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Assessment of municipal solid waste generation, composition and recyclable potential at selected Kelantan dumping sites, Malaysia

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Abstract: The success of waste management in developing county like Malaysia requires precise data on generation and composition of municipal solid waste (MSW) which is essential for stake holders towards the suitable waste management system. At present there is no data available on Municipal Solid Waste (MSW) generation and composition collected throughout major districts in Kelantan. This paper provides a baseline study for municipal solid waste characterization and recyclable potentials in Beris Lalang, Bukit Akil and Renok dumping sites, Kelantan, Malaysia. The samples were collected from the dumping sites which covers three districts area of Kota Bharu, Kuala Krai and Gua Musang. Manual sorting was used for classifying the collected wastes into the following categories: food/organics, paper, tetrapek, plastic film, plastic rigid, napkins, textiles, rubber, leather, garden, glass, metals, household hazardous waste and others; the daily average MSW for the present period estimated is 0.90, 0.60 and 0.89 kg/cap/day for all three districts. A direct sampling of MSW as disposed at three dumping sites was conducted based on MS2505:2012 standard method to determine the MSW composition. The results of the analyzed component showed that organic fraction is dominant (28-44%), followed by paper (12.5-22%), tetrapak (11.5-12.5%), plastics film (3.4-8.49%) and plastic rigid (6.22-14.84%). The study results revealed that the MSW if waste management option such as material recovery facility (MRF) is to be practiced in the future, there is a greater possibility of reducing substantial amount of waste stream getting disposed to the dumping site.

Key words: Municipal solid waste; Generation; Composition; Recyclable

1. Introduction

A holistic and efficient waste management from MSW composition studies is essential in order to estimate recyclable potential, determining sources of MSW generation, designing material recovery facilities, estimating physical, chemical, thermal properties of the MSW, monitoring and to improve existing waste management (Palanivel and Sulaiman, 2014). The study also will be a reference line to maintain compliance with local, national and global regulations or directives.

Solid waste management in Malaysia is under the purview of Ministry of Housing and Local Government. Solid Waste Management Corporation (SWCorp) is the implementation authority of the Solid Waste and Public Cleansing Management Act that is being enforced throughout the Malaysia states. In 2005, National Strategic Plan for Solid Waste Management (SWM) was enacted which emphasized for an integrated municipal solid waste management (ISWM) including waste management hierarchy prioritizing waste reduction through the 3R's i.e., reduce, reuse, recycle at both pre-and post-consumer stage (Noor et al., 2013). Local municipalities also have their jurisdiction in terms of MSW collection, transportation and disposal activities at landfills. Department of Environment Malaysia (DOE), which is the sole authority responsible in formulating and regulating environmental act covering guideline and integrated solid waste management compliance that need to be adhered by the respective stake holders (Badgie et al., 2012). According to United Nation data on MSW generation rates, Malaysian on average generates about 1.1 kg/cap/day of MSW. By taking into account the Malaysians population of 30 million residents, such a huge population will require sounds and engineered MSW management that can prevent environmental deterioration. This is because, most of MSW generated across municipalities is managed and disposed by a poorly 'controlled tipping' landfills with simple and no environment protection measures. Furthermore, conventional disposal method by landfilling is very land dependent and create aesthetics disturbance while imposing anxieties and psychological fears due to health and ecological risks to the community (Othman and Khee, 2014). Briefly, Malaysian solid waste contains a very high concentration of organic waste fraction. The MSW also contains high moisture content and a bulk density above 200 kg/m^3 as reported by Manaf et al. (2009). Besides, a waste characterization analysis has found that the main

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components of Malaysian waste were food, paper, and plastic which comprise 80% of overall weight as shown in Table 1 (Kathirvale et al., 2004). From the results, the characteristics of the MSW fraction have proportional relationship in terms of lifestyle and habits of the Malaysian population. Also, there is a large fraction in terms of food and organics component as can be seen from the table.

Recent research on MSW management suggests that despite the challenges that are currently facing to MSW management industry, there is still a need to provide base line data on MSW composition and characterization that can benefit various stakeholders. Especially, information about waste composition is important for several purposes as highlighted above that can be ranged from the decision-making pertaining waste utilization to the development of waste management systems and planning information (Sahimaa et al., 2015). In Malaysia, recycling activity has only implemented in 1993 with the introduction of Action Plan for Beautiful and Clean Malaysia. Nevertheless, concern and awareness among society in Malaysia still low and inversely proportional to the living standards and therefore participation towards sustainable waste management through recycling campaign is very minimal. At present, recycling rate among Malaysian is significantly lower which stood at 5% (Agamuthu and Fauziah, 2011). In this way, waste composition studies are needed for functional efficient waste management (Burnley, 2007). Previous work on MSW composition studies have been reported at Greece (Gidarakos et al., 2006), Kuwait (Al-Jarallah and Aleisa, 2014), Oman (Palanivel and Sulaiman, 2014), India (Suthar and Singh, 2015), Finland (Sahimaa et al., 2015), Thailand (Laohalidanond et al., 2015), Ghana (Miezah et al., 2015) and Denmark (Edjabou et al., 2015).

Table 1: MSW composition based on residential income (Kathirvale et al., 2004)

Source	High income (%)	Medium income (%)	Low income (%)	Commercial (%)	Institutional (%)
Food/organic	30.84	38.42	54.04	41.48	22.36
Mix paper	9.75	7.22	6.37	8.92	11.27
Newsprint	6.05	7.76	3.72	7.13	4.31
High grade paper	-	1.02	-	0.35	-
Corrugated paper	1.37	1.75	1.53	2.19	1.12
Plastic (rigid)	3.85	3.57	1.90	3.56	3.56
Plastic (film)	21.62	14.75	8.91	12.79	11.82
Plastic (foam)	0.74	1.72	0.85	0.83	4.12
Pampers	6.49	7.58	5.83	3.80	1.69
Textile	1.43	3.55	5.47	1.91	4.65
Rubber/leather	0.48	1.78	1.46	0.80	2.07
Wood	5.83	1.39	0.86	0.96	9.84
Yard	6.12	1.12	2.03	5.75	0.87
Glass (clear)	1.58	2.07	1.21	2.90	0.28
Glass (colored)	1.17	2.02	0.09	1.82	0.24
Ferrous	1.93	3.05	2.25	2.47	3.75
Non-ferrous	0.17	0.00	0.18	0.55	1.55
Aluminum	0.34	0.08	0.39	0.25	0.04
Batteries/hazards	0.22	0.18	-	0.29	0.06
Fine	-	0.71	2.66	0.00	0.39
Other organic	0.02	0.00	-	1.26	1.00
Other inorganic	-	0.27	0.25	-	8.05
Others	-	-	-	-	6.97
Total	100	100	100	100	100

The objective of this study was to develop a representative data on the waste characteristics and composition for Kota Bharu, Kuala Krai and Gua Musang districts, Kelantan Malaysia. A field survey was conducted for the purpose of identifying active and closed dumping sites throughout Kelantan districts. Furthermore, MSW waste characteristics study was performed on-site in order to determine the recyclable potential at the dumping site. The field work activity consisted of recording the number of trip; performing waste characteristics study from fresh MSW sent to the dumping site as-disposed by compactor and conducted survey of available dumping site at selected Kelantan districts. Therefore, it is expected that this study can be used to establish a baseline for monitoring progress in achieving waste management strategies and to assist the interested parties in setting future policy directions and management priorities as a whole.

2. Materials and methods

2.1. Field work activity

The lack of essential equipment such as weigh-bridge and existing data at Beris Lalang, Bukit Akil and Renok dumping sites have caused quantification of MSW disposed is difficult. As a result, no data on solid waste disposal at the dumping site are made available for references. Therefore, the estimation of generated quantities of MSW (kg/cap/day) is based on existing Malaysian waste generation of 1.1 kg/cap/day. Daily volume of MSW dumped is based on trips arrived at the site by compactors which estimated about 5 tonnes/compactor with 50 number of trips daily for Beris Lalang dumping site. As a result, the total MSW sent to the dumping site daily is estimated about 350 tonne/day. Meanwhile, MSW disposed at Bukit Akil for Kuala Krai district is estimated at 20 tonne/day followed by Renok dumping site with 40 tonne/day of MSW for Gua Musang district.

2.2. Waste composition study

Sampling was carried out at active portion of the dumping sites and according to Malaysian Standard MS2505:2012, Guidelines for sampling of household solid waste- Composition and characterization analysis. In the present study, truck load – coning and quartering sampling guide was used throughout the field work activity. Compactors arrive at the dumping site is randomly selected. First, the sample was collected from freshly source as disposed from compacter and mixed together. The sample was divided into 4 blocks and further discarded diagonally. 2 blocks of the samples were removing in the opposite end diagonally whereby another diagonal opposite end was remained. The remained sample was then mixed again and flatten and. Any recyclable items that were visually observed were discarded and recorded and accommodated into labelled bins.

Each of the waste fractions were weighed and recorded for further analysis. The mean waste component was calculated by using the results of the composition of each of the sorting samples. Each sorting sample weighed about 90 – 120 kg whereas, the classification of MSW were divided into 15 specific categories as shown in Table 2. Meanwhile, Fig. 1 simplifies the coning and quartering technique and the steps applied during the waste composition study as recommended by the MS2505:2012. The percentage composition of each of the components was calculated by the formula in Eq. 1:

$$Percentage\ of\ waste\ fraction = \frac{Weight\ of\ separated\ waste}{Total\ of\ mixed\ waste\ sampled}\ x\ 100 \quad (1)$$

Table 2: Waste composition criteria based on MS2505:2012

No.	Category	Description
1.	Food/organic waste	Raw food waste during food preparation, leftover food.
2.	Papers	All type of papers including newspaper, cardboards, magazines, books, black and white paper, envelopes, etc
3.	Tetrapak	Carton used for packaging liquids.
4.	Plastic film	All plastics including plastic bags/films, polystyrene, foam.
5.	Plastic rigid	All plastic bottles, container, pipes and fittings.
6.	Napkins	Disposable diapers for babies and elderly, ladies sanitary napkins.
7.	Textiles	All textiles including clothes, shirt, bed sheet, curtains, pants and other household items made from man-made or natural fibers.
8.	Rubber	All rubber including gloves, handbags, shoes, rubber mat.
9.	Leather	Leather products e.g: bags, leather coats, shoes, belts.
10.	Wood	Lumber, wood products, pellets.
11.	Garden	Branches, twigs, leaves, grass and other plant material.
12.	Glass	All glass such as brown glass, green glass, clear glass, other coloured glass and non-packaging glass.
13.	Metal	Ferrous and non-ferrous .g: copper, iron, steel, tin cans, and aluminium cans
14.	Household hazardous waste	Batteris, aerosol cans, medicines, light bulbs, pesticides, E-waste.
15.	Others	Other than above.

3. Results and discussions

3.1. Waste quantification

In order to identify the number of dumping sites in Kelantan, field survey and data collection were ascertained in the first hand from responsible municipalities including SWCorp authority. In general, baseline information on the quantity of solid waste generated is essential for every aspect in solid waste management (Samah et al., 2013). From Table 3 and Fig. 2, there are 11 active dumping sites currently in operation at which, all of them were poorly design and considered as non-engineered landfills. This is because, in order to classify an appropriate disposal site, the site must at least occupied with minimum facilities which consist of fencing and perimeter drain. From the site survey and observation, none of the active dumping sites fall under Class I landfill as highlighted by Agamuthu and Fauziah (2011). Moreover, there systematic approach to monitor the disposal process available at the dumping sites which results in no daily recorded data on the incoming waste being for disposal.

The present study also found that the dumping sites are not occupied with appropriate environmental pollution control such as leachate drain for leachate collection, bed liner and daily cover materials. Generally, the existing solid waste disposal system the study area does not follow engineered landfilling methods which may bring major environmental risks such surface and ground water pollution (Suthar and Singh, 2015). Based on the existing daily tonnage, the total MSW currently being disposed at 11 active sites are equivalent to 990 tonne/day.

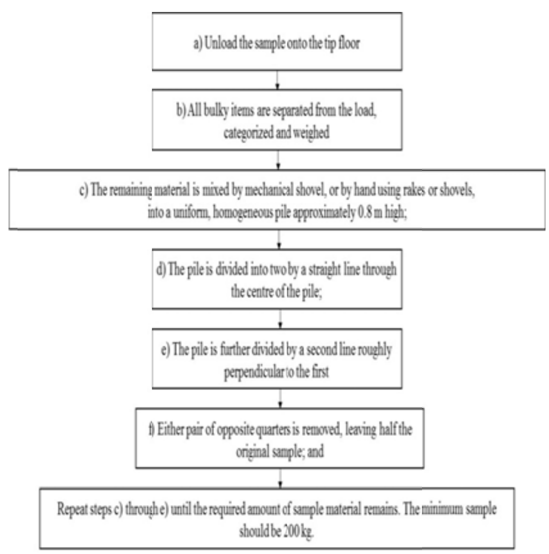

Fig. 1: Waste sampling technique

The total waste generation at Kelantan was relatively lower than other east coast states such as Terengganu (1219 tonne/day) and Pahang (1322 tonne/day) (Agamuthu and Fauziah, 2011). Most notably, relatively lower MSW generation in Kelantan is largely due to demographic factors and facilities, which currently provided by the respective local municipalities (Manaf et al., 2009).

In particular, the amount of MSW generation in Kelantan state is not only depending on the living standard and lifestyle towards the population growth, abundance of land reserve has been the main reason that lower MSW generation was recorded. In any case of daily collection is not permitted due to inaccessible route, most of the garbage is diverted by means of recycling at own backyard. As a matter of fact, unknown pathways of waste streams in the vicinity of collection route also might contribute to the lower MSW volume being disposed which led to illegal dumping (Samah et al., 2013).

In terms of MSW generation at active dumping site, Kota Bharu district had the highest MSW disposed with 350 tonne/day followed with Tumpat and Pasir Mas of 120 tonne/day. Kota Bharu, which is the main capital district of Kelantan also, has the highest population of 468,438, followed by Tumpat and Pasir Mas of 104,234 and 86,189, respectively. The results also demonstrated that waste generation has linear relationship with the population growth (Gupta et al., 2015) since Kota Bharu is considered one of the developed city as compared to other districts.

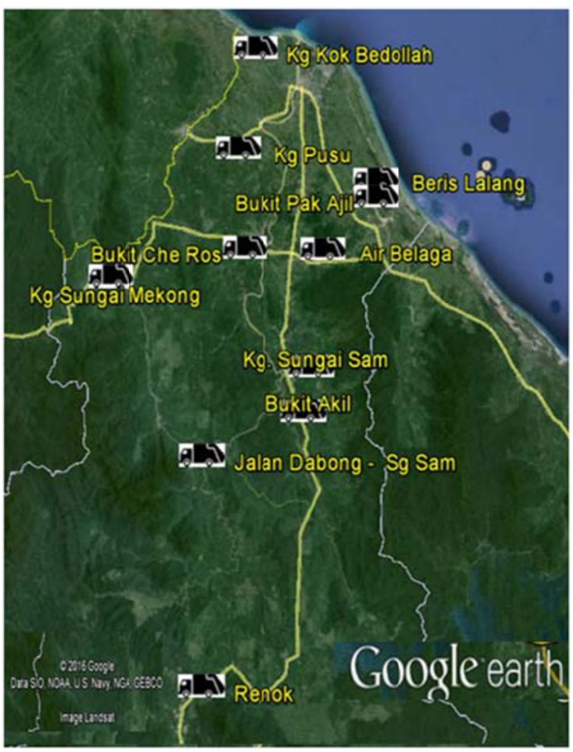

Fig. 2: Active dumping sites across Kelantan state (Google earth)

In terms of waste generation per capita determination, the calculation is based on the records of the average total waste reaching the dumping sites every day for disposal at each of the study area. The results were than divided by the numbers of residents that municipalities carried out daily MSW collection at their premise. Based on this study (data not shown), the rate of waste generation at Kota Bharu district region is calculated at 0.90 kg/day/person by weight. This value in comparison is within the generation rate reported in other state such as Kuala Lumpur (1.60 kg/cap/day), Pahang and Terengganu (0.88 kg/cap/day), respectively. In terms of waste generation in other selected countries by considering similarity in population lifestyle, it can be observed that the waste generation per capita in Kelantan state were comparable to the others developed cities in Asia region such as Bangkok (1.18 kg/cap/day) (Laohalidanond et al., 2015), Beijing (0.8-1.2 kg/cap/day), Singapore (0.96-1.10 kg/cap/day) and India (0.68 kg/cap/day) (Suthar and Singh, 2015).

3.2. Waste composition

Waste as disposed at the dumping sites was further sorted into 15 sub-components, analyzed and averaged for each of study area and presented in Table 4. The waste components were determined after sorting a known weight of sample in to different waste streams (15 components) and divided from the total weight accumulated. From the table, the major fractions of MSW component analyzed were organics, papers and tetrapak; meanwhile, plastics (film and rigid), napkins, textiles, rubber, leather, wood and garden wastes made up in the ranges of 0.4 to 14.84% of total MSW components. The results for organic component were in the range of 28 to 43% of total wastes and prevailed for all three study area.

The waste is mostly dominated by kitchen and food waste (Periathamby et al., 2009). Such a high organic waste in the study area could be due to the high consumption of edible products such as dairy, processed food, and unprocessed food. The fractions also indicated that residents of Kota Bharu produced the lowest organic fraction (33.13%) followed with Gua Musang (27.94%) and Kuala Krai (42.86%). As comparison, normal organic waste fraction for Maalaysian according to the data from Ministry of Local Government and Housing was stood at 45% of total MSW MSW (Hamatschek et al., 2010). The results also demonstrated that paper waste was the second largest fraction in terms of weight which might be due to the increasing usage of paper in daily packaging including foods, hardware and dairy products. Besides, the main fractions of paper waste ascertained in the study were cardboards and other packaging papers.

Tetrapak waste was the third largest fraction in term of weight. This could be due to the increasing soft drink sold at cheaper price than conventional metal can drinks. Also society in opinion that by drinking soft drink from tetrapak containers gives more lavish style than attractive perception towards metal can drinks which also considered safer to them. As a result, there is a potential for tetrapak recycling towards the waste minimization among society that can be nurtured and educated for sustainable waste minimization.

Table 3: Characteristics of dumping sites across Kelantan state

District	Dumping site	Area (ha)	Landfill classification	Daily incoming waste (Tonne/day, TPD)
Pasir Puteh	Bukit Gedombak	9.70	Non-engineered	64
Bachok	Kg Sungai Gali	4.49	Non-engineered	20
Kota Bharu	Telok Kitang	32.0	Non-engineered	280
	Panji	4.05	Non-engineered	90
	Beris Lalang*	30.5	Non-engineered	350
Jeli	Batu	0.5	Non-engineered	N.A
	Kg. Sungai Mekong	0.81	Non-engineered	10
Kuala Krai	Damar	0.81	Non-engineered	5
	Bukit Akil*	4.05	Non-engineered	20
Tanah Merah	Chat Rimau	4.90	Non-engineered	20
	Bukit Che Ros	5.00	Non-engineered	50
Dabong	Kg. Sungai Sam	4.50	Non-engineered	16
	Kemubu-Dabong	0.50	Non-engineered	5
	Jalan Kuala Krai-Gua Musang	0.20	Non-engineered	2
	Jalan Dabong - Sg Sam	3.65		9
Ketereh	Bukit Pak Ajil	2.90	Non-engineered	70
Machang	Air Belaga	4.04	Non-engineered	100
Tumpat	Kg. Kok Bedollah	20.23	Non-engineered	120
Pasir Mas	Kg. Pusu	4.45	Non-engineered	120
Gua Musang	Renok*	32.0	Non-engineered	40

*Study area

The analyzed data also revealed that more than 10% of the total MSW characterized can be diverted rather than directly dump for final disposal. In terms of plastic waste, two different plastics types were distinguished which were plastic film and plastic rigid. Plastic film for three study area was found in the range of 3 to 8.5% of the total waste analyzed. In this study, the plastic film was categorized into films, polystyrene and foam. Most of the plastic were derived from food and drinks packaging. Meanwhile, plastic rigid which further divided into PET bottles for bottling drinks and water, LDPEs, HDPEs, PVCs, and PSs which made up in the range of 6.2 to 14.8% of total waste. The accumulated weight percentage recorded was significantly lower than Penang (24%) (Ahmad Zamri et al., 2014), Selangor (18%) (Samah et al., 2013) and Malaysia (17%) (Agamuthu and Fauziah, 2011).

Some other fractions such as napkins, rubber, textiles leather wood, garden waste, glass and metal ranged between 0.7 to 4% which was comparable with other studies (Ahmad Zamri et al., 2014). Fig. 3 illustrates the waste component fraction analyzed for all dumping sites based on coning and quartering technique. In comparison, the figures demonstrated that combustible has the highest shared from the whole waste component in the range of 94 to 96% than incombustible fraction. The finding shows that there is possibility of turning the combustible fraction into refused derived fuels (RDF) for thermal processing in general consideration. This is because, the heat generated from RDF burning is able to generate electricity that can be supplied to national grid line which already a success project in Semenyih, Selangor (Xiang et al., 2014).

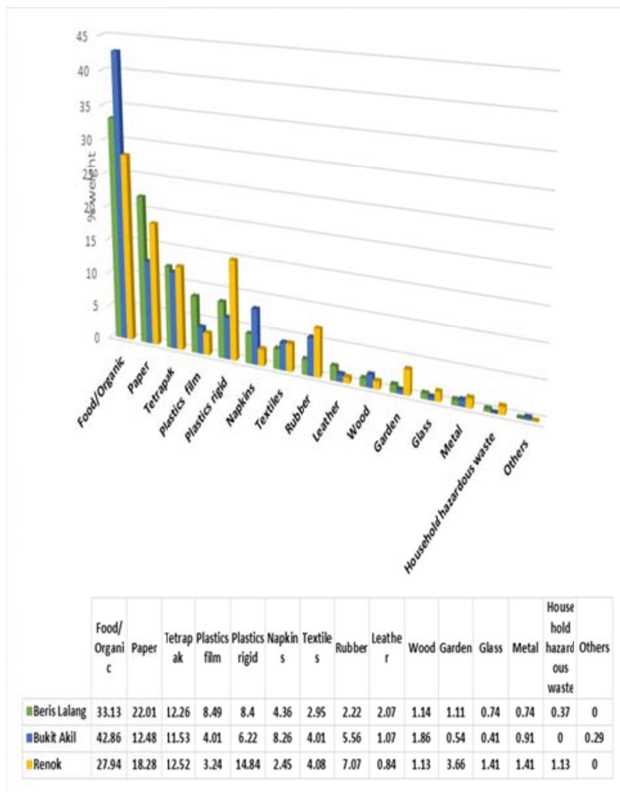

Fig. 3: Waste composition results

3.3. Availability of MSW recovery

In general, information in waste composition helps facilitating feasible and sustainable waste disposals, reuse and recycling activities. Unfortunately, information on the Malaysian waste composition is rather limited and scarce because of the unknown pathways of waste streams in the environment (Moh and Abd Manaf, 2014). Different approach of local authority, government policy and existence of various waste system and management has caused actual waste composition data to be redundant and inaccurate. Also, given the current situation in Kelantan state which most of the dumping sites are not in engineered design and well operated, MSW recovery opportunity is not top priority agenda to the local government. However, this constrain has impeded various stakeholders and decision makers especially for solid waste management planning and management for new disposal site and technology transfer.

Therefore, this study aims to provide baseline information on the recyclable potential from recovered MSW as discussed earlier. Fig. 3 illustrates the most acceptable MSW component for recovery process. In the same manner the solid waste composition of dumping sites area was described, Beris Lalang dumping site has the largest share of MSW recovery opportunity of 51.16% followed with Renok (48.88) and Bukit Akil (34.24%). Interestingly, it is estimated nearly 35% of the disposed MSW at studied area has the potential for MSW recovery. The largest recovery of MSW fraction obtained was papers which made up in the range of 36 to 43% followed with tetrapak (24 to 25.61%) and plastics (6.63 to 30.36%). It is clear from observation that there is possibility to divert these waste components for reuse and recycling or so called waste minimization.

For example, paper recycling has not been initiated on a larger scale due to the fact that paper possesses lowest recycling values as compared to others. Although few individuals and small vendors have been recycling smaller portion as sanitary tissues, larger industry still prefers virgin pulp in paper making industry because of quality and durability offers to the consumers. Nevertheless, there is still opportunity for paper waste minimization at source prior to final disposal at dumping site which can prolong its lifespan and optimizing daily MSW collection activity.

The second largest waste component that has attractive values for recycling is tetrapak which is well known for the world's leading food processing and packaging provider. Not only their packaging are innovated and fancies, the packaging offering consumer convenience, easy opening and optimum shelf life as compared to others. However, based on the data ascertained, tetrapak made up 26% of total MSW recovered for all three study area. In terms of recycling opportunity, tetrapak recycling values was comparable to paper. The recycling vendors considers tetrapak as papers and possess cheaper recycling value due to the fact that Malaysia is one of the major players in paper and pulp industry covering corrugated paper, paperboard, containers papers and paper board manufacturing thanks to abundant large pulp plantation across east Malaysia.

Although there is argument that Malaysia is relies heavily on import of pulp for paper making manufacturing (Chiew and Shimada, 2013), this scenario is yet to encourage local manufacturers to choose used paper purposely in recycling activity during product manufacturing. Plastics are made from hydrocarbon based source. Even though plastics are easily obtain at cheaper price, their presence at dumping site with enormous quantity has caused detrimental effect to the environment due to persistent nature for biodegradation. In general, plastic film made up about 16.6 % at Beris Lalang, 11.7% Bukit Akil and 6.6 % at Renok dumping site out of total MSW recovered.

Meanwhile, plastic rigid exhibits about 16.41, 18.2% and 30.3% of total MSW recovered at Beris Lalang, Bukit Akil and Renok dumping sites. Combination of both plastic types results in 33%, 30% and 37% fractions from Beris Lalang, Bukit Akil and Renok dumping sites. The results indicated that more than 30% of the recovered MSW for all dumping sites consists of plastic based component. In terms of recycling potential, plastic has lucrative recycling values as most of local recycling vendors are gearing up to reprocess the plastics waste into pellet as raw precursor in plastic manufacturing. These plastic are separated, washed, extruded and shredded into granules and sold to plastic manufacturers (Hamatschek et al., 2010).

At present, demand for processed plastic granules in Malaysia are overwhelming due to cheaper production cost, which seen China is the net importer of the product. Nevertheless, it must be noted that the market for recycled materials is highly volatile which has direct relationship with the economic condition. Lower demand from importers and stiff competition among industries usually reduce plastic waste values for reprocessing and causes oversupply to the manufacturers.

Also, it is worth to note that, in order to utilize plastic waste for reprocessing, the quality and polymer homogeneity of the material is important. In any way the plastic waste contains polymer that is contaminant free and clean, it can be used as virgin plastic replacement. In contrast, if the polymer is mixed with others, down-cycling of plastics are preferred and less expensive and demanding application (Sevigné-Itoiz et al., 2015).

4. Conclusions

This study formally established recent weight and composition of MSW fractions generated in three Kelantan's districts namely Kota Bharu, Kuala Krai and Gua Musang. The daily average MSW for the present period estimated is 0.90, 0.60 and 0.89 kg/cap/day for all three districts. A direct sampling of MSW as disposed at three dumping sites was conducted based on MS2505:2012 standard method to determine the MSW composition.

The results of the analyzed component showed that organic fraction is dominant (28-44%), followed by paper (12.5-22%), tetrapak (11.5-12.5%), plastics film (3.4-8.49%) and plastic rigid (6.22-14.84%). Further breakdown of recyclable items indicated that paper has the highest fractions for recycling of 36.45-43.02% for all three dumping sites followed with tetrapak, plastic film and plastic rigid. In terms of waste diversion possibility, it is estimated that more than 40% of recovered MSW have the potential to be reprocessed for further use in recycling. The data analyzed also indicated that MSW composition for all three dumping sites can be sustain whenever waste diversion process is carried out.

From technical point of view, material recovery facility (MRF) is the most suitable method for recyclable item recovery at all three dumping sites not only its incur low operating expenditure, employment opportunity has the advantage for policy maker to choose with as appropriate waste streams selection. Finally, the technology of the MRF needs to be developed and understood in order to be implemented it in all conventional waste disposal system for treating the waste generated in Malaysia.

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