Overview of the Potential of MSW as Fuel on the Power Plant in Indonesia

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Abstract

Municipal solid waste (MSW) is one of the problems in urban areas because it can damage aesthetics and contaminate the environment, especially the plastic solid waste (PSW). However, it has the potential for energy waste which can be used as fuel in power plants. Implementation of WTE conversion method is one of the handling of MSW and PSW effective compared to landfill. This method can reduce significant volume of waste to 90% and reduce the waste mass to 75%, as well as the combustion energy can generate electrical energy. Utilization of MSW and the PSW is optimal as a fuel in power plants is one of the alternative MSW management problems and also can overcome the electrical energy crisis in Indonesia.

Key words: MS, PSW, WTE, waste, energy, electric, power plant.

1. Introduction

Municipal solid waste (MSW) is a source of environmental pollution and damage the aesthetics. MSW is generally composed of plastic, paper, paperboard, glass, aluminum, steel, yard waste, food waste, etc (Environmental and Plastic Industry Council, 2004). Impact on the environment due to disposal of MSW that is polluting the water and soil, as well as causing global warming, stratospheric ozone depletion, acidification, photochemical ozone formation, chronic toxicity, acute toxicity, and physical disturbance (Claus, 1995). However, the waste has economic value and energy content of which can increase the income and welfare of the community, such as a source of income for scavengers, raw material for making compost (fertilizer), fuel in small industry, and as a fuel in power plants.

Problems in Indonesia are not only the waste problem, but also the electric energy deficiency problems. In rural areas there are still many people who do not use electricity and in urban areas are still frequent rolling blackouts. In 2010, Western and Eastern Indonesia is still experiencing a crisis caused by the limited ability of PT. PLN plant to fulfill the needs. It is characterized by the presence of severe rolling blackouts. In anticipation of this, the Government issued a policy development of New and Renewable Energy, including the development of biomass energy (Decree of the Minister of Energy and Mineral Resources, 2010). Some countries in Asia have been using MSW and plastic solid waste (PSW) as a fuel in power plants by the method of converting waste to energy (WTE) such as Japan, South Korea, Taiwan (Tsai & Kuo, 2010), Thailand (Krause, 2012), and Malaysia (Kathirvale, Muhd Yunus, Sopian, & Samsuddin, 2004). Even in China (Kefa, 2002) there are several power plants in operation, namely Shenzhen MSW incineration power, Pudong MSW incineration power, Ningbo MSW incineration power, Longgang Power MSW incineration, etc. Similarly in Europe, there are several countries that have used the MSW as WTE plants such as Italy about 30%, Denmark about 65%, France about 42.3%, Germany about 40%, and Sweden about 55% (MGM Engineering & Contracting, 2009). Targets are reduces MSW volume drastically and simultaneously generate electricity for the community.

Therefore, the combustion of WTE conversion method needs to be optimized and developed, especially in Indonesia, which handles the problem of MSW and is still lack electrical energy. The WTE conversion process can reduce the volume of MSW about 90% and reduce the weight of MSW to 75% (C-Tech Innovation Ltd, 2003), and can produce energy for electricity generation. MWS handling advantages by using incinerator technology (WTE) which can reduce the volume waste up to 90%, thereby reducing disposal of MSW in landfill (Cheng & Hu, 2010). Thus it would make more efficient use of the landfill by 90%. Even with a combination of WTE conversion method can be obtained by recycling of MSW increased energy savings is 40% (Lea, 1996).

Based on the above, there are two main problems faced by Indonesia, namely the increasing volume of MSW per year and increasing need electrical energy due to the increase of population and lifestyle changes. Thus, the handling of MSW by WTE method is an appropriate method than by landfill because it can significantly reduce the volume of MSW and can simultaneously generate electrical energy to overcome the electrical energy crisis in Indonesia.

2. Methodology

To determine the potential of MSW as a fuel in power plants in Indonesia, conducted review of of energy content of MSW generated every day in every city in Indonesia. In a review of potential MSW as fuels in power plants, Indonesia sampled by the consideration that Indonesia is still experiencing problems handling MSW in big cities and are still experiencing power shortages, especially in rural areas. The data used to assess the potential of MSW as a fuel in power plant in Indonesia is a secondary data obtained from the Environmental Statistics of Indonesia (2009) and the data obtained from the Journal the results of previous studies. MSW data that is used to analyze the potential energy of MSW as a fuel is the data of 2007 and 2008. The unit of analysis selected seven central city of provinces representing 33 provincial cities in Indonesia that produces a large volume of MSW, namely Jakarta, Semarang, Surabaya, Bandung, Palembang, Medan, and Makassar.

Data analysis includes: a) Estimation of MSW Potential in Indonesia; b) Estimation of Potential Energy Contents of MSW; c) Estimation of the Potential Electrical Energy Generated; d) Techno-Economic Utilization of MSW as a Fuel; e) Feasibility of MSW Power Plant. In analyzing the energy potential of MSW in Indonesia, required MSW volume of data generated and owned calorific value. Calorific value of MSW and other fuels can be obtained based on secondary data from previous studies.

3. Result and Discussion

3.1 Estimation of MSW Potential in Indonesia

To estimate the potential energy contained in the MSW can be determined by knowing the volume of waste generated and the calorific value of the owned by the waste. The volume of MSW generated is influenced by population and lifestyle of the people. The magnitude of the volume of MSW generated per person on average about 0.21 kg to 0.50 kg per day in India by volume of plastic solid waste (PSW) of about 8% of the total MSW generated (Gautam, 2009), it can even result in PSW for about 10% of the volume MSW (C-Tech Innovation Ltd, 2003). While in Malaysia each person generates an average MSW 0.5 kg - 0.8 kg per day and increased to 1.7 kg per person per day in the big city (Hussain, Ani, Sulaiman, &

Adnan., 2006). Similarly in Italy, every year produces 25 million tons of MSW and every person generating 1.25 kg MSW per day (MGM Engineering & Contracting, 2009).

Production and the volume of MSW generated per day in Indonesia can be obtained from Environmental Statistics in Indonesia (2009). In the statistical data obtained from the amount of MSW volume 33 of the province in Indonesia in 2007 amounting to 100,953 m^3 (24,228.72 tons) and increased to 105,219 m^3 (25,252.56 tons) in 2008, indicates an increase of about 4.2% or 4,266 m^3 (1,023.84 tons). In Table 1, presented seven cities (provincial capital) from 33 provinces in Indonesia which is used as a sample review of the potential energy produced by MSW.

Table1. Potential of MSW Generated in Seven Major Cities in Indonesia

No.	City	Years	Production of MSW per day		Estimated Production PSW per day	
			(m^3)	(kg)	(m^3)	(kg)
1	DKI Jakarta	2007 2008	27,654 29,217	6,636,960 7,012,080	2,765.4 2,921.7	309,724.8 327,230.4
2	Semarang	2007 2008	20,160 21,880	4,838,400 5,251,200	2,016.0 2,188.0	225,792.0 245,056.0
3	Surabaya	2007 2008	8,700 8,708	2,088,000 2,089,920	870.0 870.8	97,440.0 97,529.6
4	Bandung	2007 2008	6,904 7,500	1,656,960 1,800,000	690.4 750.0	77,324.8 84,000.0
5	Palembang	2007 2008	4,981 3,829	1,195,440 918,960	498.1 382.9	55,787.2 42,884.8
6	Medan	2007 2008	5,495 2,236	1,318,800 536,640	549.5 233.6	61,544.0 26,163.2
7	Makassar	2007 2008	3,662 3,813	878,880 915,120	366.2 381.2	41,014.4 42,694.4

Source: Environment Statistics of Indonesia, 2009.

In Table 1, it appears that the DKI Jakarta as the first order of largest production of MSW is about 27,654 m^3 and increased in the year 2008 to 29,217 m^3, an increase of 5.7%. Semarang increased 8.5%, Makassar an increase of 4.1%. Meanwhile, Surabaya as the second largest city and populous after Jakarta but increased only a very small volume of MSW that is equal to 0.1%. This could be due to lifestyle of the people who are increasingly aware of the environment, thus optimizing the reuse and recycling waste that is like the use of plastic bags over and over again.

In Table 1, it appears the production of plastic solid waste (PSW) are produced every day of every large city that is about 10% of the total production of MSW and has a large potential energy because it has a calorific value of about 30,030 kJ kg^{-1} to 41,500 kJ kg^{-1} (C-Tech Innovation Ltd, 2003). Waste has been widely used as a fuel in power plants in both developing countries and in developed countries such as Japan, India, Taiwan, Malaysia, and others.

3.2 Estimation of Potential Energy Contents of MSW

Energy potential of MSW can be estimated by using the calorific value of MSW = 9,165 kJ kg^{-1} (Cheng & Hu, 2010) and the calorific value of PSW = 39,030 kJ kg^{-1} (C-Tech Innovation Ltd, 2003). The estimation results obtained are presented in Table 2 below.

Table 2. Estimation of Energy Produced per day of MSW and PSW

No	City	Years	Production of MSW per day (ton)	Energy Total of MSW per day (GJ)	Production of PSW per day (ton)	Energy Total of PSW per day (GJ)
1	DKI Jakarta	2007 2008	6,637.0 7,012.1	60,827.7 64,265.7	309.7 327.2	12,087.6 12,770.8
2	Semarang	2007 2008	4,838.4 5,251.2	44,343.9 48,127.2	225.7 245.1	8,812.0 9,563.8
3	Surabaya	2007 2008	2,088.0 2,089.9	19,137.6 19,154.1	97.4 97.5	3,802.8 3,806.3
4	Bandung	2007 2008	1,657.0 1,800.0	15,186.1 16,497.0	77.3 84.0	3,016.7 3,278.3
5	Palembang	2007 2008	1,195.4 919.0	10,956.2 8,422.3	55.8 42.9	2,177.2 1,673.7
6	Medan	2007 2008	1,318.8 536.6	12,086.8 4,918.3	61.5 26.2	2,401.9 1,021.1
7	Makassar	2007 2008	878.9 915.1	8,054.9 8,387.1	41.1 42.7	1,600.7 1,666.2

At the Table 2, it appears that the energy contained in the MSW and PSW very large produced each day in the big cities in Indonesia. For example, in the 2008 Jakarta produces MSW per day about 29,217 m^3 (7,012.1 tons), the obtained energy content of 64,265.7 GJ. PSW generated every day by 2,921 m^3 (327,23 tons), the obtained energy content of 12,770.8 GJ PSW. In the same way the potential energy in the city of MSW and PSW are obtained. Likewise, in Makassar, the year 2008 produced approximately 915.1 tons of MSW by energy content of

8,387.1 GJ and PSW produces by total of 42.7 tons with total energy is 1,666.2 GJ. Energy potential of MSW and the PSW is eligible for use as fuel (energy source) on the power plant. Analysis of the amount of electrical energy can be generated by the waste can be seen in the following discussion.

3.3 Estimation of the Potential Electrical Energy Generated

Potential electrical energy generated by the MSW can be estimated based on the results of previous studies. Each 1,000 kg of MSW combustion will produce about 2,500 kg – 3,000 kg of steam and electrical energy will produce about 500 kWh - 600 kWh (MGM Engineering & Contracting, 2009). The same revelation that combustion of 1 ton of MSW will produce electrical energy of 500 kWh - 600 kWh (ASME, 2008). Electrical energy content of MSW depends on the calorific value and humidity levels, so the chances in 1 ton of MSW can only produce about 200 kWh of electrical energy when calorific value of only about 3,300 kJ kg^{-1} and the moisture level of about 50-55% (Cheng & Hu, 2010). Potential energy of combustion of 1,500 tons per day of MSW incinerator plant in by calorific value of 9,240 kJ kg^{-1} will produce 640 kW of electrical power per day (0.64 MW per day) or 640,000 W per day (Kathirvale, et al., 2004). Ideally (without considering losses), based on research results MGM Engineering and Contracting (2009), each 1,000 kg of MSW combustion of will produce about 2,500 kg of steam and electrical energy will produce about 500 kWh, then the amount of electrical energy to be generated in each city can be predicted, such as the Table 3.

Table 3. Estimated Production of Steam (ton), Energy Electricity Produced (MWh), and Capacity of Power Plant (MW).

No	City	Years	Production of MSW per day (ton)	Production of Steam per day (ton)	Production of Ideal Electrical Energy (MWh)	Production of Theoretic Electrical Energy (MWh)	Capacity of Power Plant (MW)
1	DKI Jakarta	2007 2008	6,637.0 7,012.1	16,592.4 17,530.2	3,318.5 3,506.0	1327.4 1402.4	138.3 146.1
2	Semarang	2007 2008	4,838.4 5,251.2	2,096.0 3,128.0	2,419.2 2,625.6	967.7 1050.2	100.8 109.4
3	Surabaya	2007 2008	2,088.0 2,089.9	5,220.0 5,224.8	1,044.0 1,045.0	417.6 418	43.5 43.5
4	Bandung	2007 2008	1,657.0 1,800.0	4,142.4 4,500.0	828.5 900.0	331.4 360	34.5 37.5

5	Palembang	2007 2008	1,195.4 919.0	2,988.6 2,297.4	597.7 459.5	239.1 183.8	24.9 19.2
6	Medan	2007 2008	1,319.0 537.0	3,297.0 1,341.6	659.4 268.3	263.8 107.3	27.5 11.2
7	Makassar	2007 2008	879.0 915.1	2,197.2 2,287.8	439.4 457.6	175.8 183.1	18.3 19.1

In Table 3 (2008), Jakarta produces about 7,012.1 tons of MSW per day by total energy of about 64,265.7 GJ. If all MSW is used as fuel in the boiler will produce steam for 17,530,200 kg by electric energy production of 3,506,040 kWh. Similarly also in Makassar an MSW used as fuel in power generation will produce 2,287,800 pounds of steam and electric energy of 457,560 kWh (457.6 MWh). This indicates that the energy potential of MSW in every city in Indonesia, especially in Makassar very decent used as fuel in power plants.

In Table 3 is obtained that in the year 2008, Makassar produced 915.1 tons of MSW per day. This means that every day available the fuel of about 915.1 tons of MSW or MSW fuel available about 38.1 tons every hour. Ideally (without considering losses), it can be said that the Makassar city can operate MSW power plant with a capacity of about 38.1 tons of furnace per hour and will be able to produce about 95.3 tons of steam as well as electric energy by 19.1 MWh. However, in theory (according to Kutz, M, 2007), the MSW power plant losses occurred about 44-53% and the transmission and distribution losses occurred about 8%, so the overall efficiency of about 30-51%. Thus, if the overall efficiency of 40%, the power generation capacity theoretically can be estimated as in Table 3. As an illustration, in Malaysia has utilized PSW of MSW as a fuel with a capacity of 1,000 tons of MSW per day and produce PSW about 100 tons per day to generate electric power of 8.9 MW (Core Competency Sdn Bhd, 2010). In this case, every 1 ton of MSW/ PSW can produce 89 kW of electrical power per day.

3.4 Techno-Economic Utilization of MSW as a Fuel

MSW economic value when used as fuel in power plants, can be estimated by performing an economic analysis by convert the energy into a fuel by coal and fuel oil based on the value of calorific coal of about 27,000 kJ kg^{-1} (United Nations Environmental Programme, 2009) and the fuel heating value of about 48,500 $kJkg^{1}$

(Environmental and Plastic Industry Council, 2004). The results of analysis and conversion into coal and fuel can be seen in Table 4 below.

Table 4. Equivalency of MSW Energy Potential in Coal and Fuel

No	City	Years	Production of MSW per day (ton)	Energy Total of MSW per day (GJ)	Equivalent with coal (ton)	Equivalent with Fuel Oil (ton)
1	DKI Jakarta	2007 2008	6,637.0 7,012.1	60,827.7 64,265.7	2,252.9 2,380.2	1,254.2 1,325.1
2	Semarang	2007 2008	4,838.4 5,251.2	44,343.9 48,127.3	1,642.4 1,782.5	914.3 992.3
3	Surabaya	2007 2008	2,088.0 2,089.9	19,137.6 19,154.1	708.8 709.4	394.6 394.9
4	Bandung	2007 2008	1,657.0 1,800.0	15,186.0 16,497.0	562.5 611.0	313.1 340.1
5	Palembang	2007 2008	1,195.4 919.0	10,956.2 8,422.3	405.9 311.9	225.9 173.7
6	Medan	2007 2008	1,318.8 536.6	12,086.8 4,918.3	447.7 182.2	249.2 101.4
7	Makassar	2007 2008	878.9 915.1	8,054.9 8,387.1	298.3 310.6	166.1 172.9

As examples of analysis, Table 4 above appear in the Year 2008, Makassar produce 915.12 tons per day of MSW with energy content of 8,387.1 GJ. The total energy when converted into coal by taking the calorific value of coal and fuel oil as described above, equivalency value will be 310.6 tons of coal or fuel equivalent 172.9 tons, or about 203,411.8 liters (203.41 m^3) assuming a density of fuel oil is 0.85. The energy content of the value when converted into a price premium (Rp. 4,500) will be obtained a value of Rp. 915,353,100. This suggests that the economic value of energy content of MSW generated every day in Makassar amounted to Rp. 915,353,100 if the energy content of MSW is converted into a price premium.

3.5 Feasibility of MSW Power Plant

To determine the feasibility of the operation of MSW power plant in Makassar, a lot of things that need to be considered and studied in more depth. One of them is the continuity of supply of fuel per day is necessary for the operation of the power plant and the environmental impact. Based on Table 3, Makassar in the year 2008 produced approximately 915.1 tones of MSW per day, or available about 38.1 tons per hour. This shows that in the city of Makassar is feasible to operate the power plant with a capacity of MSW combustion furnace of about 38.1 tons per hour, is predicted to produce 95.3 tons of steam per hour and produce electrical energy per hour of 19.1 MWh (19.000 kWh per hour). MSW volume trends will increase each year by the increase of population, given that Makassar is the largest city in eastern Indonesia and will be heading into one of the Metropolitan cities in Indonesia.

Furnace that can be used, namely Fluidized Bed Combustion (FBC), Grate Bed Furnace (GBF), Pulverized Fuel Combustion (PFC). FBC is widely used, such as in Thailand (Suksankraisorn, Patumsawad, & Fungtammasan, 2010) in China because of characteristics that can handle low heat value of MSW, maintaining a stable combustion (Yan, et al., 2006). Grate Bed Furnace (Stocker Furnace) are used for combustion of biomass with a capacity of about 1 MWh and larger. Pulverized Fuel Combustion (PFC) is used for combustion of biomass fuels in the form of powder (pulverized). Advantages of this furnace due to high power, high efficiency furnace, and good control. The furnace is used in the capacity of between 500 kWh and 50MWh. Proper mixing of fuel and combustion air are effective measures for reduction of NOx (Kaltschmitt et al., 2009). Process Flow Sheet of Incinerator by FBC can be seen Figure 1.

The environmental impact that caused from burning MSW incinerator would be anticipated with the use of which is equipped with a flue gas emissions as controller which was developed in China (Shi, et al., 2008), so that the gas-gas emissions that are harmful to the appropriate standard minimize emissions of air quality standards.

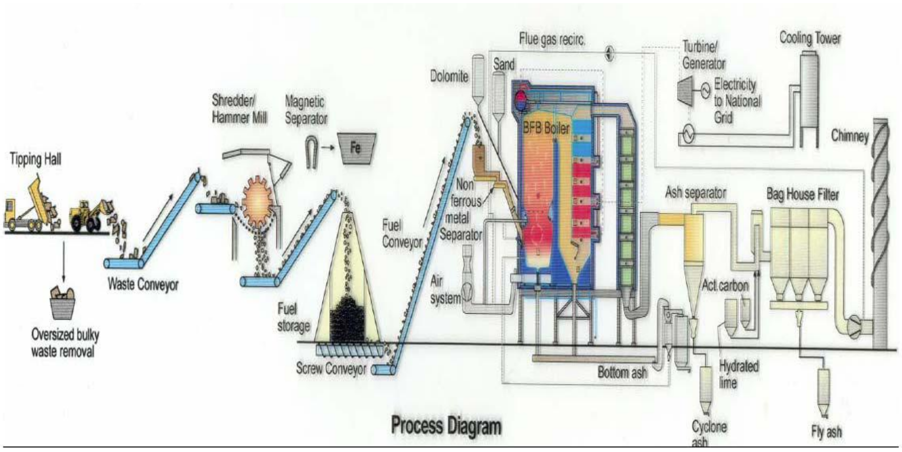

Figure 1. Process Flow Sheet of Incinerator by FBC (Mininni, 2008).

4. Conclusion

Municipal solid waste (MSW) other than one of the sources of environmental pollution, is also a great source of potential energy which can generate electrical energy. The volume of MSW generated in all cities in Indonesia tends to increase each year due to increasing population and changing lifestyle of the people. Application of the method of conversion of waste into energy (WTE) can significantly reduce waste volume by 90% and reduce the waste mass to 75%, and generating electrical energy. Utilization of MSW and the PSW is optimal as a fuel in power plants is one of the alternative waste handling problems and also can overcome the energy crisis in Indonesia. Energy potential of MSW generated and PSW depends on the content and the calorific value and the total volume of MSW generated PSW every day.

5. References

ASME. (2008). Waste-to-Energy: A Renewable Energy Source from Municipal Solid Waste.

C-Tech Innovation Ltd. (2003). Thermal methods of municipal waste treatment. *Programme on Sustainable Resource Use*(Website:www.Capenhurst.com).

Cheng, H., & Hu, Y. (2010). Municipal solid waste (MSW) as a renewable source of energy: Current and future practices in China. [doi: 10.1016/j.biortech.2010.01.040]. *Bioresource Technology, 101*(11), 3816-3824.

Claus, M. (1995). Environmental impacts by disposal of plastic from municipal solid waste. [doi: 10.1016/0921-3449(95)00013-9]. *Resources, Conservation and Recycling, 15*(1), 51-63.

Core Competencies Sdn Bhd.(2010). A Holistic Approach to Waste Management. Simenyih, Selangor, Malaysia.

Decree of the Minister of Energy and Mineral Resources. (2010). Rencana Usaha Penyediaan Tenaga Listrik PT PLN 2010 - 2019.

Environmental and Plastic Industry Council. (2004). A Review of the Options for the Thermal Treatment of Plastics. *Environment and Plastics Industry Council (EPIC)*.

Gautam, S. P. (2009). Assessment of Plastic Waste and Its Management at Airports and Railway Stations in Delhi. *Central Pollution Control Board (CPCB)*.

Hussain, A., Ani, F. N., Sulaiman, N., & Adnan., M. F. (2006). Combustion modelling of an industrial municipal waste combustor in Malaysia. *International Journal of Environmental Studies, 63*(3), 313-329.

Kathirvale, S., Muhd Yunus, M. N., Sopian, K., & Samsuddin, A. H. (2004). Energy potential from municipal solid waste in Malaysia. [doi: 10.1016/j.renene.2003.09.003]. *Renewable Energy, 29*(4), 559-567.

Kefa, L. X. Y. J. C. Y. N. M. C. (2002). Development of Municipal Solid Waste Incineration Technologies. *Better Air Quality in Asian and Pacific Rim Cities (BAQ 2002)*.

Krause, M. (2012). Thailand Biomass Case Study.

Kurtz, M.(2007). Environmentally Concious Alternative Energy Production. Canada.

Lea, R., W. (1996). Plastic incineration versus recycling: a comparison of energy and landfill cost savings. [doi: 10.1016/0304-3894(95)00117-4]. *Journal of Hazardous Materials, 47*(1-3), 295-302.

MGM Engineering & Contracting. (2009). Waste -To-Energy Power Plants. *MGM Enginnering and conttracting*, 1-9.

Mininni, G., P. De Stefanis, E. Barni, R. Chirone, M. Urciuolo. (2008). New Technologies for MSW Thermal Treatment: The State of theArt.

Shi, D.-Z., Wu, W.-X., Lu, S.-Y., Chen, T., Huang, H.-L., Chen, Y.-X., et al. (2008). Effect of MSW source-classified collection on the emission of PCDDs/Fs and heavy metals from incineration in China. [doi: 10.1016/j.jhazmat.2007.09.026]. *Journal of Hazardous Materials, 153*(1-2), 685-694.

Suksankraisorn, K., Patumsawad, S., & Fungtammasan, B. (2010). Co-firing of Thai lignite and municipal solid waste (MSW) in a fluidised bed: Effect of MSW moisture content. [doi: 10.1016/j.applthermaleng.2010.07.020]. *Applied Thermal Engineering, 30*(17-18), 2693-2697.

Tsai, W.-T., & Kuo, K.-C. (2010). An analysis of power generation from municipal solid waste (MSW) incineration plants in Taiwan. *Energy 35* 4824e4830.

United Nations Environmental Programme. (2009). Developing Integrated Solid Waste Management PlanTraining Manual. *Developing ISWM Plan, 4*

Yan, J. H., Chen, T., Li, X. D., Zhang, J., Lu, S. Y., Ni, M. J., et al. (2006). Evaluation of PCDD/Fs emission from fluidized bed incinerators co-firing MSW with coal in China. [doi: 10.1016/j.jhazmat.2005.12.007]. *Journal of Hazardous Materials, 135*(1-3), 47-51.