Appl. Res. J. Sci. Technol.
Vol 2(1), pp. 25-33, December, 2020
DOI: 10.47721/ARJST202001018
Article number: SE-J-ARJST-2020.0201002
ISSN 2695 1738
https://skies.education/journal/arjst

International Institute for Applied Research
Skies Educational

Production and performance evaluation of drilling mud using specific locally sourced materials

Otitigbe F. E.

Faculty of Engineering, Department Petroleum Engineering,
Delta State University, Abraka, Oleh Campus, Delta State, Nigeria
Correspondence to: fotitigbe@yahoo.com
Tel: +234-08055626750/ +234-08177262500/ +234-09017725501

ABSTRACT: *The importation of drilling mud into Nigeria, apart from draining the nation's reserves in hard currency, is also inimical to the local content policy being currently promoted for the oil industry in the country. Thus, the need for local sourcing of bentonitic clays or close substitutes has become imperative. This study proffers an alternative to the importation of drilling mud and shows an experimental approach on the preparation of drilling mud with readily available locally sourced materials, such as pulverized groundnut husk, tronna, burnt palm-head sponge powder, bentonite, barite and starch. Materials used for the study were collected from the Mubi local government area of Adamawa State, Akwanga local government area of Nassarawa State and Jos-north local government area of Plateau State. The mineralogical and physicochemical properties of the locally sourced bentonite and barite samples were determined by means of X-ray fluorescent spectroscopy (XRF), X-ray diffraction spectroscopy (XRD) and cationic exchange capacity (CEC), all carried out in the Nigerian Mining institute of Geosciences, Jos Plateau State. The drilling mud was produced and its physicochemical and rheological properties carried out based on the API mud production standards. Results of cost analysis showed that producing 100 kg water-base drilling mud from locally source material, cost ₦ 14, 715.75, which is 22.3% cheaper than conventional drilling mud imported into the country.*

Keywords--*Drilling mud, mineralogical properties, rheological properties, locally sourced materials*

INTRODUCTION

One of the important materials used in drilling is the drilling fluids commonly called drilling mud. They are of two types – water-based mud and oil-based mud. Therefore, the design and production of this drilling fluid become of utmost importance because of its role in drilling. Companies involved in the design and production of drilling fluids in Nigeria for the oil and gas sector have over the years imported the materials to produce drilling mud or in some cases imported already designed and produced drilling mud. In this case, industry in this sector adjusts the properties of the drilling fluid with the aid of the right types of additives which are also imported to suit the formation requirements of the area to be drilled [1].

Recently a lot of research has been conducted to provide a substitute for the imported clay and treat the clay to improve its rheological properties, by the use of additives for better performance. Drilling fluids properties such as apparent viscosity, plastic viscosity, specific gravity and yield point, play important role in designing efficient and optimized drilling operation. These properties serve the functions of cleaning the rock fragments from beneath the bit and carry them to the surface as well as cooling and lubricating the rotating drill string and bit [2].

Drilling fluid has gone through major technological evolution, since the first operations performed in the United States, using a simple mixture of water and clays, to complex mixtures of various organic and inorganic products used in recent times. These products improve fluid rheological properties and filtration capability, allowing the bit to penetrate heterogeneous geological formations under the best conditions.

A lot of works related to the production of water-based drilling mud using specifically local sourced materials have been conducted. They include amongst others, drilling fluid formulation using cellulose generated from groundnut husk [3], Rheological properties and corrosion characteristics of drilling mud additives [4], Modification of drilling fluid pH with local Nigerian additives [5], Optimization for the production of water-based drilling mud from local clay [6].

In this study, the formulation, production and performance evaluation of drilling mud from locally sourced materials was determined. Indigenous clay samples will be treated using locally sourced additives, so as to improve their swelling characteristics as well as other rheological properties. The rheological and physicochemical properties of the treated clay will be determined using standard tests and the results will be compared to data obtained from standard commercial drilling mud. It is however limited to clay samples obtained from the Northern part of Nigeria. Furthermore, a cost analysis was carried out to determine the viability and feasibility of the study.

MATERIALS AND METHODS

Materials

The equipment used for this study includes: Oven (type 48 BE Apex Tray Drier), weighing balance, measuring cylinder, beakers, Multi mixer and Cup, pH indicator strip, thermometer, knife, sieving mesh, bucket, bowl and stopwatch, Fann viscometer, mud balance. Local bentonite samples were collected from the Mubi local government area of Adamawa State-Nigeria (Lat. 10^0 16’ 6.89’’ N and Long. 13^0 16’ 1.24’’E) and the barite samples were collected from Akwanga local government area of Nassarawa State-Nigeria (Lat. 8^0 54’ 38.77’’N and Long. 8^0 24’ 23.58’’E). Other materials such as groundnut husk, palm head sponge, starch and trona were purchased from Jos-north local government area of Plateau State-Nigeria (Lat. 9^0 56’ 21.7’’ N and Long. 8^0 54’ 8’’E).

Methods

The production method of the drilling fluids and the determination of the rheological and allied properties were carried out based on the API drilling mud production standards [7]; [8]; [9]).

Test for the mineralogical and physiochemical properties of the bentonite and barite sample were carried out in the Nigerian Institute of Mining and Geosciences, Jos-Plateau State. The XRF, CEC and XRD test methods were employed and the results measured and recorded [10]; [11]; [12]). The bentonite and barite materials were subjected to size reduction by crushing and grinding to a particle size of 85 µm and 850 µm respectively. The raw materials such as water, bentonite, pulverized groundnut husk, starch, barite, trona and burnt palm head sponge powder are in the proportion; 245 ml, 75.0 g, 20.0 g, 7.0 g, 30.0 g, 30.0 g and 5.0 g respectively were measured using the graduated cylinder and electronic weighing balance as shown in Table 1. The raw materials were then poured one after the other, with an interval of 5 minutes into the steel cup of the multi mixer. The application of the raw materials was carried out in descending order as arranged in Table 1. As the materials were completely applied into the multi mixer cup, it was allowed for 30 min, under stirring condition, for a total hydration of a mixture of drilling mud, called water-based drilling mud. Drilling mud density was measured with a mud balance and the balanced value was read and recorded. A Fann viscometer was then used to evaluate the rheological properties, such as plastic viscosity, yield point, apparent viscosity, n and k values at 600 and 300 RPM dial readings, using equations (1), (2), (3), (4) and (5) respectively.

Table 1: Materials used and their functions

Raw material/reagents	Function	Justification	Quantity
Water	Base fluid		245 ml
Bentonite	Viscosifier and filtration control	Bentonite is available in Gombe, Adamawa, Borno e.t.c. It was used as a substitute to that imported into the country (usually from Wyoming U.S.A).	75.0 g
Pulverized Groundnut husk	Viscosifier and fluid loss control agent	Groundnut Husk was used as substitutes to polyionic cellulose, due to its availability. Polyionic cellulose is usually imported.	20.0 g
Starch	Viscosifier and fluid loss control agent	Starch was used because of its abundant availability in the country.	7.0g
Barite	Weighting agent	Barite is available in commercial quantity and doesn't have to be imported.	30.0 g
Trona (Akanwu)- K_2CO_3	Swelling agent	Trona with chemical formula- K_2CO_3 was used as a substitute to already processed Sodium Carbonate, due to its availability.	30.0 g
Burnt palm-head sponge powder –NaOH	pH control	This was used as substitutes to already processed Sodium Hydroxide (NaOH).	5.0 g

$$Plastic\ viscosity(PV), cP = 600\ rpm\ reading - 300\ rpm\ reading \quad ...(1)$$

$$Yield\ point\ (YP), = \frac{lb}{100ft^2} = 300\ rpm\ reading - plastic\ viscosity(PV) \quad ...(2)$$

$$Apparent\ Viscosity(AV) = \frac{600\ rpm\ reading}{2} \quad ...(3)$$

$$Apparent\ Viscosity(AV) = \frac{600\ rpm\ reading}{2} \quad ...(3)$$

$$n = 3.32 log \frac{\theta_{600}}{\theta_{300}} \quad ...(4)$$

$$k = \theta_{300}(511^n) \quad ...(5)$$

RESULTS AND DISCUSSIONS

A. Characterization of Locally Sourced Samples (Bentonite and Barite)

1. Chemical analysis of locally sourced bentonite sample obtained by XRF

Table 2 presents the result of the chemical analysis obtained by XRF for the local bentonitic clay sample. The analysis of the result indicates that Si_2O and Al_2O_3 were the main components present in the local bentonite sample i.e. 61.8% and 20.4% for Si_2O and Al_2O_3 respectively. Other oxides such as Na_2O, CaO, Fe_2O_3 and MgO were present in proportions of 1.4, 2.1, 3.9 and 2.6% respectively. This implied that the major components occurred as oxide whereas the minor or trace components occurred as elements. Similar values of these oxides were observed in the characterization of chemical analysis of bentonite clays from the municipality of Pedra Lavada [13].

Table 2. Chemical composition of locally sourced bentonite sample analyzed by XRF

Components	wt %
Na_2O	1.4
CaO	2.1
K_2O	0.6
SiO_2	61.8
Al_2O_3	20.4
Fe_2O_3	3.9
MgO	2.6
S	0.3
Cl	0.01
Trace E*	0.03
Heavy M**	0.01
CO_2	1.2

Trace E* constitutes Ti, P, Ba, Sr, Mn, Zr
HeavyM** constitutes Cu, Zn, Ni, Cr
Source: Nigerian institute of mining and Geosciences, Jos- Plateau State.

2. Mineralogical composition of locally sourced bentonite sample obtained by XRD

The characterization of the local bentonite sample using XRD, aimed to verify the existence of associated minerals and clay minerals. Figure 1 presents the X-ray diffraction result of the local bentonite sample. It can be seen that the diffractogram is an oscillating curve with several high peaks. The peaks are characterized by bands of montmorillonites, quartz, siderite and Albite, with the montmorillonites depicting the maximum peak. This implied that the local clay sample is basically bentonite. A similar XRD result was obtained by [14].

3. Chemical composition of locally sourced barite sample obtained by XRF

Table 3 presents the result of chemical analysis obtained by XRF for the local barite sample. The analysis of the result indicates that the local barite sample contains 91.68% by weight of BaO and 8.31% of SiO_2 as the major component. Other components occurred in trace amounts. This implied that the sampled material is mainly barite. Similar values of these oxides were observed in the characterization of chemical analysis of barite material according to the finding of [15].

4. Mineralogical component of locally sourced barite sample obtained by XRD

The characterization of the local barite sample by XRD, aimed to verify the existence of barite minerals. Figure 2 presents the X-ray diffraction result of the local barite sample. It can be observed that the diffractogram show the characteristic peaks of calcite, barite and quartz i.e. 5.3, 91.7 and

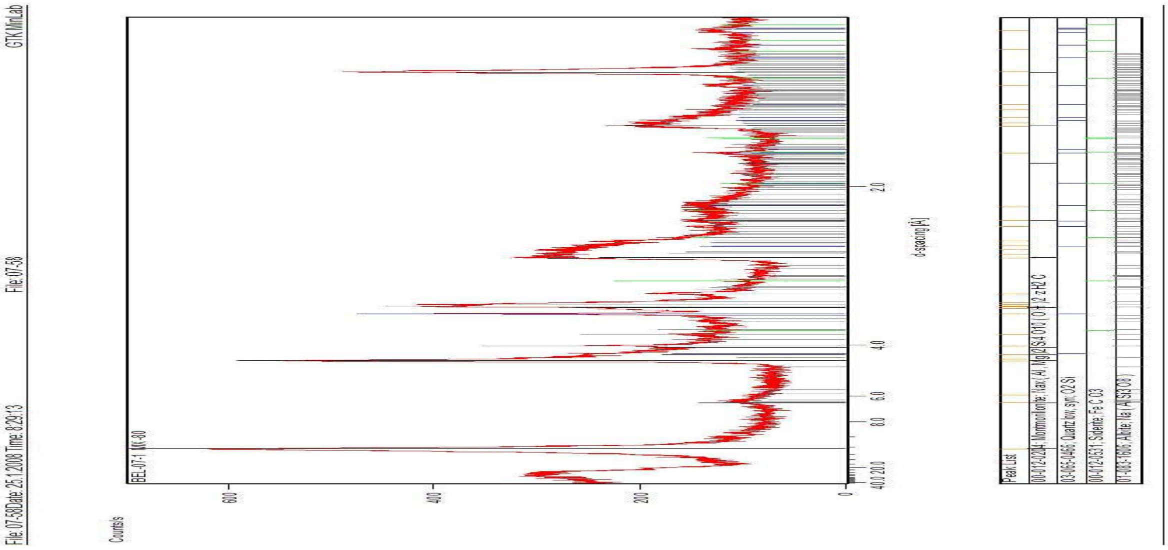

Figure 1: XRD spectrum of locally sourced bentonite sample

Table 3: Chemical components of locally sourced barite sample analyzed by XRF

Components	Percentage composition (%)
Moisture content	0.0020
Loss of ignition	0.060
BaO	91.680
Na_2O	0.025
K_2O	0.015
MgO	0.040
CaO	0.014
Al_2O_3	0.620
Fe_2O_3	0028
SiO_2	8.310

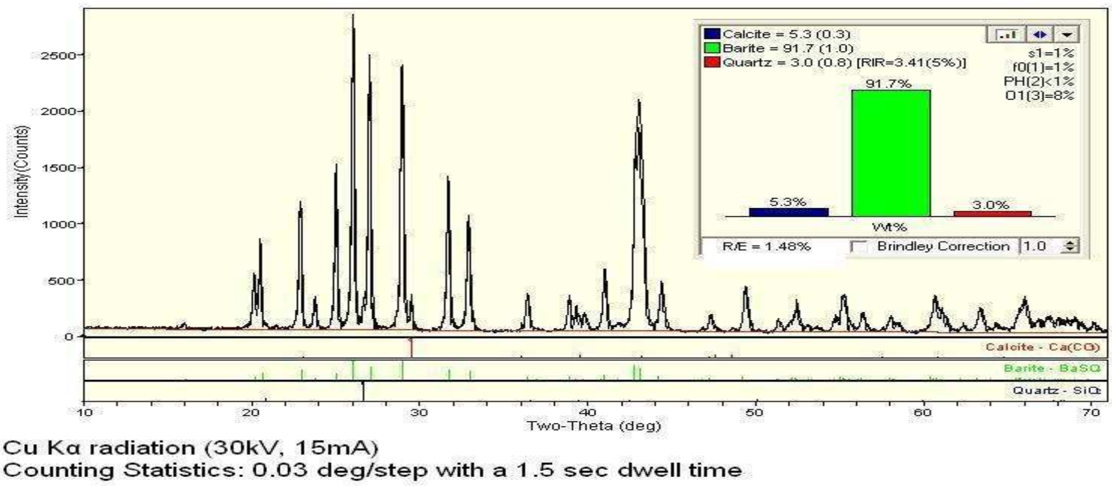

Figure 2: XRD spectrum of locally sourced barite sample

3.0% respectively by proportion. With barite (BaO) depicting the maximum peak. This implied that the local material sample is basically barite. A similar XRD result was obtained by [16].

5. Physicochemical properties

Table 4 presents the mud density and the pH of the produced drilling mud. It can be seen that the mud density after treatment for the 15 runs was found to be within the range of 1 097.4 and 1 148.9 kg/m^3. These can be attributed to the variation of additives in proportion (i.e. tronna, burnt palm-head sponge and pulverized groundnut husk). The mud density of the produced drilling mud fell within API numerical value standard for drilling mud (i.e. 1 036.3 – 1 150.1 kg/m^3), this is in agreement with the finding of [17], who observed that when drilling mud is treated with both polyanionic cellulose and potash, the sampled mud density increased appreciably. It can also be seen that the pH of the produced drilling mud after beneficiation for the 15 runs was found to be within the range of 6.1 and 11.0. The mud pH for runs 2, 6, 10 and 13 were 6.2, 6.3, 6.1 and 6.0 respectively, which is below API numerical value standard for drilling mud. This is due to the variation of additive in proportion (i.e. burnt palm-head sponge powder and tronna). While the other runs fell within the API numerical value standard for drilling mud (i.e. 9.5-12.5). This is in agreement with the finding of [17], who observed that beneficiating local mud sample with potash, raised the pH value from acidic to alkaline state in order to conform to the API numerical value standard for drilling mud.

Table 4: Physicochemical property of the produced drilling mud

Runs	Mud density (kg/m^3)	pH
1	1134.5	10.9
2	1098.6	6.2
3	1145.3	9.1
4	1132.1	9.3
5	1097.4	9.2
6	1133.3	6.3
7	1144.1	11
8	1147.7	9.2
9	1099.8	9.1
10	1134.5	6.1
11	1134.5	10.9
12	1135.7	9
13	1148.9	6
14	1146.5	11
15	1099.8	10.9

6 Rheological properties

Table 5 presents the summary of rheological properties for the produced drilling mud (i.e. plastic viscosity (PV), yield point (YP), apparent viscosity (AV), n- factor and k- factor), as determined by substituting the dial reading data into equations (1), (2), (3), (4) and (5) as stated earlier. It can be seen that PV for runs 8, 9, 10 and 11 were 5.6, 5.5, 5.2 and 5.57 cP respectively, which fell below the API numerical value standard for drilling mud (i.e. 8-10 cP), while the other runs fell within the API numerical value standard for drilling mud. The low PV may be attributed to low amounts of viscosifiers been added (i.e. pulverized groundnut husk and starch). Therefore, other rheological properties such as YP and AV were affected also, since they are dependent on PV [18]. This is in agreement with the finding of [19], who observed that additives such as polyanionic cellulose and gum Arabic improve the rheological properties of a local bentonitic clay material to API numerical value standard for drilling mud. It can also be seen that the n- power factor was found to be within the range of 0.27 - 0.41. This implied that the fluid obeys Bhingham plastic fluid since the value is less than 0.5. Therefore, the n-power factor fell within the API numerical value standard for drilling mud (i.e. 1 max.).

Table 5: Rheological properties of the produced drilling mud

Runs	PV(cP)	YP(lbf/100ft^2)	AV(cP)	n factor	K factor
1	9.60	20.60	19.90	0.40	361.35
2	8.50	18.60	17.80	0.39	315.02
3	9.63	20.53	19.90	0.40	364.55
4	8.63	18.37	17.82	0.40	327.21
5	9.47	20.83	19.88	0.39	349.29
6	9.57	20.73	19.93	0.40	357.26
7	8.50	18.50	17.75	0.39	316.37
8	5.60	18.97	15.08	0.30	155.69
9	5.50	19.13	15.07	0.29	150.85
10	5.20	19.70	15.05	0.27	137.04
11	5.57	19.40	15.27	0.29	152.54
12	8.30	19.03	17.82	0.38	296.65
13	8.13	18.73	17.50	0.38	289.72
14	9.87	20.17	19.95	0.41	386.31
15	8.43	18.67	17.77	0.39	309.76

7. Cost Analysis

Table 6 presents the cost of producing 100 kg water-base drilling mud from locally sourced material. It can be seen that the total cost of producing 100 kg of water-based drilling mud from locally sourced materials is ₦ 14 715.75, whereas the cost of 100 kg of imported water base mud drilling is found to be ₦ 18,000. This implies that the locally sourced water-base drilling mud is more economical and profitable at ₦ 3 284.25 (22.3% increase). Thus, this shows that it is more viable and economical to produce water-based drilling mud from locally sourced materials.

Table 6: Cost of 100 kg water base drilling mud from locally sourced materials

S/No	Materials	Quantity (kg)	Cost /kg (₦ /kg)	Cost (₦)
1	Bentonite	51.51	100	5151
2	Barite	20.60	50	1030
3	Trona	6.87	50	343.5
4	Groundnut husk	12.77	33.33	425.62
5	Starch	4.81	66.66	320.63
6	Palm head sponge	3.43	1 500	5145
Total		100	1 700	12 415.75

RECOMMENDATION

The tests so far, show that both local bentonite and barite, dominate the composition of their respective materials. Hence, they are as good as those of the imported foreign water-base drilling mud and the weighing material (Barite).

In addition, the free availability of local materials for the preparation of water-based drilling mud, and the cost of transportation, drastically reduces the cost of production over the foreign water-base drilling mud and thereby making the local water base mud more economically viable and readily available than the foreign water-based drilling mud.

Other benefits include employment generations, a source of income for foreign reserve, urban-rural drift which evolve into rural area development and a high standard of living of citizen.

Therefore, the water base mud and barite prepared from local materials are good and can be substituted for the foreign materials used in the formulation of water-based drilling mud.

CONCLUSION

The production and performance evaluation of water-based drilling mud, specifically, from locally sourced materials has been conducted. The mineralogical and physicochemical properties were determined. It was found that the locally sourced bentonite contained Si_2O and Al_2O (i.e. 61.8% and 20.4% respectively) and barite contained BaO and SiO_2 (i.e. 91.68% and 8.31% respectively). The formulation and production of water-based drilling mud from local materials such as bentonite, groundnut husk, tronna (akanwu), barite, burnt palm-head sponge and starch was completed successfully. The physiochemical and rheological properties were determined. It was observed that mud density was within the range of 1 097.4 - 1 148.9 kg/m^3. The pH was found to be within the range of 6.1 - 11.0 and in addition, the n- power factor was found to be within the range of 0.27 - 0.41. Cost analysis showed that producing 100 kg water-base drilling mud from locally sourced materials, cost ₦ 14 715.75, which is 22.3% cheaper than the conventional drilling mud imported into the country.

REFERENCES

[1] B. Bennion, Formation damage—the impairment of the invisible and uncontrollable, resulting in an indeterminate reduction of the unquantifiable, Journal of Canadian Petroleum Technology, Vol. 38, Issue 2, pp. 11–17, 2012.
[2] N. A. Adam and H. Mohammed, Environmentally friendly mud additives for super Drilling fluid designs to meet the current and future technical and environmental challenges. The oil and gas review issue 11, 2013.
[3] K. K. Dagde, C. Nmebgu, and J. Godwin, Drilling fluid formulation using cellulose generated from groundnut husk. International Journal of advancement in research. Vol. 5, issue 3, 2014,
[4] S. D. Annudeep, Rheological properties and corrosion characteristics of drilling mud additives. A Master's thesis Department of Petroleum Engineering, Dalhousie University Halifax, Novia Scotia, 2012.
[5] O. M. Okorie, Modification of drilling fluid PH with local Nigerian additives. Petroleum Technology Development Journal, Vol.1, Issue 6, 12-13, 2009.
[6] T. Oyegoke, Optimization for the production of water-based drilling mud from local clay. B. Eng Research project, Department of chemical engineering, FUT Minna, 2011.
[7] American Petroleum Institute (API), Specification for drilling – fluid materials – Specification 13. American Petroleum Institute, Washington, DC. Pp. 47, 1993.
[8] F. J. Ogbonna, Design and Field Application of Drilling Cementing and Stimulation Fluids'' Chi Ikoku Petroleum Engineering Series, pp 20-22, 35-42, 2010.
[9] O. F. Joel, U. J. Durueke and C. U. Nwokoye, Effect of KCL on Rheological Properties of Shale Contaminated Water-Based Mud. Global Journal of Researches in Engineering, Vol. 12. Issue 1, 2012.
[10] Researchgate. net Chemical Composition of bentonite.
[11]Brady, Nyle C, Well, Ray R, The nature and properties of soils (14th ed.) Upper Saddle River, USA Pearson. 2008.
[12] Dann, S.E, Reaction and Characterization of Solid. Royal Society of Chemistry, USA. 2002.
[13] F. Growcock and T. Harvey, Drilling Fluids. In ASME Shale Shaker Committee, Drilling Fluids Processing Handbook. Elsevier, 2012.

[14] C. I. Oliveira, M. Paul, M. G. Rocha and L. C. Bertolino, Characterization of bentonite clay, Brazillian Journal of Chemical Engineering, Vol. 62, Issue 3, pp. 272-277, 2016.
[15] O. Femi, Y. Ibrahim and J. Ekezue, Characterizing barite Using XRF, XRD analysis of powdered samples, World academic research Journal. Vol. 1, Issue 2, pp. 006-009, 2015.
[16] D. A. Brobst, Barium minerals in industrial minerals and rocks. (6^{th} ed.), Littleton, CO.SME, 2009.
[17] C. W. Okologume and A. E. Akinade, Comparative Study of Basic Properties of Mud Prepared with Nigerian Local Clay and Mud Prepared with Foreign Clay. International Journal of Engineering and Technologies. Vol. 8, Issue 1, pp. 61-71, 2015.
[18] C. P. Mbagwu, A. Dosunmu, and J. A. Ajienka, Analysis of flow properties of bentonite clay for drilling fluid production. Journal of research and production, Vol. 5, Issue 2, pp. 1-4, 2013.
[19] A. O. Olatunde, M. A. Usman, R. Jack and T. A. Adeosun, Improvement of rheological properties of drilling fluid using locally based materials. Petroleum & Coal, Vol. 54, issue 1, pp. 65-75, 2012.