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CHARACTERIZATION OF INDUSTRIAL SOLID WASTES AND AGRICULTURAL RESIDUES FOR ENERGY PRODUCTION IN VIETNAM

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Abstract:*Solid wastes from the industrial and agricultural sectors have been recognized asin-situ and alternative fuels in addition to fossil fuel resources. However, in order to choose appropriate technologies to combust such "wastes" for energy production under a stable operational condition in an environmentally aceptable manner, there exists a need for getting insight of their initial compositions as well as the ash constituents after their complete combustion. In this study, 6 types of industrial solid wastes and agricultural residues widely available in Vietnam werecollected and analyzed. The results obtained from the proximate and ultimate analyses of these materials have shown their good fuel quality in terms of volatile content and heating value. On the other hand, their ash analysis results could help identify certain difficulties in design and stable operation of the energy systems in which these wastes are gasified or burnt.*

1. INTRODUCTION

During 2010-2017, total GDP of Vietnam increased around 6.1% per annum with a highest grow rate from the industrial sector (7.4% p.a) followed by the commercial sector (6.8% p.a). It has been seen that development of industry and transport sector, urbanization as well as improved energy access and rising living standards nationwide are major drivers for growing energy consumption. Being a net energy exporter for a long time, Vietnam became a net energy importer in 2015 abd this fact continues to grow quickly, primarily driven by increased coal imports for power and industrial sectors [1].

Industry development in Vietnam has resulted in very big industrial solid wastegeneration recently, especially in Hanoi, Quang Ninh, Hai Duong, Ho Chí Minh City, Binh Dương, Ba Ria - Vung Tau, etc. In Ho Chí Minh City in 2016 alone, the ISW generated was about 1,500 – 2,000 tons/day from over 2,000 big factories and 10,000 production units of small and medium size located inside and outside the industrial processing zones and industrial parks. Following the data of the General Department of Environment, the SW normally stems from the industrial activities, about 25 million tons/ year [2].

On the other hand, agricultural residues in Vietnam are mainly the organic waste with diversified components. The components and quantity of residues on fields depend on the cultivation system in each geological region and country. Potential of agricultural residues for energy forecasted for 2020, 2030 and 2050 was presented elsewhere [3].

In this study, characterization of some selected industrial solid wastes and agricultural residues widely available for energy services in Vietnam was conducted under laboratory conditions to get insight of their energy quality as well as possible inherent operational troubles and / or environmental risks due to their combustion for energy services.

2. EXPERIMENTAL METHODOLOGY

For this study, four (4) types of industrial solid i.e nylon, foam, cloth and recycle paper were separately collected from the four respective sub-industrial sectors which are namely electronics, textile, shoes and paper located in Hai Phong City, Hung Yen and Bac Ninh provinces (see Figure 1).

In addition, two other types of agricultural residues were also seleccted for the characterization work which are i) Rice husk, and ii) Bagasse (see Figure 2).

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Figure 1. Four types of industrial solid wastes

Figure 2. Two types of agricultural residues

2.1. Proximate analyses

All proximate analyses for the 6 selected solid wastes and residues were conducted at Laboratory 306-C4 in the School of Chemical Engineering (SCE) under the Hanoi University of Science and Technology (HUST). For each type of the selected solid wastes, it is necessary to perform 3 analyses to determine its moisture content, volatile matter content and ash content. The value taken was therefore the average one of the three analysis results.

a. Moisture content (M)

TCVN 172:2011 (Vietnamese Standard which is equivalent to ISO 589:2008)was used in this analysis. It exists two types of M as given below:

- As received moisture (AR): is the moisture content of fresh sample which is dried (normally in an electrical oven) till its unchangeableweight;

- Air dry moisture (AD): is the moisture content of the sample left in the air till its moisture is in balance with the environmental humidity.

b. Volatile matter content (V)

TCVN 174:2011 (Vietnamese standard which is equivalent to ISO 562:2010)was used in this analysis. The sample is heated in a ceramic or porcelain crucible tighlysealed at a temperature of 850 ± 5°C for 7 minutes. The formula for determining V is as follows

$$V = \frac{G1 \text{ x } 100}{G2} - M, \% \qquad (1)$$

in which:

G1 is the sample weight to be heated, in gram.

G2 is the weight loss of the sample after being heated, in gram.

W is the moisture of the sample, %.

c. Ash content

For the analysis of ash content, TCVN 173:2011 (Vietnamese standard which is equivalent to ISO 1171:2010)was aplied. One (1) gram of the sample is heated at 600^{o}C and maintained for two hours on condition that the sample crucible must be open thorough the entire heating process. Ash can be estimated as below

$$A = \frac{m1}{m2} \text{ x } 100\ (\%) \qquad (2)$$

in which:

m_1 is the weight of the sample after being heated / burned, in gram;

m_2 is the weight of the sample before being heated, in gram;

d. Fixed carbon content (FC)

FC is finally estimated by difference using the following formular:

$$FC = 1 - M - V - A, \% \qquad (3)$$

e. Heating value

TCVN 200:2011 (Vietnamese standard which is equivalent toISO 1928:2009)was emloyed in determing heating value (calorific value) of the solid wastes. The higher heating values of the 6 selected solid wastes were determined with the Parr 1266 Bomb Calorimeter device which is available at Petrochemical & Adsorption Catalyst Technology Laboratory in the School of Chemical Engineering of Hanoi University of Science and Technology.

2.2 Ultimate analyses

a. Carbon (C) and Hydrogen (H) contents

TCVN 255:2007 (Vietnamese standard which is equivalent to ISO 609:1996)was used for this

Table 1. Results of proximate analysis

Sample	Status	W(%)	V(%)	A(%)	FC(%)	HHV (MJ/kg)
Foam	AR	3.4				23.5
	AD	3.4	86.0	3.9	6.7	
	DB	0	89.0	4.1	6.9	
	DAF	0	92.8	0	7.2	
Paper	AR	16				35.3
	AD	1.3	90.4	4.7	3.6	
	DB	0	91.6	4.8	3.6	
	DAF	0	96.2	0	3.8	
Cloth	AR	5.3				20.4
	AD	7.8	78.0	0.5	13.7	
	DB	0	84.6	0.6	14.8	
	DAF	0	85.1	0	14.9	
Nylon	AR	1				22.8
	AD	0.7	91.2	1.6	6.5	
	DB	0	91.8	1.7	6.5	
	DAF	0	93.4	0	6.6	
Rice husk	AR	21.5				15.2
	AD	6.2	73.1	15.5	5.3	
	BD	0	77.9	16.4	5.7	
	DAF	0	93.2	0	6.8	
Bagasse	AR	20.4				17.5
	AD	5.3	80.9	4.1	9.7	
	DB	0	85.5	4.3	10.2	
	DAF	0	89.3	0	10.7	

Note: AD: air dry, DB: Dry basis, DAF: Dry and ash-free basis

analysis. A sample of solid waste was burnt in an oxygen stream at a temperature of 1,350°C in a gas-tight tube. All the hydrogen and carbon amounts in the sample were converted into water and carbon dioxide, respectively. These products were then absorbed by suitable reagents and determined by quantitative method. The sulfur oxides and chlorine were retained by a silver net roller at the outlet of the tube.

b. Nitrogen content (N):

TCVN 6014 (Vietnamese standard which is equivalent to ISO 333:1996) was applied to determine nitrogen content in the solid wastes based upon micro-Kjeldahl method.The specified sample amount was heated with concentrated sulfuric acid plus a catalyst mixture to convert nitrogen into ammonium sulfate. Ammonia of ammonium sulfate released from alkaline solution by steam distillation was then absorbed in boric acid and quantified by titration with sulfuric acid.

c. Sulfur content (S):

This content was determined by using TCVN 8622:2010 (Vietnamese standard which is equivalent toISO 19579:2006) with infrared spectrometry (IR) method. In general, sulfur content includes organic compound (S_{or}) and inorganic compound (S_{inor}). Inorganic sulfur is then divided into sulfur pyrite (S_p) and sulfur sulphate (S_s). In this study, the solid waste or biomass sample was burnt at a temperature of 1,350°C in the oxygen stream. Particles and steam impurities were then separated from the gas stream by traps made of glass wool and magnesium perchlorate. Then, the stream of air flew into the measurement cell where the sulfur dioxide was measured by an infrared absorption detector.

Table 2. Results of ultimate analysis (dry basis)

No.	Samples	C	H	O	N	S
1	Foam	66.05	7.06	25.40	1.48	0.02
2	Paper	77.71	10.40	11.83	0.04	0.02
3	Cloth	50.54	5.74	40.37	3.18	0.17
4	Nylon	67.08	4.25	28.28	0.38	0.01
5	Bagasse	46.79	5.62	48.52	0.58	0.63
6	Rice husk	44.2	5.06	50.75	0.5	0.51

Table 3. Metal oxide composition in the ash of the samples

No	Samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	Na_2O
1	Foam	13.76	3.47	1.29	55.27	0.34	0.46
2	Paper	40.24	13.26	5.60	26.23	1.47	0.93
3	Cloth	35.58	9.55	3.31	15.37	1.57	3.05
4	Nylon	65.54	9.68	3.50	10.72	1.66	0.53
5	Bagasse	48.40	9.21	3.89	7.33	8.48	1.44
6	Rice husk	86.7	0.8	0.5	3.2	3.1	0.8

2.3 Ash analyses

For this study, TCVN 6258:1997 (Vietnamese standard which is equivalent to ASTM D 2795)was used todetermine contents of SiO_2, Al_2O_3, Fe_2O_3, CaO, K_2O and Na_2O. Details of this analysis work was elaborated in [4].

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1 Fuel characteristics of the 6 selected solid wastes and argricultural residues

All the calculated results obtained from the proximate and ultimate analyses for the 6 selected solid wastes are given in Table 1 and 2, respectively.

From Table 1 and 2, it is found that:

- All the 6 selected wastes and residues possess a pretty high volatile content (77.9% - 91.6% on DB) that would result in a quick ignition if these fuels are burnt;

- Ash content in the rice husk is of significant (16.42% on DB) that might create troubles for the designing and continuous operation of ash handling / removal system if rice husk is fuelled for energy services;

- Cloth and foam have a higher content of nitrogen compared to rice husk and bagasse (3.18% and 1.48% in comparison with 0.5% and 0.58% on DB). N in the wastes is the main source to create NH_3 in their gasification,andalso contributes to NO_x emission if these wastes are burnt.

- For all the 6 wastes and residues, sulfur content is of acceptable value (0.02%-0.63% on DB).

3.2 Ash compositions of the 6 selected solid wastes and argricultural residues

All the calculated results from the analyses of ashes obtained when the samples of the 6 selected solid wastes were completely burnt are presented in Table 3

From Table 3, it is seen that:

- Almost the selected wastes (except the foam) have relatively high SiO_2 content of which rice husk posseses the highest value;

- Contents of aluminium and iron ash of paper and cloth are higher than that of agricultural residues;

- Mixture of Na_2O and K_2O in the ashes of industrial solid wastes is much lower in comparison to that of agricultural residues.

Normally, ash content and composition in the industrial wastes and agricultural residues have certain adverse impacts on the continous operation of the thermal systems in which the wastes and residues are used as fuels. In particular, presence of SiO_2, K_2O, Na_2O in ash would result in a low melting temperature of the ash. On the other hand, the evaporation of these oxides in the gasification or combustion chamber followed by their condensation on the surface of low temperature heat exhangers would make down-stream gas piping and valves dirty and jammed.

4. CONCLUSIONS

Industrial solid wastes and agricultural residues in Vietnam can be used as alternative fuels to meet in-situ demand for energy. In this study, 6 selected wastes and residues were analyzed for this purpose. The results obtained from their fuel and ash characterization have shown that they are pretty good sources of energy but certain operational troubles or risks should be taken care of if burning or gasifying these types of fuel.

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NGHIÊN CỨU ĐẶC TÍNH CHẤT THẢI RẮN CÔNG NGHIỆP VÀ PHỤ PHẨM NÔNG NGHIỆP ĐỂ SẢN XUẤT NĂNG LƯỢNG Ở VIỆT NAM

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Trong nghiên cứu này, sáu loại chất thải rắn ở Việt Nam đã được thu thập và phân tích. Các kết quả nhận được từ phân tích thành phần công nghệ và thành phần hóa học của các nhiên liệu này cho thấy đây là những nhiên liệu có chất lượng tốt về phương diện chất bốc và nhiệt trị. Mặt khác, kết quả phân tích tro của các nhiên liệu này cho phép nhận dạng một số khó khăn / lưu ý khi thiết kế và vận hành các hệ thống thiết bị có sử dụng chúng để sản xuất năng lượng.