Current Status and Perspectives for the Production of Refuse Derived Fuel (RDF) Using Waste Vinyl and Sewage Sludge

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Abstract: - Power and heat generation from refuse derived fuel (RDF) is a promising technology for the utilization of municipal solid waste. By this time waste vinyl from agricultural production was discarded in the field and sewage sludge were buried into landfill or discharged into the ocean resulting in land and ocean pollution in Korea. To find out the possibility of producing RDF using waste vinyl and sewage sludge, current state of waste vinyl and sewage sludge production was investigated and, heavy metal components and heating values for those materials were analyzed. Waste vinyl from agricultural production and sewage sludge could be used to produce RDF if they are mixed with proper ratio to get enough heating value required as a standard RDF.

Key-Words: - Refuse derived fuel, Waste vinyl, Sewage sludge, Heating value, Energy

1. Introduction

Refuse derived fuels represent a wide range of waste materials which have been processed to use as main or supplementary fuel satisfying guideline in terms of shape and heating value. RDF has higher heating value which also remains fairly constant, the homogeneity of physical-chemical composition, the ease of storage, handling and transportation and, the lower pollutant emissions [1, 3]. Waste materials could be used to make RDF in Korea if they satisfy the cylindrical shape with diameter of 10-50 mm and length less than 100 mm, and the heating value of above 5,000 kcal/kg.

About 323,000 tons of waste vinyl from agricultural production were generated during 2005 showing increase every year. Waste vinyl materials were usually treated by landfill or incineration resulting in land or air pollution. About 2,560,000 tons of sewage sludge were generated during 2005, most of which were discharged into the ocean [2].

This study was undertaken to find out whether waste vinyl and sewage sludge could be utilized to make RDF.

The objectives of the study are as follows:

1) To investigate the present status of waste vinyl production from agricultural industry and sewage sludge production and their usages.
2) To analyze the heavy metal component and heating value of waste vinyl and sewage sludge.
3) To present optimum mixing ratio of waste vinyl and sewage sludge to acquire required heating value as a RDF.

2. Materials and methods

To get the present status of waste vinyl and sewage sludge production, statistical materials published by the government were used. Treatment method and cost data for waste vinyl were acquired from the waste vinyl management plant. To get component analysis and heating value, waste vinyl samples were picked up from 7 collection places and sewage samples were collected from five sewage treatment plants distributed in Chonnam Province of Korea.

Water content of the materials was measured by oven methods. Combustible component was determined using muffle furnace(LEF-115S, Lab Tech).

Heavy materials components of Pb, Cu, As, Hg, Cd, Cr^{6+}, CN and Oil were analyzed by the special analysis institute to get exact results. High heating value (HHV) was acquired using Bomb calorimeter. Low heating value was determined by the following equation:

$$Q_L = Q_H\,(1-\frac{W}{100}) - 600\times(\frac{9H}{100}+\frac{W}{100})$$

Where, Q_L = Low heating value (kcal/kg)
Q_H = High heating value (kcal/kg)
W = Water content (%)
H = Hydrogen (%)

Analysis of elements(C, H, N, S) was done using element analyzing apparatus (COSTECH4010).

3. Results and discussions

3.1 Present status of waste vinyl and sewage sludge production

About 323,000 tons of waste vinyl were produced from the protected horticulture materials such as mulching and vinyl house cover in 2005 with an annual increase as shown in Table 1. Among waste vinyl, LDPE(Low Density Polyethylene) from mulching operation were 124,078 tons, only 242 tons of which were utilized as renewable resources in 2005. The remainder were treated by reclamation or incineration.

Table 1. Waste vinyl production from agricultural work

(Unit : tons/year)

Year	2003	2004	2005
Total	257,140	264,880	322,947
LDPE for vinyl house	25,965	36,732	32,418
LDPE for mulching	109,659	97,604	124,078
HDPE	106,910	117,323	160,167
The others	14,606	13,222	6,284

There were eight waste vinyl treatment plants in our country, four of which were dry type treatment system while the other four systems were wet type treatment system. Treatment costs of waste vinyl were $140.8 for the dry type system while $140.3 for the wet type system showing similar cost between two systems.

About 2,561,000 tons of sewage sludge were generated from 294 sewage treatment plants of our country in 2005. Sewage sludge are treated by reutilization, reclamation, incineration and ocean discharge as shown in Table 2. Most of them are treated by ocean discharge resulting in ocean pollution and requiring the other treatment system which can use the sewage sludge as profitable resources.

Table 2. Sewage sludge productions and their usages

(Unit : tons/year)

Year	Production (A) = (B) + (C)	Quantities treated						Quantities transferred next year (C)
		Total(B)	Reuse	Landfill	Incineration	Ocean disposal	Others	
2002	2,073,095	2,072,972	106,624	254,919	200,338	1,471,472	39,619	123
2003	2,266,888	2,266,661	152,124	113,419	279,527	1,625,676	95,915	227
2004	2,426,070	2,426,070	239,085	34,295	283,356	1,869,334		
2005	2,560,959	2,560,196	122,365	43,740	285,778	1,993,865	114,449	763

3.2 Component analysis of waste vinyl and sewage sludge

3.2.1 Three component analysis

Moisture content(M.C), combustible content(C.C) and ash of waste vinyl from seven district are shown in table 3. Moisture content varied from 0.02% to 2.80% representing small difference possibly due to weather condition of sampling date. Combustible content varied from 58.3% to 92.5% showing much difference.

Table 3. Three representative component for waste vinyl

Regions	M.C (%)	Ash (%)	C.C (%)
Naju	2.80	30.40	66.80
Gwangju	0.02	14.50	85.30
Damyang	0.02	9.80	90.10
Boseong	0.03	39.20	58.30
Youngam	1.69	31.26	67.04
Hampyeong	1.22	10.59	88.19
Hainam	0.96	28.78	70.26

Moisture content, combustible content and ash of sewage sludge from five sewage treatment plants are shown in table 4. Moisture content varied from 70.1% to 84.3% according to regions. Sewage sludge needs dewatering and drying process to reduce moisture content to about 10% for RDF formation.

Table 4. Three representative component for sewage sludge

Regions	M.C (%)	Ash (%)	C.C (%)
Suncheon	84.30	5.81	9.89
Naju	78.60	8.87	12.53
Youngam	78.68	11.68	9.64
Hampyeong	77.16	8.23	14.61
Hainam	70.10	7.56	22.34

3.2.2 Heavy metal component analysis

Heavy metal component of the RDF should not exceed the permit limit to prevent air and soil pollution after burning. Heavy metal components, Pb, Cu, As, Hg, Cd, Cr^{6+}, CN and Oil, of waste vinyl from seven regions are shown in table 5. Content of all items were less than the limit showing the usability of waste vinyl as a raw materials of RDF.

Heavy metal components of sewage sludge from five sewage treatment plants are shown in table 6. Content of all items for sewage sludge were less than permit limit showing the usability of sewage as a RDF.

Table 5. Heavy metal quantities included in waste vinyl

Regions	Pb (mg/L)	Cu (mg/L)	As (mg/L)	Hg (mg/L)	Cd (mg/L)	Cr^{6+} (mg/L)	CN (mg/L)	Oil (%)
Naju	-	0.025	0.014	-	0.003	-	-	0.02
Gwangju	-	-	-	0.0008	0.004	-	0.027	-
Damyang	-	-	0.031	0.0006	0.005	-	0.026	-
Boseong	-	-	0.012	0.0008	0.003	-	0.026	-
Youngam	0.07	-	0.012	0.0008	-	-	-	-
Hampyeong	0.05	-	0.009	-	-	-	-	-
Hainam	-	-	0.006	-	0.003	-	0.027	0.01
Remark (Limit)	3	3	1.5	0.005	0.3	1.5	1	5

Table 6. Heavy metal quantities included in sewage sludge

Regions	Pb (mg/L)	Cu (mg/L)	As (mg/L)	Hg (mg/L)	Cd (mg/L)	Cr^{6+} (mg/L)	CN (mg/L)	Oil (%)
Suncheon	-	-	0.013	0.0021	-	-	-	-
Naju	-	-	0.006	-	0.003	-	-	-
Youngam	0.06	-	-	-	-	-	-	-
Hampyeong	0.09	0.072	0.004	-	-	-	-	-
Hainam	-	0.314	0.008	0.0005	0.002	-	-	-
Remark (Limit)	3	3	1.5	0.005	0.3	1.5	1	5

3.2.3 Element analysis

Elements of carbon, hydrogen, nitrogen and sulfur for waste vinyl and sewage sludge are as shown in table 7. More than 90% of waste vinyl was composed of carbon, hydrogen and nitrogen, while 60-70% of sewage sludge consisting of those materials.

Table 7. Element analysis of waste vinyl and sewage sludge

Regions	Waste vinyl				Sewage sludge			
	C (%)	H (%)	N (%)	S (%)	C (%)	H (%)	N (%)	S (%)
Naju	73.801	17.986	2.644	-	28.244	6.000	7.920	-
Youngam	72.598	18.079	2.719	-	21.267	3.549	6.177	-
Hampyeong	69.742	18.238	2.752	-	22.447	1.644	14.193	-
Hainam	79.881	16.558	3.961	-	37.055	5.694	10.878	-

3.3 heating value of waste vinyl and sewage sludge

The heating value measured by bomb calorimeter for the waste vinyl and sewage sludge are as shown in table 8. High heating values (HHV) of waste vinyl were from 7,887 to 10,277 kcal/kg showing mean value of 9,174 kcal/kg. Low heating values (LLV) of waste vinyl were from 7,329 to 9,584 kcal/kg showing mean value of 8,291 kcal/kg.

High heating value of sewage sludge were from 2,194 to 4,015 kcal/kg showing mean value of 2,972 kcal/kg. Low heating value of sewage sludge from three plants were below zero which means that those sludge need heat to burn out. However, if they are dewatered and dried to MC of 10%, they could be used as fuel sources. Low heating value of sewage sludge when dried to MC of 15% were from 1,723% to 3,246% with a mean value of 1,998 kcal/kg.

Table 8. Heating value of waste vinyl

Regions	HHV (kcal/kg)	LHV (kcal/kg)	M. C (%)	Ash (%)	Ignition loss (%)
Naju	8,556	7,329	2.80	30.40	66.80
Gwangju	9,656	9,154	0.02	14.50	85.30
Damyang	10,277	9,584	0.02	9.80	90.10
Boseong	7,887	7,361	0.03	39.20	58.30
Youngam	9,417	8,271	1.69	31.26	67.04
Hampyeong	8,843	7,743	1.22	10.59	88.19
Hainam	9,584	8,592	0.96	28.78	70.26
Remark (Mean)	9,174	8,291	0.84	23.50	75.14

Table 9. Heating value of sewage sludge

Regions	HHV (kcal/kg)	LHV (kcal/kg)	M. C (%)	Ash (%)	Ignition loss (%)	LHV, 10% (kcal/kg)
Suncheon	3,322	-174	84.30	5.81	9.89	2,742
Naju	2,796	-197	78.60	8.87	12.53	2,133
Youngam	2,194	-196	78.68	11.68	9.64	1,723
Hampyeong	2,533	27	77.16	8.23	14.61	2,131
Hainam	4,015	472	70.10	7.56	22.34	3,246
Remark (Mean)	2,972	-14	64.81	8.43	13.80	1,998

3.4 Pretreatment of waste vinyl and sewage sludge

To acquire required heating value for RDF and to get optimum condition for RDF formation, waste vinyl and sewage sludge shoud be mixed with proper ratio. Using the mean heating value of waste vinyl and dried sewage sludge to MC 10%, heating values of mixed materials of waste vinyl and sewage sludge are calculated according to mixture ratio as shown in Table 10.

In case of higher ratio than 50% of waste vinyl, RDF could get the required heating value higher than 5,000 kcal/kg.

Table 10. Calculated heating value with different mixture ratio between waste vinyl and sewage sludge

Waste vinyl (%)	10	20	30	40	50	60	70	80	90
Sewage sludge (%)	90	80	70	60	50	40	30	20	10
Heating value (kcal/kg)	2,627	3,257	3,886	4,515	5,145	5,774	6,403	7,032	7,662

4. Conclusions

Waste vinyl are generated from the agricultural production, most of which are not used as a renewable resources. Most sewage sludge produced from sewage treatment plants are discarded into the ocean requiring alternative treatment system able to reduce ocean pollution and to use as a useful resources.

As the heavy metal component of waste vinyl and sewage sludge were below permit limit for RDF, they could be used as the raw materials for RDF.

Waste vinyl generated from the agricultural production and sewage sludge from the sewage treatment plants could be utilized to make Refuse Derived Fuel(RDF) if they are mixed properly to get RDF formation condition and enough heating value as a fuel.

To get heating value above 5,000 kcal/kg for RDF, 50:50 of mixture ratio between waste vinyl and sewage sludge was desirable.

References:

[1] A.K. Gupta, E.M. Rohrbach, Refuse Derived Fuel. Technology, processing, quality and combustion experiences, International Joint Power Generation Conference, San Diego, CA, October 6-10, 1991, pp. 49-59.

[2] Ministry of Environment of Korean Government, Statistics of Sewage, 2006.

[3] Y.H. Chang, W.C. Chen. N.B. Chang, Comparative evaluation of RDF and MSW incineration, Journal of Hazardous Materials, Vol. 58, 1998, pp. 33-45