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RESEARCH ARTICLE

THE ECONOMIC IMPLICATIONS OF COAL ESTABLISHED IN EACH OF THE FOUR DIFFERENT WELLS OF MUI BASIN IN PARTS OF MWINGI AND KITUI DISTRICTS IN KENYA

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ABSTRACT

A total of seventy nine samples from four different wells of Mui basin in parts of Mwingi and Kitui districts in Kenya were examined in order to establish the presence and quality of coal. The research was based on a proximate analysis which involved analysis of seven parameters per each sample based on ASTM standards (ASTM, 1991, Speight, 1983).The parameters were; determination of calorific value, fixed carbon, sulphur content, volatile matter, moisture content, ash content and iron. Proximate analysis is the determination of overall composition of coal sample (Spheight, 1983; Barbaras, 1991). The results obtained provided quick and valuable information regarding commercial classification and determination of the suitability of the coal from Mui basin identified for a particular industrial use (Dara, 2004). About 80% of the samples could be classified as industrial fuel, while the rest could be suitable for domestic fuel. But with reference to specific uses, 63% of the coal samples were found to be suitable for power generation, 19% for domestic fuel, gaseous fuel or tar distillation while the rest (18%) could be suitable for use in metallurgical coking.

INTRODUCTION

The coal exploration programme under the Ministry of Energy in Kenya has been going on with an aim of establishing Coal in different parts of the Country so that it can be used to limit overdependence on imported petroleum and Coal. Coal is a fossil fuel that has variety of uses-depending on its quality. It is used as a source of energy in the cement industry, while it is used in metallurgical industry in coking for the manufacture of iron metal. In addition, coal is used in the manufacture of gaseous fuels. It has remained the main fuel of choice for electricity generation Worldwide over the years; producing 38% of the Worlds electricity which is double that of oil and nuclear energy. In addition, Coal has been an essential input to two-thirds of the world steel production (W.E.O, 2002). In this paper, we report on the findings that were established regarding Kenyan coal from four drilled wells in Mui basin in parts of Mwingi and Kitui Districts. The study was based on proximate analysis based on ASTM standards (ASTM, 1991, Speight, 1983). Classification according to specific use was done with reference to South African and World energy council specification (W.E.C, 2004).

MATERIALS AND METHODS

A study was conducted in which Seventy nine samples of coal were collected from four different wells of the Mui basin between November, 2005 and July, 2006, and analyzed for calorific value, fixed carbon, moisture content, ash content, volatile matter, sulphur and iron content. Calorific value was analyzed using the bomb calorimetric method, by igniting a weighed portion of each sample in the bomb for one hour and measuring the corrected rise in temperature. For sulphur, one gram of each sample was mixed with three grams of Eschka mixture and ashed at 825°C for 1 ½ hours in a muffle furnace. The resulting residue was dissolved in hot water, filtered and the filtrate reacted with barium nitrate to precipitate barium sulphate. The Sulphur content was then determined from the total barium sulphate content. Iron in the coal sample, was analyzed using atomic absorption spectrophotometry. Samples were first ashed at 950°C in a muffle furnace before extracting the iron using aqua regia (a 3:1 mixture of concentrated hydrochloric acid and concentrated nitric acid). The objective of the analysis was to rank the coal and establish its suitability for use as an alternative energy resource in Kenya.

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RESULTS AND DISCUSSION

Calorific value

The calorific value for each sample for all the four wells was analysed using the bomb calorimetric method. The results below shows the average calorific value of coal samples obtained per well. On comparing the wells, well 4 had coal with the highest average calorific value compared to coal from other wells. Well 1 and well 3 had coal with similar calorific value. Well 2 had coal with the least calorific value compared to other wells. Thus, high quality coal was found in well 4.

Fixed carbon

Fixed carbon for each carbon sample was determined using bomb calorimetric method. From the results obtained, the average fixed carbon for all the samples per well was done and wells compared as shown below. Well 4 had coal with the highest calorific value and fixed carbon. Generally, the fixed carbon in all the wells, increased with increasing calorific value of the samples, implying that fixed carbon plays a great role in determining the calorific value of coal samples.

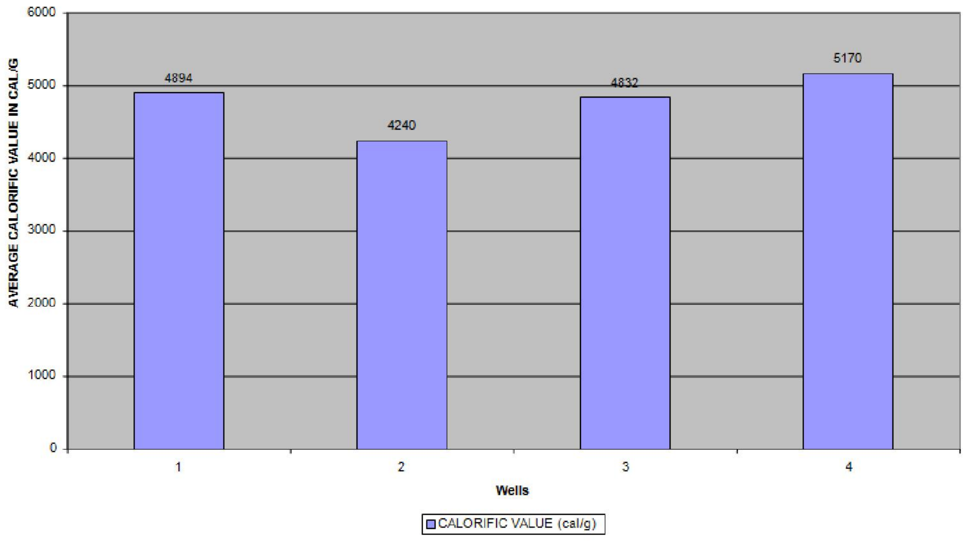

Figure 1. Average Calorific value of coal from the wells

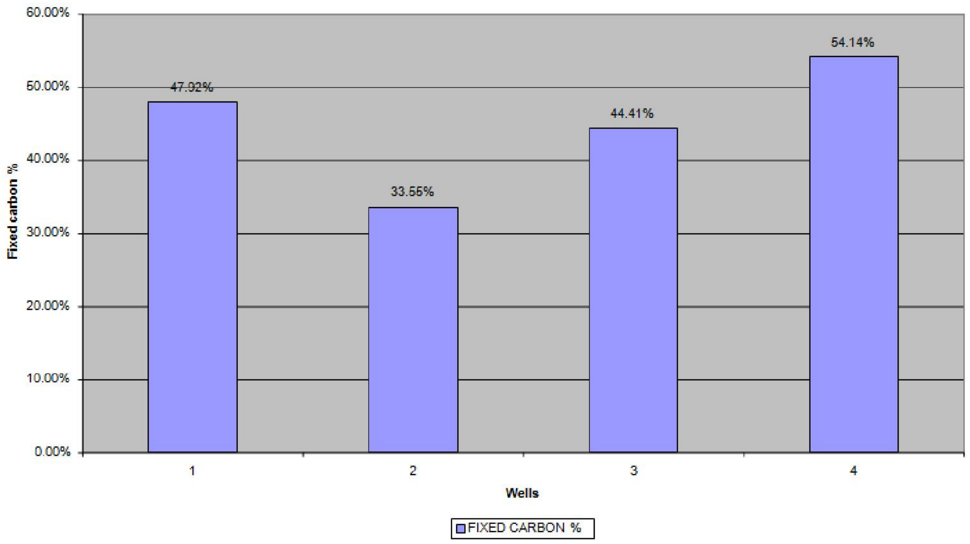

Figure 2. Average fixed carbon in coal

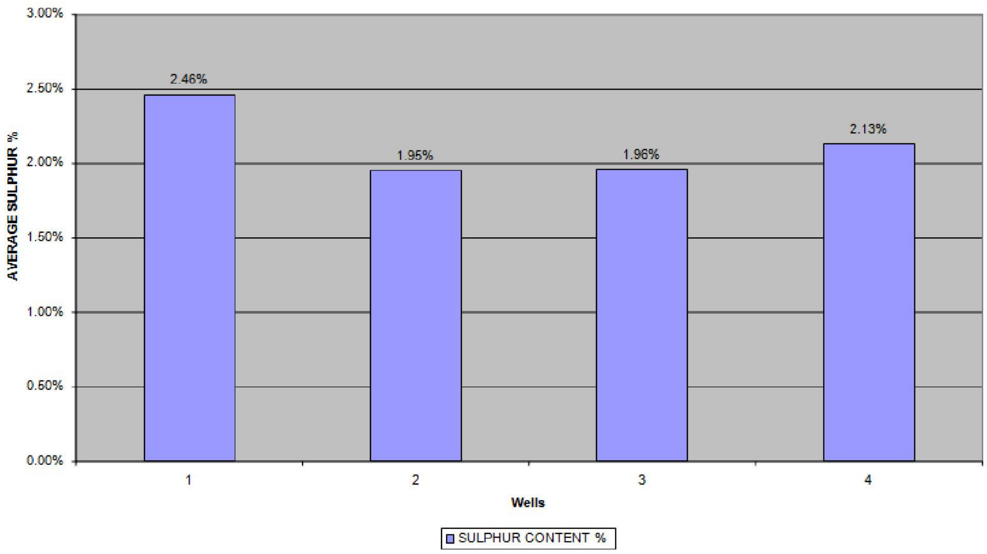

Figure 3. Average Sulphur content in coal from wells

Sulphur

The sulphur content for each coal sample was determined using the eschka method. The average sulphur content in coal from each well was worked out basing on the results obtained. The figure below shows the sulphur content obtained from coal in Well 1,2,3 and 4. The mean sulphur content in coal from all the wells is approximately 2.0%. High sulphur coal is that with sulphur content of 3 – 6% (Bailey, 2003). The range sulphur content in coal has been approximated as at (0.2 – 8%) (World Bank, 1996). The global required sulphur content into the environment is 0.05%. The sulphur content in coal from these wells is relatively high, and thus, if the coal will be used in boiler fuel or as domestic coal, then, there will be need for installations for desulphurization of flue gases in order to avoid emissions of SO_2. In power plants, the reaction between sulphur and alkalis or alkaline metals will lead to formation of complex sulphate and contribute to corrosion. There will be need to reduce the sulphur content in coal from Mui basin before using it.

Ash

Ash content for each sample was determined and average ash content determined per well. The figure below shows the average ash content per well

Coal from well 1 had the highest ash content of approximately 40%. The ash content in coal has been approximated to be (5 – 40%) (McCloskey Group, 2002). The mean ash content of coal from well 2 and well 4 was almost the same where the ash content was approximately 20%. The high ash content in coal from well 1, may affect its use in power generation. In addition, coal from well 1 had also high sulphur content (fig.3). High sulphur retention in coal ash of well 1 could have significantly contributed to the high ash content.

Moisture

Moisture content for each sample was determined and average moisture content of coal per well calculated from the results obtained for all the samples in each well. Well 2 and 4 had coal with similar moisture content of 12.11% and 12.06% respectively. The average moisture content of coal from well 3 was 15.5%. The moisture content in coal has been approximated to be between (2 - 40%) (World Bank,1996). Well 1 had coal with the lowest average moisture content, thus, less heat will be used in evaporating this moisture from coal during combustion compared to coal from other wells. Also, the transportation cost of coal from well 1 will be lower.

Volatile matter

The average volatile matter was determined as per the results obtained per sample in each well after analysis. The graph showing

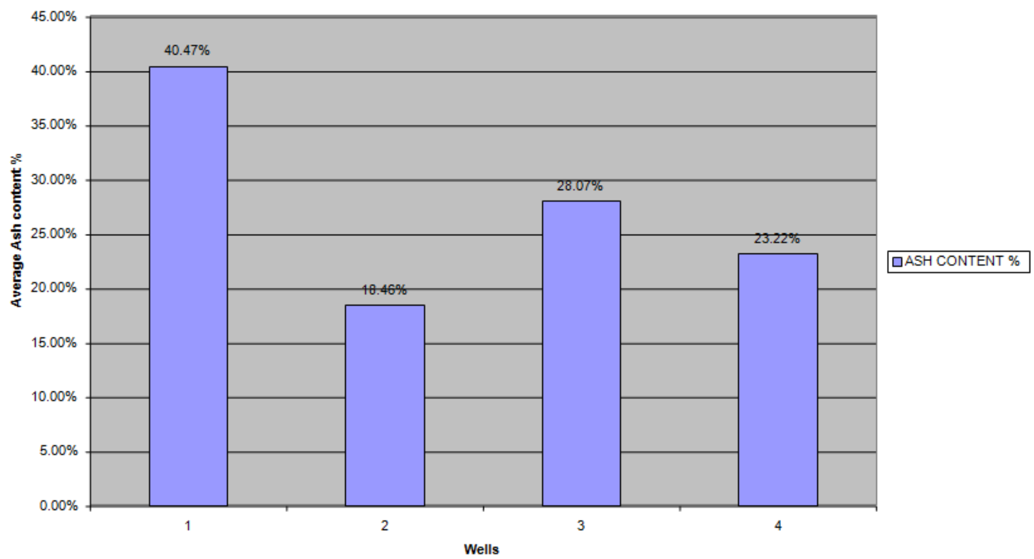

Figure 4. Average ash content in coal from the wells

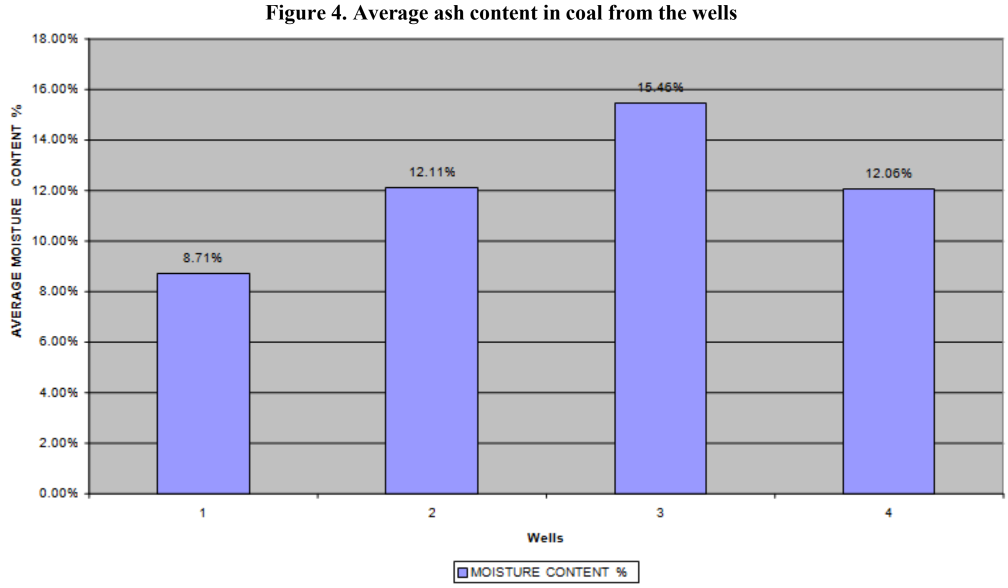

Figure 5. Average moisture content in coal from the wells

average volatile matter in coal from the wells has been illustrated below. Coal from well 1 had the lowest volatile matter content of 19.68%, while that from well 3 and 4 had the highest mean volatile matter content of approximately 60.00%, which may affect its suitability for use in metallurgical coking. In addition, the coal from wells 3 and 4 will burn with long flame and emitting high smoke, thus, the combustion space (furnace design) should be larger than that designed for combustion of coals from wells 1 and 2. However, the high volatile matter content in coal from wells 3 and 4 could be of an advantage, if this coal will be used in coal gas manufacture and in carbonization plants, where, the main objective is by –product recovery.

Iron content

The amount of Iron content found in each of the coal sample was done using AAS and the average iron content of all the samples per well determined from the results obtained as shown below. The mean iron content was higher in well 3 with 6.3%, but lowest in Well 4 with 1.20%. Well 1 and well 2 had coal having almost the same iron content of 2.83% and 2.33% respectively. The high iron content will be of significant use, if it will be removed from the coal ash and be converted into other useful application such as steel industry. However, if it will be discharged as part of the affluent, then, there will be need to monitor the iron content before discharge, since the maximum amount of iron required in the liquid affluent should be 3.5 $mg1^{-1}$ (World Bank, 1996). The presence of iron increases acidity of liquid affluent due to hydrolysis.

Well analysis and their economic implication

The mean values per parameter of coal analysed per well were critically reviewed and the economic implication of coal from each well was assessed. The mean value for the samples analysed was done per well for each parameter and the results obtained are presented below. The calorific value and fixed carbon of coal from well 1 was higher than that of South African coal. However, coal from this well is mainly bituminous coal. Due to its relatively low volatile matter content, the coal from this Well was found to be both suitable when used as metallurgical coke and also for power generation. The coal from well 2 had high mean volatile matter content, hence not suitable for metallurgical coke. However, relatively low ash content and high mean calorific value makes it suitable both for power generation and also as domestic fuel or gaseous fuel or for tar distillation. The mean calorific value also classifies this coal as mainly bituminous coal.The volatile content in coal from well 3 was relatively high. Hence, coal from this Well may not be suitable for metallurgical coke. However, it can be used for power generation and production of gaseous fuels. The coal from this well can generally be classified as bituminous coal using South African coal ranking systems. Well 4 had coal with the highest calorific value compared to other wells, although the coal is still mainly bituminous coal. The high volatile matter content makes this coal unsuitable to be used as metallurgical coke; however, this coal may be used for power generation, as gaseous fuels and for tar distillation.

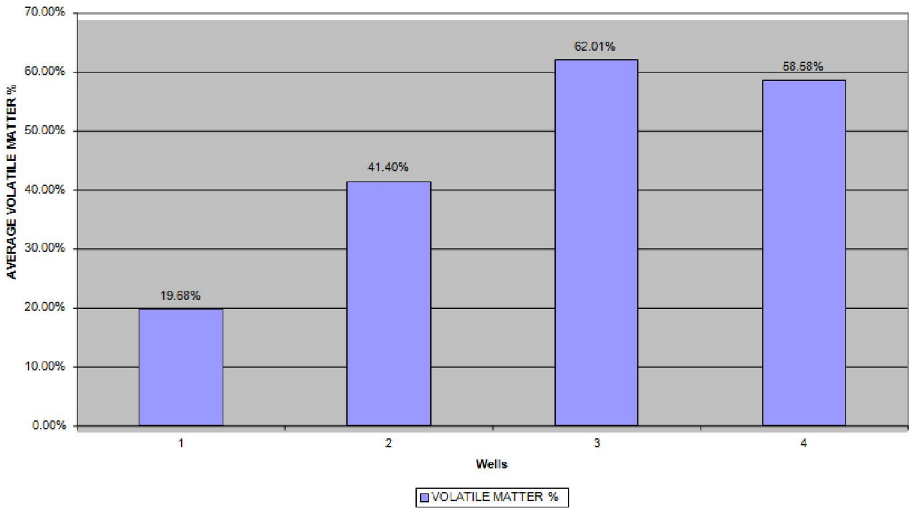

Figure 6. Average percent volatile matter in coal from Wells

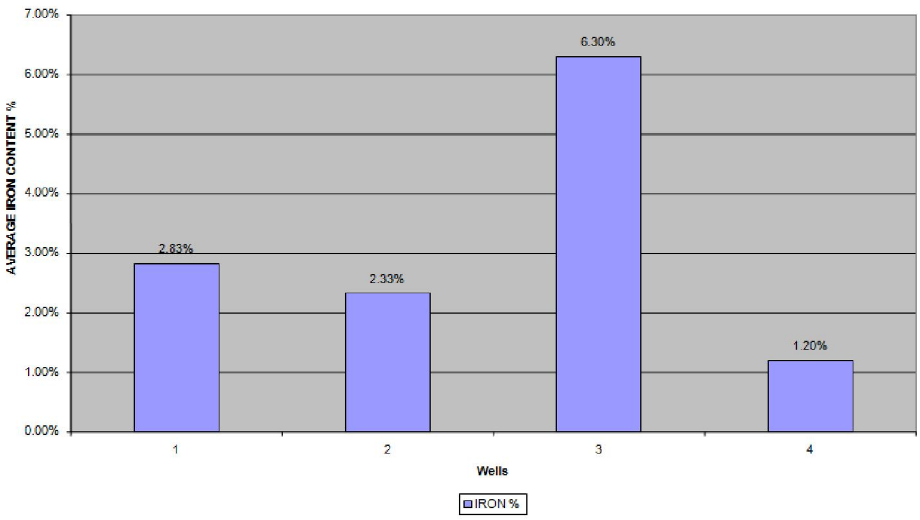

Figure 7. Average percent iron content in coal from Wells

Table 1. Average values obtained per well after analysis of calorific value, fixed carbon, sulphur content, ash content, moisture content, volatile matter and iron

Wells	Calorific value (cal/g)	Fixed carbon %	Sulphur content %	ASH content %	Moisture content %	Volatile matter %	Iron %
1	4894	47.92	2.46	40.47	8.71	19.68	2.83
2	4240	33.55	1.95	18.46	12.11	41.40	2.33
3	4832	44.41	1.96	28.07	15.46	62.01	6.3
4	5170	54.14	2.13	23.22	12.06	58.58	1.20

4.3.5 Overall quality of coal from mui basin

The mean and range value per parameter for all the samples analyzed in all the 4 wells was established and recorded in table 4.3.5a.

Table 4.3.5a. Overall Quality of Coal from Mui basin

Parameter	Range (%)	Mean %
calorific value Mj/kg	8.65 - 31.40	21.16
Fixed carbon %	20.00 - 80.12	52.16
Volatile %	4.98 - 85.90	45.89
Ash %	2.09 - 61.06	26.53
Sulphur %	0.45 - 3.98	2.01
Iron %	0.02 - 40.33	2.04
Moisture %	1.99 - 20.46	10.85

The mean sulphur content of coal from Mui basin was found to be 2.01% with 0.45% as the lowest sulphur content established and 3.98% as the highest. All coals contain sulphur and the amount depends on their type and origin. Studies done has shown that in the United States, the coals from the Eastern, mid Western and Southern States, are predominantly higher in sulphur, containing 2 – 4%, while those from Western States mostly contain less than 1%. The sulphur content of German ignite has been established as at 1 – 2% rarely > 5%, while that from the Ruhr has 0.5 – 2.5% and South African coals range from 0.3% to 2.8% (Ullmann's 1994). Recent studies have shown the sulphur content in South African coal from South Eskom general is 1% while that from South African coal from New Vaal is 0.5%. [South African coal processing society]. Elsewhere, sulphur content in coal has been established to be within the range of 0.2 – 8% (Dara, 2004), while in others, the range total sulphur content is 0.42% to 6.47% (Spheight, 1983). According to studies done by Fable (1982), sulphur content in coals range from 0.5 and 3%. In addition, analyses done on coals of different rank by McMullan in 1976, showed that, the sulphur content range from 0.23% to 5.69%. Thus, basing on these values, the sulphur content in coal from Mui basin is quite comparable. The mean iron content in coal from Mui basin samples was found to be 2.04%, with 0.02% as the lowest, while 40.33% as the highest iron content. The mean values in table 4.3.5a above were used to establish the overall rank of coal from Mui basin basing on the South African coal ranking system. The following rank was established in the table below. The mean values in table 4.3.5a above were compared with coal from South Africa (Eskom general and coal from New Vaal) as indicated below.

Table 4.3.5b. Comparison of Coal from Mui Basin with South African Coal

	Kenya	South Africa (Eskom general)	South Africa (New Vaal)
Cv Mj/Kg	21.16	21	16
Vm %	45.89	23	16
Fc %	52.16	44	36
Ash %	26.53	30	40
Sulphur %	2.01	1	0.5
Moisture %	10.85	4	6

The mean calorific value of coal from Mui basin was slightly higher that of South African coal. This was also the same with fixed carbon. This showed direct correlation between calorific value and fixed carbon. The sulphur content in coal from Mui basin was however higher than that of South Africa but the ash content was lower than that from South African coal. The moisture content and volatile matter content in coal from Mui basin were found to be relatively higher compared to coal from South Africa.

4.3.5. Classification of coal from mui basin in reference to specific use

The classification of the coal from Mui basin with reference to specific use was done using the guided table from South African coal processing society, and other literature sources. In tables 4.3.6a, 4.3.6b and 4.3.6c below, the coal samples from Mui basin have been classified with reference to either as industrial fuel, domestic fuel and according to specific use in terms of power generation, domestic fuel, gaseous fuel and metallurgical coke, after assessing the calorific value, ash and volatile matter content per coal sample. Samples found to be mere rock was excluded

Table 4.3.6a. Overall Classification as Hard Coal or Soft Coal

Coal Type	No. of Coal Samples	Percent (%)
Hard coal	42	67
Soft Coal	21	33
TOTAL	63	100

The hard coal comprised of anthracite and bituminous coal samples, and the rest were soft coal as in table 4.3.5 b Classifying the above samples as hard coal and soft coal, the hard coal comprised of 42 samples (67%). 21 samples (33%) was soft coal. Rock samples were excluded. Studies done, shows that, coal resources in most African countries are mainly hard coal (W.E.C, 2004).

Table 4.3.6b. Classification according to specific use

Use	No. of Coal Samples	%
Power generations (ash < 34%, CV >3346 Cal/g)	40	62.49
Domestic fuel	12	19.05
Metallurgical coke (vol <34%, CV 20 -32 mj/kg)	11	17.46
TOTAL	63	100

Similarly, when these samples were classified according to specific use, 40 samples (62.49%) were found to be suitable for power generation, 12 samples (19.05%) were found to be suitable for either domestic fuel or gaseous fuel, or tar distillation, and the rest 11 samples (17.46%) were found to be suitable when used as metallurgical coke. The above results showed that coal from Mui basin can basically be used for power generation while a small portion of approximately 18% can be used in metallurgical coking.

Table 4.3.6c. Classification as industrial fuel and domestic fuel

Use	No. of Samples	%
Industrial fuel	51	80.95
Domestic fuel	12	19.05

Classifying the above samples as industrial fuel or domestic fuel, 51 samples (80.95%) could be used as industrial fuel while 12 samples 19.05% could be used as domestic fuel.

5.0. Conclusion and Recommendation

The coal from Mui basin is basically anthracite coal, bituminous and lignite, which can be suitable for use both as industrial fuel and domestic fuel in power generation, metallurgy and process heat in key industries, and if cleaner coal technologies can be adopted upon establishment of enough recoverable coal in Mui basin, then coal exploitation and use in Kenya will ensure diversification of source of power supply which will limit dependence on hydro and thermal source, thereby promoting security of energy supply and save on forex for fuel imports. Should the government of Kenya approve the coal mining and use in Kenya, then, there will be need to carry out a comprehensive research on elemental analysis in Kenyan coal sample and also fly ash. Coal is a heterogeneous mixture of many minerals. It is important to measure the inorganic constituents accurately in order to be able to follow their path through various stages of coal production and utilization. The analysis will also provide important information regarding the possible conversion of coal to synthetic fuel, due to increased emphasis on the development of synthetic fuels to supplement the depleting natural petroleum resource, a viable alternative fuel source. There will also be need to carry out a comprehensive life cycle analysis of coal which include all other impact categories. Key industries that heavily rely on fuel oil or wood fuel to generate process heat that is used in boilers such as cement industry, Nzoia Sugar, Mumias Sugar, KTDA, East Africa breweries, Cement Industry, should consider carrying out both an economic and environmental survey of shifting to coal.

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