J. Appl. Environ. Biol. Sci., 3(4)1-7, 2013
ISSN: 2090-4215
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Composition on Characteristics of Solid Waste: A Case Study at Landfill, Mojokerto, Indonesia

[1,3,*]Titien S. Rini, [2]Suyadi, [2]A. Rachmansyah, [2]A.W. Muhaimin

[1,3]Doctoral Program on Environment and Development Studies, University of Brwijaya, Malang, East Java of Indonesia
[2]Environment and Development Studies, University of Brawijaya, Malang, East Java of Indonesia
[3]Department of Civil Engineering, University of Wijaya Kusuma, Surabaya, East Java of Indonesia

ABSTRACT

Solid waste composition and characteristics are important variables to consider by which appropriate management and treatment should be applied. The study was conducted to explore the composition and characteristics of the solid waste at Landfill Randegan, Mojokerto City, Indonesia. The Landfill consists of passive zone with deposit solid waste covering the area of 3798 m^2 and active zone with new transporting solid waste covering 5726.809 m^2 in area. In the passive zone, the composition and characteristics of deposit solid waste were explored by manual excavation of 3.0 - 5.0 m in depth. Composite samples of solid waste-soil were obtained at the depth of 1,0 m each and analyzed in the laboratory. From the total predicted volume of deposit solid waste of 14,718 m^2, the dominant composition observed of ranged 60.15% - 72.30% was soil-like texture. In the active zone, the daily solid waste volume was determined by prediction the total volume of all trucks transporting and loading the solid waste in the landfill. Of the average new waste transporting the landfill of 231.33m^2/day, the dominant composition of 48.59% was food waste. The new solid waste consisted of 80.21% wet waste and 19.79% dry waste one. It was concluded that dominant composition of solid waste in passive zone was soil-like texture and showed high potential for covering soil and modified compost material by landfill mining. In the active zone, the solid waste was dominated by wet waste and appropriate for modified composting technology or Material Recovery Facilities (MRF)

Keywords: composition, characteristics, solid waste, passive zone, active zone, landfill.

INTRODUCTION

Solid waste is the by-product of human activity that discarded and unwanted because its use value has run out [1]. Meanwhile, in another sense, solid waste is the residue of human's daily activities and/or natural processes [2]. Solid waste management was defined as systematic, comprehensive, and continuous activities that involving waste reduction and solid waste handling [2]. Solid waste reduction activities include: (a) reducing, (b) recycling, and / or (c) recovering. Handling activities include: (a) sorting, in the form of grouping and separating waste according to the type, amount, and/or the characteristics of the solid waste, (b) collecting, in the form of waste collection and transfer of solid waste from the source to a temporary shelter or regional scale reuse, reduce, recycling (3R) solid waste treatment facility, or an integrated solid waste treatment facility, (c) transporting, in the form of collecting waste from the source and/or from a temporary shelter or from the integrated 3R waste processing facility to the landfill or the integrated solid waste processing unit, (d) processing, in the form of changing the characteristics, composition, and the amount of solid waste, and / or (e) the final processing solid waste in the form of returning solid waste and/or residues of previous processing results to the environment safely [3]. The solid waste that transported to landfill has a certain composition and characteristics depends on the source, climate and the volume of solid waste generated. Social-economic household conditions, lifestyle, and behavioural characteristics will reflect the amount of and the composition of the solid waste produced [4] chemical compounds of solid waste which consists of water, organic, and inorganic, and their percentage depends on the type and climate. Domestic solid waste are usually very diverse, but generally consists of a minimum of 75% organic matter, while the rest is inorganic. Both composition and characteristics of the solid waste are very important variables used to identify potential (state of the art solid) waste management in a region. Landfill as the final solid waste processing has alternative solid waste management method that will be costumed to the composition and characteristics of solid waste that goes to the landfill [5].

Mojokerto is a city in East Java Province with high population density of 134,222 in total and 2.040% as the average annual population growth. With that population, Mojokerto produces about 237 m^3 waste daily. The solid waste was daily collected and processed finally at Landfill in Randegan Village consisting total area of 2.5 Ha. Randegan Landfill has separated three zones, which is consists of two passive zone and one active zone. Limited wide active zone, the lack of an integrated landfill management, and lack of land for landfill

***Corresponding Author:** Titien S. Rini, Doctoral Program on Environment and Development Studies, University of Brawijaya, Malang, East Java of Indonesia. Email: asfindateknika@yahoo.com, suyadi@ub.ac.id

development are leading to limited landfill capacity and life span. The volume reduction of the waste in the Randegan Landfill only happens from the natural decomposition and waste collection by waste pickers at the landfill. Waste pickers, coached by Government, can significantly reduce the cost of waste management programs in urban areas. Waste pickers help reducing the amount of waste that must be collected, transported and disposed of, so that the lifetime of the landfill can be extended [6]. To overcome the limitations of active zone at Randegan, the study was conducted to the composition and characteristics of the solid waste.

The present study was conducted to evaluate the composition and characteristics of solid waste in two passive zones that covers the deposit solid waste and one in active zone covering new inflowing solid waste from family activity, in Randegan Landfill, Mojokerto.

MATERIALS AND METHODS

Material and Location

The study was conducted in Randegan Landfill, Mojokerto, Indonesia from September to November 2012. Randegan Landfill covers 2.5 ha area and has been operated since 1990. The study of the solid waste composition and characteristics was done on both passive and active zones. Passive zone is a zone that had not received solid waste anymore, while the active zone was a zone that still accepts new incoming solid waste in then landfill. The passive zone area was 3798.595 m^2 includes two separated zones, 2184.621 m^2 and 1613.974 for zone 1 and 2 respectively, and the active zone area was 5726.809 m^2.

Methods

The research methods used were survey with observational methods. The volume of solid waste deposits in passive zone was predicted by calculating the area multiplied by the height of solid waste deposit. The measuring methods for both the area and the height were by using polygon method aided with Total Station equipment, water pass and ruler. Soil investigation by manual excavation method was used up to the existing solid waste depth to find out the solid waste composition at passive zone visually for 5.0 m depth of well. Visual observation performed on every one meter of solid waste layer and a depiction of composition description was carried out. Besides visually, samples of solid waste in each zone passive were taken from each meter layer of solid waste as much as two 2 kg, mixed, then analysed in Environmental Engineering Laboratory, ITS Surabaya.

In the active zone, the research for the volume, composition and characteristics was performed on new solid waste. The volume of solid waste transporting the landfill was recorded by the container volume of each incoming waste trucks by considering solid waste compaction factor in the truck for 8 study days. Research methods and characteristics of the waste composition are performed by Indonesia National Standard (SNI) 19-3964-1995 on retrieval methods and measurement examples municipal solid waste generation and composition [7]. The steps of solid waste composition studies were waste sampling at each truck from each service area as much as 100 kg. The collection of 100 kg solid waste was done by using intersection technique. The solid waste mixed in four equal parts. A quarter solid waste were then subdivided into four equal parts. After the collection from each truck, solid waste was remixed using intersection technique and taken until 100 kg. Solid waste was classified according to their composition, pondered and calculated the percentage by weight or volume. Physical and chemical characteristics of solid waste was done by taking samples from each solid waste waste as their composition - two kg each for analysed in the laboratory. The solid waste characteristics test included tests on water content, calorie content of the solid waste, the carbon (C), Nitrogen (N), and phosphorus (P) contents of solid waste, and the calculation of the C/N ratio based on the value of C and N measured [8].

Data analysis

Data collected were analyzed descriptively and the numerical data with percentages, mean and standard deviation.

RESULTS AND DISCUSSION

Mojokerto City has only one centralized Landfill namely Randegan Landfill. This landfill consists of three zones, passive and active zones. The parts of the waste zones could be seen in Figure 1.

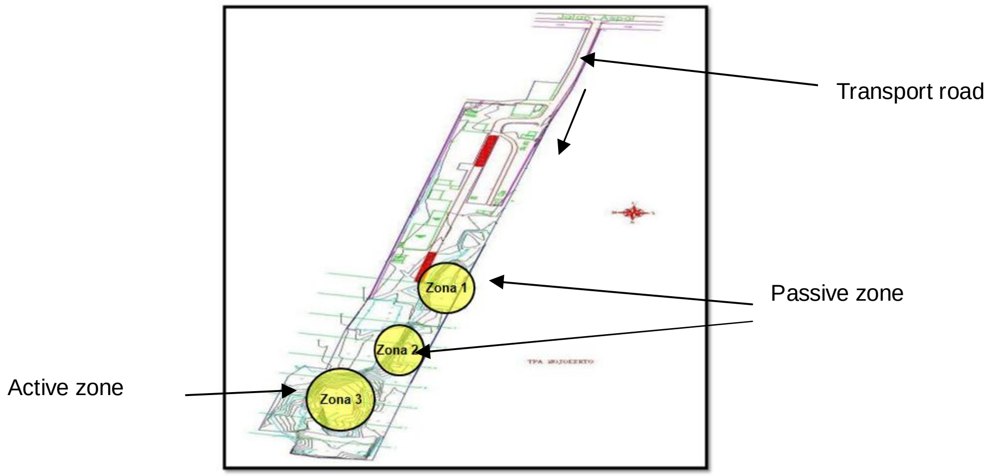

Figure 1 Randegan Landfill Waste Zone: The new transporting solid waste was de-loading directly from the trucks in zone 3, zone 1 and 2 contain deposit solid waste.

Zones 1 and 2 were a passive zone and zone 3 is the active zone. The passive zone is an area that has undergone the decomposition in recent years and the active zone is a zone that is still able to accept new solid waste. Passive Zone 1 has an average height of 4.0 m and Passive Zone 2 was 3.702 meters high. The waste deposit in Randegan Landfill passive zone can be seen in Tabel 1 below.

Table 1 Volume of Deposit Waste Randegan Landfill in Passive Zones

	Passive Zone 1	**Passive Zone 2**	**Predicted Lifetime**
Area	2.184,621 m^2	1.613,974 m^2	20 years
Height	4,002 m	3,702 m	
Predicted Volume*	8.742,7958 m^3	5.974,73 m^3	

*) Area x Height of solid waste deposit

From visual observation, the composition of the deposit solid waste in zone 1 and zone 2 in every of 1 meter layer depth of solid waste tend to be similar, which were soil like texture, plastics, textiles and others.

The results of laboratory analysis of the solid waste deposit composition in the Passive Zone 1 indicates that the deposit consists of 15.44% plastic waste, 72.30% soil, 0.70% rubber, 0.33 % glass, and 11.23% fabrics. For the waste deposit composition in the Passive Zone 2 consists of 34.42% plastic, 60.15% soil, 2.90% rubber, 1.20% glass, and 1.33% fabric. While the research held on Passive Zone 1 for the physical and chemical characteristics indicated that of it had 18.11% moisture content nitrogen of 4.61% N, phosphorus of 0.32%P, total carbon of 38.41%C, 8.33 % C/N and 3107.92 Cal/g heat. The results of research on Passive Zone 2 shows that it had 6.60% moisture content, phosphorus of 0.07%P, nitrogen of 4.3%N, total carbon of 46.24% C, % C/N of 10.75 and 3186.37 Cal/g heat.

Composition of the deposit waste in zone 1 and zone 2 are shown in Figure 2 and 3. The dominance composition of deposit soil waste is soil like texture, as shown in the picture below:

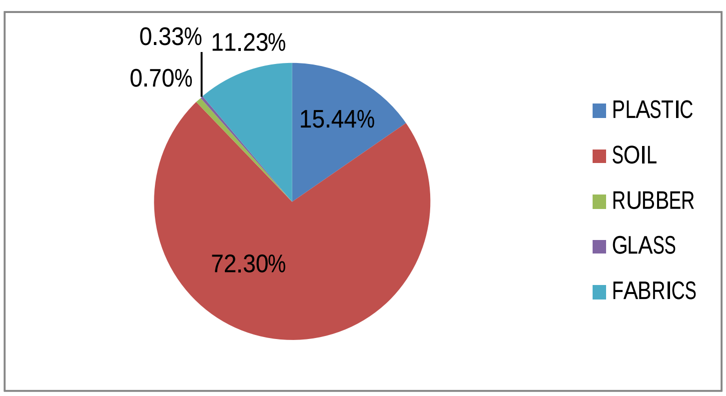

Figure 2 Solid Waste Deposit Compositions at Passive Zone 1

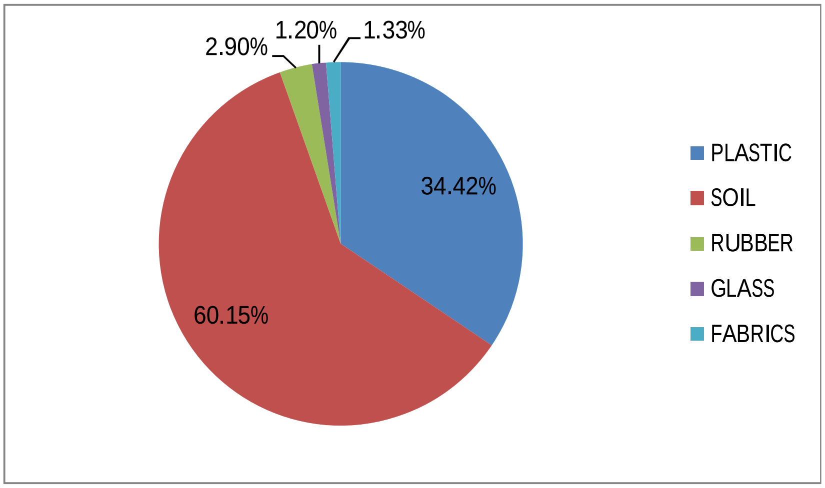

Figure 3 Waste Deposit Compositions at Passive Zone 2

A similar research has been done in Salonta, Romania Landfill. The purpose of this study was to assess the soil quality status in the Salonta Landfill, Romania which has been operating since 1975. Salonta Landfill had an area of 114,900 square meters or 11.49 hectares with uncontrolled landfill or open dumping system and now the current capacity of existing landfill has been about 50% used. The conducted research on the active and passive zones with 3 sampling points of subsoil quality was taken at 0.2 m and 0.4 m depth. The sampling points represent the samples taken outside the landfill area; the samples taken within the inactive landfill area, and the sample taken in the active landfill area. The sampling was done by hand drilling. The indicators analysed included humus, organic C, total N, and C/N ratio. The research concluded that the samples taken outside the landfill at 20-40 cm depth had 9.04% humus content, 5.24 %C, 0.412 %N, and the C/N ratio 12.72. In the samples taken from the passive zone, there were 9.85% humus content, 5.71 %C, 0.442 %N, and the 12.92 C/N ratios, and the samples taken from the active zone there were 15.03% humus content, 8.72 %C, 0.564 %N and the 15.46 C/N ratio. [9] The result in Randegan Landfill showed that the C/N ratio ranged from 8.33 to 10.75. The difference of the C/N ratio values with previous studies depends on the quantity of waste, geography, landfill age, and various disposed waste [9].

The active zone which had 5726.809 m^2 of areas, filled with solid waste by the average height of 7.472 meters. The volume of new solid waste was observed based on the total number of waste trucks transporting the landfill for 8 observation days. The results of calculation of trucks transporting and the solid waste volumes can be seen in Table 2.

Table 2 the number of incoming transporting vehicles and volume of solid waste transporting the Randegan Landfill

Vehicle	**Average of incoming transporting vehicles (X units/day) ± SD**	**Average Volume of solid waste (X m^3/day) ± SD**
Dump truck	6.0 ± 3.0	100.1±7,66
Armroll	7.0 ± 3.0	108.32±7,96
Tossa	6.0 ± 3.0	12.56±2,71
Pick up	1.0 ± 1.0	7.70±2,13
Cart	1.0 ± 1.0	1.50 ±0,93
Diesel car	1.0 ± 1.0	1.15±0,82
Total		231.33

The average volume of solid waste transporting Randegan Landfill was 231.33 m^2/day. The result of the study was that solid waste composition distribution consisted of plastic, metal, textiles, glass, wood, paper, road waste (leaf), hazardous waste, food waste, vegetable waste, and other plastic types with a percentage of 13.22 plastic, 0.34% metals, 2.95% textiles, 0.42% glass, 4.23% wood, 6.43% paper, street waste 10.43%, 5.30% hazardous waste; 48.59% food waste and vegetable waste 7.58% and 0.5% others. The percentage of the distribution composition of the waste in Randegan Landfill is shown in Figure 4 below.

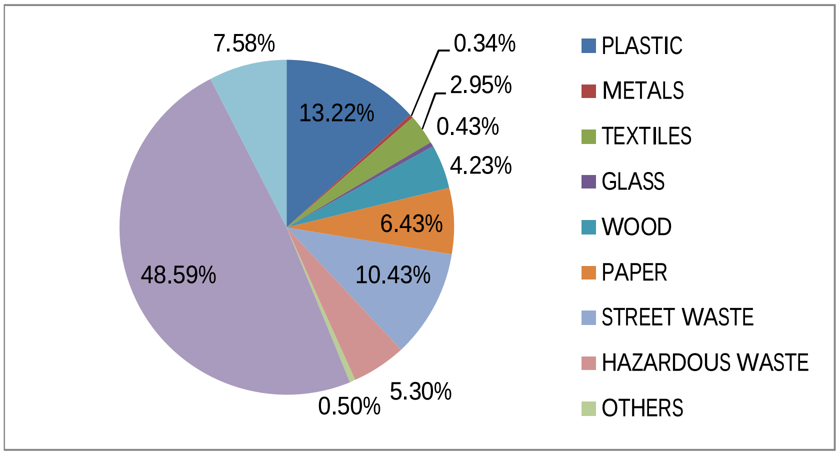

Figure 4 Percentage Composition of inflowing new solid waste in Randegan Landfill

Figure 4 showed that the highest composition was food waste by 48.59%. The composition fraction measured was 80.21% for wet waste and 19.79% for dry waste. The similar study in Lagos Landfill, Nigeria, which operated with open dumping system, resulting composition was 68% vegetables and leftover food, 10% papers, 4.0% cloths, 3.0% metals, 7.0% plastics, 4.0% glasses, 3.0% others, 0.70% bones. [10] Another study in China showed that food waste was the dominant composition of 64.48%, followed by plastic, paper, glass, textiles, metal, and wood and bamboo. The potential of waste that can be recycled such as paper, plastic, glass, metal and textiles was as much as 20.39% of household waste [11].

To determine the physical and chemical characteristics of the solid waste, each composition of identified waste then analysed in the laboratory with the parameters of moisture, calorie, % C, % N, % P and C/N ratio. The results of physical and chemical characteristics and analysis on the solid waste are as shown in Table 3.

Table 3 Physical and Chemical characteristics of solid waste at Randegan Landfill according to laboratory analysis

Composition	Mean ± SD
Moisture (%)	40.64 ± 7.94
Nitrogen (% N)	3.31 ± 0.51
Phosphorus (% P)	0.14 ± 0.05
Carbon (% C)	40.04 ± 6.29
Calor (Cal / g)	3992.59 ± 198.24
% C/N	12.31 ± 2.50

One of the indicators to determine the alternative for waste treatment by composting process was the value of the C/N ratio. The values of carbon and nitrogen content as well as the value of C/N ratio of the solid waste in Randegan Landfill was relatively small when compared with the C/N ratio in past studies. The C/N ratio of the waste in Randegan Landfill ranged from 7.7 to 15.45, while the C/N ratio of the new solid waste in Thailand was about 40-47 with an average of 43.5 [12]. A study of urban waste in Guwahati, India generated C/N ratio of 31.0-38.0 [13] meanwhile, the C/N ratio research of domestic waste in Accra, Ghana obtained the C/N ratio value of 27-100 [14]. The C/N ratio was very different to previous studies because it highly depended on the solid waste composition generated by local communities. The specificity of various places / regions as well as the different types allowed different properties of solid waste. The composition of municipal waste in developing countries will be different from the waste in developed countries [8]. The optimum value of C/N ratio for composting is between 20 to35 [15]. Higher C/N ratio will cause the composting process takes a longer time to oxidize the carbon into carbon dioxide. Lower C/N ratio will cause the nitrogen, which is an important result the final compost, comes off as ammonia [16]. The optimum C/N ratio value can be achieved by adding an element that has relatively high C/N ratio, such as sawdust that has 200-400 C/N ratios [8].

From the conducted research, the water content of the solid waste transporting Randegan Landfill was about 28% - 57%. Efficient composting process requires moisture content above 45-50% [1], while from some past studies concluded that waste with 50-60% moisture content was appropriate and efficient for composting [17]. Research conducted in China illustrates that the highest water content contained in food waste, which is 70.61 w/w%, followed by the water content of paper, which is 26.15%; Plastic 12.87%; linen 43.24%; 0.31% glasses; metal 2.17%, wood and bamboo 27.27%, so the average water content in waste at 56.50 w/w%, which became the most influential factor in determining the separation of recyclable materials and materials with low calor value. Although the lowest calorie value were still suitable for incineration, but the value is still too low to take advantage of the heat and incineration with consideration of cost effectiveness [11]. With the high water content of Mojokerto municipal waste, composting solid waste can be considered more optimal as alternative treatment.

From the results, the waste in Randegan Landfill could be treated according to their composition and characteristics. Some alternative treatments could be used are (1): Solid Waste Composting Technology in an aerobic process by a biological degradation of biodegradable organic waste such as garden waste and food waste. Composting is a relatively fast process, which takes about 4-6 weeks to achieve product stability [16]. The things to consider in the composting process, i.e. composted materials; microorganisms; moisture; availability of oxygen; carbon and nitrogen content; conditions of acid-base (pH); temperature; and levels of decomposition. [8] The optimum value of C/N ratio is between 20 and 35 while the C/N ratio of Randegan Landfill waste only ranged from 7.7 to 15.45. To obtain the ideal %C/N ratio conditions in the composting process, it required some material addition to raise the level of C so that the waste can be composted. Wood elements (such as sawdust) can be added to the waste because the wood has high C/N ratio, which is 200-400. [8] From the water content, Mojokerto solid waste met the criteria value of composting; (2) Solid Waste Mining, to recover and reuse the materials from solid waste closed and deposited for 5-10 years, namely in the form of materials such as compost or soil cover, by digging and sifting the waste. Landfill mining is one of the final solutions to mine the deposit solid waste at minimal cost. Landfill mining of solid waste deposit is a simplest treatment to get the benefit from the yearly waste deposit. Landfill mining particularly seen as a way to solve the problem of solid waste management with limited landfill area and the concerns over environmental pollution [18]. Zone one and zone two of Randegan Landfill were the passive zones suitable for landfill mining process, had soil as dominant composition with a percentage of 72.30 in zone one and 60.15 in zone two; and (3) Material Recovery Facilities (MRF), solid waste material recovery for new and deposit wastes, and independent on the solid waste composition. The solid waste should be separated and sold as raw material or recycled to other products [19]. Solid waste is separated as wet and dry waste. Dry waste includes paper, plastic, glass and metal, while wet waste can be used as compost. According to the composition and characteristics of waste in Randegan Landfill Mojokerto with the 80.21% wet waste and 19.79% dry waste, the concept of MRF can be applied.

CONCLUSION

In conclusion the solid waste deposit in passive zone showed as soil-like texture 60.15 % - 72.30% of the volume 14.718 m^3 and has high potential used as cover soil or solid waste composting material by landfill mining process. The amount of solid waste transporting the landfill active zone has an average volume of 233.31 m^3/day and the composition was dominated by food waste by 48.59%. From the volume of solid waste transporting the landfill, the measured wet waste was 80.21% and dry waste was 19.79%. The recommendation for Randegan Landfill waste is composting by some addition of treatment, landfill mining, and establishing MRF *(Material Recovery Facilities)* by combining the management for wet waste and dry waste.

ACKNOWLEDGEMENT

Authors are very grateful to the Department of Hygiene and Landscape Gardening of Mojokerto City, Indonesia, and all parties who has helped by providing data and facilities as well as giving various thought in this research.

REFERENCES

1. Tchobanoglous, G.H. and Frank Kreith. 2002. *Handbook of Solid Waste Management*: Second Edition. McGraw-Hill, New York.
2. Pemerintah Republik Indonesia. 2008. *UU Republik Indonesia No 18 Tahun 2008.*
3. Kementerian PU. 2011. *Dasar-Dasar Sistem Pengelolaan Sampah*. Direktorat Jenderal Cipta Karya Kementeriaan Pekerjaan Umum, Jakarta.
4. S.J. Burnley, J.C. Ellis, R. Flowerdew, A.J. Poll, H. Prosser, 2006,Assessing the composition of municipal solid waste in Wales, Resources, *Conservation and Recycling* 49 (2007) 264–283
5. Sudrajat, H.R. 2006. *Mengelola Sampah Kota*. Penerbit Penebar Swadaya, Jakarta..

6. Assaad, Ragui. 1996. Formalizing the Informal The Transformation of Cairo's Refuse Collection System. *Journal of Planning Education & Research*, vol.16, p.118.
7. Badan Standarisasi Nasional (BSN), 1995, *Standar Nasional Indonesia (SNI) 19-3983-1995. Spesifikasi Timbulan Sampah Untuk Kota Kecil dan Sedang di Indonesia*, Departemen Pekerjaan Umum, Jakarta
8. Tchobanoglous G, Theisen H, and Vigil S. 1993. *Integrated Solid Waste Management, Engineering Principles and Management Issues*. New York: McGraw-Hill, Inc. pp. 381-417
9. Vicaş Gabriela, Mintaş Olimpia, Analele Universităţii din Oradea, *Fascicula Protecţia Mediului* Vol. XVI, 2011 (p.501-506)
10. Kofoworola O.F, Recovery and recycling practices in municipal solid waste management in Lagos, Nigeria, *Waste Management* 27 (2007) 1139–1143
11. Ying Zhuang, Song-Wei Wu, Yun-Long Wang, Wei-Xiang Wu *, Ying-Xu Chen, Source separation of household waste: A case study in China. *Waste Management* 28 (2008) 2022–2030
12. Visvanathan, C., Ing. Josef Traenklar, Kuruparan, dan Tenzin Norbu. 2002. Sustainable Solid Waste Landfill Management in Asia: *Final Report Phase-I. Environmental Engineering and Management Program, Asian Institute of Technology*. Pathumthani, Thailand.
13. Pradhan, P. K., C. R. Mohanty, A. K. Swar, dan P. Mohapatra. 2012. Urban Solid Waste Management of Guwahati City in North-East India. *Journal of Urban and Environmental Engineering*, v.6, n.2, p.67-73.
14. Carboo, D. dan J.N. Fobil. 2005. Physico-Chemical Analysis of Municipal Solid Waste (MSW) in the Accra Metropolis. *West African Journal of Applied Ecology*, Vol. 7, 2005, p. 31-39.
15. Williams T, Paul. 2005. *Waste Treatment and Disposal. Second Edition*. England: Wiley & Sons, Ltd
16. Dalzell, H.W., A.J. Biddlestone, K.R. Gray, K. Thurairajan. 1987. Soil Management: Compost Production and Use in Tropical and Subtropical Environments. *Food & Agriculture Organizations of The United Nations: Rome, Italy.*
17. Féniel Philippe, Marc Culot, Household solid waste generation and characteristics in Cape Haitian city, Republic of Haiti. Resources, *Conservation and Recycling* 54 (2009) 73–78.
18. Joakim Krook, etc. Landfill mining: A critical review of two decades of research. *Waste Management*.Volume 32, Issue 3, March 2012, Pages 513–520
19. Davila, E., Chang, N.-B.Sustainable pattern analysis of a publicly owned material recovery facility in a fast-growing urban setting under uncertainty, *Journal of Environmental Management* Volume 75, Issue 4 SPEC. ISS., June 2005, Pages 337-351