Malaysian Journal of Science ***29*** *(3): 231-238 (2010)*

Closure and Post-closure of Landfills in Malaysia: Lessons Learnt

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Received on 7th August 2010, accepted by 9th November 2010

ABSTRACT The disposal of approximately 90% of more than 30,000 tonnes of municipal solid waste (MSW) generated daily into 167 sanitary and non-sanitary landfills depict the importance of landfill in Malaysia. The objective of this paper is to explore issues pertaining to the closure and post-closure of landfills in Malaysia using four types of disposal facilities. The closure of a properly planned Air Hitam Sanitary Landfill (AHSL) saw the management of the closure and post-closure activities at the utmost efficiency. The landfill has become the blueprint of energy conversion technology with a capability of 2MW. Unfortunately, closure of non-sanitary disposal sites were not as successful as that in AHSL. Kundang landfill, a non-sanitary landfill was ordered to be closed immediately in 2007 since it continues to contaminate the surrounding area. Regardless of its non-active status, untreated leachate with 280 440.00 g/day of COD pollutes the river which may affect the environmental quality of the area. Similar scenario was also observed at other sites, namely two reclaimed ex-mining land for commercial and residential area. One was operating as dumping area before its closure in 2000. It was developed and converted into residential and commercial area including terrace houses, high rise apartments, and commercial buildings. Improper planning of the closure resulted with contamination of arsenic (64.4 mg/kg) and mercury (11.5 mg/kg) to the surrounding soil. Another case study saw extensive reclamation of an ex-mining pond with MSW including domestic, industrial, and construction debris. The lack of appropriate planning of the conversion of the land-use resulted with contamination of surface water with hydrogen sulphide alarmed the residents. The area recorded presence of hydrogen sulphide gas which reached approximately 200 ppm. Thus, it can be concluded that proper closure and post-closure strategies are crucial for landfills and disposal sites. The need for proper policies and guidelines on post-closure and the uniformity of these regulations would ensure standardised landfill remediation with minimal environmental impacts.

(**Keywords**: Reclamation, ex-mining areas, environmental impacts)

INTRODUCTION

Disposal of solid waste into landfills and other waste disposal facilities has been the most economical strategy to manage solid waste in many countries. Since it involved simple and easy technology, it is also favoured because of its low cost requirement [1]. The landfilling method applied differs from one country to the other as each nation has its own rules and regulations pertaining to solid waste disposal [2, 3, 4, 5]. Other option in waste disposal includes burning where it was a practice used to be rid of unwanted materials [6,7]. However, burning of waste by individual household became inappropriate when larger housing schemes emerge over the years.

As a result to the expansion of urban population in Malaysia in the 1960s, the disposal of municipal solid waste (MSW) was handled by an authorized body. Until 1983, municipalities and local authority were responsible to manage MSW in the areas within their jurisdiction [8]. In 1990s, open burning has been totally banned that wastes were no longer burned but disposed off into landfills [8]. This had caused the emergence of many landfills throughout the nation.

Unfortunately, the concept practiced back then was the typical "out of sight and out of mind" that the environmental concerns were not given the proper attention. Most landfills were just mere open-dumps without appropriate facilities and measures to curb pollution emissions. The siting of a landfill was based on the convenience of the waste managers to reduce transportation cost which resulted with landfills being located at the fringe of a town in 'unwanted' lands [9].

To date, the disposal of approximately 90% of the 30,000 tonnes of municipal solid waste (MSW) generated daily into 167 landfills indicates the importance of landfill in Malaysia. Less than 10% of the total landfills throughout the country are sanitary landfills with appropriate technology and facilities while others are typical dumping grounds which emitted leachate and landfill gases without sufficient monitoring.

Due to the scarcity of land and increase in land price, municipalities and city councils saw fit to redevelop ex-dumping sites to accommodate the high demand for housing areas. However, improper closure and post-closure of the dumping areas complicate the matter with waste residue contaminations to soil and water bodies [10]. The objective of this paper is to explore issues pertaining to the closure and post-closure of landfills using four Malaysian case studies.

MATERIALS AND METHODS

Four closed disposal sites were identified for the study which included Air Hitam Sanitary landfill, Kundang landfill, and an ex- landfill and an ex-mining area in Selangor. Samples were collected from these areas and analyzed to determine the pollution intensity. Among others are leachate samples, groundwater samples and gas monitoring. The results obtained were analyzed to derive the impact of the landfill to the environment.

RESULTS AND DISCUSSIONS

The consecutive sections discuss the issues related to the closure and post-closure of the four case studies in detail.

Air Hitam Sanitary Landfill

Air Hitam Sanitary Landfill (AHSL) was constructed with the appropriate technology which includes lining and piping systems. This engineered landfill was to accommodate the disposal of MSW from Klang Valley with an annual capacity of 550,000 tonnes. The landfill begun its operation in 1995 where landfill gas particularly methane is harvested. Originally the landfill was planned for closure in 2007, however, due to the 3% increase of MSW generated every year the landfill space was exhausted three year earlier than planned. The total deposited waste reached approximately six million tonnes. In addition to the lack of space for waste disposal, the landfill has to be closed due to the encroachment of residential area to the landfill's buffer zone. The increase in population density within the area made it no longer suitable to receive and manage waste [11]. The closure of this properly planned landfill was not of an issue due to the proper leachate and gas collection system. Leachate collected is sent to leachate treatment plant where chemical and biological treatments are conducted.

Typical of leachate from sanitary landfills in other developing countries, the raw leachate contained high concentration of pollutants namely BOD (3,500 mg/l) and COD (10,200 mg/l). Thus, the on-site leachate treatments facilities play a significant role to remove the pollutant so that the effluent discharged from the landfill are within the limit allowed. The quality of leachate adheres to the Malaysia EQA 1974.

In addition to leachate management, the landfill gas system is also properly regulated. An active system has been implemented where landfill gases were extracted from vertical wells. Approximately 50-60% are methane (CH_4) while CO_2 and other gases contributes the remaining 50-40%. CH_4 harvested from the landfill is sent to two power generation plants to produce one megawatt power each. The electricity produced is sold at RM0.30 (US$ 0.08) per kilowatt hour with 5% royalty under a 15-year Renewable Energy Power Purchase Agreement [12]. With the newly approved policy on the national sustainable energy quotas, the economic value of the electricity produced is expected to increase. The energy conversion technology with a capability of 2MW applied in AHSL has become the blueprint for other landfills in the country.

The closure of this landfill is conducted according to plan followed by post-closure procedures. The closure of the landfill involved the capping of waste cell with non-permeable liner which primarily containing PVC and appropriate gas venting system. This is mainly to prevent the deposited waste from getting into contact with precipitation that may generate larger volume of leachate. The gas venting system is installed to ensure a proper extraction of landfill gas. Post-closure procedures for the landfill include the layering of black soil and rehabilitation of the area with suitable plants. Overall, the closure and post-closure of the landfill was smoothly conducted in accordance to the planned procedures. However not all disposal sites in the country had undergone similar closure and post-closure procedures. Thus, some caused serious environmental problems.

Kundang Landfill

Unlike AHSL, Kundang landfill was a mere open-dumping ground which lacked appropriate lining and landfill gas management system. Situated in Rawang district, this landfill has been operating since late 1996 until it is ordered to be closed in 2007. During operation, it received 300 to 400 tonnes of waste daily from the surrounding area and the outskirt of Kuala Lumpur. Additionally, the siting of this dumping ground was to cater the critical need for MSW disposal when other disposal sites were much further.

Kundang landfill is one of the larger non-sanitary disposal sites in Selangor covering approximately 80 acres of land. Leachate flows from higher ground and accumulate on lower ground due to the fact that this landfill is a non-sanitary landfill that lack proper lining and leachate management system. During the landfills operation period, the risk of contaminations to the surrounding area was not a concern since the authority has presumed that pollutants released from the landfilling activities will be confined within the area. This is due to the records by the municipality which had indicated that this site is lined with natural clay liner that it is deemed suitable as waste disposal site.

Relying on the natural clay layer, the landfill management did not foresee any problem of groundwater system contamination with leachate. Thus, less importance was given to the management of the leachate. The leachate collected in the ponds was left unattended to mix with surface water and become slightly diluted. Eventually, it seeps into the ground or flows into the adjacent river. The pollution parameter of the leachate sample is depicted in Table 1.

The leachate which flows into Kundang river will eventually cause environmental degradation. Although the river has its own cleansing mechanism, the continuous flows of contaminants will eventually cause disruption to the balance of the ecosystem via bioaccumulations and biomagnifications. The daily pollutant load into the river system was calculated and results indicated that approximately 1,240 g/day BOD and 280 440.00 g/day COD were released into the river, as shown in Table 2.

Public uproar in October 2006 due to the leachate contamination to Klang Valley water catchment area resulted with the immediate order from the government that Kundang landfill ceased its operation. This is because Kundang landfill was identified to be one of the contributors that pollute the river system with leachate. Immediate closure procedures was implemented which included covering of the exposed areas with soil and a total stop of waste dumping.

Table 1 Characteristics of Leachate from Kundang landfill

Parameter	Kundang landfill (Urban)	EQA 1974	
		Std A	Std B
BOD_5 (mg/l)	27.5 ± 0.7	20	50
COD (mg/l)	6232 ± 1824	50	100
pH	7.43 ± 0.04	6-9	5.5-9
TSS (mg/l)	0.06 ± 0.01	50	100
Hardness ($CaCO_3$) (mg/l)	429 ± 240	-	-
Cd (mg/l)	Not detected	0.01	0.02
Cr (mg/l)	0.19 ± 0.02	-	0.05
Cu (mg/l)	0.003 ± 0.002	0.2	1.0
Pb (mg/l)	0.03 ± 0.01	0.1	0.5
Zn (mg/l)	0.06 ± 0.04	0.2	1.0
Mg (mg/l)	4.25 ± 0.42	-	-

Table 2 Impact on river pollution caused by leachate contamination

Parameter (g/day)	River adjacent to Kundang landfill
BOD_5	1 238
COD	280 440
TSS	2.7
Hardness ($CaCO_3$)	19 320
Cd	Not detected
Cr	8.7
Cu	0.14
Pb	1.22
Zn	2.7
Mg	191

Additionally, the landfill manager covered the waste cells with suitable covering material to prevent precipitation intrusion into the waste layer. Also, the whole areas were covered with geo-membrane layer. Covering of the waste cells reduces 40% of the volume of leachate generated by the landfill.

However, leachate continues to flow and contaminate the river adjacent to the landfill though in a smaller volume.

In addition to the absence of leachate treatment facility, Kundang landfill also lacked of proper gas venting system. Approximately 7 m high of perforated PVC pipes with 25cm diameter were erected to allow passive release of the landfill gas into the atmosphere. However, this installation of vertical gas pipes was not effective to collect and release the landfill gas properly.

Therefore, landfill gases were also escaping naturally from any crevices and cracks. Besides, the installation of gas pipe was a post-operational procedure. The monitoring of the landfill gas within the landfill area indicated that these gases, particularly CH_4, ranged at a low level (0.05 ppm to 2.0 ppm). It is likely that landfill gases also escape to the atmosphere passively from all possible openings.

Even though Kundang landfill has been closed, the pollutions emitted from the landfill still continue. This is mainly resulted from the improper planning of the landfill that no precautionary measures were taken into consideration neither during the operation nor the closure phase. The final procedure of the closure phase which had taken place is the planting of *Bromus hordeaceus* on the top soil cover to prevent erosion. The landfill currently is left without any post-closure activities since leachate and landfill gas issues are yet to be solved. It can be concluded that the closure of Kundang landfill currently failed to achieve the aim to confine the landfill contaminations from polluting the surrounding environment.

Considering the pollution emitted, the inactive Kundang landfill has no other potential rather than being left undeveloped as many other closed dumping-ground in Malaysia. This based on the fact that these areas are not ready for other land-use or development, particularly sites which are isolated and has low-value. However, this scenario changes if it involved disposal sites in urban areas. Due to land scarcity and increase in the price of land, many unsafe areas such as disposal sites and ex-mining areas undertake development to accommodate needs and demands for more housing and commercial areas. Reclamation of landfills for various types of land use

Table 3: Average concentration of metal and non-metal elements in surface and deep soil from the ex- landfill

Parameter	unit	surface soil (5cm from ground surface)	deep soil (5m below the ground surface)	Dutch Intervention Standard
Phosphate	mg/kg	2.5- 5.5	0- 13.6	-
Flouride	mg/kg	2.4- 7.0	0.5- 0.9	-
Sulfate	mg/kg	30.2 -946.3	4.2- 10.2	-
pH	na	5.8- 9.9	7.3- 8.2	-
Chloride	mg/kg	6.3- 238.3	2.1- 8.1	-
Nitrate	mg/kg	4.7- 83.3	0.5- 5.0	-
Nitrite	mg/kg	1.1- 2.9	Not detected	-
Zn	mg/kg	7.7- 129.8	Not detected	720
Sb	mg/kg	0- 3.0	Not detected	15
Cd	mg/kg	0- 0.6	Not detected	12
Cr	mg/kg	0.5- 14.1	Not detected	380
Cu	mg/kg	2.3- 17.3	Not detected	190
Pb	mg/kg	2.7- 148.0	Not detected	530
Ni	mg/kg	0.3- 5.0	0- 9.0	210
Ag	mg/kg	0-1.2	Not detected	15
Tl	mg/kg	0- 58.0	Not detected	15
As	mg/kg	8.8- 64.5	0.3- 2.7	55
Hg	mg/kg	0-1.4	8.5-11.5	10

has been successful in many parts of the world. This is possible with proper post-closure procedures. However, reclamation of landfill without appropriate procedures will cause problem and risks to the inhabitants.

Ex-Landfill in Selangor

An ex- landfill located in Kelana Jaya district in Selangor was closed in 2000. The area covers approximately 138 acres of which more than 1.57 million m^3 of MSW were deposited with approximately 40% organic materials. The area was used as a disposal site since 1981. In late 2007, most of the area was excavated to remove the deposited waste. This is to convert the area into residential and commercial land. During the study, the area is approximately 70% completed with the development of terrace houses, high rise apartments, and commercial buildings. However, no record of post closure assessment is available that the site is assumed not properly closed. The MSW deposited during the disposal site operation period had resulted with leachate and landfill gases generation. These cause contamination to the surrounding area since the landfill emissions are released without appropriate treatment. Pollution parameters of the leachate collected from the area namely BOD_5 and COD exceeded the level allowed in Standard B, EQA 1974.

The BOD_5 level averaged at 78 mg/l while COD averaged at 230 mg/l (exceeded the EQA Standard B limit of 50 mg/L and 100mg/l, respectively). The random sampling activities conducted indicated that the highest contamination point concentrated at one main sampling point. It was due to the presence of the deposited waste which was not excavated by the developers. TOC of the groundwater samples collected from the same area was approximately 460 mg/l. This is probably due to the infiltration of leachate from the waste layer into the groundwater system, thus contaminating the groundwater.

Additionally, investigation on the soil samples revealed that the surrounding soil was heavily contaminated with metal elements which exceeded the Dutch Intervention Value. Results obtained from the surface and deep soil analysis is shown in Table 3.

Arsenic was found to range from 0.3 mg/kg to 64.4 mg/kg in surface and deep soil. The presence of As in the soil is probably due to the disposal of used batteries and other As-containing materials into the area. Another possible source of As was from the disposal of As-containing industrial waste during the operating period of the disposal site.

Hg was also recorded to exceed the limit allowed. It was detected as high as 11.5 mg/kg, 5m from the

Table 4: Leachate analysis from study area

Parameter	Unit	Range	Average	Standard B
BOD	mg/l	23.5 - 42.0	33.0	50
COD	mg/l	51.5-128.0	82.9	100
pH	-	4.7-7.1	6.5	5.5-9.0
Sulphide	mg/l	0.9- 10.4	3.8	0.5
Ammoniacal-N	mg/l	13.4-17.8	16.1	Not available
Phosphate	mg/l	1.6 - 315.6	80.2	Not available
Sulfate	mg/l	55.0 - 132.5	101.6	Not available
Chloride	mg/l	22.1 - 37.8	27.3	Not available
Nitrate	mg/l	0- 2,687.1	671.8	Not available
Cd	mg/l	Not detected	0.0	0.02
Cr	mg/l	Not detected	0.0	0.05
Pb	mg/l	Not detected	0.0	0.5
Fe	mg/l	0.1- 16.3	4.4	5
Ag	mg/l	0- 0.6	0.2	Not available
As	mg/l	0 – 0.3	0.2	0.1
Hg	mg/l	Not detected	0.0	0.05
Se	mg/l	Not detected	0.0	Not available
Ba	mg/l	0.2-0.3	0.2	Not available

ground surface, most likely originated from disposed batteries or fluorescent bulbs. Thus, it calls for an immediate attention to prevent long-term effects to the occupants of the area. Although wastes have been removed from most of the area which has already been developed with houses and buildings, the soil are seriously contaminated by the waste disposed earlier. The extremely toxic nature of both As and Hg are of particular concern which warrant appropriate remediation measures. Additionally, soil contamination can result to the contamination of the surface and ground water via run-off.

Gas monitoring was also conducted randomly on the study area where concentrations of H_2S and CH_4 were found to be below the detectable limit. However, in area where waste is yet to be excavated, 5% LEL (equivalent to 0.25% CH_4) was recorded. Yet, the emission was intermittent and very likely to be diluted and dispersed by wind to a concentration below detection limit.

Investigation and monitoring at the study area indicated that pollutions are detectable in areas where waste has not been excavated yet. Hence, in order to develop the area, waste need to be excavated to reduce the risk of contamination to the surrounding area. Additionally, appropriate remediation measures are necessary to prevent detrimental exposure to the inhabitants. However, since remediation of soil namely surface and deep soil in the area is extremely expensive, the development should be accomplished by ensuring that inhabitants are totally prevented from the any exposure to soil to remove the risk of As and Hg contamination.

With suitable and appropriate remediation measure, development of an ex-disposal site can be possible. Yet, it requires proper planning to ensure that all factors are looked into to avoid exposure to toxic substances. Improper reclamation procedures proved to be detrimental not only to the environment but to the inhabitant as well.

Ex- mining area

The ex-mining area is located at the southern of Petaling Jaya, one of the fastest developing cities where the price of land is extremely high. This area was abandon for a few years that it is seen as an opportunity for development. Therefore, an extensive reclamation activity began in 1980s on the approximately 114 acres of ex-mining pond. It is aimed to reclaim the area for more economically viable development. Reclamation was conducted by disposing wastes into the ponds which included domestic, industrial, and construction debris. Lack of monitoring resulted with the disposal of all possible types of waste including toxic and hazardous wastes. Among the waste deposited into the ponds was gypsum board from the construction sector. This resulted with the emission of tremendous amounts of H_2S to the surrounding area when gypsum board reacts with water. The high concentration of H_2S released to the surrounding area created a lot of problem to the residents. As high as 200ppm H_2S was disposal site, in order to avoid disastrous environmental impacts in the future.

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Malaysian Journal of Science **29** *(3): 239-246 (2010)*

Establishment of Geographical Information Technology to be Used as The Aid for Plant Ecology Study in Carey Island, West Malaysia

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Received on 28th September 2010, accepted by 15th November 2010

ABSTRACT This study was carried out to establish a technological means of mapping the location of plant in the West Malaysia ecosystem with a simple approach with geographical information tools covering 10 000 m^2. Conventionally, the mapping of plant uses perpendicular grid lines as X-Y axis according to the distance from the point of origin (X_o and Y_o). This technique was found to be challenging especially at the heavily shrub areas. Acquiring the perpendicular grid lines connecting the X-Y axis was replaced with the use of hand-held global positioning system (GPS). It used the World Geodetic System 1984 (WGS 84). Coordinates information from GPS was uploaded into Geography Information System (GIS). The tools in geographical information technology (GIT) have enabled the plot for X-Y axis gridlines to be redrawn with GIS instead of using the ordinary graph technique. Statistical comparison with the analysis of regression has shown that the use of GIT could replace the conventional technique for the mapping of plants' ecosystem. Statistical comparison between conventional and GIT, using correlation coefficient for both X axis and Y axis have given values of R^2= 0.97 and 0.99, respectively. Therefore, tools in GIT were found to be suitable for the used of plant mapping in West Malaysia.

(**Keywords**: Plant Ecology, GIS, GPS, WGS 84, Carey Island)

INTRODUCTION

Technology in geographical information technology (GIT) has been progressing extensively and could be used to conduct the spatial analysis in any related studies. 15 years back, Aschbacher *et al* (1994) had prepared an inventory of wetland habitats in the Phangnga Bay of Southern Thailand with the geographical information system (GIS) [1]. The establishment suggested that the geographical instrumentation and its technology should replace the existing conventional technique for the mapping of plant distribution in ecosystem.

For the conventional technique, plots for the plant distribution were selected by conducting a quick survey on the availability of on-site samples. Once the availability is established, a pebble was randomly tossed against the gravity. Once it landed to the terrain, it would become the cornerstone of the plot. A pole is fixed at this point and the boundary was marked with the other three poles at the distance of 20 meter for each perimeter. The boundary is marked

with a plastic rope connecting the quadropoles. The rectangular shape for the plot was ensured by placing each of the quadropoles with a compass pointing exactly to north-south and east-west. A minimal of six plots with the size of 400 m^2 for each, was set up. This size is large enough to contain a representative samples [2]. Plotting the location according to individual coordinates (X-Y axis) in selected plots will describe distribution of selected plants in the ecosystem. To determine the positioning of each sample gives the greater challenge when the conventional technique is used in the field. Most samples are located randomly either in the cleared or leveled area. Physical obstruction by other trees either hardwood or shrubs and bushes would have been the obstacle during the data collection and shall make the positioning of samples to become less accurate.

Similarly the conventional approach as quoted directly from Domini and Duncan (2001) [3] .... *the classic methods of ground-based mapping frequently involve triangulation from a known point, which, in a rain forest, may involve extensive labor without being outstandingly accurate.*

Distance accuracy using reconnaissance-type mapping is at best only 1 part in 80 (4.5°) with a hand-held compass, and 1 part in 300 (1.2°) with a staff-held forester's compass [4]. These techniques have served the study of tropical forest ecology, but mapping accuracy and efficiency can be greatly improved today by utilizing global positioning system (GPS) and geographic information system (GIS) technologies. The relatively recent development of GPS and GIS technologies appear ideally suited to conservation efforts because they empower ecologists to expeditiously acquire, store, analyze, and display spatial data on organisms and