14	90.71
Jan-15	95.15
Feb-15	90.20
Mar-15	86.75
Apr-15	81.55

Table 4.3 continued

May-15	93.39
Jun-15	97.03
Overall Average	89.94
Min	72.56
Max	98.70

It would appear that there is still a distinct opportunity for the Sejingkat coal power plant to improve, particularly on some relevant factors which include plant design versus actual mode of operations and dispatch viability; stability of electric grid; consistency in fuel supply; availability in parts and maintenance, etc. The plant should analyze the causes of unavailability and determine areas for improvement. The plant could establish a 2-year midterm goal of 85% of EAF, as the minimum availability indicator to be benchmarked. As a step further, the stretch target could be set at 95% for all the generating units by 2020, provided that the midterm goal is achievable by 2018. These targets are deemed realistic and rational considering other case studies of other coal-fired power plants whereby availability of 94-97% is recommended after taken into consideration some of the common factors affecting EAF (Ogieva *et al.*, 2015). All these require management improvement in moving the plant towards more preventive approach by formulating action plans to prevent, manage and mitigate any incident of malfunction to achieve and sustain a higher availability value. In this regard, performance monitoring is important in providing useful information to identify cost effective options for workable action plans. ISO 14001 is able to manage this process as it incorporates key steps to address the issue which include problem identification, analysis of issues, review process, options evaluation, planning and implementation.

4.1.2.3 Equivalent Unplanned Outage Factor (EUOF) and Equivalent Planned Outage Factor (EPOF)

Throughout the operation from April 2012 to June 2015, the generating units of Sejingkat coal power plant has recorded the averaged EUOF of less than 3.0%, with theoverall averaged performance of 0.87% to 2.34% as shown in Table 4.4.

Table 4.4: EUOF and EPOF data of generating units from April 2012 to December 2015.

	Unit No. 1	Unit No. 2	Unit No. 3	Unit No. 4	**Overall Average (%)**
Averaged EUOF reading (%)	1.75	2.34	1.42	0.87	**2.09**
Averaged EPOF reading (%)	6.51	6.34	5.08	6.87	**6.45**

The monthly averaged readings of EUOF, however, recorded higher inconsistency of EUOF ranging from 0% to 6.92% as shown in Figure 4.6. These were mainly due to occurrences of equipment malfunction which result in unit outages or transmission downtime where the units couldn't transmit power. Other causes such as grid connection and substation failure, transmission operating and repair errors and unavailability in the fuel supply were occasionally happened and are outside the control of the plant management.

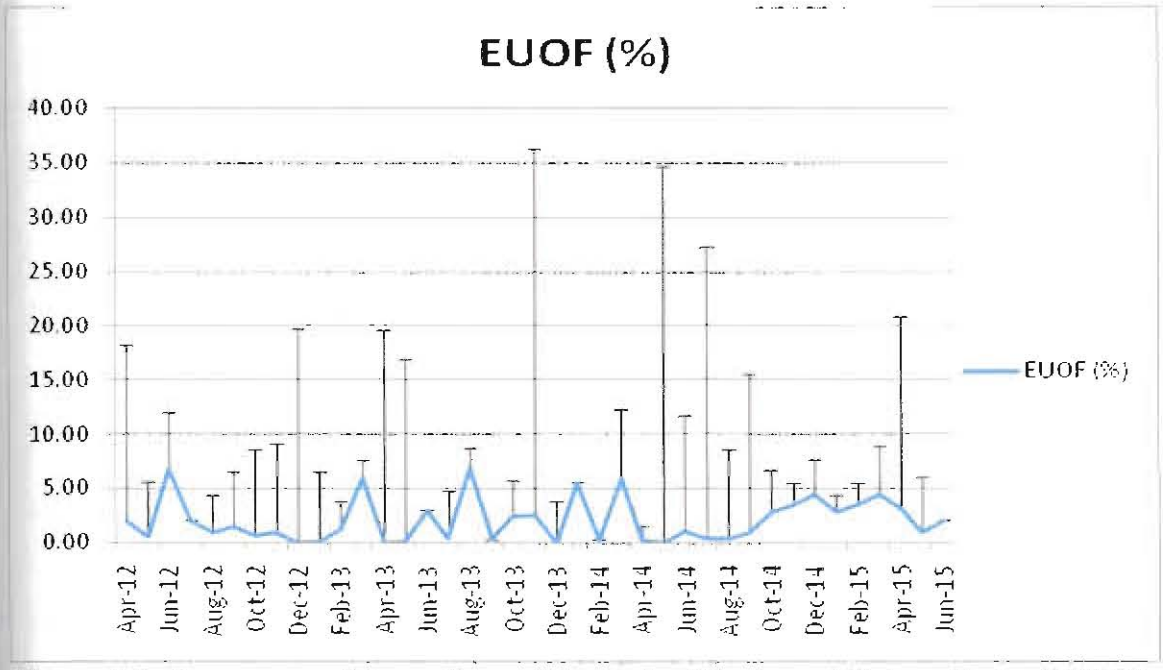


Figure 4.6: Average monthly readings of Equivalent Unplanned Outage Factor (EUOF) (%) (April 2012 to June 2015) at Sejingkat Coal Power Plant.

Table 4.4 shows that the plant has recorded 5.08% to 6.87% (averaged readings) of EPOF from April 2012 to June 2015, for all 4 generating units. The overall averaged reading of 6.2% of EPOF is relatively high compared with study conducted by Ogieva et al. (2015) where reading of 3.69% was reported. Observation on the monthly averaged readings of EUOF reveals that greater disparity recorded on monthly EPOF readings of 0% to 25.00% as shown in Figure 4.7. This was due to the higher frequency of planned outage schedule allocated for maintenance works. This reading could be higher taken into consideration that in some cases where opportunity exists during unplanned outages for the staff to perform some of the repairs or maintenance that would have been performed during the next planned outage.

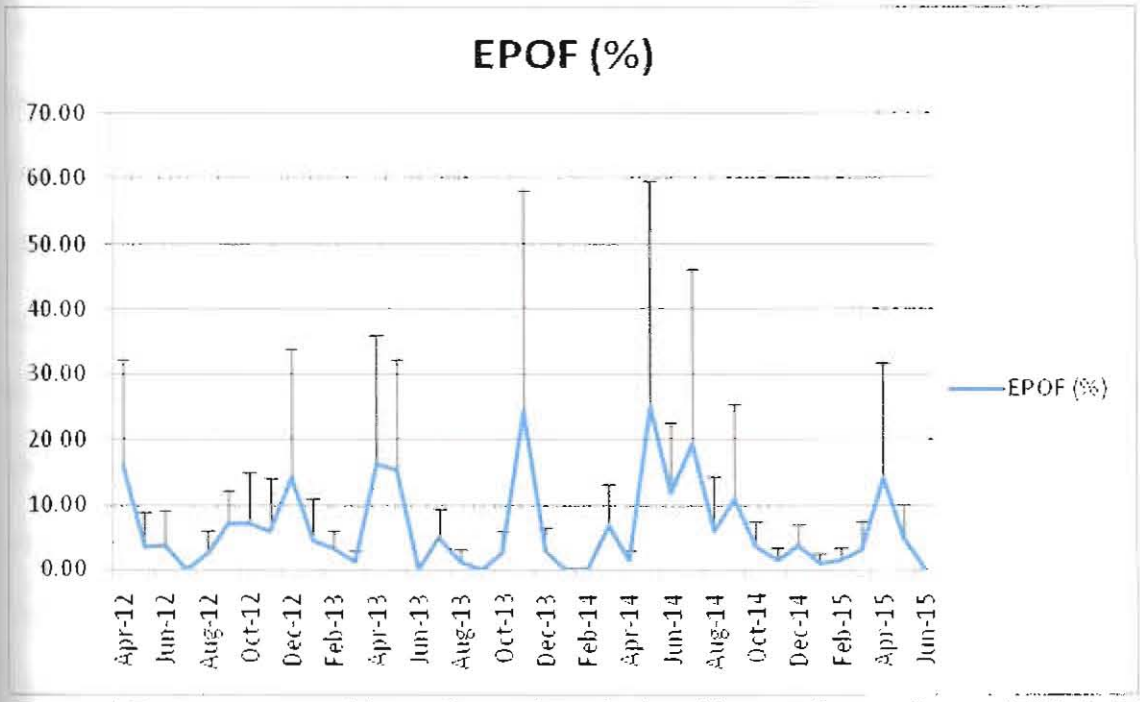


Figure 4.7: Average monthly readings of Equivalent Planned Outage Factor (EPOF) (%) (April 2012 to June 2015) at Sejingkat Coal Power Plant.

Both unplanned outages and planned outages are two recognized sources of energy losses and these outages will need to be tracked and analyzed. Besides, both outages could result in the interruption of service to one or more customers. A small number of interruption events could have amplification effect by affecting a large number of customers and may last for an exceedingly long duration. This unreliability will pose to customer cost of unreliability which is the cost of power outages to the customers. This cost is a combination of the initial cost of an outage and accumulated costs during the outage. The magnitude is significant for those energy intensive customers with hundreds megawatts of energy needs.

As the preventive measure, the plant should provide a projection of its forecasted outage for the coming year and the projection should divide into unplanned and planned outages. In this connection, it is important for the plant to carry out continuous

performance monitoring to obtain statistical information on outage rate, i.e. cause and frequency of outages as well as time between outages. This can serve as baseline information to estimate the probability of outage during certain period of times. Modifications from time to time are needed to improve this probability and over the time, accuracy of the probability can be further enhanced. In this regard, supplemental controls can be instituted particularly during normal outages resulting in a shorter response time and eventually making improvements on outage time. Reducing unplanned outages will improve reliability and safety aspects of the operation which eventually will benefit the plant in the sense of better energy availability and reliability. In addition, reducing planned outages will lead to increasing in number of operating hours, decrease the planned energy losses and increase the energy availability factor. To achieve this, effective implementation of ISO 14001 can serve as an ideal option to provide overall management approach for evaluating risks and disasters arising from the outages.

4.1.3 Recommendations for Performance Improvement

Table 4.5 summarized all performance parameters from the plant throughout this study. Comparatively, the plant has recorded a better environmental performance than operational performance. This could be due to the fact that being a polluting industry, the plant management was putting more focus to ensure compliance with the existing environmental regulations which are legally enforceable. As the government is imposing specific qualitative or quantitative limits on emissions, all of which could have contributed considerably pressure to help the plant to reduce the environmental impacts of its

operations. There are possibilities arise that the effectiveness of ISO14001 is considered in relation to environmental regulations or due to greater regulatory requirements. In addition, the ISO 14001 which is specifically designed for industry sector, has contributed in facilitating the consistency of the plant to comply with the environmental requirements.

Table 4.5: Summary of all environmental and operational performance parameters for Sejingkat Coal Power Plant (April 2012 to December 2015).

Performance Parameters	TSP	PM_{10}	SO_x	Thermal Efficiency	EAF	EUOF	EPOF
Overall averaged reading	50.38µg/m^3	32.15 µg/m^3	<0.00001 g/Nm^3	30.86%	89.94%	2.09%	6.45%
	January 2013 – December 2015			April 2012 – June 2015			

Monitoring results on operational data showed that ISO 14001 was implemented in isolation from efforts for continual improvement on the plant's operational performance. As compared with environmental performance, the plant management should put equal priority towards the operational performance as it can serve better representative for a successful implementation of ISO 14001. Lack of awareness and knowledge of ISO 14001 could be one of the most notable barriers that hamper this initiative. Eventually, the operational staffs are keen to retaining their existing operating model without significant voluntary efforts to strive for operational improvement. In general, their office hours are solely occupied with the daily routines and this day-to-day working behavior has been becoming the norm and priority for them to sustain their businesses operation. The gravity of the

Besides, governmental efforts are deemed important to promote the true spirit and concept of ISO 14001 EMS. There are wide varieties of government-supported policies and programs that can be considered. For instance, in Canada, the Canadian General Standards Board is the core authority in helping organizations on ISO 14001 certification and its related information (CGSB, 2015). The Canadian General Standards Board offers comprehensive standards development as well as product and service certification in support of the regulatory, economic, health, safety and environmental interests of various stakeholders. On the other hand, effective implementation of ISO 14001 EMS by energy industry can benefit government in a variety of ways. For instances, ISO 14001 EMS can complement the effectiveness of existing government policies and regulations by revealing to companies the true environmental requirements that those policies and regulations impose. Furthermore, operational-related EMS data from the industry could be useful to government for policy design and decision-making. Should the industry players are able to recognize the cost benefits of resource conservation and operation efficiency, this will lower the financial, political and other burdens of environmental protection and enforcement works shouldered by the government.

4.2 Development of Water Quality Modeling for Sg. Besai and Btg. Kemena Discharge

4.2.1 Baseline Water Quality for Water Quality Modeling

Results of the baseline water quality modeling for 12 water sampling stations are as shown in Table 4.6.

Table 4.6: Baseline water quality modeling results of 12 water sampling stations.

Parameter (s)	WQM1	WQM2	WQM3	WQM4	WQM5	WQM6	WQM7	WQM8	WQM9	WQM10	WQM11	WQM12
Chromium, Hexavalent (as Cr^{6+}), mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Chromium, Trivalent (as Cr^{3+}), mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Iron (as Fe), mg/L	2.51	1.34	3.35	3.72	3.49	3.75	2.24	2.33	2.16	1.5	1.56	2.02
Manganese (as Mn), mg/L	0.51	0.32	0.23	0.14	0.1	0.09	0.06	0.07	0.07	0.14	0.13	0.06
Mercury (as Hg), mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	< 0.001	< 0.001	< 0.001
Silver (as Ag), mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Tin (as Sn), mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Arsenic (as As), mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	< 0.006	< 0.006	< 0.006
Aluminium (as Al), mg/L	0.93	0.55	1.14	1.74	3.45	3.26	1.12	1.47	1.33	0.66	0.89	0.99
Barium (as Ba), mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Selenium (as Se), mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	< 0.002	< 0.002	< 0.002
Phenols, mg/L	<0.001	0.002	0.003	0.002	<0.001	<0.001	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01
Boron (as B), mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	< 0.1	< 0.1	0.3	0.1	< 0.1	0.2
Cyanide (as CN), mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sulphide (as S^{2-}), mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Formaldehyde, mg/L	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
WATER QUALITY INDEX (WQI)												
DOSI	66	65	61	76	30	41	82	71	70	82	82	74
BOD SI	96	96	96	96	96	96	96	96	96	96	96	96
COD SI	83	82	82	76	70	71	82	86	80	80	86	84
AN SI	49	55	59	60	63	63	91	95	95	92	90	95
SS SI	86	85	85	83	78	78	80	82	79	83	82	80
pH SI	60	60	84	41	81	84	68	80	84	67	88	84
WQI	74	75	77	75	68	71	86	85	84	85	87	82
Parameter (s)	**WQM1**	**WQM2**	**WQM3**	**WQM4**	**WQM5**	**WQM6**	**WQM7**	**WQM8**	**WQM9**	**WQM10**	**WQM11**	**WQM12**
CLASS	III	III	III	III	III	III	II	II	II	II	II	II
WQ STATUS	Slightly Polluted	Slightly Polluted	Slightly Polluted	Slightly Polluted	Slightly Polluted	Slightly Polluted	C	C	C	C	C	C

Table 4.6 shows that the water quality conditions in Sg. Besai were in good quality for majority of individual parameters, between Class II and III of the National Water

Quality Standards (NWQS), though the water quality index (WQI) registered a Class III denotation at most stations. The organics (BOD_5) were very low, less than 1 mg/L. This was unsurprising, as the locations were quite remote, with little to no pollution input. Correspondingly, the COD and heavy metal levels were also low, within the Class I and II denotation between stations WQM1 and WQM6. Surprisingly, the DO readings were not in tandem with this. The DO at WQM1 was at 4.7 mg/L whereas at WQM2, WQM3 WQM4, WQM5 and WQM6 the levels were at 4.6, 4.5, 4.9, 2.9 and 3.5 mg/L, respectively. These were within the Class III denotation and can be regarded as low to moderate. Contributing factors could be poor reaeration that inhibits atmospheric oxygen transfer. The modeling results however, generally disagreed with the in-situ DO reading and predicted higher levels. This suggested there could be some deviation due to other factors (calibration error, etc.). Another interesting observation was the fact that the baseline NH_3-N was within the Class III/IV range at all stations. In fact, the level at WQM1 was at 0.96 mg/L (Class IV), whereas on Sg. Besai, the level at WQM3 was at 0.63 mg/L (upstream) before decreasing to 0.49 mg/L downstream. The NH_3-N could have originated from fertilizer application (eg. ammonium nitrate and ammonium phosphate) from the surrounding palm oil plantations. The increased NO_3-N levels further supported this hypothesis, as the levels were between 0.64 – 0.81 mg/L in Sg. Besai. These levels were still acceptable for consumption as the nitrate threshold for drinking water is 10 mg/L. Suspended solids were less than 50 mg/L (Class II), though an increasing trend was observed moving downstream from WQM3 to WQM4 (from 22 mg/L to 37.5 mg/L downstream). This indicated most probably attributed to soil erosion/runoff and is inline with the NH_3-N and NO_3-N transport hypothesis. Appearance wise, the effects were observable, as Sg. Besai was rather murky. The turbidity readings reflected this, as the

values increased from 45 to 80 NTU from WQM3 to WQM6. Besides NH_3-N and turbidity, the water quality conditions were still acceptable for domestic application. Therefore, the baseline water quality status must be preserved.

The water quality conditions in Btg. Kemena were also recorded as good, falling between Class I and II of the NWQS (majority of individual parameters). The WQI registered a Class II denotation at all stations. The organics (BOD_5) levels were very low, less than 1 mg/L at all stations in both Sg. Sesalak and Btg. Kemena. Correspondingly, the COD and heavy metal levels were also low, within the Class I and II denotation between stations WQM7 and WQM12. Interestingly, the DO readings were on the lower side and can be regarded being as low to moderate. Again, this could have been due to poor re-aeration, which inhibits atmospheric oxygen transfer. Nitrate (NO_3-N) levels were slightly elevated, above 1 mg/L at all stations. The NO_3-N could have originated from fertilizer application (i.e. ammonium nitrate) from the surrounding palm oil plantations. NH_3-N however, was low, less than 0.1 mg/L at most locations. Despite suspended solids being less than 50 mg/L (Class II); turbidity was in excess of 50 NTUs. This hinted the presence of finer particles (eg. silt) in the water. Most of the metal analysis yielded results below the detection limit except for ferum, manganese and alumimium. Elevated ferum and manganese are "common" in Malaysian waters however, the elevated aluminium between 0.86 – 1.47 mg/L was rather anomalous.

4.2.2 Water Quality Modeling Results for Sg. Besai

A computer modelled water quality modeling has been developed to simulate the discharge of leachate from the Maskat Landfill into Sg. Besai (Figure 4.8) and to assess the carrying capacity of Sg. Besai in response to the leachate discharge.

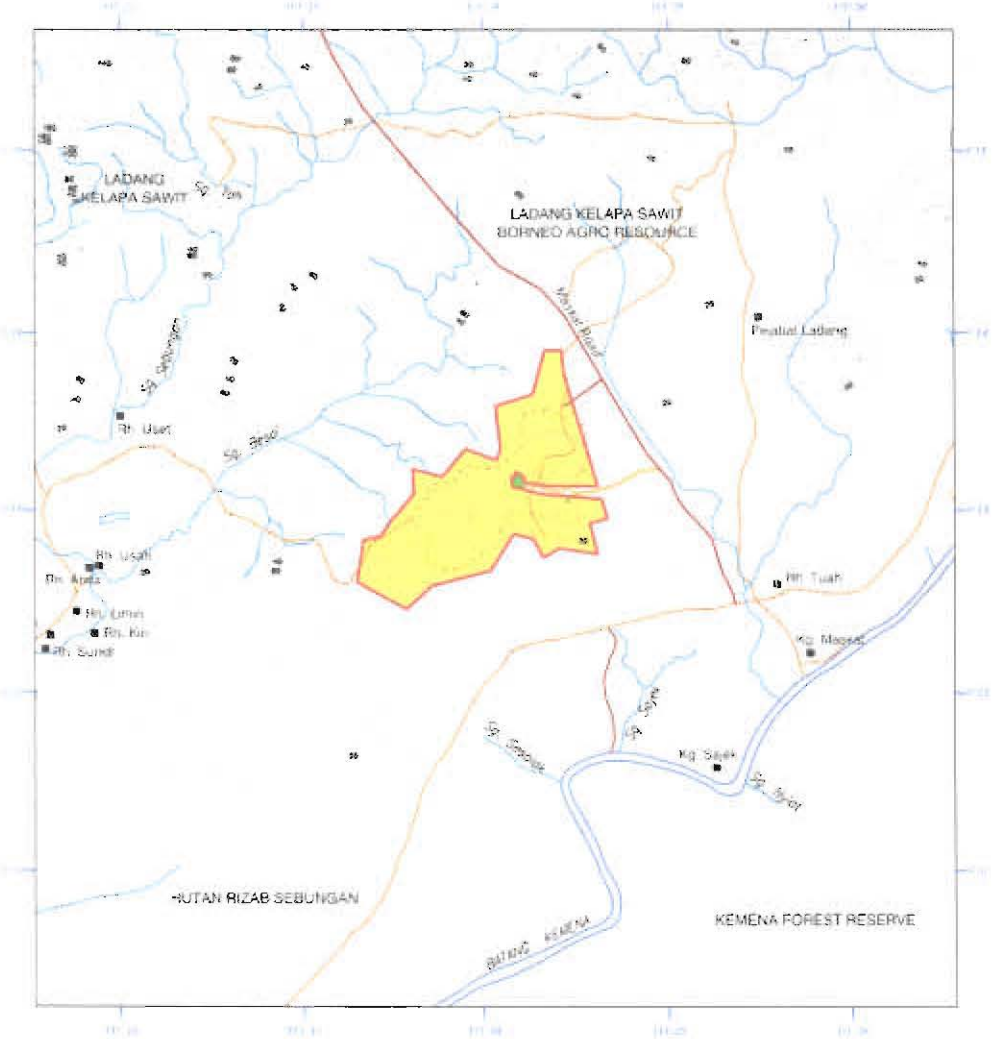


Figure 4.8: Locality of Sg. Besai and its surrounding land use.

The BOD_5 spatial modeling results (see Figure 4.9 illustrated that compliance to the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 for the constituent at 20 mg/L, would not significantly deteriorate the water quality of Sg. Besai during normal operations either under normal or

low flow conditions (Scenarios 1 and 2). Although some increment was observed, the difference was relatively marginal (< 1 mg/L) and was still within the Class II denotation. Not much oxygen would be exerted, provided the prescribed effluent flow rate of no more than 0.0075 m^3/s or 650 m^3/day is strictly adhered to. In fact, BOD_5 would recover to almost ambient levels near Rh. Usah.

Nonetheless, this is not the main issue. From a water quality standpoint, the Landfill presents a clear and present risk to all of the longhouses located downstream of the Landfill site. Any leakages or sudden release of untreated leachate (i.e. purging) would almost certainly result in serious contamination. This condition is depicted in Figure 4.10. As seen in Scenario 3, severe contamination of BOD_5 would occur if raw leachate were to enter the stream. The previous Class II denotation would immediately degrade to Class IV/V (about 12 mg/L, upstream). Under these circumstances, the Class IV denotation remained steady (at about 6 mg/L) even near Rh. Usah, despite tributary confluences and incremental inflows. This illustrated the sensitivity of Sg. Besai and the small margin-for-error. Only after this location did the values further decreased to Class III.

The shock-loading scenario (Scenario 4) of course, predicted even further degradation, as BOD_5 levels would go beyond 100 mg/L (upstream). Even after 12 kilometers from the point of discharge, the levels would only improve to between 11-12 mg/L (Class V). The heightened organic contribution would also cause severe oxygen depletion (to anaerobic conditions) in Sg. Besai, as seen in Figure 4.11. In view of this, it is imperative that no leachate (either treated or untreated) is allowed to enter Sg. Besai.

As discussed above, under normal operating conditions (Scenarios 1 and 2), there would not be much oxygen demand due to the marginal organic load. This was further strengthened by the modeling results, as the DO hovered between 5.5 and 7.5 mg/L, which were comparable to the baseline. Though again, this is very much dependent on the volumetric release rate of the effluent. For Scenario 3, the DO levels would dip to less than 2 mg/L in view of the increased organic load; before recovering to about 6 mg/L downstream. The condition worsened for Scenario 4, as the Sg. Besai would essentially be rendered anaerobic.

Mirroring the BOD_5 and DO trend is TSS; little disturbance of the baseline values would be expected due to the effluent input. In fact, in both normal operation scenarios (Scenarios 1 and 2), the Class II denotation was maintained. Only in the event of treatment system failure and shock loading (Scenarios 3 and 4), at approximately 1,000 mg/L TSS contribution, would the ambient levels deteriorate to close to 50 mg/L and 250 mg/L as shown in Figure 4.12.

NH_3-N concentration in leachate from landfills in Malaysia is known to be high due to the high organic content of municipal solid wastes (Zainudin & Mohamed, 2007). The baseline NH_3-N level in Sg. Besai however, was already quite elevated at the Class III (0.3 – 0.9 mg/L). This was probably due to fertilizer application in the surrounding oil palm plantations that utilizes either ammonium nitrate or ammonium phosphate based fertilizers. Despite this, under normal operating conditions (Scenarios 1 and 2) some increment of NH_3-N levels is to be anticipated (about 0.2 mg/L), even at compliance to 5 mg/L (see Figure 4.13). For the most part however, the Class III denotation would be maintained. In

the treatment failure scenario (Scenario 3, Figure 4.14), the ambient NH_3-N levels on the upstream reaches of Sg. Besai would be in excess of 30 mg/L, whereas near Rh. Usah, the constituent would be at about 18 mg/L. Of course, the condition was even worst for Scenario 4. In either scenario, most of the aquatic species in the water column would be wiped out. Elevated NH_3-N would also jeopardize the domestic use of the water. They must be quick to respond and mitigate any arising problems. To facilitate this, the installation of a continuous (automatic) water quality monitoring station at the outlet discharge pipe is strongly recommended. It would also be prudent for the Landfill's management to establish open communication with the residents (eg. Tuai Rumah) in the event of emergency.

Referring to Figure 4.15, the modeling results indicated that NO_3-N contribution from the effluent would increase the current levels in Sg. Besai from less than 1.0 mg/L to about 1.2 mg/L in Scenario 1 and 1.4 mg/L in Scenario 2 (upstream quadrant). Although the increment is forthcoming, from the perspective of aquatic preservation, such values should not significantly affect the ecosystem (Sawyer *et al.*, 2003) or for potable water supply. Even for Scenarios 3 and 4, the modeling results predicted that the constituent level would not go beyond 10 mg/L, which is the suitable threshold for potable use (Sawyer *et al.*, 2003). This of course is provided that the effluent NO_3-N is not in excess of 25 mg/L.

Referring to Figure 4.16 to Figure 4.17, generally, the heavy metal modeling results showed little disturbance of the ambient levels under normal operating conditions as long as the regulatory limits were adhered to. It should be noted that all metal constituents that

came under scrutiny for the modeling (lead, arsenic, cadmium, mercury and nickel) registered values below the analytical detection limit and this threshold was used in the baseline model. Firstly, for lead (see Figure 4.16 and Figure 4.17), an increment from 10 μg/L to a maximum of about 11 μg/L and 12 μg/L for Scenarios 1 and 2 is to be anticipated. This occurred in the upstream reaches before subsequent recovery downstream. In the event of a treatment system failure (Scenario 3) the river would be severely impacted; as the lead levels would be hovering close to 100 μg/L upstream (just after the discharge) before decreasing to about 50 μg/L near Rh. Usah. The consumption of such lead laden water would incur adverse health effects. Arsenic and cadmium (see Figure 4.18 and Figure 4.19) did not depict any discernable difference even in the event of a treatment system failure (Scenario 3). For these scenarios, the former only showed a maximum increase of up to 7 μg/L compared to the baseline of 6 μg/L, whereas for the latter, the maximum increment was only from 2.0 μg/L to 2.3 μg/L. For the normal operation scenarios, the increments were of course lower than these. The same was also true for mercury (see Figure 4.20), where a maximum increment of up to 1.2 μg/L compared to the previous 1.0 μg/L was observed for Scenario 3. For nickel, the increment was from 20 μg/L up to 24 μg/L (Scenarios 1 to 3) as shown by Figure 4.21. Only in the shock-loading scenario (Scenario 4) would severe contamination be apparent for all heavy metal species. Under such circumstances, the in-stream lead concentration would at certain locations be in excess of 700 μg/L, arsenic > 15 μg/L and nickel > 50 μg/L. Cadmium and mercury in Scenario 4 would be close to 4 μg/L and 3 μg/L respectively.

4.2.3 Water Quality Modeling Results For Sg. Sesalak / Btg. Kemena

A computer water quality modeling has also been developed to simulate the discharge of leachate from the Landfill into Sg. Sesalak which will eventually flows to Btg. Kemena.

The BOD_5 spatial modeling results (see Figure 4.22) illustrated compliance to the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 for the constituent at 20 mg/L, would not significantly deteriorate the water quality of Btg. Kemena ($\approx$ 1 mg/L) during normal operations either under normal or low flow conditions (Scenarios 1 and 2). Some impact however, should be anticipated in Sg. Sesalak. In either case, not much oxygen would be exerted, provided the prescribed effluent discharge flowrate of no more than 0.0075 m^3/s or 650 m^3/day is strictly adhered to. Leakages or sudden release of untreated leachate (eg. purging) would certainly result in serious contamination of Sg. Sesalak as levels deteriorated to 20 mg/L for Scenario 3 and exceeded 100 mg/L for Scenario 4 (see Figure 4.23). In Btg. Kemena, impact was marginal for Scenario 3 (to about 1.5 mg/L); however for Scenario 4, the previous Class I denotation would immediately degrade to Class IV (about 7 mg/L, upstream). Even after 11 kilometers from the point of discharge, the levels would only improve to about 4 mg/L (Class III). The heightened organic contribution would also cause severe oxygen depletion (to anaerobic conditions) in Btg. Kemena. As discussed above, under normal operating conditions (Scenarios 1 and 2), not much oxygen demand would be exerted due to the minimal organic load.

The modeling results showed under such circumstances, the DO levels in both Sg. Sesalak and Btg. Kemena would hover around 5.0 – 5.2 mg/L. This was comparable to the baseline. For Scenario 3, the DO levels would dip to 1.6 mg/L in Sg. Sesalak but recovered to 4.0 mg/L upon confluence with Btg. Kemena, and subsided to about 3.0 mg/L as shown in Figure 4.24. The condition worsened for Scenario 4, as both Sg. Sesalak and Btg. Kemena would essentially be rendered anaerobic.

The TSS modeling results showed preservation of the Class II status in the normal operation scenarios. For Scenario 3, the ambient levels in Sg. Sesalak would deteriorate to beyond 50 mg/L, whereas the levels on Btg. Kemena remained fairly unperturbed. In the event of shock loading (Scenario 4), the ambient levels in Sg. Sesalak would deteriorate to 100 mg/L before decreasing to 40 mg/L post-confluence with Btg. Kemena (see Figure 4.25).

The baseline NH_3-N level in Sg. Sesalak and Btg. Kemena were low, < 0.1 mg/L at all sations. Under normal operating conditions (Scenarios 1 and 2) increment of NH_3-N levels is to be anticipated in Sg. Sesalak to about 0.1 mg/L (Class II). Only very marginal increment was predicted in Btg. Kemena. In the treatment failure scenario (Scenario 3), the ambient NH_3-N levels on the upstream reaches of Sg. Sesalak would be in excess of 25 mg/L. The levels reduced to about 1.0 mg/L immediately after the confluence with Btg. Kemena (see Figure 4.26). For this scenario, the levels before the intake were at about 0.4 mg/L (Class III). Of course, the condition was even worst for Scenario 4 as levels before the intake were beyond 4.0 mg/L. Either way, if the prevailing circumstances for Scenarios

3 and 4 were to transpire, most of the aquatic species in the Sg. Sesalak (and Btg. Kemena) would be wiped out. Elevated NH_3-N would also jeopardize the potability of the water.

Referring to Figure 4.27, the model predicted that NO_3-N contribution from the effluent resulted in increment of the baseline levels in Sg. Sesalak, from 1.3 mg/L, to about 1.5 mg/L in Scenario 1 and 1.7 mg/L in Scenario 2. Although the increment is forthcoming, from the perspective of aquatic preservation, such values should not significantly affect the ecosystem (Sawyer *et al.*, 2003). Only marginal impact was predicted on Btg. Kemena. The model also predicted the constituent concentration would not go beyond 10 mg/L (the suitable threshold for potable use) in Btg. Kemena in Scenarios 3 and 4, even after inculcating nitrification effects (Sawyer *et al.*, 2003). This is provided that the effluent NO_3-N is not in excess of 25 mg/L.

Referring to Figure 4.28 till Figure 4.32, the modeling results showed little disturbance of the ambient heavy metal levels under normal operating conditions as long as the discharge were within the regulatory limits. All metal constituents that came under scrutiny for the modeling (lead, arsenic, cadmium, mercury and nickel) registered values below the analytical detection limit and this threshold was used to develop the baseline model. It is therefore imperative these low levels be preserved. For lead (see Figure 4.28), an increment from 10 µg/L to a maximum of about 11 µg/L and 12 µg/L for Scenarios 1 and 2 is to be anticipated in Sg. Sesalak. This occurred in the upstream reaches before recovery to baseline levels upon confluence with Btg. Kemena. In the event of a treatment system failure (Scenario 3), Sg. Sesalak would be severely impacted; as the lead levels would be hovering close to 80 µg/L upstream (just after the discharge), before decreasing

to about 13 μg/L after confluence with Btg. Kemena. Arsenic and cadmium (see Figure 4.29 and Figure 4.30) depicted marginal increment in Sg. Sesalak even in the event of a treatment system failure (Scenario 3). For this scenario, the former only showed a maximum increase of up to 7 μg/L compared to the baseline of 6 μg/L, whereas for cadmium, the maximum increment was only from 2.0 μg/L to 2.2 μg/L. The normal operation scenarios of course depicted even lower arsenic and cadmium values. The same was also true for mercury (see Figure 4.31), as a maximum increment of up to 1.2 μg/L compared to the previous 1.0 μg/L was observed in Scenario 3. In terms of nickel, the increment was from 20 μg/L up to 24 μg/L (Scenarios 1 to 3).

This trend is mainly due to metals are conservative species that do not undergo transformation in the water column, unlike other organic constituents. Removal is primarily attributed to settling and as a consequence of this, there may be accumulation of the constituents in the bottom sediment as time passes; resuspension may also occur if the sediment is disturbed. Besides this, there have also been recorded cases of "flushing" where metals constituents in the sediment is resuspended by sudden increase in river momentum, such as during a precipitation event, which of course may lead to higher constituent levels in the downstream reaches before settling down again.

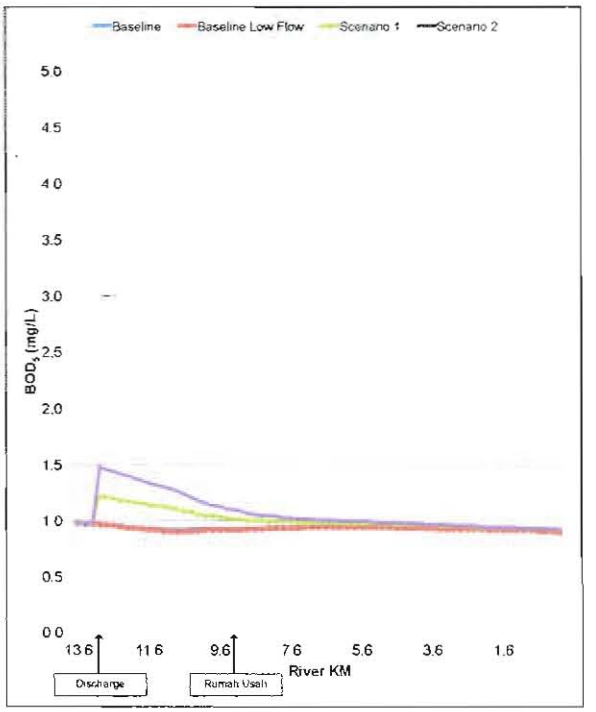


Figure 4.9: Sg. Besai BOD_5 Spatial Prediction (Low Range).

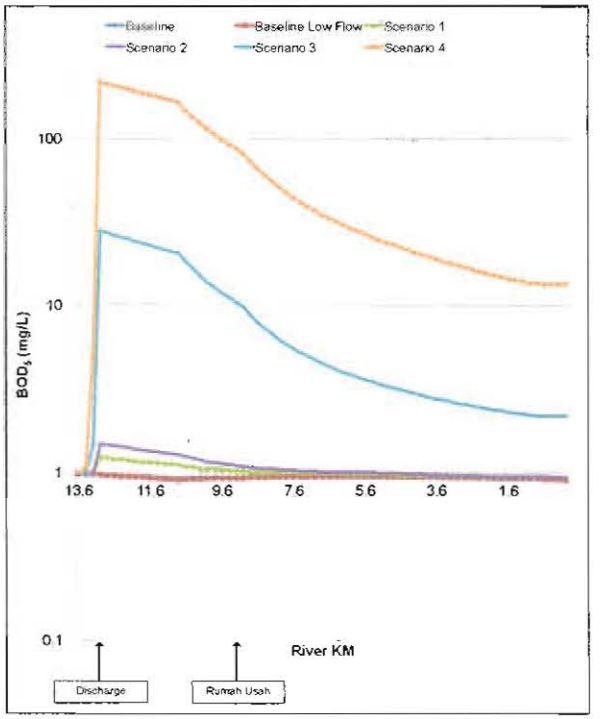


Figure 4.10: Sg. Besai BOD_5 Spatial Prediction (High Range).

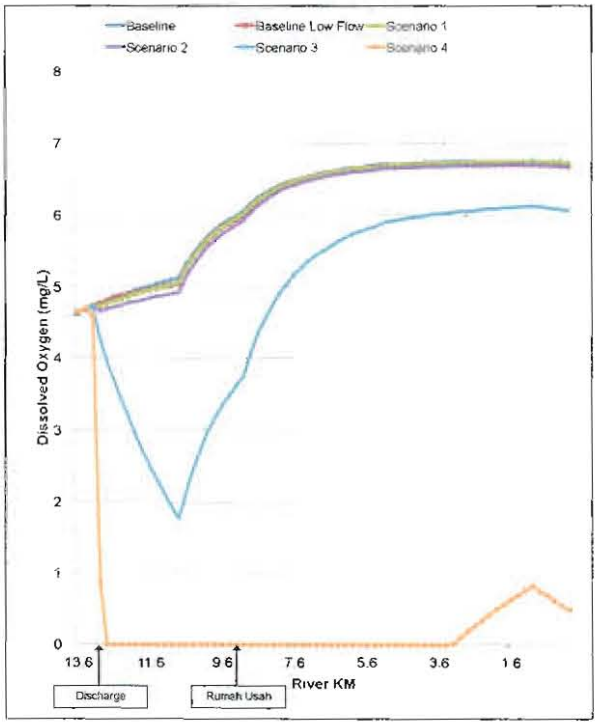


Figure 4.11: Sg. Besai DO Spatial Prediction.

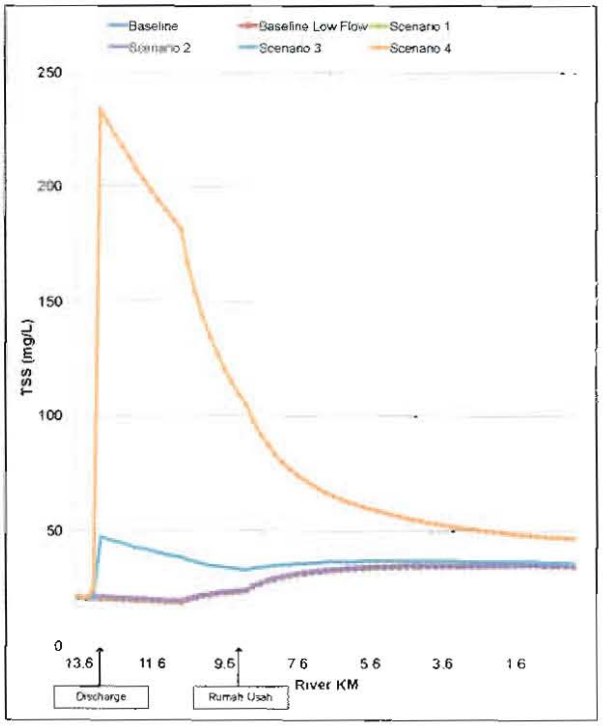


Figure 4.12: Sg. Besai TSS Spatial Prediction.

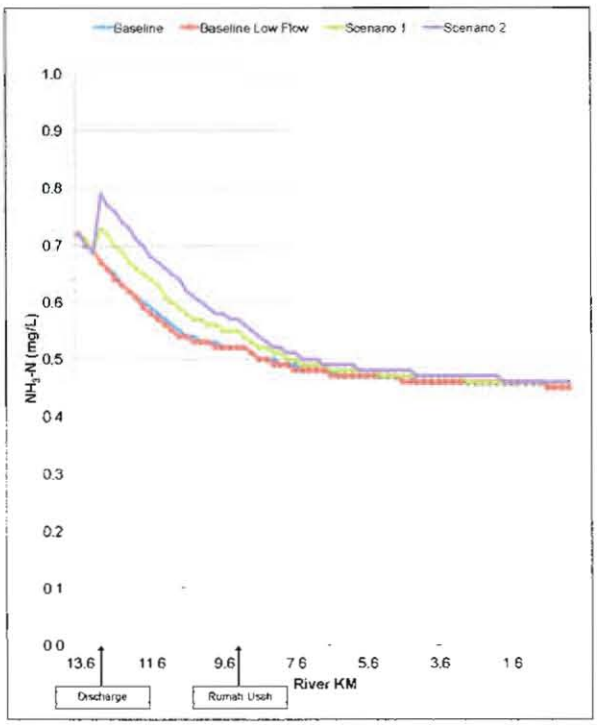


Figure 4.13: Sg. Besai NH_3-N Spatial Prediction (Low Range).

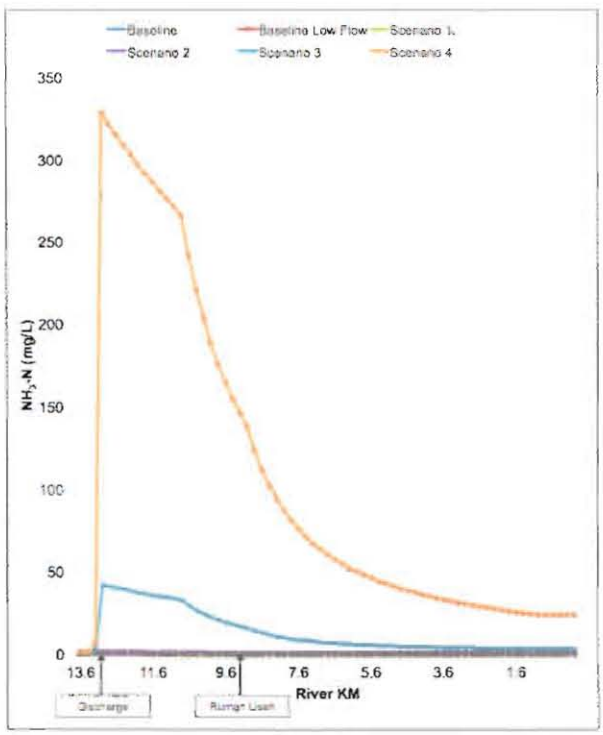


Figure 4.14: Sg. Besai NH_3-N Spatial Prediction (High Range).

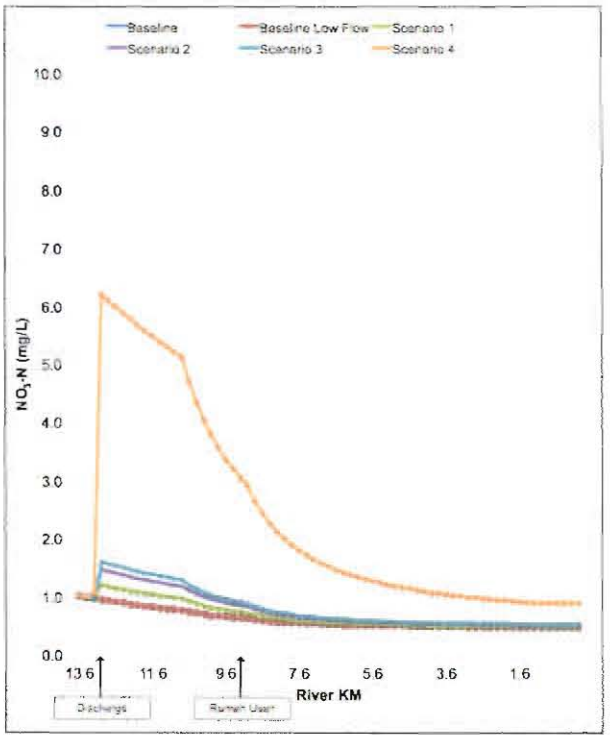


Figure 4.15: Sg. Besai NO_3-N Spatial Prediction.

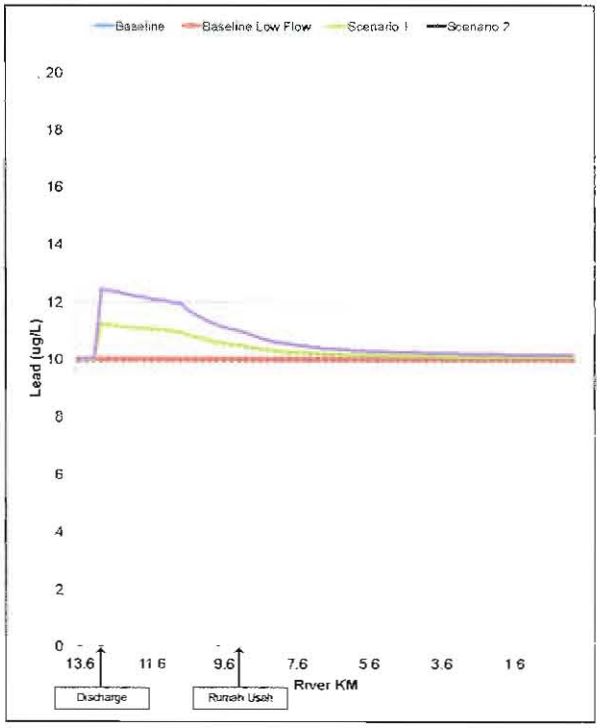


Figure 4.16: Sg. Besai Pb Spatial Prediction (Low Range).

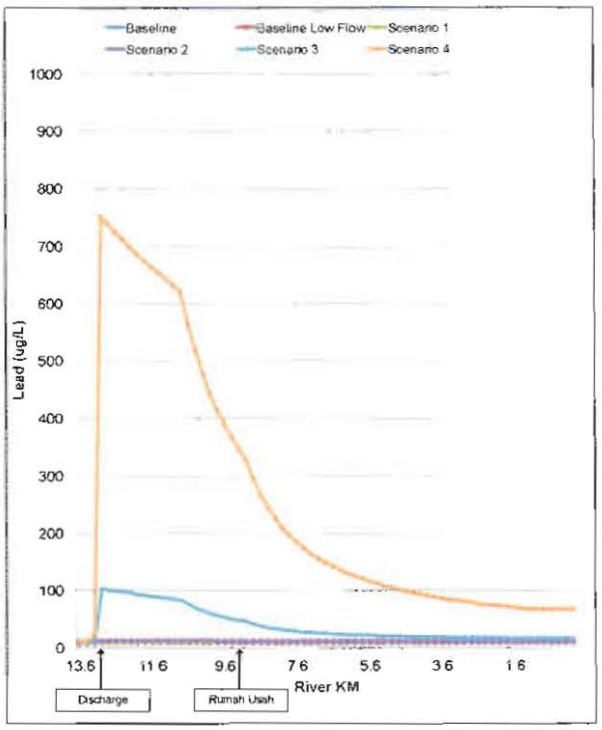


Figure 4.17: Sg. Besai Pb Spatial Prediction (High Range).

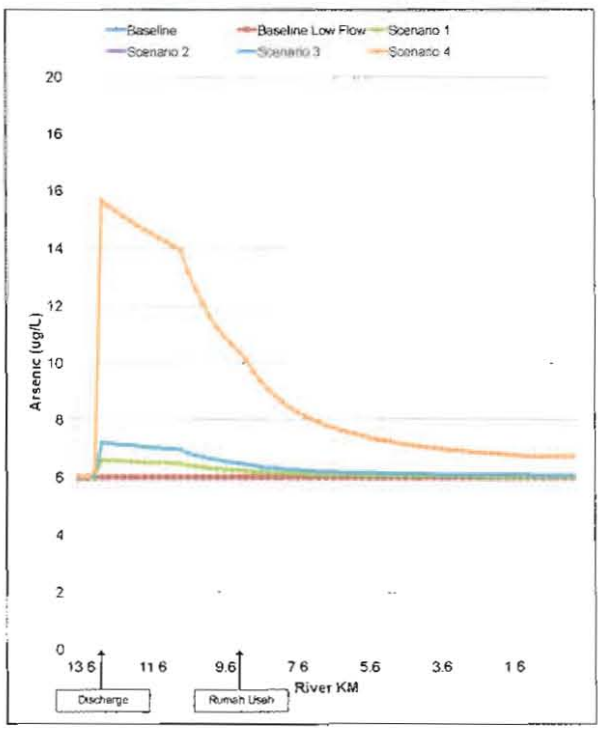


Figure 4.18: Sg. Besai As Spatial Prediction.

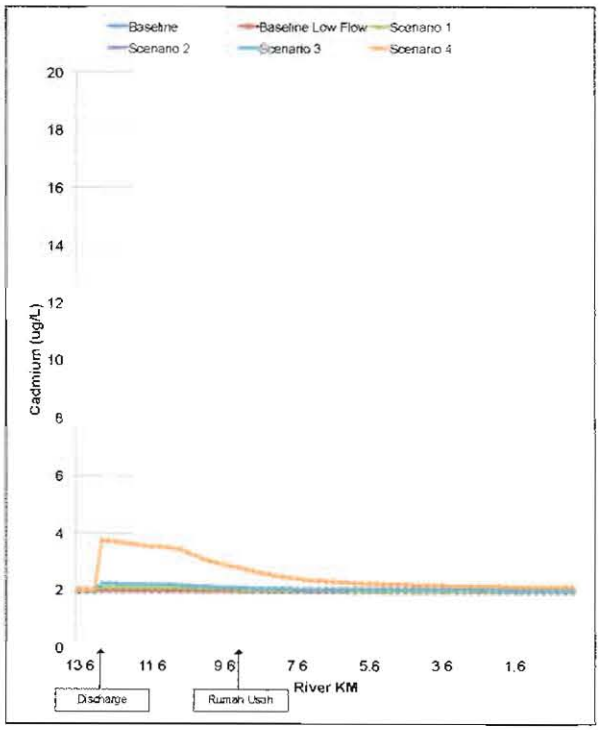


Figure 4.19: Sg. Besai Cd Spatial Prediction.

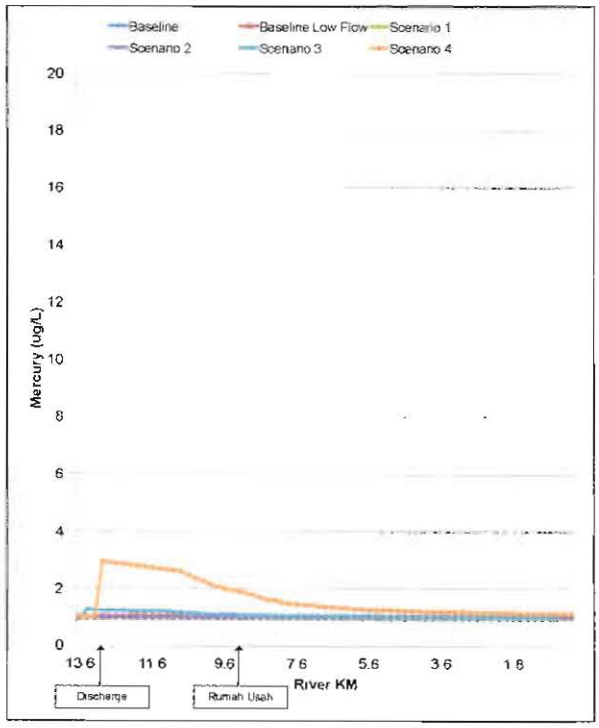


Figure 4.20: Sg. Besai Hg Spatial Prediction.

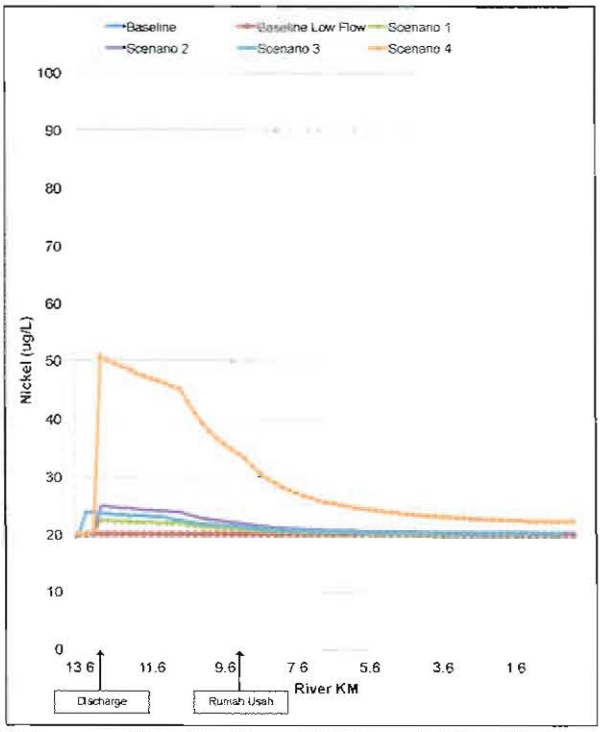


Figure 4.21: Sg. Besai Ni Spatial Prediction.

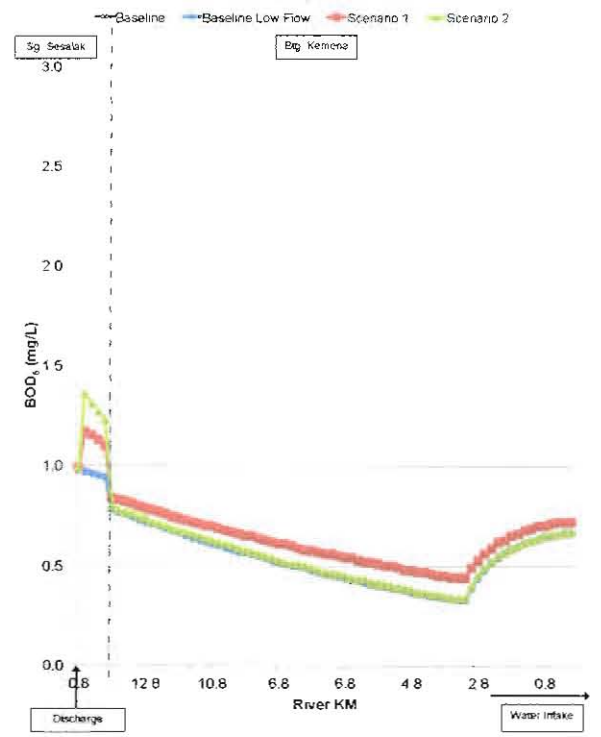


Figure 4.22: Batang Kemena and Sg. Sesalak BOD_5 Spatial Prediction (Low Range).

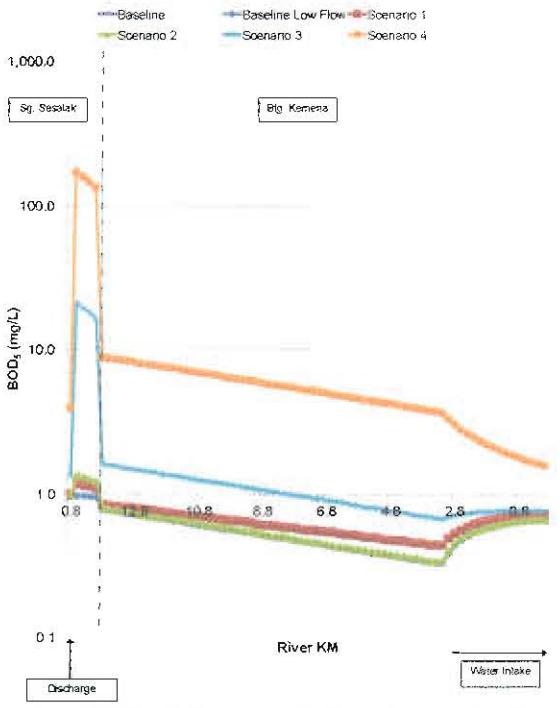


Figure 4.23: Batang Kemena and Sg. Sesalak BOD_5 Spatial Prediction (High Range).

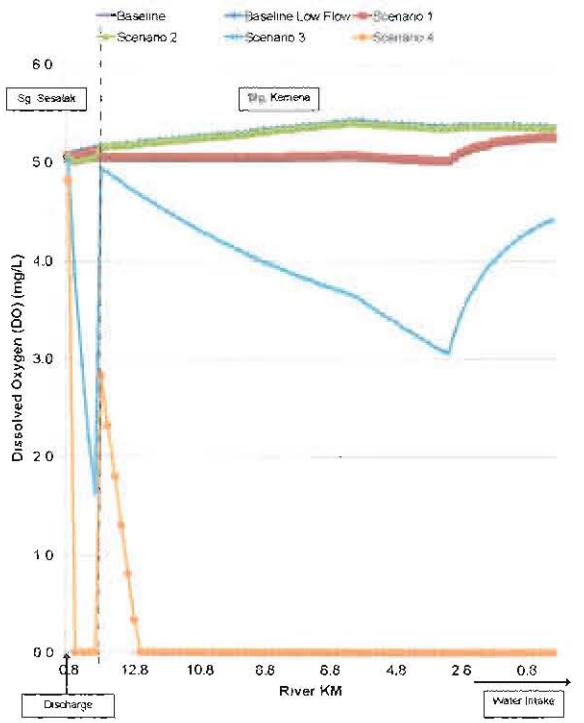


Figure 4.24: Batang Kemena and Sg. Sesalak DO Spatial Prediction.

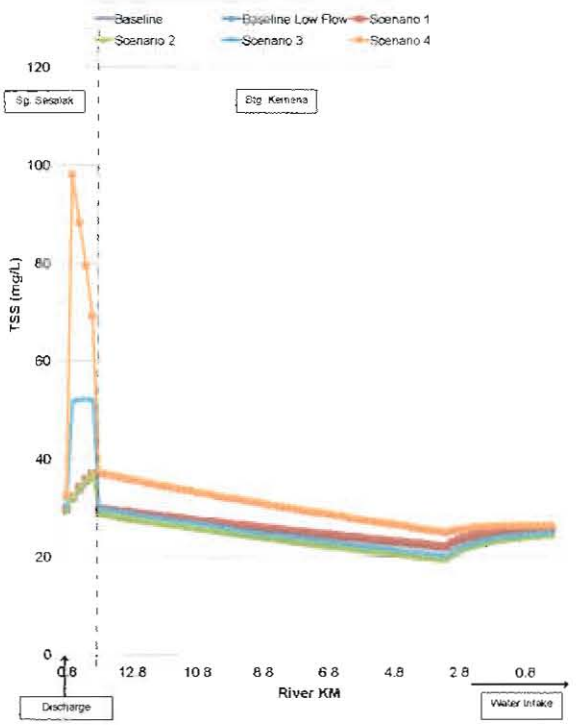


Figure 4.25: Batang Kemena and Sg. Sesalak TSS Spatial Prediction.

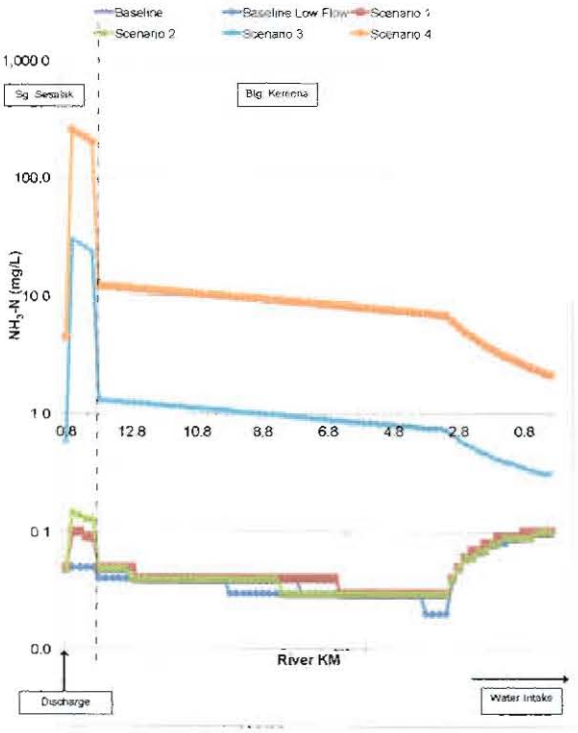


Figure 4.26: Batang Kemena and Sg. Sesalak NH_3-N Spatial Prediction.

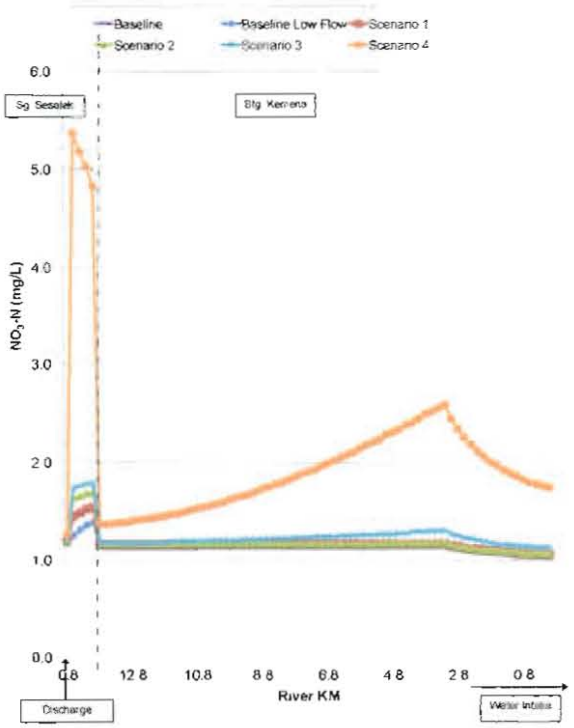


Figure 4.27: Batang Kemena and Sg. Sesalak NO_3-N Spatial Prediction.

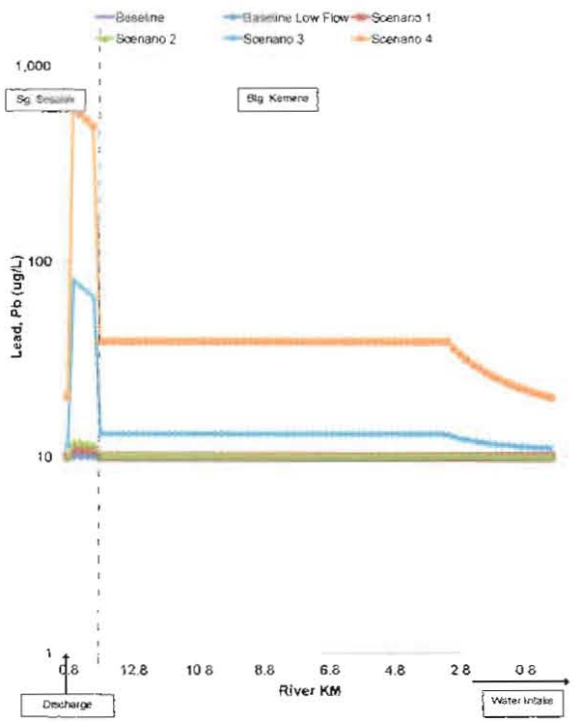


Figure 4.28: Batang Kemena and Sg. Sesalak Pb Spatial Prediction.

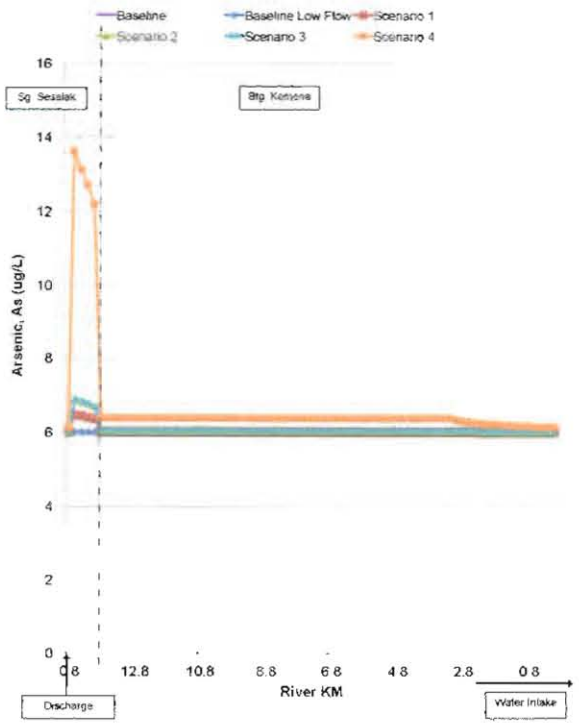


Figure 4.29: Batang Kemena and Sg. Sesalak As Spatial Prediction.

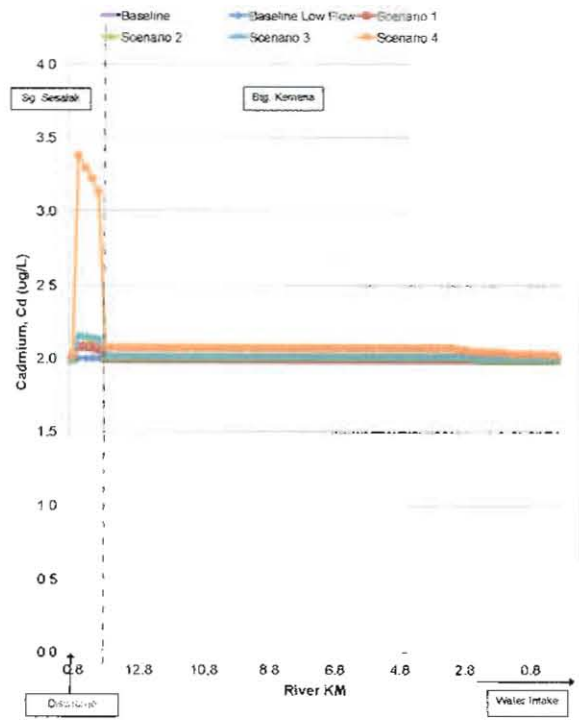


Figure 4.30: Batang Kemena and Sg. Sesalak Cd Spatial Prediction.

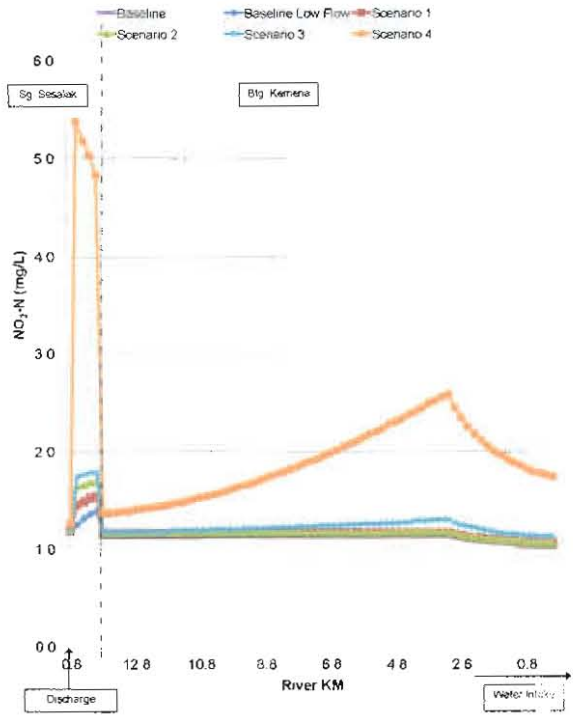


Figure 4.31: Batang Kemena and Sg. Sesalak Hg Spatial Prediction.

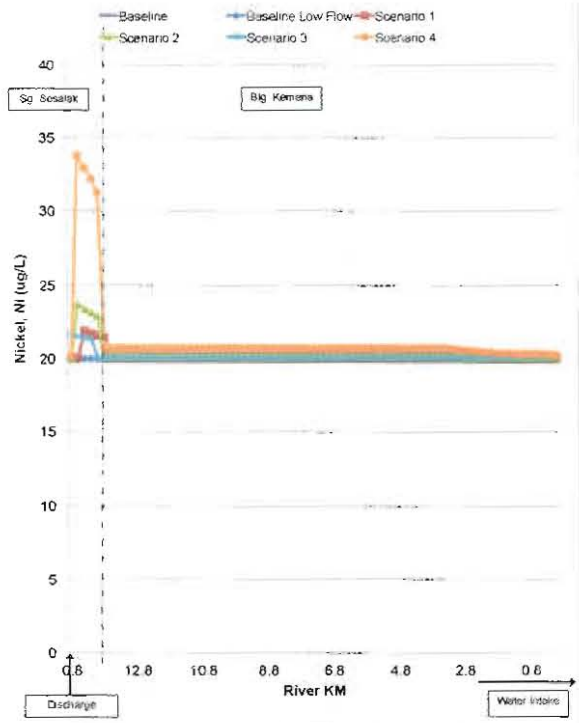


Figure 4.32: Batang Kemena and Sg. Sesalak Ni Spatial Prediction.

4.2.4 Recommendations for Management of the Landfill Effluent

Water quality modeling results indicate that at a total effluent discharge rate of 0.0075 m^3/s (650 m^3/day), the secured landfill effluent should not adversely affect the water quality of both Sg. Besai and Btg. Kemena for majority of the parameters modeled. In addition, this is to ensure compliance to the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 for Sanitary Landfill Effluent Discharge and Environmental Quality (Industrial Effluent) Regulation 2009.

Sg. Sesalak is a very small tributary of Btg. Kemena with the maximum width of approximately 7m and a depth of not more than 1.7m at its river mouth, before the confluence with Btg. Kemena. The upstream reach of Sg. Sesalak starts from a few inter-connecting of seasonal earth drains within the oil palm plantation estate. During the dry season, the flow rate of Sg. Sesalak is low with flow velocity of less than 0.1 m/s. This river is not used by the locals or the plantation workers as their water source. It only serves as a drainage path during rainy days to channel surface runoff from the area into Btg. Kemena as the main river, which flows adjacent to the Project site. Thus, leachate discharge to Sg. Sesalak (which subsequently joins to Btg. Kemena) may be a viable option as this river has no inherent beneficial use. The proposed discharge location at Sg. Sesalak is shown in Figure 4.33.

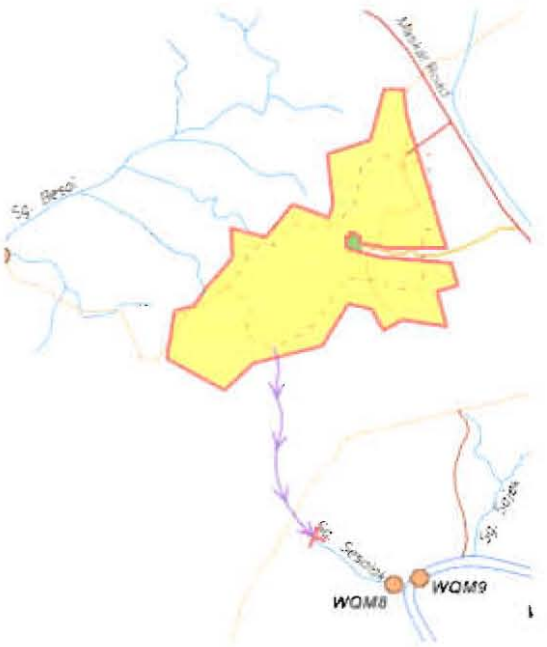


Figure 4.33: The Proposed Discharge Locations of the Landfill Effluent at Sg. Sesalak.

Only in the event of treatment system failure would the water quality of Btg. Kemena be adversely affected. Should that being the case, Sg. Sesalak as the immediate stream to receive the effluent before Btg. Kemena would definitely be affected by the discharge due to its small waste assimilative capacity. Hence, this river would ultimately be sacrificed due to the effluent input. As mentioned above, Sg. Sesalak is neither been used by any villagers nor the plantation workers, hence, it is of low risk river compared to Sg. Besai which is currently serving the nearby community as their daily water source. Currently, Sg. Besai is utilized by long-house residents such as residents of Rh. Usah. Besides, there are also several other longhouses along Sg. Besai, this includes Rh. Anita, Rh. Sundi, Rh. Suring, Rh. Marepat and Rh. Muli. The tributary is small to moderate in size (< 10 meters) and more sensitive to pollution. Thus, effluent discharge of the landfill should not be allowed to entering Sg. Besai as it clearly presents significant risk to the sensitive receptors (nearby longhouses community).

This study recommends that in the event of leachate treatment plant fails, the untreated leachate from the proposed wastewater / leachate treatment plant shall be diverted and temporary retained in the 5 days capacity (i.e 3,250 m^3 capacities) emergency retention pond. The untreated leachate shall be returned flow to its treatment plant for retreatment prior to discharge into Sg. Sesalak before entering Btg. Kemena water catchment.

Btg. Kemena is relatively large, spanning beyond 80 meters in width adjacent to the Project site. There are several water intakes located on Btg. Kemena. Despite the presence of the water intake downstream, Btg. Kemena's larger size infers a larger carrying capacity, which should be able to assimilate effluent. This is provided that the leachate volumetric discharge is not excessive and within the regulatory limits.

The possibility of post-treated leachate effluent discharge to a constructed wetland may also be considered, as this will help further reduce contaminant levels before entering Sg. Sesalak. There is a strip of land between the Project site and Sg. Sesalak which can be a potential site for the constructed wetland. However again, only treated effluent (which already meets regulatory limits) should enter the wetland, NOT the untreated leachate.

Besides physico-chemical aspects, the possibility of other debris and floatables entering the river also needs to be addressed. It is recommended that a garbage traps be installed on the river/waterways to block potential debris/floatables from traveling downstream. There are two potential sources of floatables, one from the landfill itself and

second from the garbage trucks (moving in and out of the site). Therefore, one garbage trap should be set up within the Landfill site before the waterways exit the boundary of the site.

Although no leachate should be allowed to enter Sg. Besai, a comprehensive monitoring regime should be conducted here to ensure the water quality continues to be preserved. Monitoring should be done once a month at selected locations for all parameters listed in the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 for Sanitary Landfill and Environmental Quality (Industrial Effluent) Regulations 2009 for Secured Landfill leachate throughout the life-period of the landfill.

Similarly, frequent river water quality monitoring should be conducted on Btg. Kemena particularly during the construction and operational stages. This monitoring should be captured as part of Environmental Management Plan (EMP) of the site. A quarterly sampling regime for all parameters listed in the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 for the Sanitary Landfill leachate and Environmental Quality (Industrial Effluent) Regulations 2009 for the secured landfill leachate should be done throughout the life-period of the landfill. Any significant deterioration of water quality in comparison to the baseline values should immediately be reported to the DOE and other relevant authorities for further action.

Due to the urgency of the water intake point located downstream of Btg. Kemena, the installation of a continuous (automatic) river water quality monitoring station, prior to

the water intake point, is highly recommended. This is to serve as an additional precautionary measure as well as to function as an early warning system in ensuring the downstream communities are protected.

4.3 Overall Framework on Environmental and Safety

For a better management of environmental and safety issues particularly in industry sector, it is vital that the Federal and State governments, as well as other relevant agencies and stakeholders carry out their respective jurisdictions and responsibilities and complement each other in achieving shared goals in addressing the issues. The involvement of different governmental departments and stakeholders in managing environmental and safety issues requires the existence of a coordination and collaboration mechanism.

This study proposes an environmental management framework which requires a coordination mechanism of all activities necessary to protect and preserve the environment as well as the nearby communities. The environmental management framework shall include some key subjects as stipulated in Table 4.7 to offer an integration approach for managing environmental issues in industrial perspective.

Table 4.7: Key subjects in the environmental management framework.

Institutional Capacity	Establishment of necessary institutional set up for environmental and safety issues within the governmental levels.
Coordination	Specify strategic coordination amongst stakeholders. This includes operational mechanisms and level of coordination.
Preventive, Mitigation, and Preparedness	Specify strategies to prevent and mitigate the possible occurrence of environmental and safety incidents from having negative impacts on the environment and communities. *As shown in this study, adoption of ISO 14001 EMS can serve as one of the strategies to address this subject. Therefore, ISO 14001 EMS Manual (as in Appendix 1) can be applied as a reference document for the implementation of the environmental and safety management system. *Besides, this study also shows that QUAL2K water quality modeling ' system can serve as one of the strategies for the protection and management of the quality of water resources.
Response, Recovery and Restoration	Development of emergency response plan which is based on the requirements for an integrated, coordinated approach to ensure rapid and effective response to environmental and safety issues.

This study also suggests that the framework shall define coordinating structures and align key roles and responsibilities of environmental management stakeholders in Sarawak as shown in Figure 4.34. The proposed coordinating structure shall also provide precise roles of the relevant agencies in dealing with monitoring and evaluation; emergency response plan; information management and communication; environmental and safety awareness as well as research and development.

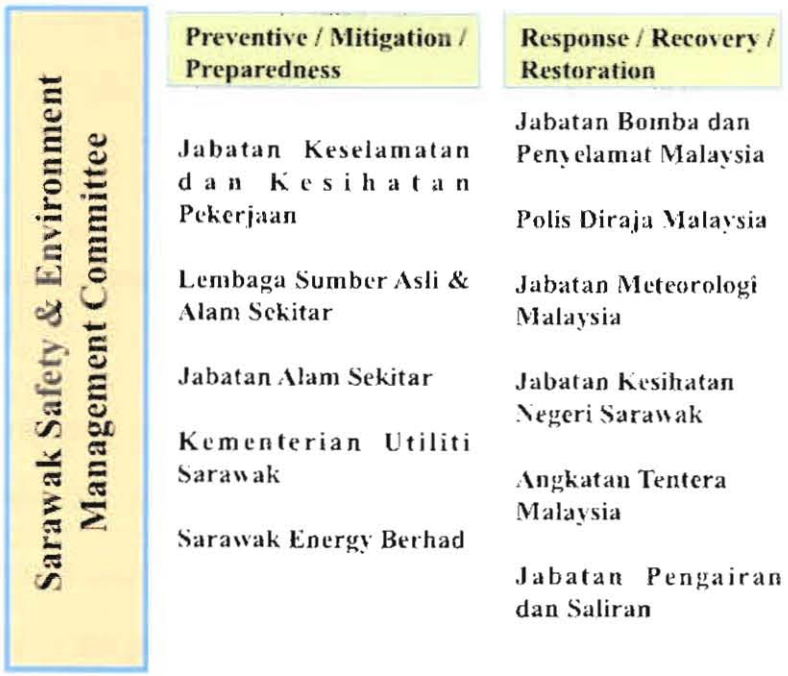


Figure 4.34: The proposed coordinating structure of the environmental management for energy industry in Sarawak.

CHAPTER 5

CONCLUSIONS

5.1 Performance Monitoring of Sejingkat Coal Power Plant

Monitoring works of performance conducted in this study serve as a key to have an in-depth understanding on the coal-fired power plant's operational performance in the sense of improving reliability and availability. This study is considered a leading research work particularly in the power plant industry on performance monitoring and evaluation. This work has recommended that the current ISO 14001 adopted in the power plant should be realigned and reintegrated to accentuate more effective and self regulating approaches to resolve these issues. The recommendations for improvement presented in the study are relevant to stress the importance of an effective ISO 14001 in addressing better operational management which will enhance power availability and reliability for securing customers' power needs. This study provides a useful structure method on the design, monitoring and evaluation of performance parameters. It offers benchmarking opportunities for other certified and non-certified ISO 14001 power plants and guidance in improving plants' performances. Besides, it appears to be an important reference material and serve as a positive step towards achieving more effective ISO 14001 implementation in the industry.

This work acknowledges that lack of reliable pre-ISO 14001 data for comparison of the performance parameters before and after adoption of ISO 14001 EMS is a key limitation of this study. This greatly affecting the ability to determine whether adopting ISO 14001 has any significant performance benefits. Further to this, a better theoretical

treatment is needed to explain whether firms adopt ISO 14001 would or would not result in some behavioral changes which are linked to environmental and operational performances.

5.2 Development of Water Quality Modeling for Sg. Besai and Btg. Kemena Discharges

This study helps in assessing the potential of QUAL2K model for predicting the water quality along the studied rivers. The water quality model developed in this study also has shown that the model can serve as a scientific and operational tool which allows to precise the water quality management policies. Probably the most significant contribution of this study was to provide reliable and useful information that are essential for policy makers and authorities in Sarawak in making more accurate and sustainable decisions before any irreversible action is taken. This is crucial for a sustainable environment as well as the State's economic and social well being. Nevertheless, there are always neccessity to perform various simulations of different pollutants for a given time period, to create many different scenarios for every sensitive river reach along Btg. Kemena, especially those reaches approaching to water intake point.

Overally, the objectives and aims of the research were achieved. The research methodologies were developed to incrementally fill the gaps through the boundary of literature reviews and the research work.

5.3 Recommendations for Future Works

Referring to the work on performances monitoring of Sejingkat coal power plant, future study should look into possibility to include a full case study for identifying more internal and external contributing factors which are likely associated to ISO 14001 in influencing the plant's performances. Other future works should also focus on financial benefits aspect. The ultimate direction of this effort is meant to promote seriousness and commitment of power plant players' in the implementation of ISO 14001 EMS, while allowing increased economic benefits and reputation besides improved performances.

For the study on water quality modeling on Sg. Besai and Btg. Kemena discharges, and as part of the State's goal to implement environmental management in these rivers, there are some recommendations suggested for the future works as follows:

a. Include a modelling framework that is designed to model the river water quality in seasonal and long-term trends of river pollutants. This is relevant as Btg. Kemena water level fluctuations encompass both seasonal and tidal conditions and these variables can have significant influence on the models that are ultimately produced; and

b. Apply the GIS tools for linking the water quality model output to the natural phenomena in order to better understand the characteristics of the Kemena catchment. Eventually, the QUAL2K model output will be transformed to the GIS platform and the river water quality can be clearly represented and spatially mapped along the Btg. Kemena catchment. Thus, an easier analysis, faster evaluation and more accurate decision making with regard to the river water management can be achieved.

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APPENDICES

Appendix 1: Environmental Management System Manual

Name of Organisation
(e.g. ABC Company)

Environmental Management System Manual (EM-01)

Revision No. : 1

Date : 13–7–2014

Prepared by : _____
(EMR)

Approved by : _____
(General Manager)

Revision History

Revision Date	Description	Sections Affected	Revised By	Approved By
13/7/2014	First issue	-	-	

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Appendix B Controlled Document List

0.0 Terms and Definitions

Auditor	Person with the competence to conduct an audit
Continual improvement	Recurring process of enhancing the environmental management system in order to achieve improvements in overall environmental performance consistent with the organisation's environmental policy.
Corrective action	Action to eliminate the cause of a detected nonconformity.
Document	Information and its supporting media
Environment	Surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation.
Environmental aspect (EA)	Elements of an organisation's activities or products or services that can interact with the environment.
Environmental impact	Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation's environmental aspects.
Environmental management system (EMS)	Part of an organisation's management system used to develop and implement its environmental policy and manage its environmental aspects.
Environmental objective	Overall environmental goal, consistent with the environmental policy, which an organisation sets itself to achieve.
Environmental performance	Measurable results of an organisation's management of its environmental aspects.
Environmental policy	Overall intentions and directions of an organisation related to its environmental performance as formally expressed by top management.
Environmental target	Detailed performance requirement applicable to the organisation or parts thereof, that arises from the environmental objectives and that needs to be set and met in order to achieve those objectives.
Interested party	Person or group concerned with or affected by the environmental performance of an organisation.
Internal audit	Systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which the environmental management system audit criteria set by the organization are fulfilled.
Nonconformity	Non-fulfilment of a requirement.
Organisation	ABC.
Preventive action	Action to eliminate the cause of a potential nonconformity.

Prevention of pollution	Use of processes, practices, techniques, materials, products, services or energy to avoid, reduce or control (separately or in combination) the creation, emission or discharge of any type of pollutants or waste, in order to reduce adverse environmental impacts.
Procedure	Specified way to carry out an activity or a process
Record	Document stating results achieved or providing evidence of activities performed.

1.0 General

1.1 Company Profile

The core business activity undertaken by ABC Company (hereafter name as ABC) is an integrated energy utility. This means that ABC generates, transmits, distributes and retails electricity around Sarawak. Sarawak Energy is increasingly involved in the development of new hydropower, coal, gas and transmission projects related to the Sarawak Corridor of Renewable Energy (SCORE).

1.2 Purpose of this Manual

This Manual defines the Environmental Management System (EMS) of ABC's activities and contains:

a) The Environmental Policy;

b) Statements of responsibility and authority;

c) An overview of the company's environmental procedures and controls;

d) The identification of the resources and training allocated to management, performance of work and verification activities including internal audit;

e) The appointment of the Environmental Management Representative (EMR); and

f) The arrangement for periodic management reviews.

The purpose of this Manual is to demonstrate that this EMS meets all ISO14001:2004 requirements and provide guidance and direction for the implementation and operation of the EMS to all personnel including all relevant documents.

1.3 Scope of EMS

The scope of the EMS applies to the ***Scheduled Waste Management*** related to power generation operations by ABC. Also the locations and areas to be covered in the EMS.

2.0 Policy

ABC Company

ABC Company undertakes coal/gas power plant and hydropower projects in Sarawak. Protecting the environment is the responsibility of everyone in the organization. ABC is committed to sustainable energy production and minimise any adverse impact on the environment resulting from the daily operations.

We are committed to delivering services with minimal impact to the environment through the following principles: -

- ★ Focus on prevention of pollution, waste minimization and resource conservation as critical considerations within our core management processes.
- ★ Compliance with applicable legal requirements and other requirements to which the Corporate subscribes which relate to its environmental aspects.
- ★ Regular performance reviews to ensure that environmental objectives and the requirements of Interested Parties are met.
- ★ Provision of staff training to ensure understanding, implementation and development of these principles throughout our operations.
- ★ Continual improvement

All staff will follow the requirements of the Environmental Management System in the performance of their tasks and will ensure this policy is supported and maintained. This policy will be communicated to our customers, suppliers, and contractors. It will also be made available to the public whenever requested.

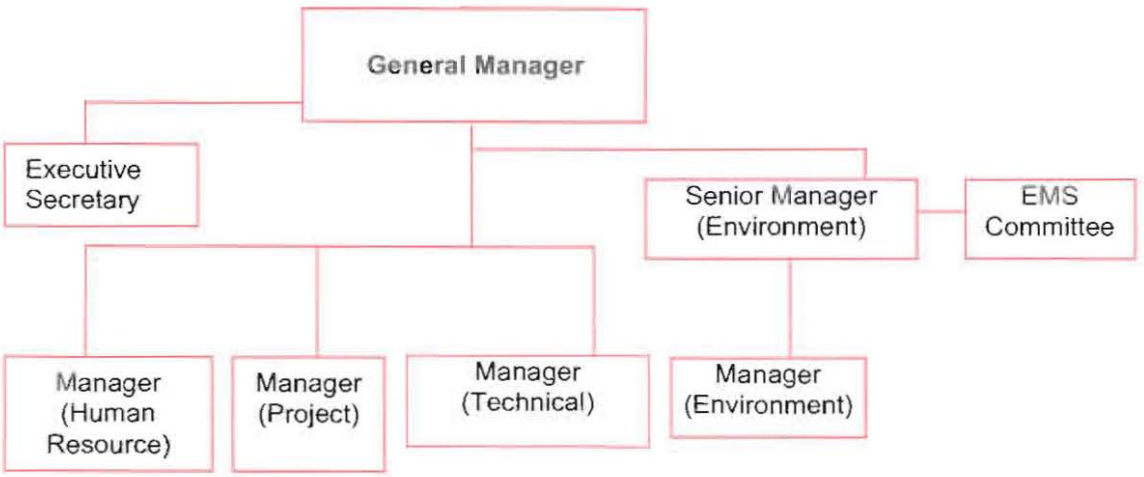
Signed : _____ Date: _____

Mr. X

General Manager

3.0 Organisation

3.1 Organisation Chart



3.2 Responsibility

3.2.1 General Manager

The General Manager is committed to developing and implementing the Environmental Management System. Resources requirements are reviewed to ensure that adequate resources are provided to plan, do, check and act for continually improving its effectiveness.

General Manager is responsible for:

a) endorsing the environmental policy;

b) ensuring appropriate resource allocation to enable the effective operation and continual improvement of the EMS.

3.2.2 Environmental Management Representative (EMR)

The Senior Manager (Environment) is the appointed EMR and has the responsibility and authority for:

a) ensuring that EMS requirements are established, implemented and maintained in accordance with the ISO 14001 standard, including the following tasks;

- to control and issue all EMS documentation;
- to ensure the promotion of awareness of customer requirement and environmental awareness throughout ABC;
- to receive staff suggestions for improvements or additions to the EMS and taking the necessary action to implement them where they are beneficial;
- to keep staff informed of developments in the EMS.

b) ensuring that sufficient resources are allocated for the proper implementation of the environmental policy and the EMS;

c) regularly reviewing the policy and the effectiveness of the EMS, and ensuring that the necessary changes are made.

EMR is also the Chairman of the EMS Committee and has the responsibility and authority for :

a) leading the EMS Committee to establish and implement the EMS according to ISO 14001 standard, and monitoring the performance of the EMS;

b) coordinating internal EMS audits to ensure the EMS has been properly implemented and maintained;

c) handling and investigating nonconformity and ensuring corrective and preventive action has been taken to mitigate any impacts caused;

d) reporting on the performance of the EMS to the top management for review and as a basis for improvement of the EMS.

The EMR, the Deputy Environmental Management Representative (DEMR), the EMS Committee and General Manager shall undertake the EMS management review annually to ensure top management commitment and integration of the EMS with business strategies for its implementation and continual improvement.

3.2.3 Deputy Environmental Management Representative (DEMR)

The Manager (Environment) is the appointed DEMR and has the responsibility and authority for:

a) assisting the EMR to ensure the EMS is effectively implemented and maintained in accordance with ISO 14001 standard;

b) assuming the responsibility and action of the EMR when the EMR is unavailable.

3.2.4 Environmental Management System Committee (EMS Committee)

This committee is responsible for:

a) the establishment and implementation of the EMS;

b) the establishment and review of objectives, targets, and programmes;

c) ensuring the effective implementation of environmentally-related operational controls and programmes;

d) the internal communication of environmental matters between management and employees; and promoting environmental awareness among company staff;

e) the review of complaint records, nonconformity, corrective action and preventive action reports and the adoption of preventive actions as necessary;

f) providing leadership in the pursuit of environmental issues;

g) any other EMS activities that are assigned by the EMR;

h) initiating regular meeting (every 4 months).

3.2.5 Management Review Committee

The Committee systematically examines the EMS to ensure the suitability, adequacy and effectiveness of the EMS. The Committee comprises of the General Manager, EMR, DEMR and the EMS Committee.

3.2.6 Manager (Project)

Manager (Project) is responsible to plan, organize, co-ordinate and control individual project activities, the responsibilities related to EMS include:

a) assisting the General Manager in the pre-contract review;

b) reviewing the project and formulates the detailed contract program;

c) implementing contracts through the co-ordination and instruction of site and office based staff;

d) resolving problems encountered during the contract (e.g. any environmental issue) and refer to the General Manager if necessary;

e) liaising with all other managers in order that the contract can be completed in accordance with the specified requirements and within the program;

f) to be accountable for the Technical Services and environmental management;

g) controlling overall cost of the projects;

h) to foster good client relationships;

i) promoting and develop the company image at all times;

j) to keep up to date with all new business related developments, new statutory requirements and implements them accordingly.

k) to evaluate the performance of the suppliers and sub-contractors.

l) to handle client complaints (e.g. any environmental issue).

3.2.7 Manager (Technical)

Reporting to the General Manager, Manager (Technical) is responsible for the proper estimating of the tender and project planning in accordance with policy and directives given by General Manager, maximizing profit and making the most efficient use of resources under his control.

a) to advise and make recommendations on technical engineering policy relative to the efficiency of the company.

b) to provide technical advice and proposals to support projects.

c) to carry out tender estimation.

d) to ensure adequate resources are made available for tendering.

e) to co-ordinate the estimating and planning works with Joint-Venture partners (as appropriate)

f) to adjudicate the prices of suppliers and subcontractors in each tender.

Environmental Procedures (EPs)	Define the roles, responsibilities, and actions to be taken to ensure that activities are performed and the EMS implemented in accordance with the environmental policy and the requirements of ISO 14001. A cross-reference of the ISO 14001 clauses to the EPs is listed in Appendix A.
Register of Environmental Aspects	Compiles the environmental aspects that are derived from the activities and services of ABC. The register also denotes the significance of the environmental aspects and the respective operational controls for significant environmental aspects.
Register of Legal and Other requirements	Compiles the legal and other requirements, which include legislation, codes of practice, regulatory and non-regulatory guidelines that are applicable to ABC.
Environmental Instructions (EIs)	Describe which and how activities should be performed to manage significant environmental aspects and to achieve the EMS ISO 14001 requirements.
Environmental Forms/Records	Record information for the audit trail and the assessment of environmental conditions and performance.

* Objectives and Targets, and associated Programmes are provided as a single document.

4.2 Environmental Policy

(ISO 14001 Standard Clause 4.2)

The environmental policy of ABC is included in Section 2 of this document. It outlines the environmental commitments of ABC with respect to its operations, activities, and overall environmental performance. During the development of this policy, the appropriateness to the nature, scale and environmental impacts of ABC's activities, products and services has been considered. The policy is endorsed by the General Manager and the policy shall be reviewed during the management review meeting.

The policy shall stipulate the commitments of ABC to continually improve its environmental management and prevention of pollution. ABC is also committed to comply with applicable legal requirements and other requirements to which ABC subscribes which relate to its environmental aspects.

The environmental policy shall provide a framework for setting and reviewing objectives and targets, and must be maintained, implemented and communicated to all employees of ABC and its contractors.

This policy shall be available to the public.

4.3 Planning

ABC shall follow a "plan-do-check-act" process to facilitate continual environmental performance improvements. The planning process includes the identification and updating of ABC's Register of Environmental Aspects, and the Register of Legal

by which they are to be achieved.

The General Manager shall approve the objectives, targets and programmes proposed by the EMS Committee before implementation. The EMR shall ensure that the objectives and targets are measurable if possible, and that the progress towards achieving the objectives and targets is continually monitored and reviewed.

The achievement of objectives, targets and programmes shall be reviewed by the EMS Committee every 4 months. The EMR shall lead the EMS Committee in revising the objectives, targets and programmes as necessary.

ABC shall ensure that the programmes are amended as appropriate for new projects and new or modified activities, products or services in order to ensure that environmental management applies to such projects and activities.

In the event that objectives and targets in the programmes are not met, the EMR shall revise the programme as necessary and maintain documented evidence / records for the actions taken to mitigate the problems.

The EMR shall also maintain obsolete objectives, targets and programmes as an EMS record for three years.

4.4 Implementation and Operation

The implementation of the EMS requires ABC to clearly define roles, responsibilities and authorities of key personnel, commit to staff training, maintain effective communication channels, adopt effective document and operational controls, and maintain sufficient awareness on emergency preparedness among the staff.

4.4.1 Resources, Roles, Responsibility and Authority

(ISO 14001 Standard Clause 4.4.1)

Top management of ABC shall commit to provide resources (including human resources and specialized skills, organizational infrastructure, technological and financial resources) essential to the implementation and control of the EMS. The roles, responsibilities and authorities of key personnel shall be defined, documented, and communicated in order to facilitate effective environmental management.

ABC has appointed the Senior Manager (Environment) as the Environmental Management Representative (EMR), and the Manager (Environment) as the Deputy Environmental Management Representative (DEMR) for the implementation and maintenance of the EMS. Their EMS responsibilities are described in section 3 of this manual.

4.4.2 Competence, Training and Awareness

(ISO 14001 Standard Clause 4.4.2)

ABC shall ensure all persons performing tasks for it or on its behalf, whose work may have a significant impact on the environment, are competent on the basis of appropriate education, training and/or experience, and shall retain associated records.

ABC will need to ensure that all people performing tasks for or on behalf of the organization, have had an appropriate assessment for their potential to cause a

significant environmental impact and the associated competence required.

ABC shall establish, implement and maintain procedures to identify the training needs associated with its environmental aspects and its EMS, and develop programmes to ensure awareness and competence, at each relevant function and level, by addressing:

- the roles and responsibilities in achieving conformity with the EMS;
- the importance of conformity with the environmental policy, the procedures and the requirements of the structured EMS;
- the significant environmental aspects and potential impacts associated from their work activities and the environmental benefits of improved personal performance;
- the potential consequences of departure from specified operating procedures;

Relevant procedure : EP-03 Training

4.4.3 Communication

(ISO 14001 Standard Clause 4.4.3)

For internal communication, the EMR shall ensure information regarding the EMS (such as the policy, objectives, targets and programmes) and environmental performance is readily available to employees on notice board, or is published on the intranet or newsletters.

Employees with enquiries / complaints regarding to the EMS and/or environmental issues of ABC shall inform their Manager (Project). The designated member of EMS Committee representing each division shall maintain a log for the relevant enquiries / complaints. Depending on the nature and scope of the enquiry / complaint, the EMR shall determine the corresponding action and maintain relevant records to demonstrate the response / corrective actions taken.

For external communication, the environmental policy is available at the office and company web page. All internal and external enquiries / complaints / communications shall be discussed and reviewed during the EMS Committee meeting and the decision shall be recorded on meeting minutes.

The EMS Committee may discuss and decide whether to communicate externally about its significant environmental aspects, the decision shall be documented in the meeting minutes. If the decision is to communicate, the EMS Committee shall establish and implement a method(s) for this external communication, e.g. publish environmental report.

Relevant procedure : EP-07 Enquiry / Complaint / Nonconformity Handling

4.4.4 Documentation

(ISO 14001 Standard Clause 4.4.4)

The Environmental Management System documentation encompasses four levels as described below :

The first level is the *Environmental Management System Manual* (this document) which includes ABC's environmental policy (specifying the principal objectives and environmental commitments of ABC), and a broad description of how ABC addresses the ISO 14001 requirements. The EMS Manual serves as an interface to interpret the relationship between ABC's EMS and the ISO 14001 Standard. An

individual document of *Objectives, Targets and Programmes* is developed based on the company's environmental policy. It demonstrates the company's commitment on continual improvement in environmental performance.

The second level is the *Environmental Procedures (EPs)*, which include all procedures that ABC shall follow as specified in the ISO 14001 Standard. These procedures provide a detailed description of the EMS elements and define who should do what, how and when. Appendix A shows the relationship between various environmental procedures and the ISO 14001 Standard clauses. Register of Environmental Aspects, and Register of Legal and Other Requirements are derived from the procedures and act as the foundation of the EMS which the company subscribed to.

The third level is the *Environmental Instructions (EIs)*, which are operational control procedures or instructions, with defined responsibilities, to control the identified significant environmental aspects associated with ABC's operations and activities.

The fourth level is *Environmental Records* which arise from the implementation of the Environmental Management System Manual, Environmental Procedures and Environmental Instructions. Environmental Records include various checklists, reports and meeting records, etc, as defined in each Environmental Procedure and Environmental Instruction.

4.4.5 Control of Documents

(ISO 14001 Standard Clause 4.4.5)

The essences of EMS documentation controls are:

- they shall be reviewed, revised as necessary and approved for adequacy by authorized personnel;
- that current version of relevant documents shall be available at all locations where operations essential to the effective functioning of the environmental management system are performed;
- that documents of external origin determined by the organization to be necessary for the planning and operation of the EMS are identified and their distribution controlled;
- obsolete documents shall be promptly removed from all points of issue and use, or are otherwise assured against unintended use; and
- any obsolete documents retained for legal and / or knowledge preservation purposes shall be suitably identified.

ABC shall ensure that documentation is legible, dated (with dates of revision) and readily identifiable, maintained in an orderly manner, and retained for a specified period. ABC shall establish, implement and maintain a procedure for the creation and modification of the various types of documents and the respective responsibilities for such creation and modifications.

Relevant procedure : EP-04 Control of Documents

4.4.6 Operational Control

(ISO 14001 Standard Clause 4.4.6)

ABC shall establish, implement and maintain operation control procedures to manage its significant environmental aspects.

ABC shall ensure that all operations and activities, carried out by ABC's employee or contractors, that are associated with the significant aspects are properly controlled, and that appropriate operational control procedures, in terms of Environmental Procedures (EPs) and Environmental Instructions (EIs), are communicated to personnel whose tasks may result in significant environmental aspects. ABC shall influence its staff and contractors by communicating its environmental policy and other relevant EPs and/or EIs to them.

Relevant procedure : EI-01 to 06

4.4.7 Emergency Preparedness and Response

(ISO 14001 Standard Clause 4.4.7)

ABC shall establish, implement and maintain a procedure to identify potential emergency situations and responses to such situations in order to prevent and/or mitigate environmental impacts that may associate with them.

ABC shall review and revise its emergency preparedness and response procedures, in particular after the occurrence of accidents or emergency situations.

ABC shall also periodically test the procedure and the preparedness where practicable.

Relevant procedure : EP-05 Environmental Emergency Preparedness and Response

4.5 Checking

While implementing the EMS, ABC shall monitor and measure the key characteristics of its operations and activities on a regular basis. These results shall be recorded together with nonconformity and the corrective action and preventive action. As part of the checking process, a periodic audit on the EMS shall provide a basis for management review.

4.5.1 Monitoring and Measurement

(ISO 14001 Standard Clause 4.5.1)

ABC shall establish, implment and maintain procedures to monitor and measure, on a regular basis, the key characteristics of its operations and activities that have significant impacts on the environment. This shall include procedures for tracking of performance, applicable operational controls and conformity with the company's objectives and targets, as well as the calibration and maintenance of monitoring equipment. The information of environmental monitoring shall be documenting.

Relevant procedure : EP-06 Environmental Monitoring and Evaluation of Compliance

4.5.2 Evaluation of Compliance

(ISO 14001 Standard Clause 4.5.2)

To meet the company's commitment to compliance, ABC shall regularly monitor and evaluate the compliance status of the applicable environmental legal requirements (section 4.5.2.1) and other requirements (section 4.5.2.2) that the company subscribes to. The records of the results of the periodic evaluations shall be retained.

Relevant procedure : EP-06 Environmental Monitoring and Evaluation of

ABC shall ensure that all operations and activities, carried out by ABC's employee or contractors, that are associated with the significant aspects are properly controlled, and that appropriate operational control procedures, in terms of Environmental Procedures (EPs) and Environmental Instructions (EIs), are communicated to personnel whose tasks may result in significant environmental aspects. ABC shall influence its staff and contractors by communicating its environmental policy and other relevant EPs and/or EIs to them.

Relevant procedure : EI-01 to 06

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Relevant procedure : EP-05 Environmental Emergency Preparedness and Response

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While implementing the EMS, ABC shall monitor and measure the key characteristics of its operations and activities on a regular basis. These results shall be recorded together with nonconformity and the corrective action and preventive action. As part of the checking process, a periodic audit on the EMS shall provide a basis for management review.

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Relevant procedure : EP-06 Environmental Monitoring and Evaluation of Compliance

4.5.2 Evaluation of Compliance

(ISO 14001 Standard Clause 4.5.2)

To meet the company's commitment to compliance, ABC shall regularly monitor and evaluate the compliance status of the applicable environmental legal requirements (section 4.5.2.1) and other requirements (section 4.5.2.2) that the company subscribes to. The records of the results of the periodic evaluations shall be retained.

Relevant procedure : EP-06 Environmental Monitoring and Evaluation of

Compliance

4.5.3 Nonconformity, Corrective Action and Preventive Action

(ISO 14001 Standard Clause 4.5.3)

Continual improvement of the EMS can be achieved by identifying nonconformity, correcting nonconformity and preventing nonconformity from occurring again. Regarding non-conformity and its subsequent corrective / preventive action, ABC shall establish, implement and maintain a procedure which defines the responsibilities and authorities to:

- Handle and investigate nonconformity;
- Take action to mitigate the impacts caused;
- Initiate and complete corrective and preventive actions;
- Ensure that the corrective or preventive actions taken to eliminate the causes of actual and potential nonconformity are appropriate to the magnitude of problems and commensurate with the environmental impacts encountered;
- record the results of corrective and prevention actions taken;
- Review the effectiveness of corrective action and preventive action taken; and
- implement and record any changes in the documented procedures resulting from corrective and preventive action.

ABC shall also ensure that any necessary changes are made to environmental management documentation.

Relevant procedure : EP-07 Enquiry / Complaint / Nonconformity Handling

4.5.4 Controls of Records

(ISO 14001 Standard Clause 4.5.4)

Records shall be maintained to keep track of ABC's environmental performance, to demonstrate conformity to the requirements of the EMS, legal compliance, and to maintain audit trails in accordance with the requirements of ISO 14001 Standard, and the results achieved.

ABC shall establish, implement and maintain a procedure to denote the identification, storage, protection, retrieval, retention and disposition of environmental records, to ensure that such records are legible, identifiable, and traceable to the activity, product or service involved, and that they are stored and maintained in such a way that they are readily retrievable and protected against damage, deterioration or loss. The retention period of each type of environmental records shall be specified.

Relevant procedure : EP-08 Control of Records

4.5.5 Internal Audit

(ISO 14001 Standard Clause 4.5.5)

ABC shall plan, establish, implement and maintain a programme and procedures to carry out periodic environmental management system audits to:

a) determine whether or not the environmental management system:

- conforms to planned arrangements for environmental management including the requirements of ISO 14001; and

- has been properly implemented and maintained;

b) provide audit results and information for management review for environmental improvement.

The audit programme, including the schedule, shall be based on the environmental importance of the activities concerned and results from previous audits. The audit procedures cover the audit criteria, scope, frequency and methods, as well as responsibilities and requirements for conducting audits and reporting results and retaining associated records.

ABC shall conduct EMS audits on a regular basis. Timely site environmental audits are required to ensure appropriate preventive actions being taken as planned, and corrective actions being carried out on a timely basis.

Relevant procedure : EP-09 Internal Audit

4.6 Management Review

(ISO 14001 Standard Clause 4.6)

The "plan-do-check-act" cycle shall require the top management of ABC to act and review the environmental management system periodically to ensure its suitability, adequacy and effectiveness.

Before the Review, the EMR shall schedule for the management review and inform all the participants, and gather all relevant records/requirements (such as change in legal requirements) and prepare a summary report (if necessary) for discussion.

The General Manager, EMR and DEMR together with the EMS Committee shall take part in the annual management review. They shall assess the work done in the past year in environmental management and evaluate the existing EMS with respect to changes in legislation, concerns of interested parties, business activities, technology and product requirements, and lessons gained from previous experience, etc.

Topics to be discussed in the management review shall include but not be limited to:

- review of the environmental policy, objectives, targets, and programmes;
- review of legal compliance and compliance with other requirements (including contractor compliance on ABC's activities);
- environmental aspects of activities and their disclosure to public;
- findings of the internal audits;
- review of nonconformities and the status of corrective/preventive actions;
- areas for improvement with respect to environmental performance;
- adequacy of emergency preparedness and response;
- changing circumstances, including developments in legal and other requirements related to its environmental aspects,
- identify the need for modification of the existing EMS in light of the above items, and
- follow-up action from previous management reviews.

Appendix A Cross Reference of ISO 14001 Requirements* and Sections in the EMS Manual and Environmental Procedures.

ISO 14001 Clause		EMS Manual Section No.	EP Ref. No.
4.1	General Requirements	4.1	–
4.2	Environmental Policy	4.2.	–
4.3	Planning	4.3	–
4.3.1	Environmental Aspects	4.3.1	EP-01
4.3.2	Legal and Other Requirements	4.3.2	EP-02
4.3.3	Objectives, Targets and Programme(s)	4.3.3	–
4.4	Implementation and Operation	4.4	–
4.4.1	Resources, Roles, Responsibility and Authority	4.4.1	–
4.4.2	Competence, Training, and Awareness	4.4.2	EP-03
4.4.3	Communication	4.4.3	–
4.4.4	Documentation	4.4.4	–
4.4.5	Control of Documents	4.4.5	EP-04
4.4.6	Operational Control	4.4.6	All EIs
4.4.7	Emergency Preparedness and Response	4.4.7	EP-05
4.5	Checking	4.5	–
4.5.1	Monitoring and Measurement	4.5.1	EP-06
4.5.2	Evaluation of Compliance	4.5.2	EP-06
4.5.3	Nonconformity, Corrective Action and Preventive Action	4.5.3	EP-07
4.5.4	Control of Records	4.5.4	EP-08
4.5.5	Internal Audit	4.5.5	EP-09
4.6	Management Review	4.6	–

* ISO 14001:2004 is referred.

Appendix B Controlled Document List

Document No.	Document/Form Name
CP-01	Environmental Policy
O&T-YYYY	Objectives, Targets and Programmes
EAR-01	Register of Environmental Aspects
LR-01	Register of Legal and Other Requirements
EM-01	Environmental Management System Manual
EP-01	Identification of Environmental Aspects and Significance Evaluation
EP-02	Review of Legal and Other Requirements
EP-03	Training
EP-04	Control of Documents
EP-05	Environmental Emergency Preparedness and Response
EP-06	Environmental Monitoring and Evaluation of Compliance
EP-07	Enquiry / Complaint / Nonconformity Handling
EP-08	Control of Records
EP-09	Internal Audit
EI-01	Environmental Impact Assessment
EI-02	Environmental Management Plan
EI-03	Environmental Audit
EI-04	Best Practices for Storage of Scheduled Waste
EI-05	Best Practices for Inventory of Scheduled Waste
EI-06	Best Practices for Disposal of Scheduled Waste

Appendix 2: List of Publication

Journal papers:

Georgie Wong Abdullah, Mohammad Omar Abdullah, Rubiyah Baini, Yie Hua Tan (2017). Performance monitoring: A study on ISO 14001 certified power plant in Malaysia. Journal of Cleaner Production, 147, 165-174, Impact factor: 5.715.

Yie Hua Tan, Mohammad Omar Abdullah, Cirilo Nolasco-Hipolito, Nur Syuhada Ahmad Zauzi, Georgie Wong Abdullah, (2017). Engine performance and emissions characteristics of a diesel engine fueled with diesel-biodiesel-bioethanol emulsions. Energy Conversion and Management, 132, 54-64, Impact factor: 5.589.