International Journal of Engineering and Science Applications
ISSN 2406-9833 **IJEScA**

Geochemical Characterization and Its Implication for Beneficiation of Coal from Tondongkura Village, Pangkep Regency South Sulawesi Province

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ABSTRACT

Coal from Tondongkura, Pangkep Regency, South Sulawesi Province recently was used only as fuel in some industries, although it has high ash and sulfur content. This study is conducted to determine coal quality using proximate, mineral matter and geochemical inorganic matters analysis, as well as to recommended proper method of beneficiation of Tondongkura coal, so it can be used in various industries. Analysis result showed that seam 1 of Tondongkura coal can be classified into medium ash and middle sulfur coal. Meanwhile seam 2 of Tondongkura coal can be classified into high ash and high sulfur coal. Major elements were moderately high such as SiO_2, Al_2O_3, Fe_2O_3 and CaO. Major element Fe_2O_3, and CaO had negative correlation with ash content of Tondongkura coal, while SiO_2 and Al_2O_3 had positive correlation. Trace elements that need to be considered are the trace element which cause negative effect to health namely As, Cr, Mo and Pb. Lead (Pb) is inversely with coal ash from both seams and it is interpreted to be associated with organic matter, while As, Cr and Mo had various distribution for each seam of Tondongkura coal. Rare earth element in Tondongkura coal can be classified as Medium REY type, because Eu, Gd and Dy had high enrichment than the other REY. Pyrite contained in Tondongkura coal was syngenetic pyrite. Pyrite removal from coal can be done by using flotation method, because this method was combine physical and chemical method to separate pyrite mineral from coal. This method can decrease sulfur and ash content before the Tondongkura coal is used in various industry.

Keywords: Tondongkura, coal quality, mineral matter, inorganic elements, coal beneficiation.

1. INTRODUCTION

Coal can be regarded for many purposes as consisting of two classes of material: organic components or macerals on one hand, and a range of minerals and other inorganic constituents, broadly referred to as ‘‘mineral matter’’, on the other. The organic components are fundamental to defining the nature of coal (e.g. rank and type), and to its value in different utilization processes. All of the benefits derived from coal, including its energy output on combustion, its role in metallurgical processing, its capacity for insitu methane absorption, and its potential as an alternative hydrocarbon source, are derived essentially from the maceral constituents [1].

The inorganic fraction typically contributes little if anything to the value of the coal in utilization activities. At best it is a diluent, displacing more useful organic matter with a non-combustible component that leaves an ash residue when the coal is burned, or that needs to be removed as slag from the blast furnace during metallurgical processing. Mineral matter may also be a source of unwanted abrasion, stickiness, corrosion or pollution associated with coal handling and use. Most of the problems associated with coal utilization arise in some way from the incorporated mineral matter, rather than directly from the maceral components [1].

The primary objectives of coal preparation have been to achieve a greater degree of uniformity of coal particle size, and to reduce ash content to acceptable levels, thereby also reducing transportation costs. However, physical coal cleaning also can reduce the sulfur content of coal by removing pyritic sulfur, which takes the form of discrete particles. The exact method for coal to be processed can be determined by knowing minerals and the geochemical characteristics of the coal. Process selection depends on the size of coal to be washed and the extent to which coal qualities are to be enhanced. In operation, all of these processes (apart from froth flotation) may be characterized by a "specific gravity of separation." Coal particles of higher density, which tend to have higher concentrations of ash and pyritic sulfur, are discarded as refuse while the product coal (the "float") consists of the lighter particles [2]. This study was conducted to determine the properties of inorganic elements and its implication for coal beneficiation. Coal in Tondongkura is currently only used as a fuel in cement factories. By doing this, the study is expected to optimize the use of this coal in other fields of industry [3].

2. RESEARCH METHODS

2.1 Sample Preparation

Sample preparation is performed in sample preparation laboratory, Hasanuddin University. This preparation aiming to reduce the size of the sample that is ready for analyzes. Sample preparation includes crushing using Jaw Crusher, grinding manually using Agate Mortar, and sieving using Automatic Sieve Shaker. The results of the preparation is divided according to the analysis to be performed, such as for proximate analysis required sample size of 65# (212 µm), the analysis of geochemical and mineral matter required sample size of 200# (75 µm) and microscopy analysis required sample size of 18# (1 mm).

2.2 Sample Analysis

In this study, analyzes undertaken are the proximate, sulfur content, geochemical of inorganic, mineral and microscopic analysis.

2.2.1 Proximate Analysis

This analysis covers the determination of moisture, volatile matter, ash content and the calculation of fixed carbon on coals.

2.2.1.1 Moisture Content

There are few steps of procedure for sample passing a 250 µm (No.60) sieve in MC analysis. First, heat the empty capsules under the conditions at which the sample is to be dried and place the stopper or the cover on the capsule, cool over a dessicant for 15 to 30 minutes and weigh. Dip out with a spoon or spatula from the sample bottle approximately 1 gram of the sample. Put this quickly into the capsule, close, and weigh at once. After removing the covers, quickly place the capsules in preheated oven (at 105 to 110°C). Close the oven at once and heat for 1 hour. Open the oven, cover the capsules quickly, cool it in a dessicator over dessicant and weigh as soon as cold. Use the percentage of moisture in the sample passing a 250 µm (No.60) sieve to calculate the result of the other analyses to dry basis [4] using formula below:

Moisture (%) = [((grams of sample used-grams of sample after heating))/(grams of sample used) ×100]

2.2.1.2 Ash Content

There are few steps of procedures for ash analysis. First, transfer approximately 1 gram of the sample to a weighed porcelain capsule with spoon or spatula and quickly establish the weight to the nearest 0.1 mg. Place the porcelain capsule containing the sample in a cold muffle furnace or on a hearth at a low temperature, and gradually heat to 500°C in 1 hour and 815°C in 1 and half hour to avoid mechanical loss from too rapid expulsion of volatile matter. Finish the ignition to constant weight at a temperature between 750 to 815°C. Cool in a dessicator over dessicant, and weigh as soon as cold. Calculate the ash content using formula below:

Ash (%) = [((grams of capsule and ash residue-grams of empty capsule))/(grams of analysis sample used) ×100]

2.2.1.3 Volatile Matter

The procedures for volatile matter analysis are, first weigh 1 gram of the sample in a weighed platinum crucible, close it with a cover. Insert it directly to the furnace which shall be maintained at a temperature of 950 ± 20°C. After heating for a total of exactly 7 minutes, remove the crucible from the furnace and without disturbing the cover, allow it to cool. Weigh as soon as it cool.

Weight Loss (%) = [((grams of sample used-grams of sample after heating))/(grams of sample used) ×100]

The percentage loss of weight minus the percentage moisture equals the volatile matter.

Volatile Matter (%) = Weight Loss (%) - Moisture (%)

2.2.1.4 Fixed Carbon

The fixed carbon is a calculated value. It is the resultant of the summation percentage moisture, ash, volatile matter subtracted from 100. All percentages shall be on the same moisture reference base [4]. To calculate fixed carbon, use Formula:

Fixed Carbon (%) = 100 - [Moisture (%)+Ash (%)+Volatile Matter (%)]

2.2.2 Sulfur Content Analysis

The analysis is performed using a LECO SC-144DR in Mineral Analysis and Processing Laboratory, Hasanuddin University. This instrument uses a High-Temperature Combustion method, where a weighed sample was burned in a tube furnace at a temperature of 1350°C in a stream of oxygen.

2.2.3 Inorganic Geochemical Analysis

This analysis aims to determine the elements that contained in the coal sample, of which form a major element, trace element and rare earth element. This analysis was conducted at PT. Intertek Utama Services Laboratory in Jakarta using XRF, ICP-MS and ICP-OES.

2.2.4 Mineralogical Analysis

This analysis aims to determine the minerals that contained in the coal samples. This analysis divided into two methods, there are XRD and Microscopic analysis. XRD analysis aims to identify and determine minerals in samples, while Microscopy analysis aims to determine the physical characteristic of the minerals (especially its size). The XRD analysis was conducted at Department of Geological Engineering, Gadjah Mada University, and the microscopy analysis was conducted at sample preparation laboratory of Geological Engineering Department, Hasanuddin University.

2.2.5 Microscopic Analysis

Microscopic analysis was done using polarizing microscope (Nikon-Eclipse) on the coal samples after preparing of polished block with epoxy resin as binder. This analysis aims to determine the appearance of the minerals contained in the coal sample. Analysis was conducted at the Laboratory of Geology, Hasanuddin University.

3. RESULTS AND DISCUSSIONS

3.1. Quality of Tondongkura Coal

The proximate analysis results in Table 1 shows Tondongkura Coal Seam 1 (TK-1, TK-2 and TK-3) ash yield from 8.25 to 14.68% with average 11.03% which means that it can be classified as medium ash coal. Seam 2 (TK-4, TK-5 and TK-6) has higher ash yield between 17.48% and 47.08% with average ash content of 28.65% so that seam 2 can be classified into high ash coal [1].

The results of chemical analysis of coal shows the total sulfur content of seam 1 vary from 1.96 to 3.86% with an average of 2.88%, so it can be classified as medium sulfur coal. As for the seam 2 between 2.23 and 6.01% with average sulfur content of 3.76% and can be classified as high sulfur coal [1].

Coal from seam 1 had inherent moisture range from 11.09 to 12.25% with average of 11.65% and volatile matter from 46.50 to 48.70% with average of 47.89%. Seam 2 had inherent moisture lower than seam 1, the value vary from 8.25 to 12.96% with average of 10.69% and lower volatile matter from 32.98 to 54.51% with average of 43.54% (Table 1).

Table 1. Result of Quality Analysis for Coal from Tondongkura

Samples Number	Analysis Parameters				Total Sulfur (%)
	IM (%)	Ash (%)	VM (%)	FC (%)	
TK-1	11.09	10.16	48.46	30.29	2.80
TK-2	12.25	8.25	48.70	30.79	1.96
TK-3	11.60	14.68	46.50	27.22	3.86
TK-4	10.87	47.08	32.98	9.07	2.23
TK-5	8.25	17.48	54.51	19.76	3.03
TK-6	12.96	21.39	43.13	22.52	6.01

Fixed carbon content of coal from Tondongkura (coal seam 1) shows value between 27.22 to 30.79% with average of 29.43%. On the other hand fixed carbon content of coal from seam 2 vary from 9.07 to 22.52% with average of 17.12% (see Table 1).

3.2. Mineral in Tondongkura Coal

Fig. 1 shows the interpretation of the XRD analysis result for coal seam 1 along with the roof and floor layer. The minerals contained in the seam 1 include quartz, kaolinite, illite, smectite, hematite, pyrolusite, and pyrite. In the roof layer, all minerals legible with peaks that are still visible. The highest peak is the quartz and the shortest are the peak of the smectite and pyrite. In the coal seam 1, some peaks appeared in the roof layer such as illite, smectite and pyrolusite, did not occur in the coal layer. While in the floor layer, more peak illegible than the layers above. However, there is no differences in mineral legible in each layer of seam 1.

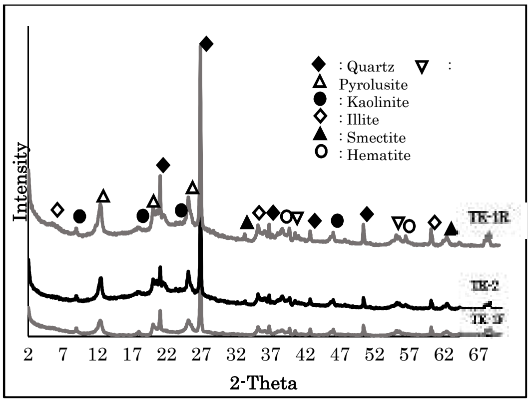

Fig.1. Diffractogram of Tondongkura Coal (seam 1) and associated of roof and floor layer

Fig. 2 shows the interpretation of the XRD analysis result for coal seam 2 along with the roof and floor. The minerals contained in the seam 2 include quartz, kaolinite, illite, smectite, hematite, pyrolusite, pyrite, gypsum and calcite. In the roof layer, all minerals legible with peaks that are still visible. The highest peak is the quartz and the shortest are the peak of the smectite, illite, and pyrite. In the coal seam 2, some peaks were appeared on the roof layer such as illite, gypsum, smectite and pyrolusite did not occur in the coal seam. While in the floor layer, more peak illegible than the layers above. However, gypsum only appear in roof layer of seam 2.

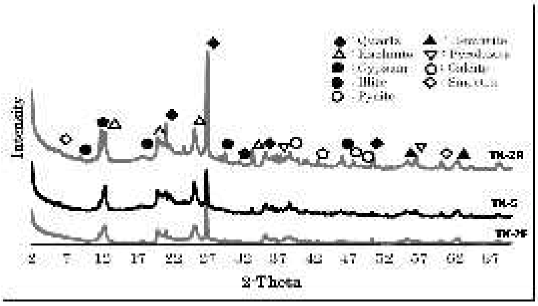

Fig. 2 Diffractogram of Tondongkura Coal and associated rock strata (seam 2).

3.3. Geochemical Characterization of Tondongkura Coal

The results of geochemical analysis of inorganic matter were divided into three parts, namely major elements, trace elements and rare earth elements.

3.3.1 Major Elements

Based on the results of XRF analysis (Table 2), some elements show high enough percentage such as Al_2O_3, Fe_2O_3, CaO, and SiO_2. Each element has an influence on the quality of coal, especially ash content. Coal ash is a residue from mineral matter when the coal is burned.

Table 2. Result of major element analysis (ash basis).

Major Elements (%)	**Coal seam 1**				
	Roof	**TK-1**	**TK-2**	**TK-3**	**Floor**
Al_2O_3	20.59	32.68	35.70	29.47	23.80
CaO	0.52	4.06	6.70	5.34	0.45
Fe_2O_3	5.38	16.30	14.73	19.02	2.45
K_2O	1.14	0.18	0.11	0.17	1.53
MgO	0.93	0.57	0.52	0.76	0.92
MnO	0.02	0.04	0.05	0.05	0.01
Na_2O	0.13	0.12	0.13	0.11	0.11
P_2O_5	0.03	0.09	0.07	0.03	0.02
TiO_2	1.13	1.48	1.02	0.98	1.01
SiO_2	70.14	44.48	40.96	44.06	69.71
Major Elements (%)	**Coal seam 2**				
	Roof	**TK-4**	**TK-5**	**TK-6**	**Floor**
Al_2O_3	23.80	28.52	25.50	24.93	28.34
CaO	8.09	3.59	13.0	8.70	0.67
Fe_2O_3	8.28	7.52	11.63	19.02	4.00
K_2O	1.15	0.91	0.32	0.45	1.39
MgO	0.81	1.62	1.56	1.43	0.99
MnO	0.03	0.03	0.04	0.03	0.01
Na_2O	0.19	0.14	0.18	0.13	0.10
P_2O_5	0.05	0.06	0.06	0.03	0.03
TiO_2	0.71	1.18	1.31	0.85	0.96
SiO_2	67.09	56.43	46.36	44.44	63.51

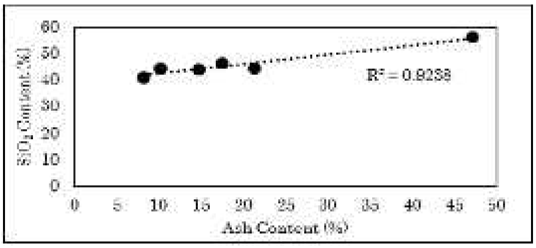

Fig. 3 Relationship between SiO_2 and ash content in Tondongkura Coal (ash basis).

Coal from seam 1 contained SiO_2 from 40.96 to 44.48% with average 43.17%, while coal from seam 2 had SiO_2 between 44.44 and 56.43% with average 49.07%. Fig. 3 shows the relationship between the ash yield and SiO_2 content. The graph shows the relationship between the ash yield and SiO_2 with R value is equal to 0.9238 . Based on the classification correlation coefficients, the relationship is very good correlation. The SiO_2 content affects the ash yield of the Tondongkura coal. In other words if SiO_2 content is high, then the ash yield would be high as well. It is said that SiO_2 had very significant contribution to the ash yield.

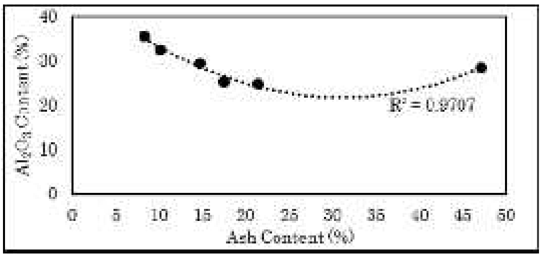

Fig. 4 Relationship between Al_2O_3 and Ash Content in Tondongkura Coal (ash basis).

The relationship between Al_2O_3 content and ash yield is more likely to show a negative correlation (Fig. 4). Seam 1 contained Al_2O_3 from 29.47 to 35.70% with average of 32.62% and seam 2 contained between 24.93 and 28.52% with average of 26.32%. The coefficient R shown is equal to 0.9707, meaning that the relationship between the two classified into very good correlation. So the relationship between the content of Al_2O_3 and ash content is positive with very good correlation, in other words Al_2O_3 had significant contribution for ash yield.

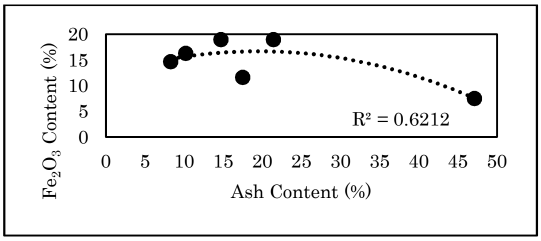

Fig. 5. Relationship between Fe_2O_3 and Ash Content in Tondongkura Coal (ash basis)

Coal from seam 1 contained Fe_2O_3 from 14.73 to 19.02% with average of 16.68%, while seam 2 contained Fe_2O_3 between 7.52 and 19.02% with average of 12.72%.The relationship between Fe_2O_3 and ash yield has a negative relationship (Fig. 5), it can be ascertained from a higher R_{value}, which amounted to 0.6212 into the category of good correlation. It can be concluded that Fe_2O_3 in Tondongkura coal likely has an affinity with the organic matters.

The other major element that had high percentage is CaO. Coal from seam 1 contained CaO from 4.06 to 6.70% with average of 5.37%, while seam 2 contained CaO between 3.59 and 13.03% with average of 8.44%. It has negative correlation with the ash yield of Tondongkura coal (Fig. 6). Its R value equal to 0.4881 and can be classified into poor correlation. It is said that CaO did not have contribution to the ash yield and has slight affinity with the organic matters.

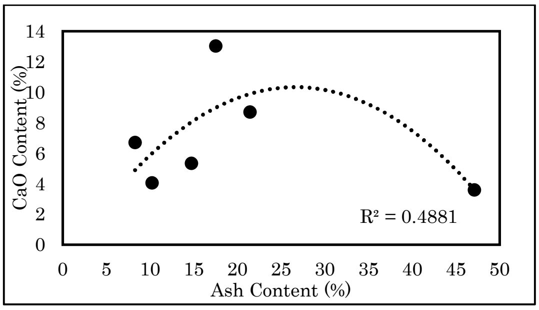

Fig. 6 Relationship between CaO and ash content in Tondongkura Coal (ash basis)

Other major elements such as K_2O, MgO, MnO, Na_2O, P_2O_5, TiO_2 as shown in Table 2 were not discussed in this paper because the elements were not have significant contributed to the precentage of ashes on coal. The concentration (percentage) of these elements is lower compare to the other major elements that identified on coal sample.

3.3.2 Trace Elements

From the analysis of trace elements that had been done, the content of the elements contained therein in ppm, most of trace elements below 0.1 ppm were not detected by the instrument. The elements that need to be considered are elements that can cause negative effects in the processing of coal include arsenic, chromium, molybdenum and lead

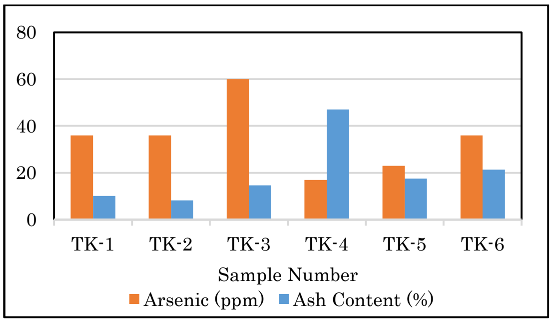

Fig. 7 Relationship between Arsenic and Ash content in Tondongkura Coal.

Table 3. Result of trace element analysis (ash basis).

Trace Elements (ppm)	**Coal seam 1**		
	TK-1	**TK-2**	**TK-3**
Arsenic (As)	36	36	60
Chromium (Cr)	155	222	229
Molybdenum (Mo)	8.5	6.6	5.7
Lead (Pb)	31	32	30
Trace Elements (ppm)	**Coal seam 2**		
	TK-4	**TK-5**	**TK-6**
Arsenic (As)	17	23	36
Chromium (Cr)	122	127	175
Molybdenum (Mo)	11.5	6	9.7
Lead (Pb)	24	25	71

Arsenic content in Tondongkura coal is vary from 17 to 60 ppm with average of 34.67 ppm (Table 3), it is still below the average value for arsenic in brown coal ashes. Based on the chart above (Fig.7), the relationship between the arsenic and ash content of Tondongkura coal Seam 1 (TK-1, TK-2, TK-3) is directly proportional. So it can be seen that the arsenic in Tondongkura in coal seam 1 belonging to the inorganic matters because when its content increases, the amount of ashes will increases. Unlike with seam 2 (TK-4, TK-5, TK-6), the arsenic is inversely proportional to the ash content of the coal seam 2. It can be classified into organic matters because when the amount of arsenic decreases, the ash content of the coal is likely to increase.

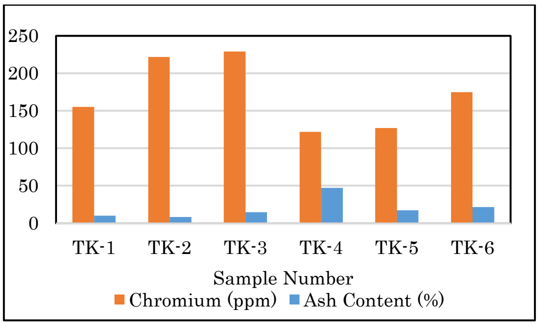

Fig. 8 Relationship between Chromium and Ash content in Tondongkura Coal.

Chromium content (Fig. 8) in the coal seam 1 is directly proportional to the ash content in the coal. So it can be stated that the chromium in the coal seam 1 included in an inorganic matters because when the number is increasing, the amount of ash also increased. While in the seam 2, chromium is inversely proportional to the ash content of the coal. When the amount of chromium increases, ash content in coal is likely to decrease. In other words, the chromium in the coal seam 2 included in the organic matters. Chromium content in Tondongkura coal is vary from 122 to 229 ppm with average of 171.67 ppm, it is above the average value for chromium in brown coal ashes.

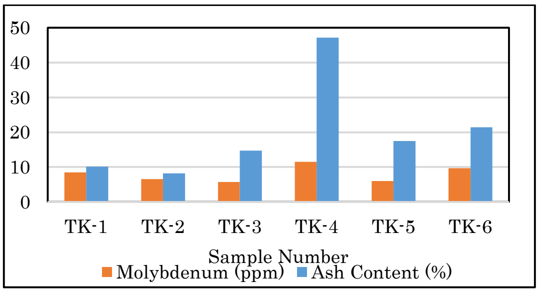

Fig. 9 Relationship between Molybdenum and Ash content in Tondongkura Coal.

Molybdenum content in Tondongkura coal is range from 5.7 to 11.5 ppm with average of 8 ppm, it is below the average value for molybdenum in brown coal ashes. The content of Molybdenum at the seam 1 (Fig.9) tends to inversely proportional to the ash content of the coal. Based on the result of this analysis, Mo can be classified into organic matters. But at the seam 2, Mo directly proportional to the ash content in coal. So that Mo is contained in the seam 2 included in the inorganic matters.

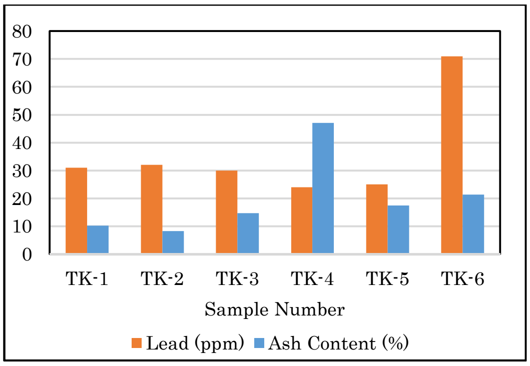

Fig. 10 Relationship between Lead and Ash content in Tondongkura Coal.

Lead content in Tondongkura coals vary from 24 to 71 ppm with average of 35.5 ppm, it is below the average value for lead in brown coal ashes. Lead content contained in seam 1 is around ± 30 ppm and tends to be inversely proportional to the ash content of the coal seam 1 (Fig. 10). It can be seen through the trend of ash levels content in coal is declining when Lead levels increased. Lead content in the seam 2 is more varied than seam 1. Coal seam 2, which has a lower levels lead tends to have higher ash content. But at the bottom ply seam 2, the lead content is more than the other ply. This is probably caused by contamination of the rock floor from seam 2. The relationship between lead and ash content in the seam 2 tends to inversely so that the elements of lead in Tondongkura coal can be stated that lead had affinity with organic matters.

3.3.3 Rare Earth Elements

Based on the results of ICP-MS analysis, there are some elements with a high enough percentage. Fig. 11 show graphs of Rare Earth Elements and Yttrium in Tondongkura coal seam.

Based on Serendin-Dai's classification [7] the REY distribution patterns in can be classified into three groups, namely Heavy-REY, Medium-REY and Light-REY (Fig.11). The seam 1 (Fig. 11.a) can be characterized as M-REY enrichment because it had positive anomaly on medium-REY type (Eu, Gd, and Dy) but also had a negative anomaly on Terbium. The seam 2 (Fig. 11.b) has a lower M-REY enrichment than seam 1. It also had positive anomaly on medium-REY type (Eu, Gd, and Dy) but also had a negative anomaly on Terbium.

The REY distribution patterns in the roof dan floor layer samples (Fig.11.c) are characterized by M-REY type enrichment with positive anomaly on medium-REY type (Eu and Gd) but also had a negative anomaly on Terbium. Based on the classification of REE, it is known that Tondongkura coal seam (seam 1 and 2) as well as the roof and floor layer included in the category of Medium REY. The most dominant of REY in the Tondongkura coal are Medium REY type (Eu, Gd, and Dy).

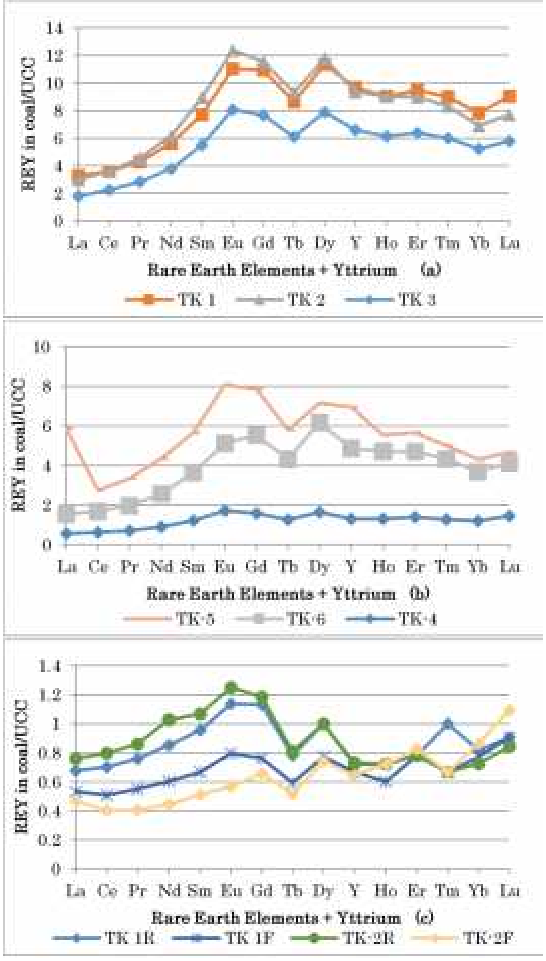

Fig. 11 Distribution patterns of REE + Y in the coal samples. REY are normalized to Upper Continental Crust (UCC). (a) REY in Tondongkura coal seam 1 (b) REY in Tondongkura coal seam 2 (c) REY from roof and floor layer (strata).

3.4 Mineral appearance on coal

The mineral that need to be considered in this study is pyrite. Based on photomicrograph obtained from microscopic analysis (Fig. 12 and 13), pyrite is the most visible mineral from the analyzed samples. Pyrite appearance in a sample is very clear with a fromboidal shape from the coal seam 2. The appearance showed that the pyrite contained in Tondongkura coal formed syngenetic or simultaneously with peatification process.

Fig. 12. Photomicrographs show the appearances of pyrite in Tondongkura Coal.

Fig. 13. Photomicrographs show various size of pyrites in Tondongkura Coal. (a) The biggest pyrite observed. (b) Framboidal pyrites. (c) Irregular pyrites. (d) Irregular with fine grained pyrites.

It can be seen from pyrites which do not fill the fractures in the coal. During peatification, syngenetic or early-diagenetic fine-crystal-line or fine concretionary pyrite appears, commonly in the form of framboids.

Most of framboidal pyrite that clustered possibly formed from sulfuric bacteria [5].

Pyrite that formed syngenetic is more difficult to be separated from coal compared to formed epigenetic pyrite. Because epigenetic pyrite formed by filling the fractures in the coal so that it does not require additional treatment to be removed, so it only need a physical treatment like comminution to resize the coal and separate it from pyrites. Meanwhile the syngenetic pyrite needs additional treatment to be removed such as chemical treatment to do desulfurization process. There are two methods to do a desulfurization process, namely chemical leaching and flotation method.

3. 5 Beneficiation of Tondongkura Coal

In determining the proper beneficiation method, it is important to know which mineral should be removed to increase the quality of the coal.

Chemical leaching is a desulfurization method to separate the pyrites in coal by mixing some acid solution with coals. The mixed solution then will be heated and stirred to make it more effective. The acid will extract the pyrite directly from the coal. This method is a common and effective method for desulfurization, but its only used in experimental stage but not in industrial stage because of high cost.

Flotation method is the most effective method to do desulfurization for Tondongkura coal. This method uses reagent such as oily collectors, frother, and surfactants. It can be operated in industrial condition. This method combines physical (using density to separate coal from inorganic matters) and chemical methods (using reagents to collect coal pulp from process).

The other impurities such as clays, quartz, and other minerals also can be separated using flotation method. Finkelmen explained about the modes of occurrence of trace elements in coal, arsenic occurs as solid solution in pyrite, chromium occurs in clays, and molybdenum occurs in sulfides or organic constituents [6]. Lead usually occurs in galena or as Lead Selenide (PbSe), but in this case lead likely occur as organometallic in Tondongkura coal. Organometallic is a chemical compounds containing at least one bond between a carbon atom of an organic compound and a metal, such as Hg, Zn, Pb, Mg and Li or to certain metalloids such as Si, As and Se. Meanwhile, REY occurs in phospates or some organic constituents [7]. Based on analysis (XRF and ICP-OES) result phosphate percentage in Tondongkura coal is very low. Based on XRD analysis, phosphate minerals were not detected since it had low percentage, so it can be expressed that REY likely occurs in some organic constituents.

Grinding treatment is the most important factor in flotation. By determining the exact size of coal, it will be easier to separate the pyrites from coal. Based on the photomicrograph (Fig. 13), it is known that the biggest pyrite from Tondongkura coals is ±875 μm and the smallest is ±12 μm, the size of quartz is ±60 μm, and the size of clays is

±150 μm. So the product from grinding step should not more than 875 μm and should not less than 12 μm to separates the impurities by flotation method.

4. CONCLUSIONS

Based on the study result coal seam 1 of Tondongkura coal can be classified into medium ash and middle sulfur coal and seam 2 can be classified into high ash and high sulfur coal. There are four major elements that have high percentage, namely SiO_2, Al_2O_3, Fe_2O_3 and CaO. Elements Fe_2O_3 and CaO have negative correlation with ash yield, while SiO_2 and Al_2O_3 has positive correlation with ash yield. Trace elements that must be considered are As, Cr, Mo, and Pb. Only Pb that has negative relationship with ash yield for each seam, meanwhile the others have various relationship with ash yield implying that most of trace elements have inorganic affinity. Rare earth elements in Tondongkura coal can be classified as MREY-type (rich in Eu, Gd, and Dy).

The proper method for beneficiation of Tondongkura coal is flotation technology. This method is believed to be more effective to separate impurities (mineral matter) from coal in order to increase the quality of coal.

5. ACKNOWLEDGEMENT

Thanks to PT. Intertek Utama Services Laboratory and Geological Laboratory, Gadjah Mada University for helping on sample analyses. Thanks to all members of Mineral Analysis and Processing Laboratory, Hasanuddin University for their help during sample preparation process. This study was supported by Research Intitute and Community Services of Hasanuddin University via a Research Project of World Class University-International Research Collaboration (WCU-KLN). Our gratitude also to editors of International Journal of Engineering and Science Applications, Professor Dr. rer. nat. A.M. Imran and Professor Dr. Ing. Herman Parung, M. Eng., as well as anonymous reviewers for their helpful comments which improved the manuscript.

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