ASSESSMENT OF STANDARD LANDFILL CRITERIA FOR PLANNING NEW LANDFILL SITES

by

MOHAMED OSMAN SAEED

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PENILAIAN KRITERIA TAPAK PELUPUSAN PIAWAI UNTUK PERANCANGAN TAPAK PELUPUSAN BARU

oleh

MOHAMED OSMAN SAEED

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LIST OF ABBREVIATIONS

AHLS	Air Hitam landfill site
AHP	Analytical hierarchy process
AJLS	Ampang Jajar landfill site
Alt	Alternative
ANOVA	Analysis of variance
AQ	Air quality
AR	Access road
BTLS	Bukit Tagar landfill site
CH	Cultural heritage
CI	Consistency index
Cri	Criteria
CR	Consistency ratio
EC	Expert choice
DEFRA	Department of Environment, Food and Rural Affairs
DOE	Department of Environment
DMs	Decision makers
DS	Drainage system
EEA	European Environmental Agency
DEIA	Detailed environmental impact assessment
ELECTRE	*Elimination et choix traduisant la realité* (in French)
Eng	Engineering
Env	Environment

EPSM	Environmental protection society Malaysia
EULDs	European Union landfill directive
EU	European Union
G	Geology (soil)
GHG	Greenhouse gas
GIS	Geographical information system
GOs	Government organizations
GWR	Groundwater resource
HS	Human settlement
JICA	Japanese International Cooperation Agency
JLS	Jelutong landfill site
IDRISI®	One type of GIS software
ISWM	Integrated solid waste management
JUPEM	Jabatan Ukur dan Pemetaan Negara Malaysia
KL	Kuala Lumpur
KLS	Kulim landfill site
L	Land use
AL	Availability of land
LP	linear programming
MaCGDI	Malaysian Centre for Geospatial Data Infrastructure
MCE	Multiple criteria evaluation
MCDM/A	Multiple criteria decision making/aid
MHLG	Ministry of Housing and Local Government
MOH	Ministry of Health

MSW	Municipal solid waste
MPPP	Majlis Perbandaran Pulau Pinang
MPSP	Majlis Perbandaran Pulau Pinang
MRSA	Malaysian Remote Sensing Agency (ARSM)
NGOs	Non government organizations
NPP	Negeri Pulau Pinang
OC	Operation cost
PASW	Predictive analyses software
PBLS	Pulau Burong landfill site
PCA	Principle component analysis
PI	Public impact
PP	Political power
Pro	Proximity
PROMETHEE	Preference ranking organization method for enrichment evaluations
RH	Risk to human
RI	Random index or Random consistency index (RCI)
RIWs	Relative important weights
SA	Sensitivity analysis
SI	Suitability index
Soc	Socioeconomic
SP	Seberang Perai
SPS	Seberang Perai Selatan
SPT	Seberang Perai Tengah
SPU	Seberang Perai Utara

SWM	Solid waste management
SWR	Surface water resource
T	Topographic (slope)
TE	Tidal (wave) effect
U	Utility
UK	United Kingdom
UNESCO	The United Nations of Educational, Scientific, and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USEPA	Untied States Environmental Protection Agency
UNIMAS	Universiti Sarawak Malaysia
UPM	Universiti Putra Malaysia
USM	Universiti Sains Malaysia
V	Vegetation
WB	World Bank
WD	Waste disposal
WHO	World Health Organization
WLC	weighed linear combination
WQ	Water quality
WS	Waste source

PENILAIAN KRITERIA TAPAK PELUPUSAN PIAWAI UNTUK PERANCANGAN TAPAK PELUPUSAN BARU

ABSTRAK

Pemilihan tapak pelupusan sanitari yang mengambil kira kriteria alam sekitar, kejuruteraan, ekonomi dan sosio-politik adalah penentu utama dalam perancangan dan pembangunan bandar. Matlamat utama kajian ini adalah untuk menilai aspek-aspek kejuruteraan dan alam sekitar bagi tapak pelupusan menggunakan maklum balas langsung daripada pembuat keputusan (DMs) dalam komuniti pengurusan tapak pelupusan di Malaysia. Hasil keputusan ini disahkan dengan menjalankan pemilihan tapak pelupusan menggunakan sistem maklumat geografi (GIS) di kawasan kajian yang terletak di Seberang Perai, Pulau Pinang. Keseluruhan proses dilaksanakan dengan menggunakan data input (kriteria keputusan) yang dikumpul dan dinilai menggunakan model statistik dan matematik. Satu model keputusan berwajaran yang sesuai telah dicadangkan untuk menilai kriteria tapak pelupusan berdasarkan keutamaan DMs yang memainkan peranan penting dalam mereka bentuk tapak pelupusan sanitari yang sesuai bagi Pulau Pinang. Ia seterusnya disokong oleh perisian GIS mengunakan model penilaian berbilang kriteria melalui kaedah Proses Analiktikal Hierarki (AHP) dalam menentukan tapak yang sesuai untuk pelupusan sanitari baru di Seberang Perai Selatan (SPS). Satu kaji selidik AHP disediakan dan soal selidik dibuat terhadap DMs yang dipilih dari kalangan organisasi kerajaan (GOs), terutamanya majlis-majlis perbandaran serta pertubuhan-pertubuhan bukan kerajaan (NGOs). Kepakaran mereka adalah berdasar pengalaman

pengurusan di majlis-majlis perbandaran, universiti, syarikat-syarikat swasta dan pusat penyelidikan. Keputusan kaji selidik telah dianalisis dengan menggunakan tiga perisian yang berlainan iaitu perisian analisis ramalan (PASW), pilihan pakar (EC) dan sistem maklumat geografi (GIS). Hasil ANOVA menunjukkan bahawa tiada perbezaan yang signifikan di antara lima kumpulan pembuat keputusan (P> 0,938), dan hasil keputusan menunjukkan hubungan yang kukuh dengan hasil keputusan pemetaan GIS yang membuktikan bahawa kebanyakan kawasan yang sesuai terletak di bahagian utara Seberang Perai Selatan. Perisian EC menentukan pemberat untuk setiap lima kumpulan utama yang mengandungi lapan orang pakar. Kaedah geometri purata digunakan untuk mengira pemberat umum yang digunapakai dalam model WLC di IDRISI®GIS. Hasil menunjukkan bahawa tapak pelupusan baru pilihan kumpulan dari pertubuhan bukan kerajaan (NGOs) (Kumpulan 5) sangat mirip dengan pembuat keputusan Kumpulan 2 (kawasan pantai timur). Ia berbeza dengan tapak pelupusan yang dipilih oleh pembuat keputusan Kumpulan 1, 3 dan 4 (kawasan barat laut, kawasan tengah dan kawasan selatan). Kerjasama orang awam dan maklum balas politik dikenalpasti sebagai komponen yang penting dalam memahami perihal pengurusan sisa dan kesan negatif tapak pelupusan. Lawatan tapak untuk tujuan pengesahan juga telah dijalankan untuk memastikan ketepatan hasil keputusan yang perolehi. Dalam usaha mengelak konflik pemilihan sesuatu tapak pelupusan untuk projek di masa hadapan, garis panduan yang dicadangkan dalam penyelidikan ini adalah disyorkan.

ASSESSMENT OF STANDARD LANDFILL CRITERIA FOR PLANNING OF NEW LANDFILL SITES

ABSTRACT

Selection of sanitary landfill site based on environmental, engineering, economic and socio-political criteria are the key determinants in urban planning and development. The primary goal of this study is to evaluate the engineering and environmental aspects of landfill site using direct feedback from decision makers (DMs) of landfill management communities in Malaysia. These results were further validated by carrying out landfill site selection using geographic information system (GIS) on a study area at Seberang Perai, Pulau Pinang. The entire process is accomplished firstly by using input data (decision criteria) collected and evaluated using the statistical and mathematical models. A suitable weighted decision model was proposed for quantifying landfill criteria based on DMs' preferences which play a significant role in designing suitable sanitary landfill for Pulau Pinang. This was further supported by GIS software for multiple criteria suitability model which utilizes AHP in determining feasible sites for new sanitary landfill in Seberang Perai Selatan (SPS). An AHP survey was designed and carried out among selected DMs of government organizations (GOs), mainly from municipalities of selected cities and towns as well as non-government organizations (NGOs). These selected experts are basically from municipalities, universities, private companies and research centers. The survey results have been analyzed using three different softwares namely predictive analysis software (PASW), expert choice (EC) and geographic informa-

tion system (GIS). The ANOVA result indicates that there is no significant difference between the five groups (P>0.938), and this result has a strong correlation with the GIS mapping results which shows that most of the suitable areas are located in the northern part of Seberang Perai Selatan. EC software determines the weights from each of the five main groups having eight experts each. Geometric mean was used to adjust the weights of the region into one WLC application in IDRISI®GIS. The result shows that new landfill sites preferred by non-government organizations (NGOs) (Group 5) are very similar with Group 2 (east-coast region), but differs from sites preferred by Groups 1, 3 and 4 (north-west region, central region and southern region, respectively). Public and political inputs and cooperation in understanding waste management and landfill negative impacts were identified to be a very essential component. Site visits for validation purposes were also accomplished in order to ensure the correctness of the results determined. In order to avoid conflict in selecting a landfill for future projects, it is recommended therefore to follow the guidelines as proposed in the present research.

CHAPTER ONE

INTRODUCTION

1.0. General Introduction

Management of solid waste is one of the major problems afflicting most of the developed cities in the world comprising those in Malaysia. The management of solid waste in Asian communities including Malaysia has put tremendous pressure on Local Governments, making them continually seeking new management strategies in order to deal with the wastes generated, specifically on demand management, as well as supply management such as finding new dumping sites (Idris et al., 2004). It was reported that more than 91% increasing of solid wastes generated in Malaysia over the past ten years (Agamuthu et al., 2009). Consequently, construction of new dumping sites has become more difficult because of land scarcity, increase in land prices and high demands for nearest sites, especially in urban areas. Site selection of dumping sites such as landfill is a complex process involving social, environmental and technical parameters as well as government regulations (Agamuthu, 2003).

Environmental problems related to waste management such as selection of dumping sites, are commonly resolved using multiple criteria decision making (MCDM) method because of its flexibility. MCDM is a branch of a general class of operation research model dealing with decision complex problems under the presence of a number of decision criteria. Multiple criteria analysis methods are indicatively used as a decision maker's supporting tool for the assessment and selection of waste

treatment or management technologies (Mourmouris, 2006; Gomes et al., 2008), and site allocation of waste management plants and landfill sites (Sumathi et al., 2008; Calijuri et al., 2004; Dulmin and Mininno, 2003).

1.2. Municipal Solid Waste Generation in Malaysia

In Malaysia, solid wastes are generally classified into three major categories, and each category is under the responsibility of different government agencies (Manaf et al., 2009):-

1. Schedule/hazardous waste (such as chemical waste) under the Department of Environment (DOE);
2. Clinical (medical) waste under the Ministry of Health (MOH); and
3. Municipal solid waste (MSW) (i.e. non-hazardous waste) under the Ministry of Housing and Local Government (MHLG).

For example, in Kuala Lumpur (KL) City, waste generation rate is continuously rising up every year owing to the increasing population, consumerist attitude of the people living in the metro cities, and commensurate with the increased purchasing power and living standard of the people. It is expected that the amount of solid waste generated in Kuala Lumpur will be doubled in the next twenty years (Saeed et al., 2009). The amount of waste generated continues to increase in response to rapid increase in population, accelerated urbanization and industrialization process.

The official figure for Kuala Lumpur city's population in 2007 was 1.604 million as reported by the Department of Statistics, Malaysia. The daily quantity of waste generation in Kuala Lumpur city alone was projected to increase from 2620 tons in

1995, 3070 tons in 2000 and up to 3478 tons in 2005 (Saeed et al., 2009); with more influx of population from other cities and rural areas to the capital city, an exponential increase is predicted for the coming years. The city was reported to have an estimated solid waste generation of 4000 tons per day in the year 2000 (Murad and Siwar, 2006).

1.3. Municipal Solid Waste Management Policy and Regulations

Traditionally, the Malaysian local authorities control the management of solid waste in Malaysia (Chong, 2010). The breakthrough in Malaysian solid waste management can be dated back to 8th National Plan (1996-2000) and 9th National Plan (2001-2010). In the 8th National Strategic Plan, the decision to privatize waste management was taken, and two companies were awarded central and southern contracts. In the 9th National Strategic Plan additional one more company was given the responsibility to control and manage solid waste in the northern region.

Table 1.1 shows the privatization policy for handling waste collection and cleaning in Malaysian west peninsular with the sole objective of achieving a cost-effective solid waste as well as to improve the quality management of MSW in the country. In addition the States of Sabah and Sarawak have their own companies. Under the 9th National Strategic Plan, the National Solid Waste Management Department (NSWMD) was established in 2007, under the Ministry of Housing and Local Government (MHLG) as per the Act 2007. This Act consists of Act 672 and Act 673, which are new additions and also the three amendment acts such as Act 1311, Act 1312 and Act 1313 (see Table 1.2). According to the Environmental Quality Act 1974 (amended in 2009), landfill means “a waste disposal site for deposit of solid

waste into land". "Solid waste has the same meaning assigned to it in the Solid Waste and Public Cleansing Management Act" (Act 672), and "solid waste transfer station" means "another facility for further processing, treatment, transfer or disposal".

Table 1.1 Descriptions of three MSW companies in operation

Company's Name	Operation regions
E-idaman Sdn. Bhd. (9^{th} National Strategic Plan)	Northern regions: Perlis, Kedah, Pulau Pinang and Perak.
Alam Flora Sdn. Bhd. (8^{th} National Strategic Plan)	Central regions: Kelantan, Terengganu, Pahang, Selangor, Purajaya and Kuala Lumpur Federal Territory.
SWM Environment Sdn. Bhd. (8^{th} National Strategic Plan)	Southern regions: Negeri Sembilan, Melaka and Johor.

(*Source: The 8^{th} and 9^{th} National Strategic Plan of Malaysia*).

Table 1.2 Solid Waste and Public Cleansing Management Act 2007

Acts	Details
Act 672	Solid Waste and Public Cleansing Management Act 2007.
Act 673	Solid Waste and Public Cleansing Management Corporation Act 2007.
Act 1311	Local Government (amendment) Act 2007; amend the Local Government Act 1976.
Act 3112	Street, Drainage and Building (amendment) Act 2007; amend the Street, Drainage and Building Act 1974.
Act 1313	Town and Country (amendment) Act 2007; amend the Town and Country Planning Act 1976.

Source: Environmental Quality Act 1974 Amendment 2009 in Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009.

Act 672 provides a very significant monitoring mechanism in managing solid waste in Malaysia. It is stated clearly that the Federal Government needs to approve and license any construction of new facilities, alteration, closure and operation. The

license requirement ensures that only entities considered fit and proper for the purpose may venture into the waste business to ensure quality of the services and compliance with regulations enacted under the waste management laws (Kabit, 2010).

Rules and regulations pertaining to solid waste management in Malaysia are governed concurrently under the list of the 9th National Strategic Plan of the Federal Constitution (Nasir, 2007). Under this list, public health and sanitation works can be carried out by the Federal Government, State and the Local Authorities. The work includes collection, transportation, treatment and disposal of wastes.

Despite bringing up prosperity, economic growth has also resulted in adverse impact due to industrial pollution and degradation of the urban environment (Aye and Widjaya, 2006; Afroz and Masud, 2010). The management of solid waste in Malaysia is under the responsibility of the Local Government. Solid waste management can be defined as the discipline associated with the control of generation. Although there has been an aggressive economic development in Malaysia, the solid waste management is still relatively poor and haphazard (Saeed et al. 2008/2009). Waste minimization strategic control will be the objective of Kuala Lumpur for the coming few years in order to achieve the UN Agenda 21 that place emphasizes on human and environment.

Kuala Lumpur City has spent roughly about RM 25.2 million in 2009 for managing the cost of solid waste alone. The comparative figures of the damage costs of haphazard due to open dumping landfill being practiced were RM 178.30 per ton

(Saeed et al. 2009). In 1979, the Environment Protection Society Malaysia (EPSM) called for an official policy for recycling and recovering solid wastes (Saeed et al. 2008). Moreover, EPSM statement recommended separation of wastes component at its generation point. Separated waste must be placed in separate containers and the organic waste should be used in biogas plants for composting and/or for energy generation. Domestic rubbish collection was far from satisfactory. The industrial sites on the other hand are mainly concentrated at Kuala Lumpur, Pulau Pinang and Johor (Saeed et al. 2009). With the increase in municipal waste generation from 0.90 kg/capital/day in 2005 up to 0.95 kg/capital/day in 2009, there is an urgent need for a better managed disposal option (JICA, 2010; Saeed et al., 2009).

1.4. Problem Statements

With the rapid urban development, Pulau Pinang currently is the fifth highest in terms of population (DOS, 2010), and second in industrial activities in Peninsula Malaysia, after Kuala Lumpur. However, it is still facing a poorly managed sanitary landfill. The old, active and inactive landfills were not located accordingly. Presently, most of the disposal sites in Malaysia are practicing open dumping landfill with no environmental control measures (LGD, 2005) which considers level zero (L0). Nevertheless, the State Local Governments started adhering to new trends of sanitary landfill with an engineered facility for the disposal of solid wastes, designed and operated to minimize public health and environmental impacts. The Federal Government has also given positive support and permission towards this trend of urbanism planning. In the year 2000, there were more than 230 landfill sites across Malaysia as per Ministry of Housing and Local Government and it was estimated that by the year 2004 the landfills would reduce to 170 registered disposal sites (Lee, 2007). However, only few

have been designed taking into account the locality in a proper way. This leads to unsanitary and unhygienic environment. Some landfills are located near to coastal or shore areas where it requires higher design techniques and funding.

For instance, the Pulau Burung landfill site (PBLS), is located near the shore area, and is primarily in an area gazette for conventional ecosystem comprising of mangrove forest which is significant for fish breeding environment and saving the flora and fauna (MASTIC, 2002). Similarly, political influences or inclinations play a negative role in planning sanitary landfill through improper choice of land preferred for or to be landfill. Open landfill or unplanned landfill has caused lot of problems to human being and the environment (Heimlich, 2011; Ludwig et al. 2003). The well-known problems associated with landfill project are the contamination of air of the surrounding area by landfill's gases and groundwater table contamination by leachate (Aziz et al. 2004) due to the presence of high amount of rainfall and subsequent degradation mechanism of organic waste in the landfill with the existence of some microorganisms (e.g. bacteria, fungi, etc) (Umar et al., 2010). The open dump was a hazard because of its potential for producing leachate, becoming a rodent and insect breeding ground, and its general health dangers (Heimlich, 2011). Malaysia being in a tropical area faces the problem of mix up of municipal organic waste with rainfall. There have been a number of research works on finding optimal solution to leachate treatment (Aziz et al. 2011; Bashir et al., 2009; Umar et al., 2010).

Implementation of the proper method of new landfill siting that follows local or Federal Government's guidelines can play a major role in town planning initiates. This will reduce the negative impact of landfill to the environment over a long period.

Considering the problems due to the existing landfills, local municipality council is looking for alternative plans in locating sanitary landfill that can take into account all the environmental and health impacts of the people in the surrounding area. Thus the current study is focused on assisting Majlis Perbandaran Seberang Perai (MPSP) in its identification and evaluation of the landfill site properties.

Ampang Jajar, Jelutong and Pulau Burung are three of the famous landfill sites in Pulau Pinang. Ampang Jajar landfill site (AJLS) located in Seberang Perai Tengah (SPT) (i.e. central district of Seberang Perai), Pulau Pinang, is currently converted to a transfer station. Jelutong landfill site (JLS), on the island, is restricted for garden, construction and demolition waste, and has reached its capacity; it is an inactive landfill. Presently, PBLS is active in its operation and is identified solely for domestic waste. Most landfills in Pulau Pinang were formally constructed with minimum evaluation procedures.

As part of the town planning process, local authorities must consider certain key environmental criteria while planning for future landfill sites as an alternative to the current PBLS. The tidal effect from the sea side and public health impact are the current drawbacks of PBLS (Frihy et al. 2006; Aziz, 2008) which is located in the coastal area in Nibong Tebal. Therefore, attention must be made to tackle the aforesaid disadvantages. Local decision makers such as elected representatives and appointed advisors (i.e. environmental officers, heath inspectors, legal officer, etc.) and experts (e.g. landfill engineers and technical advisors) must play a significant role in deciding the location for future sanitary landfill project (Saeed et al., 2011).

Jelutong landfill, Ampang Jajar landfill, Kuala Sepetang landfill, Kulim landfill and Air Hitam landfill sites each has current siting problem i.e. houses/flats Jelutong highway, wastewater treatment plant for Jelutong landfill site; residential area expanding , highway, Juru river, transfer station for Ampang Jajar landfill site; North-south highway, Kamunting river, plastic factory for Kuala Sepetang landfill site; Kulim High Tech school and industrial area for Kulim landfill; urban residential area for Air Hitam landfill site.

In Kuala Lumpur urban city a total of seventeen unsanitary waste disposal sites were closed because it was a risk to the environment. The current operated sites (around 32) will be upgraded from unsanitary to sanitary landfill sites and provided with leachate treatment plant (Hmetro, 2012). The State Government of Kedah is identifying a new site which is more appropriate to replace the solid waste disposal site near the home town of Pineapple White Water Village. This is causing odor and fly problem to the people living around and a lot of complaints received as per the Chief Minister (Johordt, 2012).

Due to high number of open landfill practice in Malaysia, there is big amount of greehouse gases (GHGs) released directly into the athmosphere. This is considered a big loss of energy (Appendix M). For example, one part of Bukit Tagar Sanitary Landfill Site, operated for two years and closed in Nov., 2007 generating 1.0 MegaWatt of electericity used for operation of the landfill itself (Ali, 2012). Gas piping system installation is necessary to avoid incidents of fire as high as 300 feet (91.4 meters) piles trash fire at illegal disposal site in the Paper River Village, Gombak, Selangor, in Sep., 2009 held in connection with the releases of some

methane (CH_4) (Abihulwa, 2012). The Malaysian society is not particularly inclined and aware to the recycling effort of the country. Though the recycling strategy launched earlier in the 1990s and is expected to reach 22% by 2020, however its achievement is only 5% in 2011. This figure seems to be far less when compared with developed countries like Japan, with percentage of 50% of recycled items. This is one of the reasons for dramatic increase of municipal waste in the country. With the absence of funds, experts, public awareness and improper management leads to the existence of large number of open landfill sites (Ali, 2012). The cost effective achievement is an important figure in waste management. The construction of the landfill in Malaysia would cost around RM120 million with a capacity of 3,500 tons of daily domestic waste (Abihulwa, 2012). Seven sanitry landfills were distributed as follows; three landfill site in Selangor, one site each in states of Kedah, Johor, Pahang and Melaka (Ali, 2012).

1.5. Description of the Study Area

The State of Pulau Pinang comprises of Pulau Pinang Island (PPI) and Seberang Perai (SP) on the main land. More details of the study area are presented in Chapter Four.

1.6. Objectives of the Study

The aim of this study is to assess relevant environmental and engineering criteria for planning of new sanitary landfill sites which will be appropriate for Pulau Pinang. Its main focus is to statistically determine the most suitable sanitary landfill site parameters quantified by weighting preferences of decision makers from selected experts in landfill management in Malaysia. The results will form the input

parameters for geographic information system (GIS) suitability analysis model that implements quantitative MCE (multiple criteria evaluation) technique in determining the feasible sites for new sanitary landfill. Emphasis of the sensitivity assessment will be on the effect of criterion weight and landfill criteria towards the feasible sites. Accordingly, the current study attempts to meet the following specific objectives:

1. To determine important landfill site criteria pertaining to engineering and environmental aspects through direct input from decision makers in landfill management community.
2. To evaluate the input data (decision criteria) collected using rigorous statistical and mathematical models such as T-test, ANOVA, PCA, AHP and WLC.
3. To identify the suitable weighted decision model for quantifying landfill's criteria based on decision-makers' preferences, that contributes significantly in designing sanitary landfill suitable for Pinang.
4. To evaluate the feasibility of GIS multiple criteria suitability model utilizing the weighted matrix of decision makers in determining feasible sites for new sanitary landfill in Seberang Perai Selatan (SPS) that are sustainable to human and the environment.

1.7. The Importance of the Study

Municipal solid waste has become an important issue in the society today because of two main reasons i.e. solid waste if not managed well may cause damage on the environment and at the same time affect the health of human population. Thus, municipal solid waste in this era forms a new challenge in line with the rise in population everywhere. Disposal of these wastes is the concern of many municipalities all over the world. Therefore, spatial decision making is very critical

while looking for important solutions in finding new locations for sanitary landfill by applying criteria that meets the needs of the people and their environment. Managing sanitary landfill with respect to site selection and design operation is a complex issue and very time consuming. Selection of sanitary landfill site differs from one country to another and is duly based on manpower, funds, and their willingness to appreciate environmental awareness. Factors that can influence decisions on urban landfill planning and management practices are the national and international polices, public awareness, politics, and regional, biophysical and infrastructural conditions.

This study was aimed at tackling the issue of searching the proper sustainable manner of siting sanitary landfill sites in Malaysia, using Pulau Pinang as the study area. In future, this approach could be extended to other target areas in Malaysia. The primary objective is to address the importance of local decision maker's view in drawing new rational procedures without external influence in fulfilling the needs of environmentally sustainable urban planning development. This research also utilizes statistical packages, spreadsheet programming and GIS software to analyze, build the database, and display digital maps of the study area and interpret the research findings.

1.8. Hypothesis

As part of a proposition set forth as an explanation for the occurrence of some specified groups of phenomena in this research, several hypotheses related to the definition of decision maker are explained as follows:

- All decision makers working in the field of landfill engineering and related departments share the same experience irrespective of their age and hence there is

no significant difference pertaining to experience and age in decision making with respect to new landfill location.

- The decision makers working in different positions and departments in landfill management community in Malaysia share the same opinion and hence there is no significant difference in their decision making with respect to new landfill location.
- Some of the decision makers who are currently working in various government and private sectors in Malaysia face common environmental and landfill issues, and hence there is no significant difference in their idea with respect to new landfill location.
- Decision-makers' knowledge related to factors and objectives in the hierarchy mode are similar and hence there is no significant difference in preferences of the decision makers with regard to new landfill location parameters.

1.9. Scope of the Thesis

The research is focused on the aspect of urban planning in line with the implementation of Malaysian DOE guidelines for siting new landfill project. In addition, the research involves participation of related decision makers through comprehensive qualitative survey in acquiring the relevant land fill siting criteria making allowance for the nature and condition of the study area. Their opinion or preferences on parameters (defined as factors/criteria and sub-criteria) will be tested in the landfill siting model for the case study problem in Pulau Pinang. This research has designed a hierarchy decision model where pairwise comparison of criteria is performed. A total of 21 parameters (criteria) are considered, mostly adopted from the general parameters in Malaysian DOE's guidelines that vary from one state to

another. The decision makers are given appropriate allocation of time to compare and decompose their preferences based on the importance of the criteria towards Pulau Pinang case study scenario.

As for the research outcome, it has applied the best management practice where local decision makers are directly involved and benefitted with siting of future landfills. Nevertheless, the limitation of this research will be that it only applies to Pulau Pinang where some of the results may particularly be location-specific, dependent of local decision makers' knowledge, logical assumptions and their level of awareness during the provisional survey. Any attempts to make the result universal and applicable to other states must be done with utmost care by applying additional specific criteria of that area.

Some factors and properties were not considered or beyond the scope of this study. For example, landfill's gas collection technology, leachate treatment, and groundwater resource properties such as direction, volume, velocity and depth were not included in the research. Additionally, certain criteria cannot be spatially presented through digital maps for the input in GIS spatial model due to the nature of the criteria or its attribute data.

1.10. Structure of the Thesis

This thesis is organized in six chapters. Chapter One provides the introduction that mainly covers general information of waste management in Malaysia (i.e. Kuala Lumpur and Penang) and the current landfill site in Pulau Pinang, the problem statement, research objectives, and the scope of the research. The issues concerning

the landfill technology are discussed in Chapter Two. Chapter Three presents an in-depth review of the background for this research wherein previous work related to the proposed study is presented. Relevant theories and techniques pertaining to landfill have been presented. Factors that should be taken into consideration for the project planning of new landfill siting have been summarized. A review of all the available techniques particularly the integration and usefulness of AHP/GIS has also been presented.

Chapter Four explains the research methodology. The application of hierarchical decision model, advance statistical definitions, the concept of weighting using analytic hierarchical process (AHP), and GIS suitability model using multiple criteria technique for landfill siting, are explained in detail. Chapter Five illustrates the research findings, and how the objectives of this study are achieved. Detailed discussions on the results and interpretation of each finding are also provided. Finally, Chapter Six presents the conclusion and recommendations for future study.

CHAPTER TWO

SANITARY LANDFILL TECHNOLOGY

2.0. Introduction

Landfills are well-engineered and well controlled land disposal sites for solid nonhazardous waste in which the delivered wastes are spread and compacted in layers a few feet thick. At least once a day the wastes are covered with a layer of earth (i.e. soil) and then compacted again (Heimlich, 2011). There are more than 230 landfills in Malaysia and most of the landfill sites are classified as unsanitary sites (where only less than 8% are classified as sanitary landfills) that provide leachate treatment plants and install-designed gas system. These landfill gas emissions are released directly to open air resulting in air pollution, insect infestation, waste scattering, pungent smell, groundwater and surface water pollution, and other inconveniences to the public and the environment at large. When untreated leachate pollutants are discharged into water resources (rivers), they may cause damage to the ecosystem and drinking water as well. Moreover, despite the abundant amount of methane gas discharged at these sites, there are no landfill gas collection centres or business establishments available for tapping this source of energy.

2.1. Detailed Environmental Impact Assessment (DEIA)

DEIA is a comprehensive study of the expected negative impact on the environment when a proposed project would take place. The study may identify, assess, evaluate

and communicate information about the project and carry out mitigation measures prior to project approval and implementation (DOE, 2010). DEIA provides machinery decision making tools towards better actions. The DEIA report is aimed at preventing associated environmental problems and also to reduce any costly mistakes in project implementation. This may be due to (1) damages on environment may arise during project; and (2) modification of project that is required so that the action is environmentally accepted. DEIA is necessitated for landfill project under section 34A of the Environmental Quality Malaysian Act, 1974. The preparation of EIA report depends of the project type and there are DOE guidelines published by the Ministry of Environment, Malaysia.

2.2. Procedure of DEIA in Malaysia

The Malaysian DEIA procedures contain three main steps: preliminary assessment, detailed assessment and review; these steps are described as shown in Figure 2.1. Preliminary assessment is the stage of the DEIA procedure that should normally be started at the pre-feasibility study stage of the development of an activity. This step is an initial assessment of the impacts owing to the activities that are prescribed. Project options are identified at this stage and any significant residual environmental impact should be known. The preliminary report that is prepared is reviewed by an internal technical committee within DOE. However, where decision makers and experts within the Department are lacking, assistance from other government and non government agencies may be required. The detailed assessment step is undertaken for those projects for which significant residual environmental impacts have been predicted in the preliminary assessment step. The assessment should continue during project feasibility, and the DEIA report be submitted for approval by the director

general of environmental quality prior to the giving of approval by the relevant Federal or State Government authorities for the implementation of the project. Detailed assessment is carried out based on specific terms of reference issued by the review panel which should be appointed by the director general, and their duty is to review the report.

The third step is to review the DEIA reports prepared by the DOE, and the recommendations of the review panel are transmitted to the relevant project approving authorities for decision making on the whole project. The period allocated for this preliminary assessment report and review is one month, while that for a detailed assessment report is two months. DOE maintains a list of experts who may be called upon to sit as two members of any review panel established. The selection of the experts depends on the areas of environmental impacts to be reviewed. Some DEIA features are shown in Figure 2.1.

The approving authority includes: (1) the National Development Planning Committee (NDPC) for Federal Government sponsored projects; (2) the State Executive Council (EXCO) for State Government sponsored projects; (3) the various local authorities or regional development authority (RDA) with respect to planning approval within their respective area; and (4) the Ministry of Trade and Industry or MIDA for industrial projects. This approving authority has the right to approve or negate the project. The recommendations arising from the review of the EIA reports should be forwarded to the relevant project approving authorities. At the completion of the review period for a detailed EIA, a detailed assessment review document is issued by the review panel. This document may include: (1) comments on the detailed assessment report; (2)

recommendations to the project proponent and the project approving authority including any specific conditions attached to the project approval; and (3) recommendations for environmental monitoring and auditing.

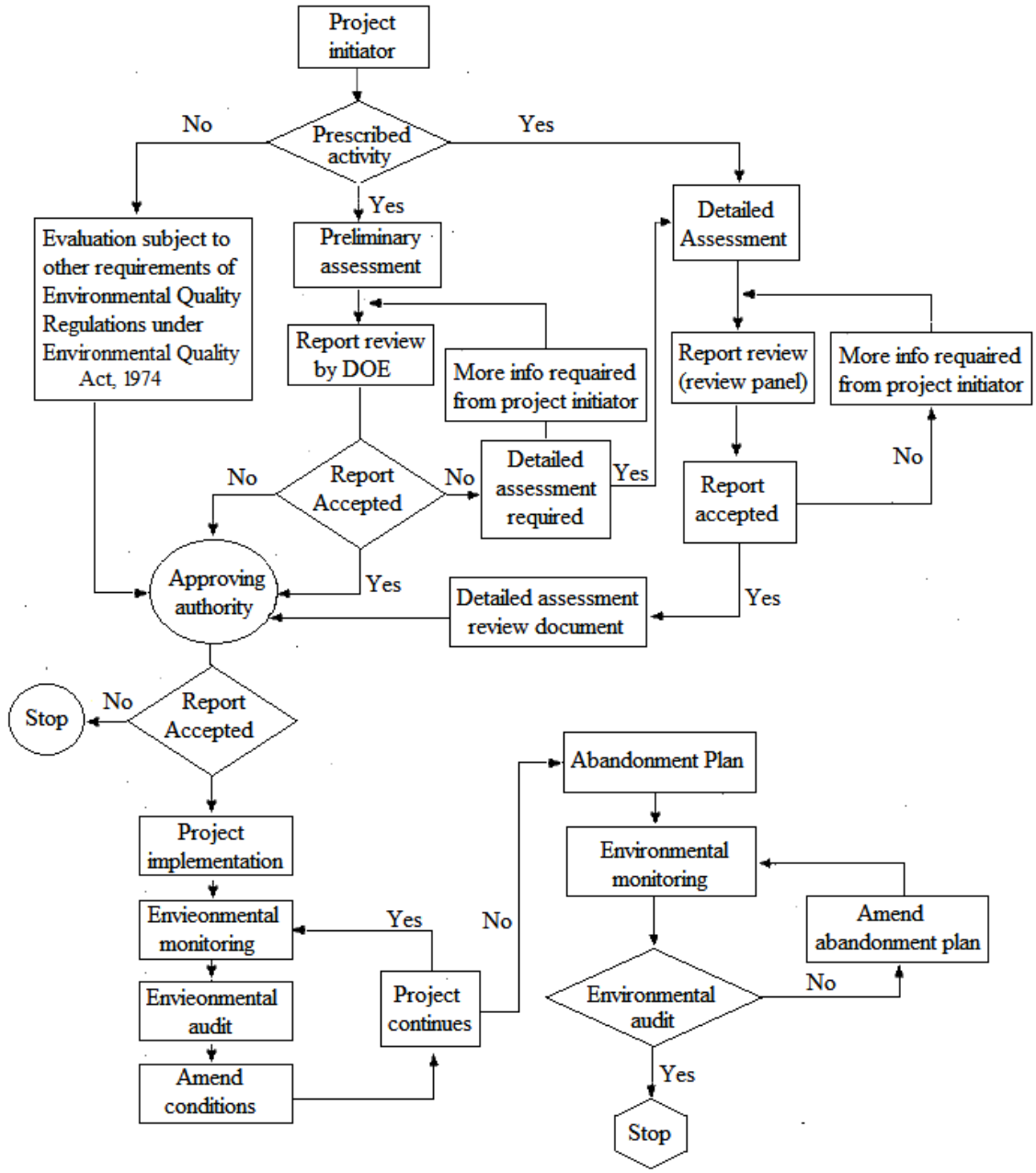

Figure 2.1 DEIA diagram framework procedure.

(*Source: MAB Environmental Consultant Sdn. Bhd., 2010*).

2.3. Integrated Project Planning Concept

The DEIA procedure in Malaysia is designed to follow the integrated project planning concept as shown in Figure 2.2. The features of the concept include the following: (1) at the onset, during the project identification stage, the need to conduct an EIA study is also determined; (2) if the project requires preliminary assessment, it is done in parallel with the pre-feasibility study for the project; (3) similarly, if detailed assessment is required, it is conducted as part of the Feasibility Study for the project; and (4) the preliminary assessment and detailed assessment reports are reviewed simultaneously with the pre-feasibility and feasibility reports, respectively, before a final decision on the project is made.

During project construction and project operation, environmental monitoring is carried out. The concept is recommended to be followed to minimize project delay and improve project planning.

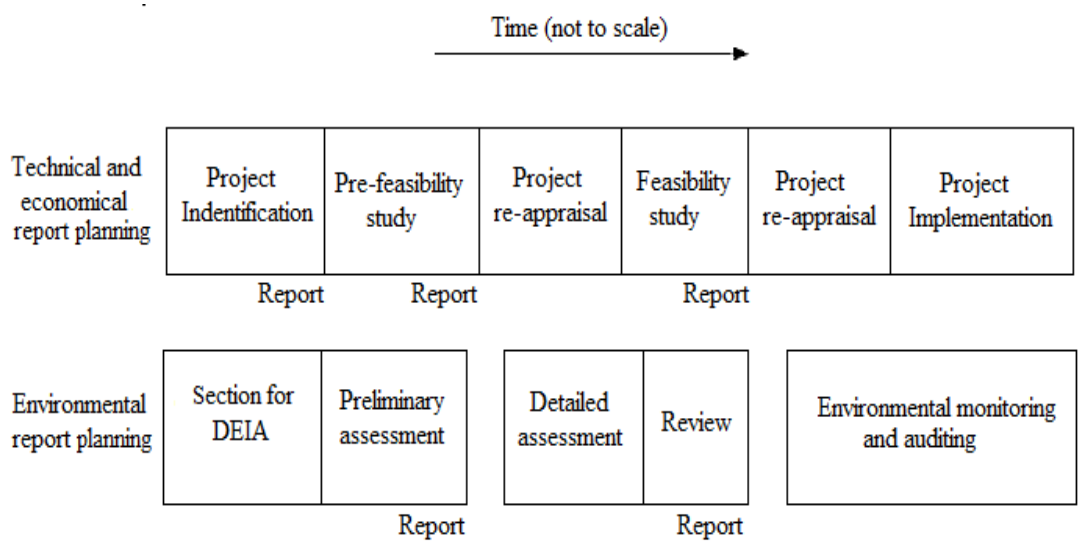

Figure 2.2 The concept of integrated project planning.
(*Source: MAB Environmental Consultant Sdn. Bhd., 2010*).

2.4. The DEIA Reports Processed and Approved

The preliminary DEIA report should be approved by the DOE State Officer at the headquarters. However, DEIA project within the EEZ (exclusive economic zone) at both States of Perlis and Kedah and involving other states are subjected for further evaluation. The DOE organizational structure is led by the State Director who has the authority to accept or reject the DEIA report based on one stop agency meeting comprising of DEIA technical committee and other related departments or agencies.

Their comments, verifications and recommendations are required for certain cases like sanitary landfill project. The State Director is assisted by environmental control officers and assistant environmental control officers. DEIA organizational structure for process and approval is shown in Figure 2.3.

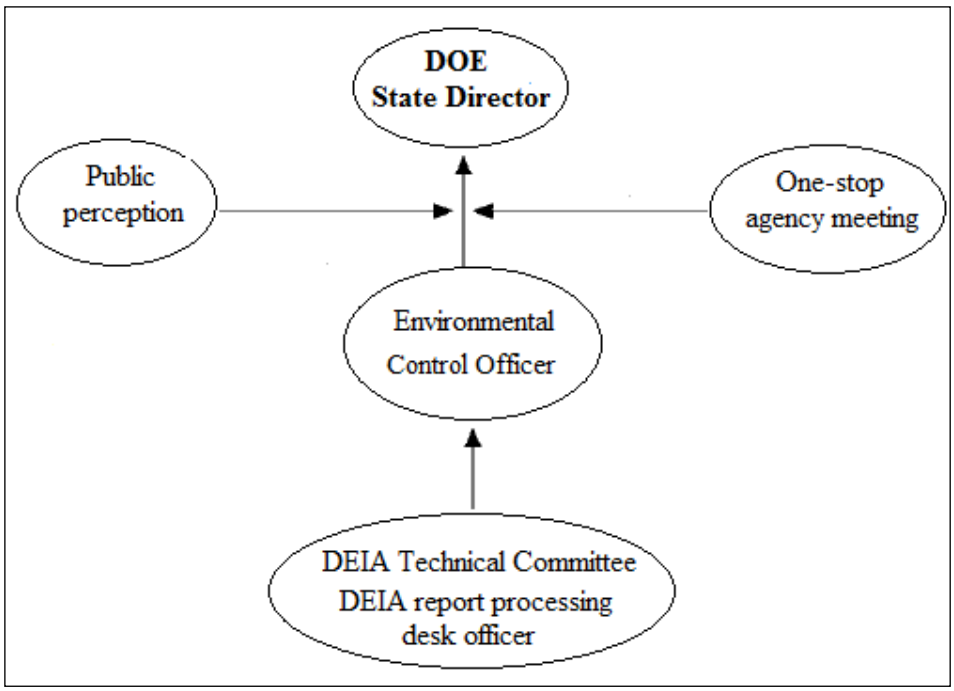

Figure 2.3 DEIA organizational structure for process and approval.

(*Source: MAB Environmental Consultant Sdn. Bhd., 2010*).

The director of prevention division heads the structure of DEIA organization and is assisted in general by two officers who are head of evaluation section and senior environmental control officer chairing the DEIA technical committee meeting. The technical committee examines the preliminary DEIA reports. The one-stop agency meeting is conducted when necessary, and verifications and comments are noted. Figure 2.4 shows the structure of the DEIA organization.

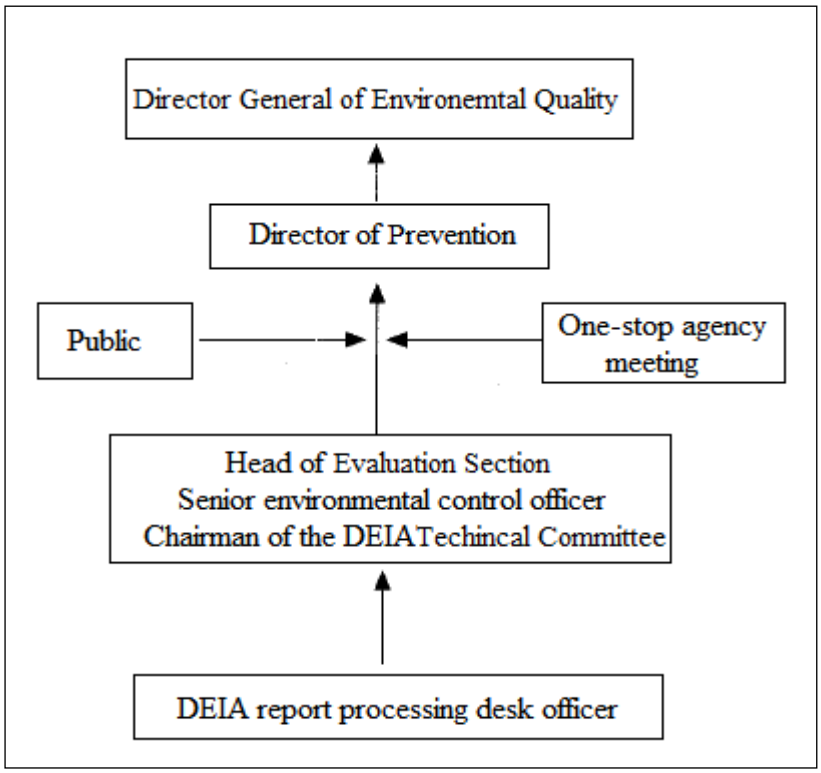

Figure 2.4 Structure of the DEIA organization.

(*Source: MAB Environmental Consultant Sdn. Bhd., 2010*).

2.5. Detailed EIA Reports

The DEIA report approval procedure conducted by the organizational set-up that is headed by the Director General of Environmental Quality as the chairman is responsible for approving or rejecting the DEIA report. He is assisted by the Director

of Prevention Division, who also functions as secretary to the DEIA ad hoc review panel. Figure 2.5 illustrates the organizational structure of the DEIA.

The DEIA review panel comprises independent members of relevant disciplines, from different organizations such as universities and non government organizations (NGOs). Their duty is to critically review DEIA reports and devise recommendations to the relevant project approving authorities within certain period. DEIA reports are also displayed at all DOE Offices as well as public and university libraries, for public comments. The public is widely notified through the mass media when and where the DEIA reports are available for review and comment. The environmental control officers cooperate and asses the DEIA report processing desk officers in order to evaluate the total reports of the review panel and the DEIA report. The desk officers are trained in different disciplines including environmental engineering, agricultural engineering, chemical engineering, civil engineering, electrical engineering, mechanical engineering, environmental sciences, biology, chemistry, environmental studies, physics, economics, sociology and ecology.

2.6. Landfill Technologies

Landfill is a method of dumping the wastes. The engineered landfill is the modern one that may need a budge from the respective government to fulfill the basic public health control and environmental protection. Landfill has been classified based on the existence of air (O_2) in the entire waste of landfill system that is to be used by the microorganisms to survive and be active in biodegradation process. Basically, there are three main types of landfills i.e. aerobic, anaerobic and semi aerobic. These types of landfill are also called hygienic or sanitary landfills.

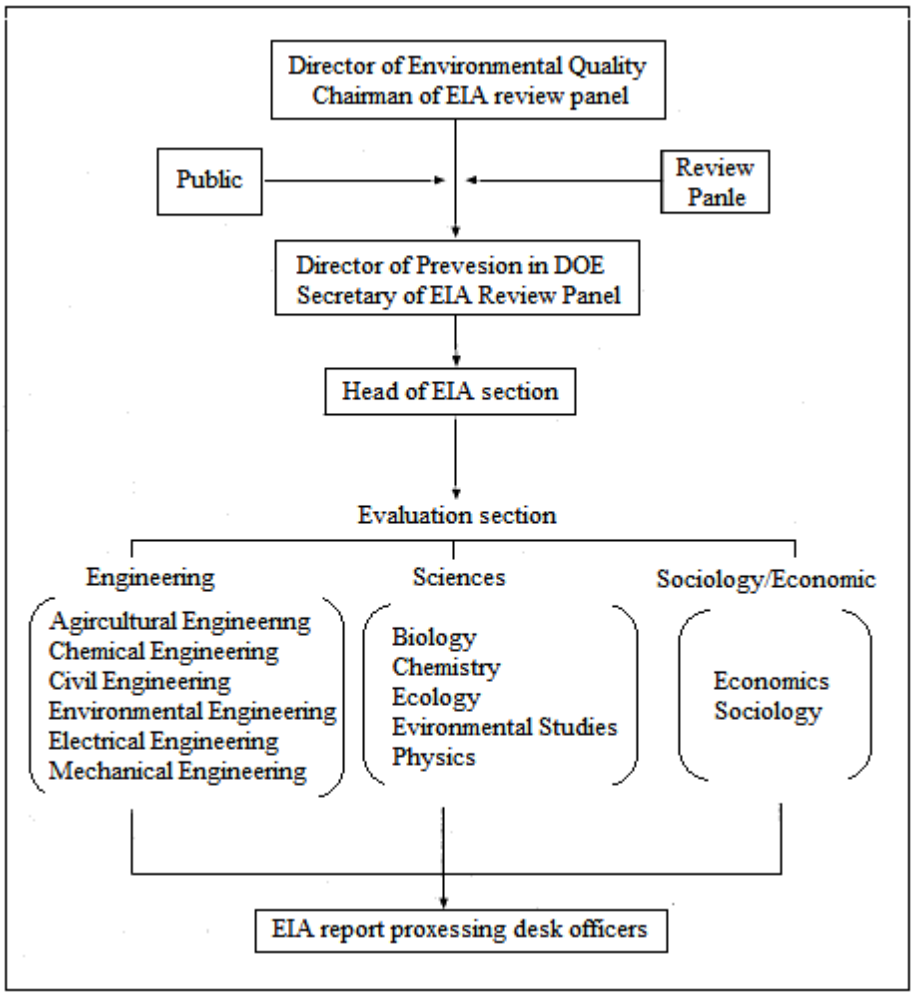

Figure 2.5 The organizational structure of the DEIA.

(*Source: DOE website, 2010*).

2.6.1. Anaerobic Landfill

In this type of landfill no air is supplied to come in contact with the landfill and mix up with the domestic solid waste. The activities of microorganisms take place mostly in the absence of fresh air. However, this leads to disastrous environmental impact and potential health hazard due to toxic landfill gases (e.g. CH_4) under anaerobic condition (Cornelius, 2005).

The leachate result has many complicated components like toxic matter, strong offensive odour and dark leachate in colour. This makes the leachate treatment

difficult and costly; therefore it is considered as one of the main disadvantages of this method. Non separation of domestic solid waste also results in very complicated leachate structure. An example for this method is Kuala Sepetang landfill site in Taiping, Perak. Figure 2.6 shows the schematic of anaerobic landfill system where there is no air being pumped into.

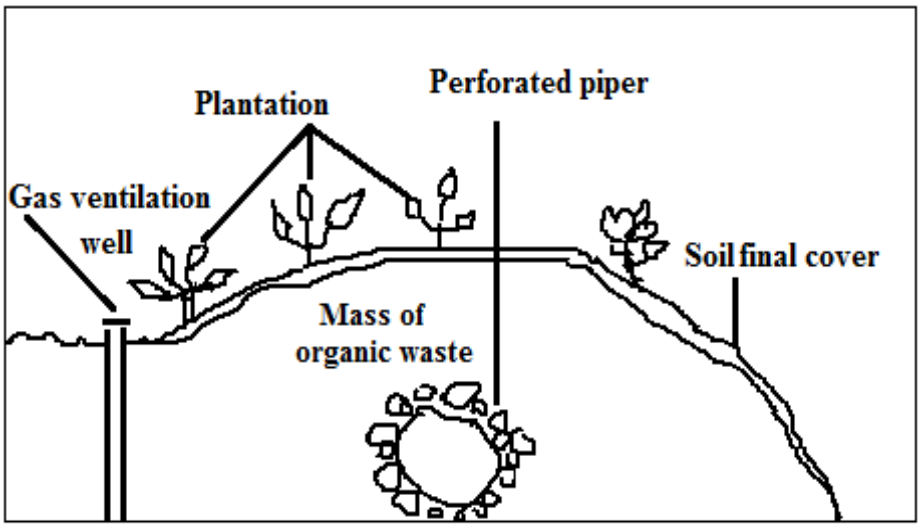

Figure 2.6 Anaerobic landfill systems (Matsufuji et al., 1993).

2.6.2. Aerobic Landfill

This type of landfill receives air which is pumped into the domestic solid waste in the landfill. This helps to have a clean leachate better than the one received from the system, brown in colour and has easier and cheaper treatment. The high-density polyethylene (HDPE) pipes are generally perforated. The entire O_2 activates the microorganisms which consume the organic matter faster (i.e. decomposition), and this leads to less odour due to the reduction of methane gas and total life span of the site. The disadvantage of this type of landfill is that the maintenance of the pipe system is higher. Figure 2.7 shows an aerobic landfill system with an air pump system.