GASIFICATION: WAY TO REDUCE BOTH DIOXIN AND AIR POLLUTION

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Introduction

Poor air quality is a significant environmental problem in urban areas of Mongolia, particularly in Ulaanbaatar. According to the National Agency for Meteorology and Environmental Monitoring (AME), average PM10 reached 210 µg/m^3 in 2008, 4.2 times higher than the WHO air quality guideline level of 50 µg/m^3 [1]. Some parts of the city fared worse than others, with the most polluted parts having PM10s of 430 µg/m^3. Primary sources of air pollution in Ulaanbaatar are three thermal power plants (use more than 5M ton of coal per year), about 200 small and medium sized heating boilers, which burn over 400,000 ton coal every year. Also there are over 150,000 automobiles and 200,000 traditional gers and wooden houses, which use about 1M ton of coal per year [2].

Also, it is known that in practically all combustion processes, dioxins (polychlorinated dibenzo-p-dioxins – PCDDs) and furans (polychlorinated dibenzo-furans –PCDFs) are produced as undesirable side products. PCDDs and PCDFs are known as one of the most toxic group of anthropogenic organic substances. Furthermore, they perceived to be carcinogenic. Although the toxicological effects of PCDD/PCDF are still unanswered, all possible reduction measures should be taken to minimize their release into the environment.

Contemporary waste incineration plants emit flue gases containing dioxins and furans in such a concentration that is usually present in the polluted city air. However, one may account uncontrolled combustion of household waste in domestic furnaces and combustion of solid fuels of low quality, including hard and brown coal in small and obsolete boiler roof as main sources of dioxin releases in Mongolia . The incineration parameters are beyond standards if one is to consider the thermodynamics and chemistry of incineration [4].

Inventory calculations estimate annual emissions of dioxins/furans in Mongolia at 750,713 gram TEQ. Emissions of dioxins/furans from thermal electric stations, power plants, households heating are estimated to account for approximately 5 % of total releases [5]. Mongolia's primary energy demand is expected to grow from 1047 MW in 2010 to 3924 MW in 2020, driven primarily by increase of coal for power generation. In order to meet the increased energy consumption, the Mongolian government has planned to build 7 coal fired power plants over the next 4-5 years. The domestic application of coal will be increased by 2 and 5 times by 2015 and 2020, respectively. It means that the emissions from coal fuelled power plant may also increase [2].

Coal gasification is the process of reacting coal with oxygen, steam, and carbon dioxide to form a product (syngas) gas containing hydrogen and carbon monoxide. Potential trace substance emissions from coal- fueled power plants include ionic species, trace elements, and trace organic compounds. These trace substances can be emitted in flue gas, aqueous discharges, and solid effluents. Ionic species of environmental concern in the effluent streams of coal-fueled power plants include sulfate, nitrogen-containing ions, chloride, fluoride, phosphate and cyanide. Release of trace organic compounds is also an environmental concern, since some of these compounds, such as dioxins, furans, and formaldehyde, can have deleterious effects on the environment or human health. While there isn't much corroborating data available on trace organic releases from gasification systems, detailed test results from the Louisiana Gasification Technology Inc (LGTI) plant indicate extremely low levels of trace organic emissions, in- line with emissions expected from conventional coal-fired plants. Furthermore, results from both LGTI and a Shell coal gasification pilot plant, corroborate that dioxins and furans are not present at the detection limit of 1 part per billion by volume in the synthesis gas, nor were there any precursors at the same detection level [6].

Due to the effects of dilution and combustion, the concentration of dioxins and furans in the HRSG stack gas should be less than one part per trillion by volume. Dioxins and furans need sufficient oxygen to form or re-form, and the oxygen-deficient atmosphere in a gasifier does not provide the environment needed for dioxins and furans to form or reform. Dioxins need fine metal particulates in the exhaust to reform; syngas from gasification is typically cleaned of particulates before being used. In gasification facilities that use the syngas to produce downstream products like fuels, chemicals and fertilizers, the syngas is quickly quenched, so that there is not sufficient residence time in the temperature range where dioxins or furans could re-form. Coal-based gasification systems provide an energy production alternative that is more efficient and environmentally friendly than competing coal fueled technologies [7]. Unlike waste incinerators and conventional coal fired power plants, the facility will have no primary stacks, and be capable of exceeding the most stringent environmental regulations. Tests show that no detectable dioxins or furans are produced in the gasification process and, furthermore, the closed system prevents an atmospheric release [8].

The development and commercialization of cleaner and more efficient coal technologies is one way to improve the environmental performance of coal and to minimize its impact on world climate. Mongolia is rich in coal, however the resources are currently not fully exploited due to deficiencies in the national infrastructure, lack of investment in the coal industry and the need for research for adapting existing technologies to work with indigenous coals [9]. Furthermore, Mongolia is a net oil importer, mainly supplied by Russia and there is potential to reduce this dependency by introducing a new generation of more efficient and cleaner coal technologies. In this context, gasification is considered to be a suitable and viable technology option for solving all issues mentioned above. Understanding the kinetics of char formation/oxidation is useful for the understanding, design and modelling of industrial processes. Especially it has a great importance for coal gasification, which involves a complex set of reactions. Many researchers are well used specific reactivity as kind of indication on evaluation for gasification reactivity [10-11].

This study aims to investigate the specific reactivity of the Mongolian low rank coals for evaluation on gasification.

Experimental

Brown (subbituminous) coal samples from Baganuur(BN) and Shivee-ovoo(SHO) deposits of Mongolia have been used for tests on gasification. Proximate and ultimate analyses of the used samples were shown in Table 1.

Table 1. Proximate and ultimate analyses of Mongolian coals

Sample name	Ash, dry base, %	Elemental analyzer, daf, %				
		C	H	S	N	O, by diff.
Shiveeovoo	12.1	70.3	4.6	2.2	0.8	22.8
Baganuur	23.2	74.3	4.6	0.92	0.9	19.28

The char reactivity in air was measured using a thermogravimetric analyser (Bruker, model TG-DTA 2000S).

Results and discussions

The char reactivity of the BN and SHO coal samples was measured in air at 400°C in relation to pyrolysis temperature and holding time and calculated specific reactivity are shown in Fig. 1. Fig. 1 shows reactivity of BN coal samples pyrolyzed at 600, 700, 800 and 900°C and the specific reactivity of the chars reduces with increasing pyrolysis temperature, i.e. reactivity of chars pyrolyzed at 600°C was much higher than at 900°C. This is very interesting point. The specific reactivity of the chars in relation to holding time and there is general tendency of reactivity to decrease with increasing holding time at different pyrolysis temperature.

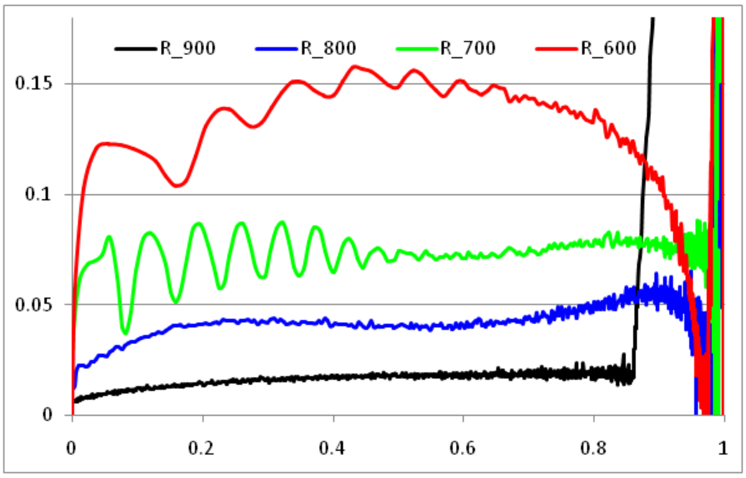

Fig.1. Specific reactivity of chars prepared in N_2, measured in air in relation to final temperature

Based not only on the intensity of the reactivity, but also the reaction time at 50 % conversion, was quite different for chars prepared at different pyrolysis temperature. Calculated values showed that these were 5, 9, 18 and 40 min for 600, 700, 800 and 900°C, respectively. It means that chars prepared at lower temperature losses weight very rapidly, i.e. very reactive on air oxidation. The specific reactivity of the BN has been tested on different atmospheres of pyrolysis. The tests have been done at low temperature, while at higher temperature there could occur CO_2 gasification and results obtained at 600°C show that char prepared at CO_2 is more reactive than prepared in pure N_2. The SHO was tested on both N_2 and CO_2 and compared results with BN are shown in Fig. 2.

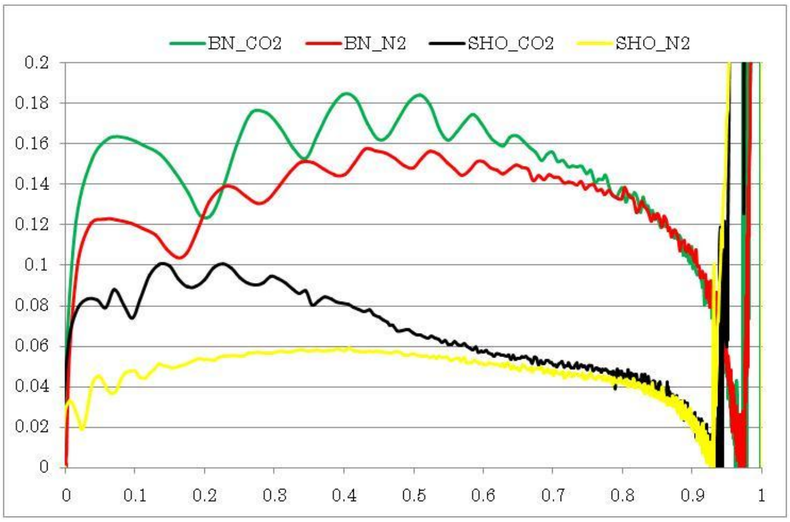

Fig.2. Specific reactivity of chars prepared in N_2 or CO_2 at 600°C of the BN and SHO coal samples

The tendency of the reactivity for SHO coal in terms of pyrolysis temperature and holding time was similar to the BN coal, however, it had much less reactivity than BN coal in same condition. We have expected that SHO coal will be more reactive than BN coal. Previous results tell that SHO coal is a reactive fuel under conditions that produce combustible gases [12]. This observation is probably due to its high inherent alkali and alkaline earth metal (Na+Ca) content.

Obtained results show that Baganuur coal is very reactive for gasification or the coal is suitable for gasification technology. It means that there is a possibility to produce clean fuel like dimethyl ether (DME) or syngas via gasification using the Baganuur coal and those obtained clean fuels can be used for power generation in bigger scale or in houses, which will reduce simultaneously both air pollution and dioxin from coal fired utilities. As DME does not contain sulfur or ash, it does not generate any SOx or particulate matter when combusted. It is a clean fuel of high cetane number, excellent combustion characteristics and extremely low toxicity, which is not believed to cause global warming or destroy the ozone layer.

Once the coal is reactive in gasification, it opens a door for building of an integrated gasification combined cycle (IGCC), a technology that uses a gasifier to turn coal and other carbon based fuels into gas—synthesis gas (syngas). It then removes impurities from the syngas before it is combusted. Some of these pollutants, such as sulfur, can be turned into re-usable byproducts. This results in lower emissions of sulfur dioxide, particulates, and mercury. As mentioned, Mongolia is going to build 7 power plants in near future and decision makers should consider these findings.

Conclusions

- The specific reactivity of the Mongolian low rank coals has been investigated using the thermogravimetric analyser and it show that both coal have good reactivity on gasification. The BN coal is more reactive than the SHO coal.

- Once the low rank coal from Mongolia is reactive fuel under conditions that produce combustible gases, it means that there is a possibility to produce clean fuel like dimethyl ether (DME) or syngas via gasification using the low rank coal, especially Baganuur coal and those obtained clean fuels can be used for power generation in bigger scale or in houses, which will reduce simultaneously both air pollution and dioxin from coal fired utilities.

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References:

1. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, WHO/SDE/PHE/OEH/06.02
2. G. Purevdorj, Energy outlook of Mongolia, Report to the UNIDO, 2012, 15 p.
3. UNEP Chemicals, 2005. Standardized toolkit for identification and quantification of dioxin and furan releases. UNEP Chemicals, Geneva
4. G.Wielgosiński, The Possibilities of Reduction of PCDDs and PCDFs Emission, International Journal of Chemical Engineering, (2010), 11 p.
5. NIP for the Stockholm convention, Mongolia, 2006
6. Jay A. Ratafia-brown, Lynn M. Manfredo, Jeff W. Hoffmann, Massood Ramezan, Gary J. Stiegel, An environmental assessment of IGCC power systems, US.doe/national energy technology laboratory , Nineteenth annual Pittsburgh coal conference, Sept., 2002
7. Response to the Energy Review Consultation, January 2006, By Global Energy & Mining Scotland Ltd
8. Huang, J., Fang, Y., Chen, H. and Wang Y., Energy & Fuels, 2003, 17, 1474-1479
9. Avid, B., Sato, Y., Maruyama, K., Yamada, Y. and Purevsuren, B., Fuel Processing Technology 85 (2004) 933– 945
10. Jenkins, R.G., Nandi S.P. and Walker, P.L., Reactivity of heat treated coals in air 500^{O}C, Fuel, 1973, 52, 288-293.
11. Koranyi, A.D., The relationship between specific reactivity and the pore structure of coal chars during gasification, Carbon, 1989, 27 (1) 55-61
12. Avid, B., Purevsuren, B., Paterson, N., Zhuo, Y., Peralta, D., Herod, A.A., Dugwell, D. and Kandiyoti, R., An exploratory investigation of the performance of Shiveeovoo coal and Khoot oil shale from Mongolia, Fuel, 83 (7-8) (2004) 1105-1111.