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Desulfurization of Mae Moh Coal from Thailand by Leaching with Sodium Hydroxide and Potassium Hydroxide

Bantita Terakulsatit
School of Geotechnology, Institute of Engineering, Suranaree University of Technology,
Muang, Nakhon Ratchasima 30000, Thailand

Email: tbantita [AT] sut.ac.th

ABSTRACT---- ***Low rank coal of Mae Moh coal field in Thailand is suitable only for feeding coal fired power plants due to a high ash and sulfur contents, and low heating value. Reduction of sulfur and heavy metal elements are also in use physical, chemical and biological methods. Many chemicals such as HF, HNO_3, HCl, NaOH, KOH and others are used to reduce sulfur and ash for upgrading coal. The objective of this investigating to determine the effects of KOH and NaOH solutions on the desulfurization from K and Q coal seams in the high sulfur of Mae Moh coal. The analysis result of the K coal seam, the sulfur content is mainly reduced about 6.8% by KOH and 3.6% by NaOH. Pyrite content has reduced about 67% by either of KOH and NaOH. Gypsum content has decreased 86.9% by KOH, 73.5% by NaOH. Moisture content reduced about 36.6% by KOH and 41.1% NaOH, and the hydrogen content also decreased 69.6% by NaOH and increase 56% by KOH. The carbon content has increased about 3.7% by NaOH, but decrease 7.2% by KOH. The volatile mater and fixed carbon contents have reduced by both of base solutions. The increasing of calorific value is 45.2 MJ/kg by KOH. The result of the Q coal seam, the sulfur content is mainly reduced about 20% by KOH and 4.1% by NaOH. The pyrite content can be approximately reduced 60.5% by NaOH and 48.2% by KOH. The gypsum content is reduced 91.7% by KOH and 90.1% NaOH. The moisture content can be reduced 41.1% in NaOH and 31.1% by KOH. The volatile content increases 5.8% by KOH and 7%. The sodium hydroxide solution is also increased 0.4% of the fixed carbon and 7.5% carbon contents. The potassium hydroxide decreases 0.3% and 23.4%, 0.4% and 7.5% of the fixed carbon and carbon contents, respectively. The calorific value has only increased by KOH about 14.64 MJ/kg. Both of base solutions have increased the ash content. In conclusion of this investigation, the potassium hydroxide is higher efficiency than the sodium hydroxide solutions, due to its potential to the optimum sulfur, pyrite and gypsum reductions and also increases the carbon, fixed carbon and calorific value contents.***

Keywords--- desulfurization, sulfur, Mae Moh coal, sodium hydroxide, potassium hydroxide

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1. BACKGROUND/ OBJECTIVES AND GOALS

Most of coal for the electricity production in Thailand that from the Mae Moh coal field, which located in the Mae Moh District of Lampang Province between 18° 18’ 21” north latitude and 99° 44’ 02” east longitude (Fig. 1). There are about 814 million tons of economical reserve and 484 million tons of lignite remaining (Department of Mineral Resources, 2001). The Mae Moh coal quality is classified as a low rank coal. This coal is suitable only for feeding coal fired power plants due to a high ash and sulfur content, and low heating value. The proximate analysis of Mae Moh coal varies: moisture 30-32%, ash 20-26%, volatile matter 22-32%, and fixed carbon 15-23%. There is an average sulfur content in Mae Moh coal about 2.4-3.5% and sulfur dioxide concentration of the Mae Moh power plant about 4,600 ppm (Supasri et al., 2013).

Generally, the combustion of high sulfur coal produces high sulfur oxides, hydrogen sulfide and toxic gas, which leads to acid rain and corrosion metallic equipment. Sulfur in coal occurs in the forms of organic and inorganic sub-stances. Disulfides (mainly pyrite and marcasite) and sulfate (mainly calcium, iron and barium) are forms of the inorganic sulfur. The organic form, which is bound directly to the organic coal matrix, generally occurs in the forms of thiols, sulfides, disulfides, thiophenes and cyclic sulfides. All of these sulfur can contaminant in water, soil and air, which lead to a pollution and a poor health of communities around the power plant. Therefore, the electricity production from the Mae Moh coal combustion is very important and must be upgraded for highly efficient use.

Various methods of coal desulfurization are currently in use in many processing of combustion that are pre-combustion, combustion and post-combustion. Moreover, the reduction of sulfur and heavy metal elements are also in use: physical, chemical and biological, which the chemical method is used for this investigation for reducing the sulfur in coal. A variety of chemicals include an acid such as HF, HNO_3, HCl and others, and a base such as NaOH, KOH and others. These chemicals are effective in the desulfurization in coal, which has studied with Khamhom and Terakulsatit, 2014: Karen and John, 2000; Karen et al., 2000 and 2002; Kaushik et al., 1988; Mukherjee and Borthakur 2002; Reggel et al., 1973; Sharma and Sanjay, 1988; Yang et al., 1984. The yield of removal of sulfur depends on the potential of each chemical, and also include the structure and composition in coal (Mukherjee and Borthakur, 2002).

2. METHODS

2.1 Sampling and sample preparation

The coal samples which from K (K1 to K3 samples) and Q (Q1 to Q4 samples) coal seams were collected from the southeast (SE) pit of Mae Moh coal mine. The K and Q seams have shown in Fig. 2. The samples were dried air for a few days and ground reduces the size down using rod mill machine. Spitting of the sample for difference analysis.

2.2 Geochemical analysis

The dried coal sample was determined the quality of coal by the proximate and ultimate analyses before treating with the chemical. Fifty grams of the ground coal samples were taken into beakers. Fifty milliliters of NaOH and KOH solutions of 1M concentration were added to coal samples in different beakers. All experiments were done at room temperature and 24 hours of retention time. The reaction mixtures were filtered and the residue left was washed with deionized water. The coal residues were dried for 24 hours at 35 °C and ground to pass through 75 µm fineness before were determined by using standard methods which mineral content was analyzed by XRD of Bruker (D2 Phaser), proximate analysis were tested by moisture, volatile, and ash analyzer of Leco (TGA 701) and ultimate analysis were tested by Leco (model CHNS 628).

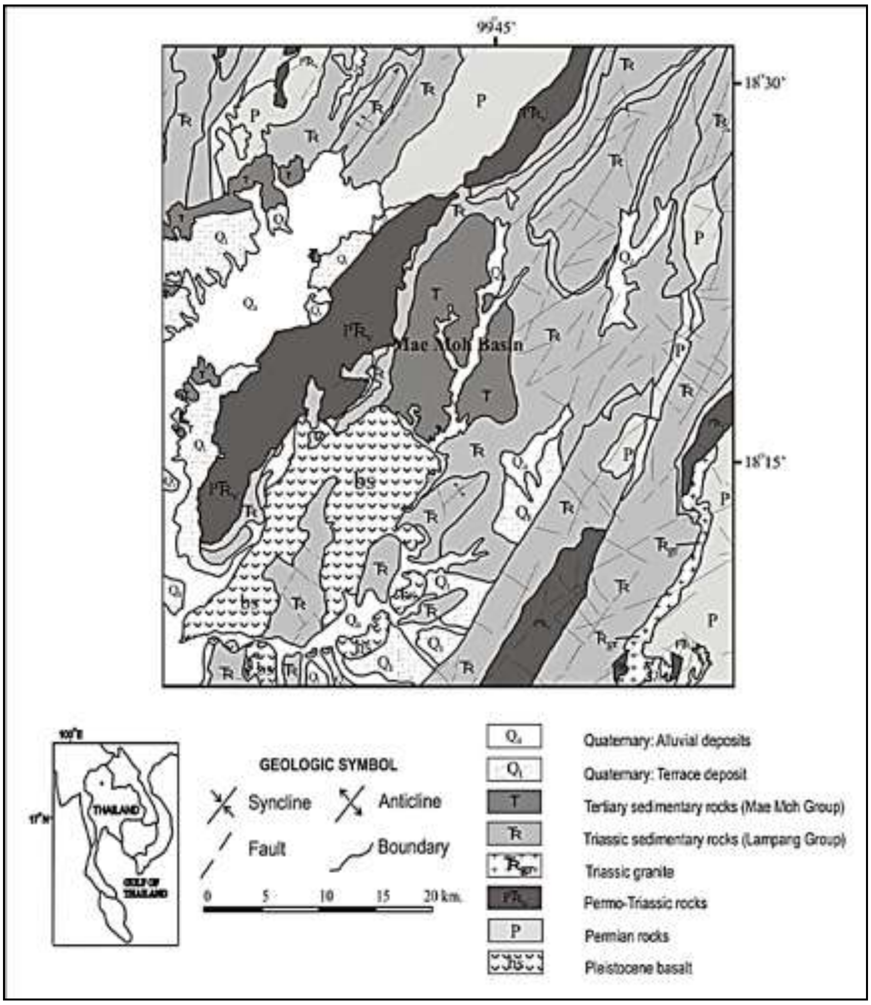

Fig. 1: Geological map of the Mae Moh basin and surrounding rock units (modified from Charoenprawat et al., 1994)

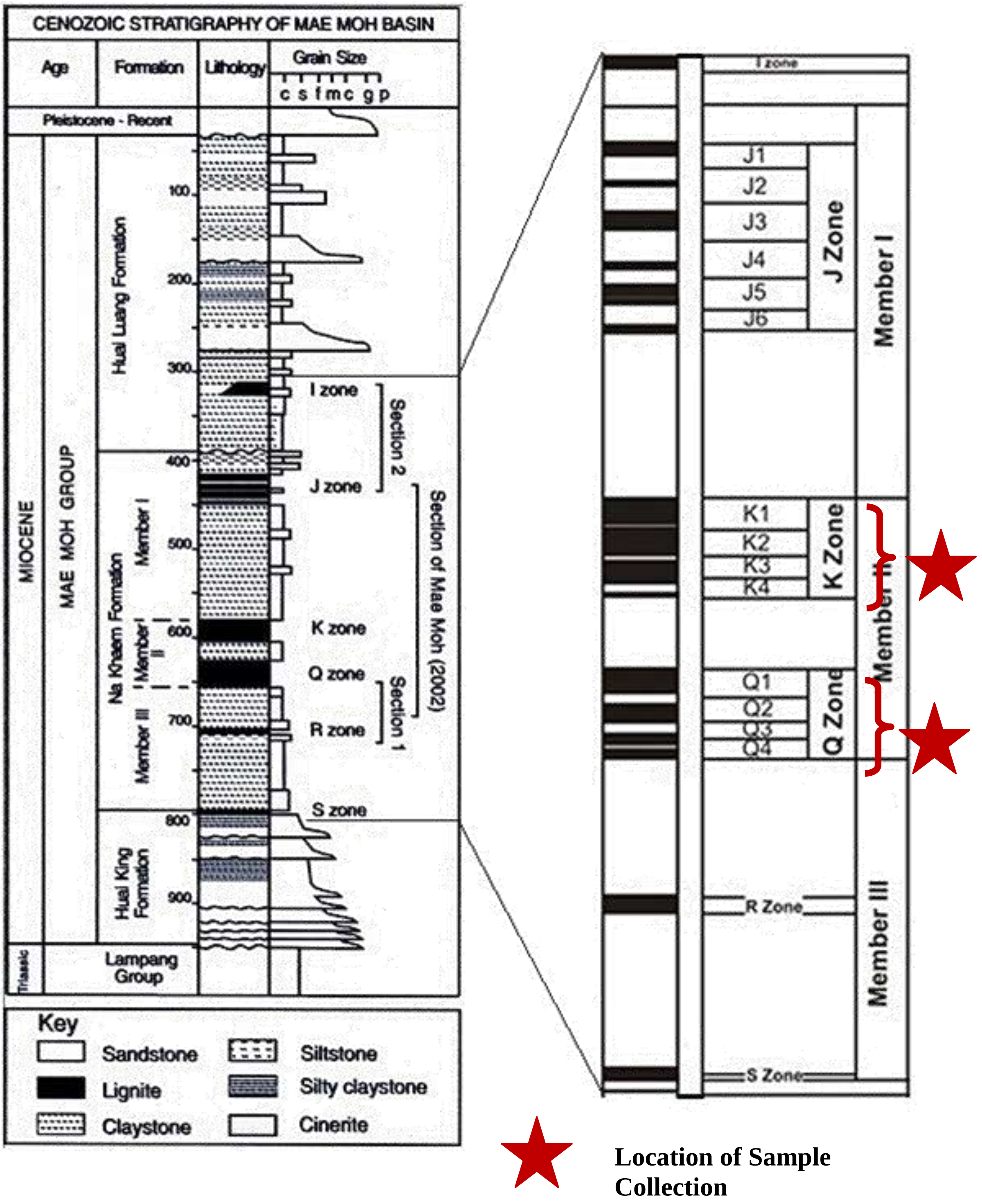

Fig. 2: Cenozoic stratigraphy of the Mae Moh basin by the letters at the right of the column indicate the nomenclature applied to the lignite zones. The range of Sections 1 and 2 are marked along the right side of the stratigraphic column (Sompong et al., 1996; Chaodumrong, 1985; Corsiri and Crouch, 1985; Benammi et al., 2002).

3. RESULTS

The analyzes result of the Mae Moh coal (K and Q coal seams) represents both before and after treating with base solutions (KOH and NaOH) (Table 1). Comparison of average sulfur content shows that the average of high sulfur from the parent coal is about 6% and 5.3% in K and Q seams, respectively. The effect of the desulfurization and coal quality increment with the different chemical has represented in Table 1 and Fig. 3. These results can be separate discussed into two properties following:

3.1 Desulfurization of the K and Q coal seam after treatment

In the K coal seam, the result of the sulfur content is mainly reduced about 6.8% by KOH and 3.6% by NaOH. Pyrite content has reduced about 67% by both KOH and NaOH. Reduction of the gypsum content is about 86.9% by KOH and 73.5% by NaOH. In the Q coal seam, KOH is a higher performance for reducing sulfur than NaOH, about 20.4% in KOH and 4.1% in NaOH. The decreasing of sulfur and gypsum have related to the reduction of sulfur, showing the decreasing pyrite is about 48.2% by KOH and 60.5% by NaOH. The gypsum has reduced about 91.7% by KOH and 90.1% by NaOH.

3.2 Quality of the K and Q coal seams after treatment

General of chemical treatment, the sodium hydroxide is more potential than potassium hydroxide due to the ability of mineral solubility in acid (Economides and Nolte, 2000). From the result of the quality of K coal samples after treatment has represented in Table 1 and Fig. 1. The moisture content has reduced about 25.4% by NaOH and 14.7% KOH, and the hydrogen content has also decreased 69.6% by NaOH, while increasing to 56% by KOH. The increment of the carbon content is about 3.7% by NaOH, but has reduced 7.2% by KOH. The increasing of calorific value is about 45.2 MJ/kg by KOH, but has decreased 17.7 MJ/kg by NaOH. The volatile matter content in the K coal seam has reduced by both base solutions. The high ash content represents in both of the base solutions about 15% by NaOH and 22% by KOH.

The result of the quality of Q coal samples after treatment has represented the potential of the chemical's effect on the extent of mineral reduction as gypsum, pyrite and clay minerals, which affects directly on extent of moisture reduction (Khamhom and Terakulsatit, 2014). The sodium hydroxide can reduce moisture content to 41.1% and increase 0.4% of fixed carbon and 7% of volatile matter. The high carbon content increase 7.5% by NaOH. The results of the slightest carbon content increment in NaOH due to the effect of reaction between acid and carbon matrix in coal from the organic matter and minerals (Mukherjee and Borthakur, 2002). The potassium hydroxide has affected only on a reduction of 31.1% moisture and 23.4% fixed carbon contents, but the slight reducing about 0.3% of carbon content. The high ash content is about 15% by NaOH and 20% by KOH due to the fraction of the organic matter and minerals in coal with chemical reaction.

Therefore, the potassium hydroxide solution is high efficiency for the increment of the calorific value and volatile matter contents, but reduced the sulfur, moisture, volatile matter, fixed carbon and carbon contents. The sodium hydroxide solution is potential for increasing the quality of the K coal seam due to there are the increment of carbon contents, but it cannot increase the calorific value. The variety of reduction of sulfur in K and Q coal seam has dominantly relates to the pyrite and gypsum contents in coal. Both of these base solutions lead to increase the ash content after combustion, and also make the waste from the chemicals.

Table 1: The variety of properties in coal samples before and after treating with chemical

Analysis methods	**K Coal Seam**					**Q Coal Seam**				
	Avg. Parent coal (K_{avg})	After treated with		Percentage of reduction and increment content after treating with		Avg. Parent coal (Q_{avg})	After treated with		Percentage of reduction and increment content after treating with	
		NaOH	KOH	NaOH	KOH		NaOH	KOH	NaOH	KOH
Proximate (%)										
Moisture	15.88	11.85	13.54	25.38	14.74	20.13	11.85	13.88	41.13	31.05
Ash	36.67	43.45	46.99	***15.61****	***21.97****	32.93	38.96	40.96	***15.48****	***19.60****
Volatile matter	31.16	32.53	32.02	4.2	2.7	31.61	33.83	33.44	7.02	5.79
Fixed carbon	16.36	12.18	7.45	25.57	54.46	15.31	15.37	11.73	***0.39****	***23.38****
Ultimate (%)										
Carbon	27.28	28.33	25.32	***3.71****	7.20	28.98	31.32	28.89	***7.47****	0.31
Hydrogen	3.69	1.12	8.38	69.56	***55.95****	4.36	1.14	4.59	73.85	***5.01****
Sulfur	5.96	5.74	5.55	3.64	6.82	5.34	5.12	4.27	4.12	20.04
Nitrogen	1.08	3.70	3.30	***70.78****	***67.24****	0.96	3.79	3.62	***74.67****	***73.48****
Oxygen (by different)	26.4	21.36	13.76	19.09	47.88	27.43	19.67	17.67	28.29	35.38
Calorific value (MJ/kg)	10.49	8.63	19.15	17.73	***45.22****	11.6	9.25	13.59	20.26	***14.64****
Mineral (%)										
Pyrite	1.77	0.58	0.58	67.04	67.04	2.03	0.80	1.05	60.47	48.15
Gypsum	7.16	1.90	0.93	73.46	86.96	19.30	2.40	2.01	90.13	91.74

* Bold and italic texts denotes the increasing of content and white cell denotes the reducing of content

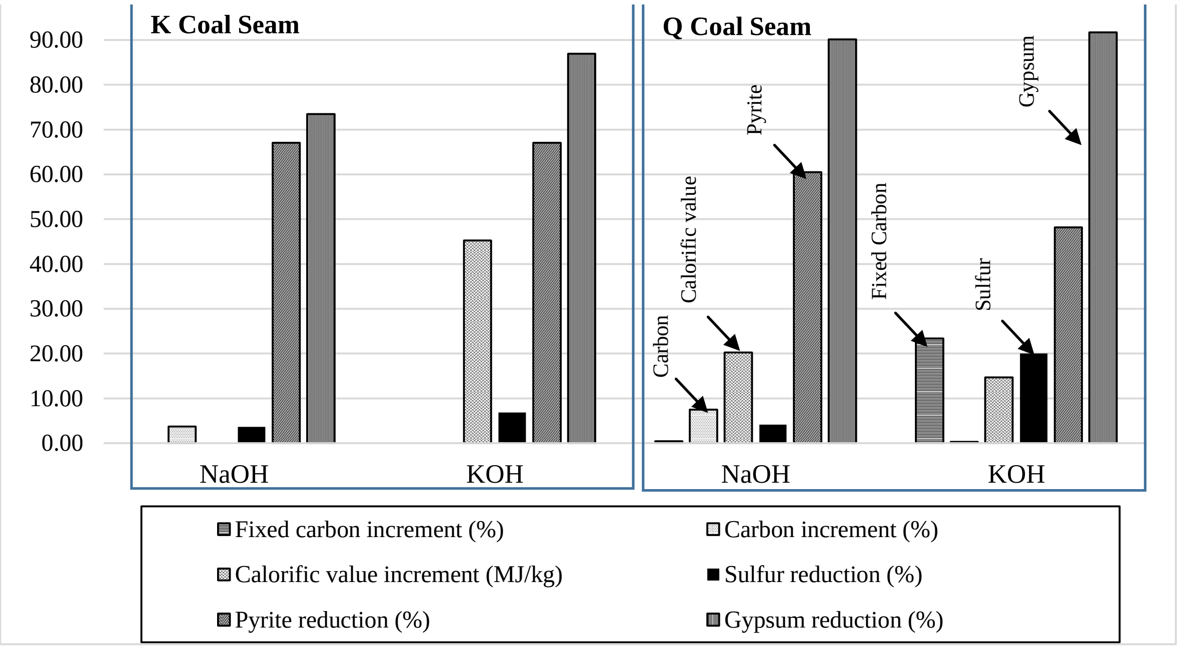

Fig. 3: The reduction and increment of the sulfur and coal quality from the K and Q coal seams in Mae Moh mine by using NaOH and KOH treatment.

3.3 Acknowledgments and Legal Responsibility

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