

BUSTHAN_DAN_RAHMAN_2019
_J._Phys._3A_Conf._Ser._1341_0
52008.pdf
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Submission date: 04-Dec-2022 12:22PM (UTC+0700)

Submission ID: 1970571076

File name: BUSTHAN_DAN_RAHMAN_2019_J._Phys._3A_Conf._Ser._1341_052008.pdf (837.43K)

Word count: 5045

Character count: 26692

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Chemical composition and physical characteristics of coal and mangrove wood as alternative fuel

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ABSTRACT. Physical properties and chemical properties of coal and mangrove wood (*rhizophora macronata lamck*) was determined by using proximate, ultimate, and calorific analysis. Proximate analysis is used to determine moisture, ash, volatile matter and fixed carbon. The ultimate analysis is the important chemical elements in biomass; use to determine carbon and sulfur content. The calorific value of coal and mangrove wood was conducted by using bomb calorimeter method. The aims in this study is to determine physical and chemical characteristics of coal from Kaltim Prima Coal Company (East Kalimantan Province), Sinjai coal and also mangrove wood from Sinjai (South Sulawesi Province). Result of chemical composition and physical characteristic (proximate, ultimate analysis and calorific value of coal and mangrove wood were as follow: coal from Kaltim Prima Coal were moisture: 16.11%, ash: 3.77%, volatile matter: 43.10%, fixed carbon: 37.01%, carbon content: 44.86%, sulfur content: 0.130% and calorific value: 4160.93 cal/gram. Sinjai coal: moisture content: 10.09%, ash: 52.41%, volatile matter: 23.54%, fixed carbon: 13.96%, carbon content: 24.37%, sulfur content: 0.272% and calorific value: 3941.21 cal/gram. Mangrove wood charcoal from Sinjai: moisture: 5.58%, ash: 6.34%, volatile matter: 19.30%, fixed carbon: 68.78%, carbon: 51.82% sulfur: 0.029%, and calorific value: 3800.1 cal/gram. After the pyrolysis process, mangrove wood produces a high enough calorific value which increases the calorific value, to: 5404.04 cal/gram. Based on the physical and chemical characteristics in this study shows mangrove wood have high potential to be used as an alternative fuel which was effective for household and industrial purposes.

1. INTRODUCTION

Coal is one of the natural resources whose existence is quite abundant in Indonesia. At present the use of coal energy resources is also increasing along with the decline in petroleum production especially in Indonesia [1]. During the last 13 years from 2003 to 2016 coal production in Indonesia has increased 11% annually in meeting domestic and export needs in the period 2009-2011 [2]. Along with the scarcity of oil and gas, coal can be used as a highly expected alternative fuel. Coal can also be



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increased for domestic use, fuel for electricity generation, industry and for export purposes [3]. Coal is an organic material composed of minerals with sizes that vary from less than one micron to hundreds of microns. The dominance of minerals contained in coal consists of sulfides, clays, carbonates, quartz, some additional phosphates and heavy minerals, and salt which functions as a small contribution to coal organic matter [4]. Kalimantan has the largest coal resources with a total of 62.80 billion tons (50.12% of the total national coal resources), one of the largest coal mines in East Kalimantan is PT. Kaltim Prima Coal which has been established since 1982. This company is a subsidiary of PT. Bumi Resources in Sangatta, East Kutai Regency [5]; [6].

South Sulawesi has coal resources of around 117 million tons or around 0.35% of total national resources [7]. In its use, coal in South Sulawesi has a serious problem, namely the high content of sulfur and ash produced during combustion so that it can have an impact on the environment/ air pollution so it is recommended to reduce as much sulfur and ash as possible when used as fuel directly on power plants, industries and households [8]. One of the South Sulawesi area that has coal resources is Sinjai Regency and in geology the coal includes Paleogen coal [9]. Before using coal for industry and steam power plants, especially those in South Sulawesi, coal quality characterization is needed first so that it does not cause negative impacts due to the sulfur content contained in the coal. Sulfur is corrosive which will have a detrimental effect on the environment and on the elements of equipment used in industry [8].

According to [10], the amount of coal resources in Indonesia reached 125.28 billion tons, consisting of measured resources of 40,039.28 million tons; indicated 29,313.11 million tons, inferred 36,464.63 million tons and hypothetically amounted to 19,466.81 million tons. In addition, Indonesia also has mining coal resources in the amount of 42.19 billion tons, so that overall coal resources owned amount to 167.48 billion tons. Based on the calorie level, Indonesian coal is low calorie coal (<5100 cal/gram) 32.64 billion tons, medium calorie (5100-6100 cal/gram) 82.26 billion tons, high calorie (6100-7100 cal/gram) 8.27 billion tons and very high calories (> 7100 cal/gram) 2.11 billion tons.

Besides coal, biomass can be used as solid fuel because it has characteristics that are not much different from coal. High-quality mangrove wood produces very good heat, is durable when burned and produces good quality charcoal [11]. The quality of fuel, especially coal and biomass contained can be determined from a number of analyzes in the laboratory, calorific value, ash, water, carbon and sulfur content [12]; [13]. In this study is a preliminary study for determining characteristic of two types of coal from Kaltim Prima Coal (East Kalimantan) and Sinjai as well as mangrove wood also from Sinjai (South Sulawesi). Characterization of physical and chemical used for proximate, ultimate analysis and calorific value.

2. SAMPLES AND METHOD

Geologically, Sinjai Regency is located $5^{\circ}2'0''$ - $5^{\circ}21'16''$ South Latitude and between $119^{\circ}56'30''$ – $120^{\circ}25'33''$ East Longitude on the East Coast of the Southern Part of South Sulawesi Province with natural resources that can be developed (Fig. 1). The potential for mining and natural resources in Sinjai Regency is quite large, one of which is the potential of coal of around 5,000,000 tons in 2010. Mangrove forests can be found in the area of East and North Sinjai Subdistrict with a land use area of around 0.06% or 50 hectare of the total area of Sinjai district [14].



Fig. 1 Map of Location of Sinjai Coal Sampling from the Village of Kaloling and Mangrove Wood in Mangarabombang Village, Sinjai Timur Regency, South Sulawesi.



Fig. 2 Map of Location of PT Kaltim Prima Coal, which is one of the East Kalimantan Province East Kutai, Regency Sangatta City.

Location of coal sampling sites obtained at PT Kaltim Prima Coal, which is one of the East Kalimantan Province East Kutai Regency Sangatta City (Fig. 2). Kalimantan is interpreted as a product of Mesozoic from oceanic crust materials (*ophiolite*), deposits of marginal basins, island arc material and microcontinental fragments to the Paleozoic continental core from the Schwener Basin to the southwest of the island [4].

The following are the preparation stages before testing the coal samples which include: the process of pyrolysis at 1 hour with temperature of 300°C-400°C [15]; [16]; [17]; [18], crushing, milling and sieving. Pyrolysis is the process of biomass casting without using oxygen through decomposition of biomass by heating methods from the liquid phase and then the gas phase [19]. Crushing is the initial stage of reducing the grain size of coal so that it is easier to process by milling machines. Milling is also called the process of reducing the size of coal particles from the coarse which ones are then changed to become finer, so that they are obtained according to their use. The next stage is sieving is a process of equalizing the size of the sieve obtained by the size of homogeneous. In the proximate and ultimate testing it takes 200 mesh size in coal samples so that it needs to be done again by using mortar [20].

The Proximate Analysis stage (direct analysis) includes 4 stages, namely: Testing of Moisture (Moisture Content) (%) (ASTM D. 3173-03) [21]; [22], Ash Content Testing (Ash Content) (%) (ASTM D. 3174-12) [21]; [23], Testing of Volatile Matter (%) (ASTM D. 3175-07) [21]; [24] and Fixed Carbon Level (%) (ASTM D. 5142) [21]; [25]. The Ultimate Analysis stage is the analysis phase of an important chemical element that forms biomass, namely carbon and sulfur can be determined through elemental analysis: Sulfur Level (S) (ASTM D. 3177) the method used in sulfur analysis is to use the High Combustion method which uses the Dual Range Sulfur Analyzer SC-144DR [26], carbon content (C) (ASTM D. 3178-89) The method used for determining carbon content is the same as that used in determining sulfur content [27] calorific Value (ASTM D-2015-96), calorific value analysis using the Hilton C200 PA digital bomb calorimeter [28].

3 RESULTS AND DISCUSSION

3.1 Proximate analysis

The result of proximate analysis in coal and mangrove wood sample is shown in Table 1.

Table 1. The following are the results of the proximate analysis of coal and mangrove wood.

Samples ID	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)
KPC	16.11	3.77	43.10	37.01
SIN	10.09	52.41	23.54	13.96
MWC	5.58	6.34	19.30	68.78

Information:

- KPC : Kaltim Prima Coal
- SIN : Sinjai Coal
- MWC : Mangrove Wood Charcoal

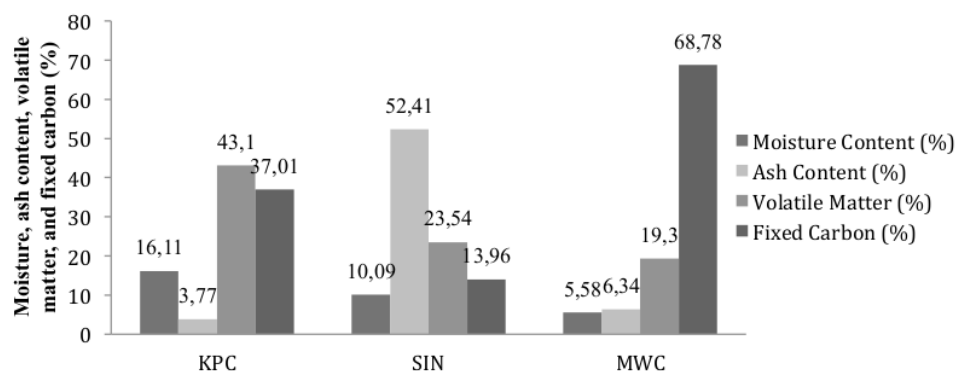


Fig. 3 Graph of Proximate Analysis of Coal and Mangrove Wood

Fig. 3 shows a significant difference the chemical and physical composition between Kaltim Prima Coal, Sinjai Coal and Mangrove Wood Charcoal. The lowest moisture content is shown on mangrove wood charcoal which is 5.58% because the moisture of mangrove wood charcoal has gone through the pyrolysis/ drying process so that some of the moisture content is reduced while the KPC c[5] has a high moisture content of around 16.11% compared to Sinjai coal [5] which ranges from 10.09%. The total moisture content contained in coal is divided into two, namely the free moisture content which is the moisture content found on the coal surface which is influenced by weather conditions and climate in the field, [29] such as the moisture content found in the coal of PT Kaltim Prima Coal analyzed. Inherent moisture content which is the moisture content contained in coal at the time of the formation of coal so that it can affect the calorific value of coal, the lower the default moisture content, the calorific value increases as well as the opposite. In the process of utilizing coal, the high moisture content contained can cause problems, especially when used directly. Inherent moisture within coal will reduce the calorific value so that more coal is needed when burning [13].

Ash content of Kaltim Prima Coal show a value of 3.77% and mangrove charcoal 6.34% produce low ash content while Sinjai 52.41% produces very high ash content so that it will impact the environment as a contributor to emissions in the environment [30]. Ash content is the remnants of organic matter from the combustion results which are derived from innate impurities when the coal process is formed as well as during the mining process which will be the waste from combustion [31]; [12]. Coal ash comes from the combustion of inorganic minerals or components [9]. Based on the results of the study [8] in South Sulawesi (Palunda, Padang Lampe, Tondongkura, and Lamuru) the resulting ash content is relatively high as the ash produced in sinjai coal. In testing the lowest levels of volatile matter in Mangrove Wood Charcoal 19.30%, while in Sinjai 23.54% and the highest in Kaltim Prima Coal 43.10%. Levels of volatile matter can affect smoke or gas produced during combustion and facilitate ignition because of the flammable organic compounds [12]; [13]. Mangrove Wood Charcoal has produced the highest fixed carbon content that is 68.78%, while the highest fixed carbon in Kaltim Prima Coal produces 37.01% and the lowest fixed carbon content is at Sinjai 13.96%. The amount of fixed carbon content is influenced by the amount of ash content, the more ash content, the less carbon content produced as well as vice versa, then this can also affect the caloric value contained in coal and mangrove wood. The fixed carbon content to coal and biomass greatly influences the calorific value so that it can affect the duration of ignition as shown in Figs. 3 and 5 [13].

3.2 Ultimate analysis

The result of ultimate analysis in sample is shown in the Table 2.

Table 2. Results of Ultimate Analysis in Coal and Mangrove Wood Samples.

Samples	Carbon (C) (%)	Sulfur (S) (%)
KPC	44.86	0.130
SIN	24.37	0.272
MWC	51.83	0.029

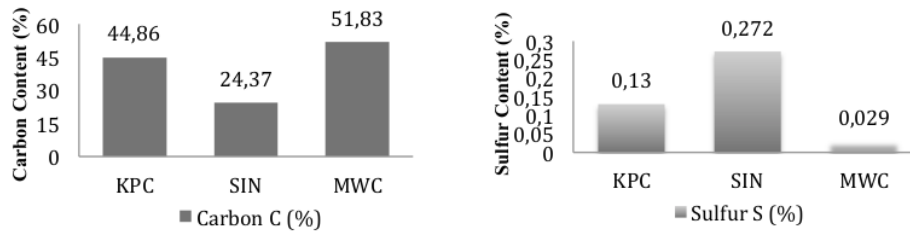


Fig. 4 Graph of the results of the coal, mangrove wood and mangrove wood charcoal ultimate analysis.

Ultimate analysis can be seen clearly the differences in the carbon content had been obtained (Fig. 4). The samples of Mangrove Wood Charcoal, KPC and Sinjai are following 51.83%, 44.86%, and 24.37%. In the ultimate analysis, it had been sulfur content values for Mangrove Wood Charcoal, Kaltim Prima Coal and Sinjai: 0.029%, 0.130%, and 0.272%. Based on Fig. 4, the higher the carbon content, the less sulfur content is contained so that this can affect the characterization of fuel quality especially in the environment. Kaltim Prima Coal has very low ash and sulfur content (the average sulfur content of Indonesian coal is $\leq 1\%$) [9]; [3] but has a high enough moisture content as shown in Figs 3 and 4. High moisture content in low rank coal can cause problems in handling coal, especially in transportation, storage, milling, and combustion. Whereas in Sinjai coal contains very high ash content, so it can cause problems in the environment [30].

One characteristic that affects the high total sulfur content in coal is where sea water containing sulfate enters the original source down to brackish water mud during or after the coal deposition process takes place. Exploitation and utilization of coal needs to consider the total sulfur and ash content produced because it has a very important role. Deposition of coal deposits in shallow marine environments (which are affected by Tonasa Limestone Formation) which causes high sulfur content of coal so that there is no significant relationship between the levels of ash and sulfur in coal [8]. In general, high levels of sulfur and ash are directly proportional to the depositional environment of coal approaching the sea so that it is affected by sea water during the deposition process of peat [32]. Coal deposited in the paralic basin contains more pyrite compared to coal deposited by the limestone basin. When the coal deposition process takes place coal will be affected by the transgression of seawater so that it forms high pyrite and organic sulfur, especially at the top of the layer. Pyrite (FeS_2) is a mineral that contributes to the formation of sulfur content in coal or also called Pyritic Sulfur [33].

3.3 Analysis of calorific value

The following results of the analysis of calorific values can be seen in Fig. 5.

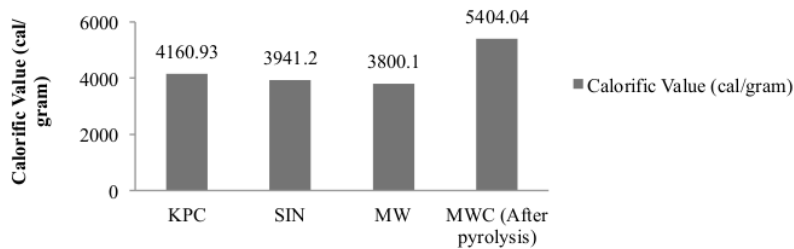


Fig. 5 Graph of the results of the analysis of caloric values coal, mangrove wood and mangrove wood charcoal ultimate analysis

Information:

MW : Mangrove Wood

Fig. 5 Shows the results of analysis of heating values of two different types of coal and mangrove wood. From the results of this study, the highest calorific value was obtained, namely mangrove wood charcoal, 5404.04 cal/gram, which was 3941.20 cal/gram before going through the pyrolysis process and then increased after pyrolysis/ drying without air with a certain temperature [34]; [35]; [36]; [37]; [38]; [39]; [40]; [41]; [42]; [43]; [44], [45]. Coal from KPC is the highest calorific value after mangrove wood charcoal, that is 4160.93 cal/gram and Sinjai coal is 3941.20 cal/gram produces the lowest calorific value. Based on the calorific value of mangrove wood charcoal and Kaltim Prima Coal meet coal quality standards for the domestic market which generally range from 4000-6500 kcal/kg or medium quality [46]. For the Sinjai and mangrove wood heating values without the process of drying not so much different, Sinjai: 3941.20 cal/gram, and mangrove wood: 3800.10 cal/gram before being hydrolyzed, the difference can be seen in Fig. 5 for the calorific value of mangrove wood still can increase after going through the pyrolysis/ drying process with a certain temperature (300°C for 1 hour). Based on the level of coal calories in Indonesia it was of low calorie coal (<5100 cal/gram) 32.64 billion tons, moderate calories (5100-6100 cal/gram) 82.26 billion tons, high calories (6100-7100 cal/gram) 8.27 billion tons and very high calories (> 7100 cal/gram) 2.11 billion tons [10].

Based on its type, Kaltim Prima Coal and Sinjai coal includes low-rank lignite and sub-bituminous coal with a calorific value of 3700 cal/gram to 4200 cal/gram. Based on the calorific value of mangrove wood also has a high calorific value so that it can compete with coal. In Indonesia, especially in South Sulawesi there are still many low quality coal such as lignite and sub-bituminous with a heating value of 1500-4500 kcal/kg which is characterized by brownish-black physical conditions, very fragile, low calorific value, the high moisture and ash content as well as high sulfur content as in the results of the analysis of coal characteristics found in Sinjai so that the use of low quality coal should be considered[13].

4. CONCLUSIONS

The physical chemistry characteristics of the quality of coal and mangrove wood based on the most significant proximate test were shown on mangrove charcoal sample which through the pyrolysis process had a low moisture content: 5.58%, lowest volatile matter: 19.30%, and produced levels high fixed carbon: 68.78%. The lowest ash content is shown in Kaltim Prima Coal sample: 3.77%. The ultimate analysis/ chemical element is the low sulfur content produced by Mangrove Wood Charcoal: 0.029% compared to Kaltim Prima Coal and Sinjai coal. The sulfur content in the two coals including those categorized as low sulfur coal (<1%) but in Sinjai coal produces very high ash content of 53.53% so that it will greatly affect the environment.

In the analysis of the heating value obtained by mangrove wood charcoal before pyrolysis: 3800.10 cal/gram, after the pyrolysis process increased to 5404.04 cal/gram so that it can meet the quality standards of the domestic market ranging from 4000 to 6500 cal/gram or medium quality. Based on its type, Kaltim Prima Coal and Sinjai coal includes low rank lignite and sub-bituminous coal with a calorific value of 3700 cal/gram to 4200 cal/gram. Based on the calorific value, mangrove wood can compete with coal. Mangrove wood can be used as an alternative energy source. Based on the characterization of coal and mangrove wood in this study, mangrove wood is feasible and prospect to use as an alternative fuel for coal briquettes mixture. Mixture of mangrove charcoal with coal will be produced the best quality bio briquettes with high heating value.

ACKNOWLEDGMENT

Thank to Hasanuddin University Mining Engineering staff (Sufriadin, Akmal Saputno and Ardi Alam Jabir Hasanuddin³ University Mining Engineering Department) and my friends Sukmawati and Wahyu Saputra were helped us in the field, laboratory to prepare samples until analysis and special thank to Prof. Dr. Dadang A. D Suriamiharja, Prof. Ir. rer. nat. Ir. A. M. Imran, Prof. Dr. Ir. Hazairin Zubair and Dr. Ulva Ria Irvan, ST. MT giving their helpful comments to improve my paper.

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