African Journal of Agricultural Research Vol. 6(17), pp. 4131-4139, 5 September, 2011
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

An improved design of gasifier equipment for Qinghai-Tibetan Plateau of China

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Accepted 11 July, 2011

Considering the disadvantage of the present home and aboard biomass gasifiers, a new design was conducted to improve the current conditions such as low combustion, high tar and dust, low heat value and so on. A suite of gasification was achieved to decrease tar, sulfur and dust during gasification process. The developing system provides a feasible strategy for improving and developing gasifier equipment. The improved gasifier equipment includes gas generator, high temperature pyrolysis apparatus, the first dust filter, the second dust filter, heat-cold exchange apparatus, washing apparatus, motive power apparatus, tar removal apparatus, and sulfur removal apparatus. The harmless combustible gases enter the gas container, and go through a dedicated pipeline, and then the gas was delivered to the house for coking, heating or generating electricity. Up to now, the improved gasifier equipment has been successfully applied to some communities in Qinghai and inner Mongolia of China. Implications of the improved gasifier equipment is improving human health, reducing fuel consumption, deforestation and global climate change. It was found cost-effective and renewable in nature and suitable for both urban and rural areas, especially in the Qinghai-Tibetan Plateau because of the anoxia. The study has applied the patent of the State Intellectual Property Office of the People's Republic of China (Patent number: 201020192115.2). The product has produced by Lanzhou MinSheng straw liquefied gas stove Co., LTD, Gansu, China.

Key words: Biomass gasification, improved design, gasifier equipment, renewable energy, Qinghai-Tibetan Plateau.

INTRODUCTION

Bioenergy is the fourth largest energy source after oil, coal and natural gas. It is renewable and environment friendly. Its development is of great significance to the social economy's sustainable development. Hence, the main research areas and practice development of bioenergy are developed sharply at home and abroad. Biomass pyrolysis technology, which can convert low-quality biomass to high-quality gas or liquid fuel, has been paid great attention world wide during these years. As the energy demand is increasing constantly with the development of the economy of China, it is very important to utilize existing energy resources fully and effectively. Bioenergy is a kind of renewable resource. There are plenty of biomass wastes including forest energy, crop straw, domestic animals waste, domestic refuse and so on in China. The proper utilization of these waste resources will effectively reduce the environment pollution and also can help relieve energy crisis. During operation of the traditional stove; incomplete combustion releases health damaging pollutants and greenhouse gases such as CO, N_2O, CH_4 and polycyclic aromatic hydrocarbon and so on (Bhattacharya and Salam, 2002).

Therefore, it is very harmful to use the traditional stove in an enclosed area which is not properly ventilated, that is in a tent, camper or in a house. It was very serious in Qinghai-Tibetan Plateau because the fuel underwent

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Table 1. Health effect due to the products of incomplete combustion in traditional biomass cook stove in different countries.

Country	Health effects	Main victim
India (Mishra et al., 1999a)	Blindness	Men and women
India (Mishra et al., 1999b)	Tuberculosis	Men and women
Kenya, India, Nepal, Papua New Guinea (Smith et al., 2000b)	Acute lower respiratory infections	Children
India (Bhargava et al., 2004)	Cancer	Women
Zimbabwe (Mishra et al., 2004)	Reduced birth weight	Women
Guatemala (Schei et al., 2004)	Asthma	Children
India (Vinod et al., 2005)	Acute respiratory infections	Children
Turkey (Ekici at el., 2005)	Chronic obstructive pulmonary disease	Women
(Mishra et al., 2005)	Stillbirth India	Women
Guatemala (Diaz et al., 2006)	Eye discomfort, headache, back pain	Women

Table 2. Combustion appliances and potential problems

Appliances	Fuel	Typical potential problems
Central furnaces Room heaters Fireplaces	Biogas	Cracked heat exchanger; Not enough air to burn fuel properly; Maladjusted burner
Central Heaters Room Heaters	Wood	Cracked heat exchanger; Not enough air to burn fuel properly; Defective/blocked flue; Green or treated wood
Central Furnaces Stoves	Coal	Cracked heat exchanger; Not enough air to burn fuel properly; Defective grate
Stoves;	Wood, Coal	Not enough air to burn fuel properly; Defective/blocked flue; Green or treated wood; Cracked heat exchanger or firebox

incomplete combustion due to the anoxia. Health effects due to the products of incomplete combustion in traditional biomass cookstove (Table 1). A mix of potentially reusable items, such as paper, dung and many types of plastic, are produced in the family living in developing countries. Toxic waste incinerators, chemical plants, and solid waste dumps are often located in low-income communities. According to statistics in our research, the waste collected from residences and business activities including paper (one-fifth), dung and firewood (one-fifth), and plastic waste (one-fifth), which were potentially recycled for reuse in the Qinghai-Tibetan Plateau. In many developing countries, firewood and dung contribute around 12% of global primary energy supply (Berndes et al., 2003).

Biomass becomes an important primary energy source, as well as renewable energy source. Biogas of high calorific value, safety and reliability, is a clean green energy products. Due to its higher efficiency, it is desirable that gasification becomes increasingly applied gasification and power generation technology may be in future rather than direct combustion. Biomass suitable for rural areas in developing countries (Bureau of State Statistics, 1997; Novem, 1997; Wu et al., 1997a, 1999; Dai, 1998). The furnaces or boilers, such as industrial heating, furnaces, collective heating, and livestock farm heating and so on, are the common usage of biomass. Several types of gasifiers have been developed, including Bubbling fluidised bed, Co-current moving bed, entrained flow, countercurrent moving bed, and circulating fluidised bed and cross-current moving bed (Stassen et al., 2002). It is the cheapest and simplest way, but it is inefficient for extensive energy production (Jankes and Milovanovic, 2001).

Despite the long experience with biomass gasifiers, reliable and large-scale operations have several problems for extensive use. Table 2 identifies some typical appliance problems that cause the release of pollutants at home and abroad. Many of these problems are hard for a homeowner to identify (Table 2). An improved gasifier system was developed and tested by Yumin et al. (2010). Further studies proved its performance was superior as

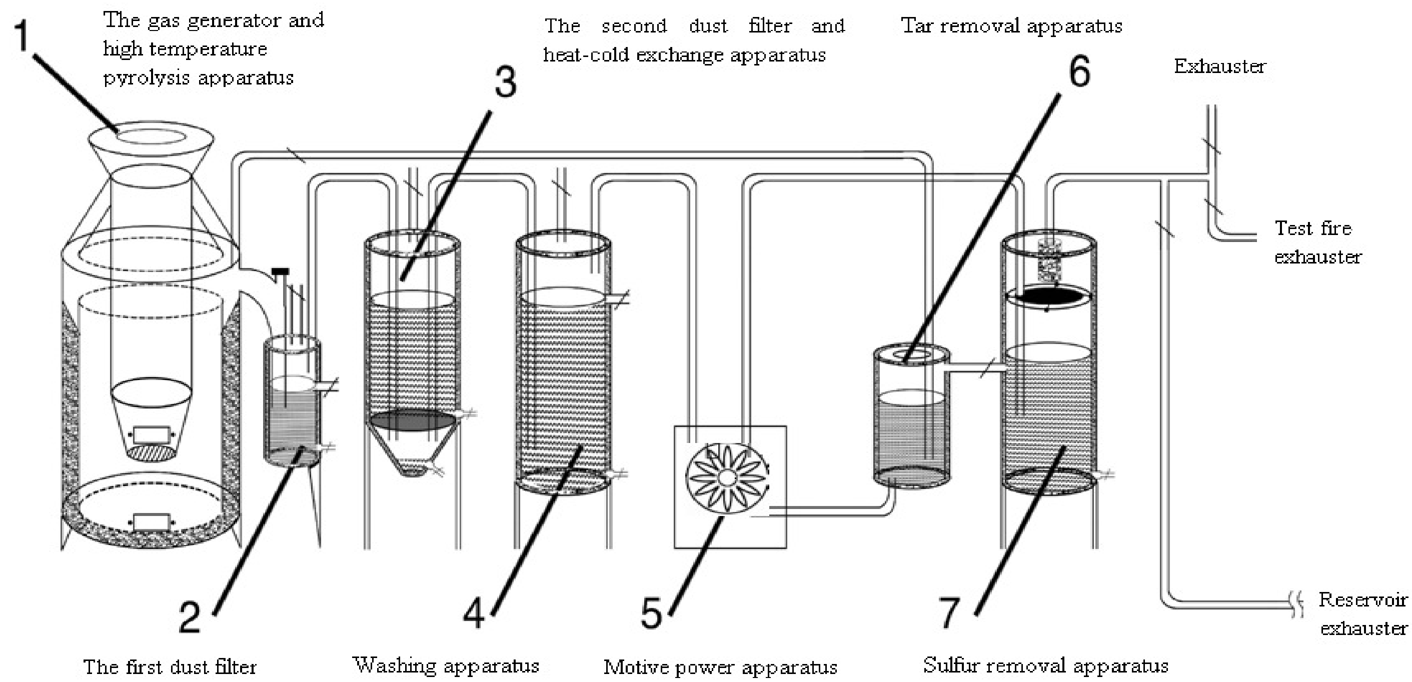

Figure 1. A schematic overview of the whole set-up is shown.

compared to traditional combustion appliances (Table 2).

MATERIALS AND METHOD

Constructive system design

The improved gasifier equipment includes gas generator, high temperature pyrolysis apparatus, the first dust filter, the second dust filter, heat-cold exchange apparatus, washing apparatus, motive power apparatus, tar removal apparatus, and sulfur removal apparatus. A schematic overview of the whole set-up is shown in Figure 1. A schematic overview of the section 1~7 are shown in Figure 3 to 9. An overview of the system is shown in Figure 2. The technical specification of the gasifier system is shown in Table 3. The dimensions of section 1 of the system component is shown in Figure 3. The thermal isolated materials are used to enhance the temperature of the gas generator until pyrolysis temperature. The thickness of thermal isolated material is 10 cm. The temperature in different areas in the gasifier was measured and the contents of the product gas were also analyzed. The dimensions of sections 2 and 3 of the system components are shown in Figure 4.The first and second dust filter and the heat-cold exchange apparatus were built in sections 2 and 3. Concentrations of solid particles in the output pipeline are set up at the bottle in sections 2 and 3. Integration of the first and second Dust filter and the heat-cold exchange apparatus reduces the output concentration of solid particles to 6.57 $m^3{}_N$.

The dimensions of section 4 of the system components is shown in Figure 5. The dust filter was replaced by the Scrubber, which did achieve the purification of the gas to the concentration of dust. The Scrubber, even at high initial concentration of solid particles could clean the gas to a concentration of 6.43 $m^3{}_N$. The pump is equipped with the right amount of water as the working fluid. When the impeller is according to the figure in clockwise direction, the water was thrown around the impeller, due to centrifugal force. The water ring vacuum pump is a pump chamber volume by the change to achieve suction, compression and exhaust, so it belongs to varactor vacuum pump. The vacuum pump that we have used, product model: 2BVA-2061, 2070 and 2071, was made in Shandong BoShan vacuum equipment manufacturing Co.,Ltd, China. The dimensions of section 6 of the system components are shown in Figure 7. The removal of tar methods includes the physical and thermochemical methods. The paper made a detailed analysis on the producing mechanism of tar and its removal method. An inner circulating fluidized pipeline was built to get rid of the tar. Cooling and quick suspended tar condensing in section 6 is carried from section 6 to section 1 for cracking. The vacuum pump creates negative pressure for correct operation of the tar recovery system from section 6 to section 1.

The dimensions of section 7 of the system component is shown in Figure 8. The product is powder, with wide distribution of active ingredients and a high utilization rate. It is applicable to removal of sulfurated hydrogen and some organic sulfur from large-scale gases and industrial emissions. Besides, it has evident effect on the removal of nitride, tar and dust, etc. Used in the gas sources containing oxygen, it can better show its price advantage.

Fuel for testing

The whole set-up was tested with two types of biomass (wood chip and rice hull). The parameters studied were volatile matter, fixed carbon, moisture content and ash content. The thermal properties of fuel used for testing purposes are shown in Table 4. The elements of fuel used for testing purposes are shown in Table 5.

Stove operation

The sized wood chip and rice hull were put into the system, then they were ignited at the top with papers. The required air flow was governed and the flame was established by negative pressure produced by motive power apparatus. The temperature inside the gas generator was increased constantly, then high temperature

Figure 2. The whole set-up in operation.

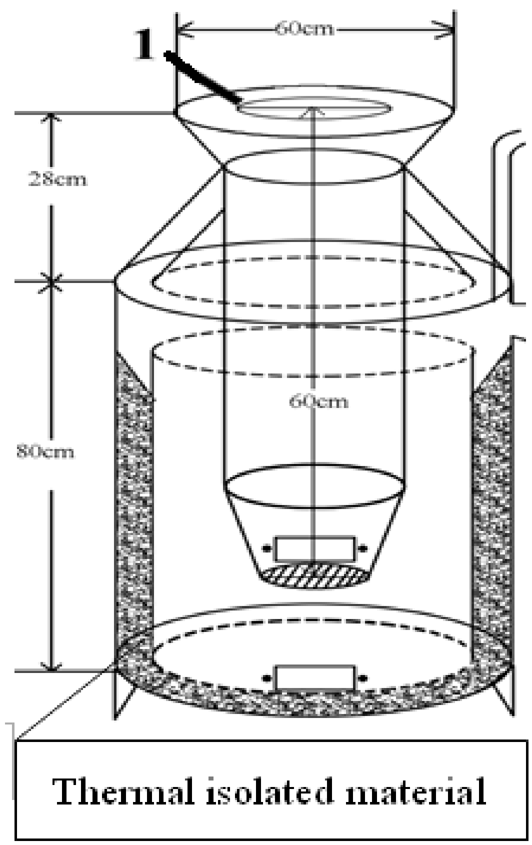

Figure 3. A schematic overview of the section 1 of the whole set up.

pyrolysis apparatus and pyrolysis zone were established. The existing volatile materials released from biomass. As the temperature increased, the combustible gaseous mixture of CO, H_2, and CH_4 and so on were released from the gasifier system. The

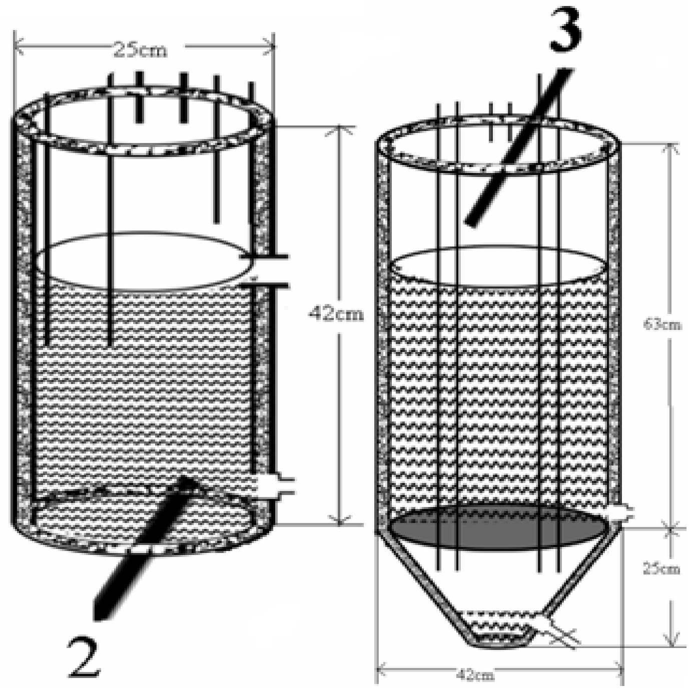

Figure 4. A schematic overview of the section 2 and 3 of the whole set-up.

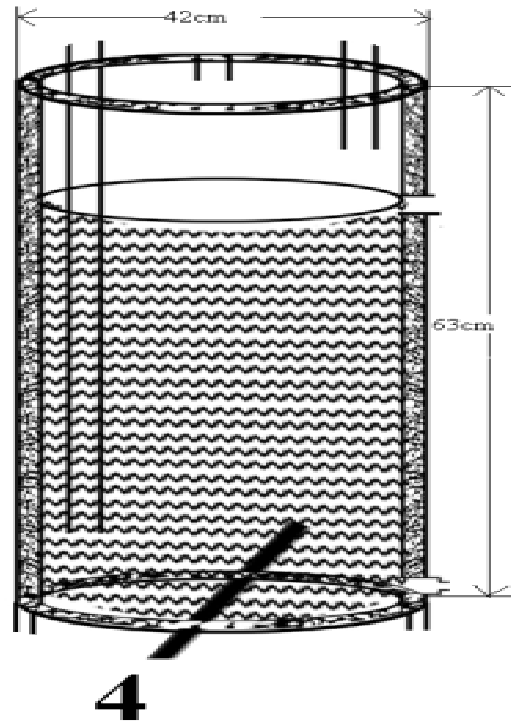

Figure 5. A schematic overview of the section 4 of the whole set-up.

sufficient system produce combustible gas as shown in Figure 2.

Instrumentation for measurements

The flame temperature was measured by the type of thermocouple (Type TIS, named by Müller Instruments, not following IEC-584 T1, made in China). The emission from the stove was measured by gas analyzer (NK-500Ex, explosion-proof infrared gas analyzer, made in China). The calorific value of feed stock was also measured by a digital bomb calorimeter (TR-9230**,** calorific value of gas analyzer, made in China).

RESULTS AND DISCUSSION

Performance of the gasifier

Once biomass waste resources were ignited from upper level, combustible gas can produce within 30 s since ignition. It has been reported that the stove burns continuously for 141 and 135 min when it operates with wood chip and rice hull respectively. Different fuel produce different ash. The ash was collected from bottom end when it operated with fuel. During the testing, temperature of the outer surface of section 1 was recorded as about 39℃, which indicates that this is a good model to minimize conduction and radiation heat, which is lost from the outskirt of the thermal isolation. Performances of the gasifier system were tested by standard water boiling test. Boiling 4 kg of water with gasifier stove needs 8.6 min, while it requires 11.7 min with natural gas. The gasification results of two types of biomass is shown in Table 6. The gas composition of the gasifier system is shown in Table 7. The results show that it could be a good feedstock as domestic fuel for combustion.

Environmental effects and socio-economic

A machine with a new environmental protection is an ideal biomass gasification equipment. Traditional cooking stoves in the rural areas are less efficient due to the incomplete combustion of the fuel wood (Hossain, 2003). Desertification is threatening the region’s eco-environment, compounded by man-made damage to the ecological environment as the economy develops of the Qinghai-Tibetan Plateau. The low efficiency is resulting in high consumption of fuel wood which is leading to the more collection of fuel wood, especially in the Qinghai-Tibetan Plateau because of the anoxia. Ultimately, it can lead to deforestation. Improved biomass cookstove can save considerable amount of fuel wood annually and consequently less requirement of firewood.

Emission from the system

Emission of pollutants from biomass fuel during

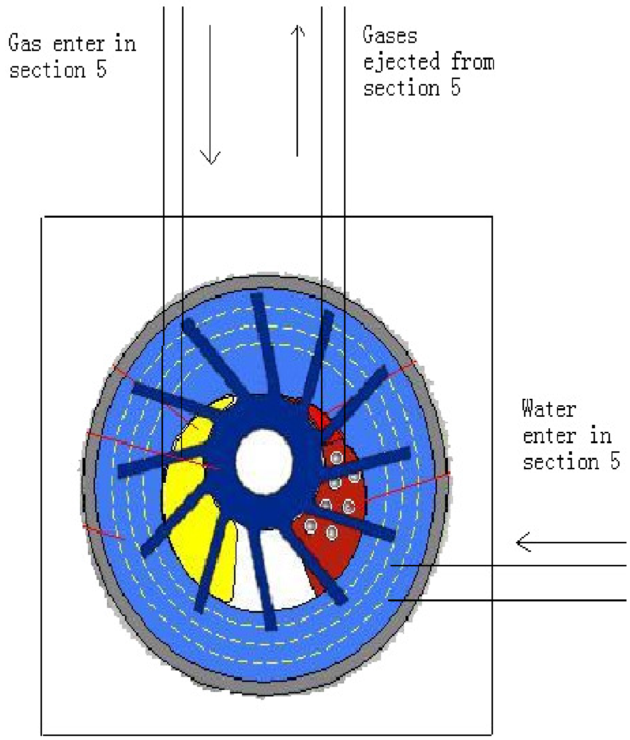

Figure 6. A schematic overview of the section 5 of the whole set-up.

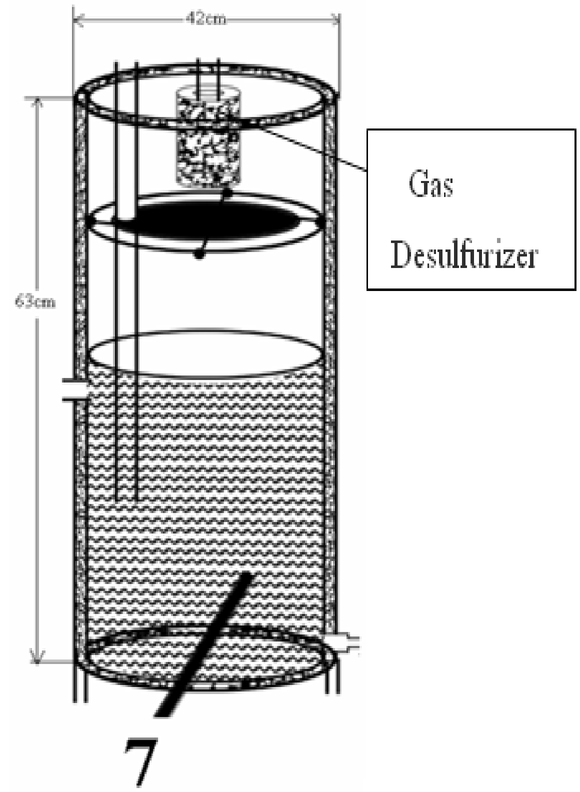

Figure 8. A schematic overview of the section 7 of the whole set-up.

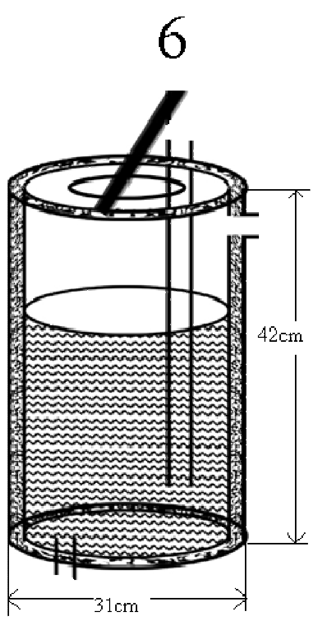

Figure 7. A schematic overview of the section 6 of the whole set-up.

combustion depends on the quantity of fuel consumed and type of combustor used. During the experiment the amount of CO and CO_2 emissions has been measured 1 m away from the test fire exhauster with the help of gas analyzer (NK-500Ex, explosion-proof infrared gas analyzer). CO emission in this equipment was within safe limits as quoted on indoor air quality fact sheet (Indoor air quality, 2009) and CO_2 emission was also found in the safe range which was within safe limit (26.8 ppm) as reported by Uma et al. (1997).

Safety standard

With the merits of technical simplicity, better adapt ability to materials, less start time (≤30 s) and operational stability, this gasification technology can produce 1.5 L/kg (dung) biomass fuel gas with low tar content (<13 mg/m^3), which entirely meets the standard of the Agricultural Ministry NY/T443-2001-technical specification of China and acceptance of standard for straw gasification system of central gas supply of China.

Cost of construction

The production cost of each unit shown in Table 8, increases with scale. Sources of more details on the

Table 3. The technical specification of gasifier.

Working principle	Material
The gas generator and high temperature pyrolysis apparatus	Steel drum and steel pipeline and Heat Insulation Material (Rock Wool material, made in GanSu, China)
The first dust filter	Steel drum , steel pipeline and scrubbers
The second dust filter and heat-cold exchange apparatus	Steel drum, steel pipeline and scrubbers
Washing apparatus	Steel drum, steel pipeline and scrubbers
Motive power apparatus	Steel drum and steel pipeline and vacuum pump (product model: product model:2BVA-2061, 2070, 2071, made in Shandong BoShan vacuum equipment manufacturing CO.,LTD, China)
Tar removal apparatus	Steel drum , steel pipeline and scrubbers
Sulfur removal apparatus	Steel drum, steel pipeline, scrubbers and gas desulfurizer(TS-F Coal Gas Desulfurizer, made in Shanxi Hengxing Catalyst and Purificant Co., Ltd, china)

Table 4. Thermal properties of two biomass fuels.

Fuel	Volatile matter	Fixed carbon	Moisture content	Ash content
Wood chip	71.7	17.3	10.5	0.5
Rice hull	62.7	15.1	7.1	15.2

Table 5. Fuels containing elements.

Fuel	C	O	H	N	S
Wood chip	45.6	43.5	7.5	2.5	0
Rice hull	39.5	36.5	5.4	0.5	0.1

Table 6. The gasification results of different types of biomass.

Fuel	Temperature of the high temperature pyrolysis apparatus (℃)	Quantity feed in raw material (kg/h)	Calorific value (MJ kg^{-1})	Oxygen rate of flow M^3/h
Wood chip	734	>42	16.15	8.9
Rice hull	839	>50	10.19	11.89

Table 7. Gas composition (%).

Fuel	CO	CO_2	H_2	CH_4	N_2	C_nH_m	O_2
Wood chip	47.4	22.4	132.4	9.09	6.91	3.8	0.8
Rice hull	39.1	20.5	7.41	7.4	18.3	2.8	2

Table 8. Cost estimates of gasifier system.

Working principle	Cost in RMB (Yuan)		
	Large-scale (11-15 households use)	Medium-sized (10 households use)	Minitype (1-2 households use)
The gas generator and high temperature pyrolysis apparatus	4000	3200	1800
The first dust filter	200	150	130
The second dust filter and heat-cold exchange apparatus	900	350	340
Washing apparatus	600	400	400
Motive power apparatus	4000	3300	2600
Tar removal apparatus	100	100	100
Sulfur removal apparatus	500	400	400
Total	13000	7900	4770

technology including training and availability of technology at the urban and rural areas can be provided by the authors, Lanzhou University, Gansu province, China.

Conclusions

In this study, improved biomass system were developed and found suitable for the urban and rural areas, especially in the Qinghai-Tibetan Plateau because of the anoxia. The developed device has many advantages such as low cost, simple operation, energy conservation, less pollutant and high efficiency and so on. It potentially brings five kinds of benefits:

(1) Using environmental fuels such as biomass are key ways to save energy,
(2) It reduce drudgery of women saving time in cooking and fuel collection and consequent health hazards. It could improve not only the indoor environment but also reduce adverse health effects. The present study suggests that biomass fuel usage is an important contributing factor in chronic bronchitis and asthma symptoms (Kürsat et al., 2003),
(3) This study showed that the purification system could decrease the temperature of biomass gas and get rid of the biomass tar and sulfur,
(4) Accelerating community for effective utilization of biomass is the promising way for these disinvested isolated regions such as the Qinghai-Tibetan Plateau to develop in a sustainable way. We have set up demonstration points in some communities in Qinghai and Inner Mongolia of China, which have large amounts of biomass wastes,
(5) Reducing emission of the greenhouse gases can contribute to increase the probability of global climate change (Smith, 1994),
(6) They also help in saving firewood leading to conservation of forests. They also create employment opportunities for people in the rural areas.

As a conclusion, we should focus on the development of biomass energy project in China in the future. There will be more large-scale academic communities and enterprises to participate in this project. It is certain that biomass energy industry will become a new growth point of Chinese national economy especially in northwest China.

ACKNOWLEDGEMENTS

The design and experiment was supported by teachers of Lanzhou Polytechnic University. The authors are thankful for the kind support of the rural energy offices of Qinghai and inner Mongolia of China, who participated in this study. This study is supported by Natural Science Foundation of Gansu Province of China (2009GS02921-1010RJZA086).

REFERENCES

Berndes G, Hoogwijk M, van den Broek R (2003). The contribution of biomass in the future global energy supply: a review of17 studies. Biomass Bioenergy, 25: 1-28.

Bhargava A, Khanna RN, Bhargava SK, Kumar S (2004). Exposure risk to carcinogenic PAHs in indoor-air during biomass combustion whilst cooking in rural India. Atmos Environ., 38(28): 4761-4767. doi:10.1016/j.atmosenv.2004.05.012.

Bhattacharya SC, Salam PA (2002). Low greenhouse gas biomass options for cooking in the developing countries. Biomass Bioenergy, 22(4): 305-317.

Dai L (1998). The development and prospective of bioenergy technology in China. Biomass and Bioenergy, 5: 181-186.

Díaz E, Smith-Sivertsen T, Pope D, Lie RT, Diaz A, McCracken J et al (2007). Eye discomfort, headache and back pain among Mayan Guatemalan women taking part in a randomised stove intervention trial. J Epidemiol Community Health, 61(1): 74-79. doi:10.1136/jech.2006.043133.

Ekici A, Ekici M, Kurtipek E, Akin A, Arslan M, Kara T et al (2005). Obstructive airway diseases in women exposed to biomass smoke. Environ. Res., 99(1):93-98. doi:10.1016/j.envres.2005.01.004.

Indoor air quality (Accessed 25 Nov 2009). http://store.cleanair4life.com/PDF/IndoorAir Quality Air Qual Test Kits. pdf.

Jankes GG, Milovanovic NM (2001). Biomass gasification in small-scale units for use in agriculture and forestry in Serbia. Therm. Sci., 5(2): 49-57.

Kürsat UZUN, Bülent ÖZBAY, Erkan CEYLAN, Mehmet GENCER, Ismail ZEHIR (2003). Environmental Health and Preventive Medicine, 8: 13-17, March.

Mishra VK, Retherford RD, Smith KR (1999a). Biomass cooking fuels and prevalence of blindness in India. J. Environ. Med., 1(4): 189-199. doi:10.1002/jem.30.

Mishra VK, Retherford RD, Smith KR (1999b). Biomass cooking fuels and prevalence of tuberculosis in India. Int. J. Infect. Dis., 3(3): 119-129. doi:10.1016/S1201-9712(99)90032-2

Mishra V, Dai X, Smith KR, Mika L (2004). Maternal exposure to biomass smoke and reduced birth weight in Zimbabwe. Ann. Epidemiol., 14(10): 740-747. doi:10.1016/j.annepidem.2004.01.009.

Mishra V, Retherford RD, Smith KR (2005). Cooking smoke and tobacco smoke as risk factors for stillbirth. Int. J. Environ. Health Res., 15(6): 397-410. doi:10.1080/09603120500288913

Novem (1997). Technical and economic feasibility of an indirectly fired gas turbine for rural electricity production from biomass (Phase 1), The Netherlands.

Smith KR, Samet JM, Romieu I, Bruce N (2000b). Indoor air pollution in developing countries and acute lower respiratory infections in children. Thorax, 55(6): 518-532. doi:10.1136/thorax.55.6.518

Schei MA, Hessen JO, Smith KR, Bruce N, McCracken J, Lopez V (2004). Childhood asthma and indoor woodsmoke from cooking in Guatemala. J Expo Anal Environ..

Stassen HEM, Prins W, van Swaaij WPM (2002). Thermal conversion of biomass into secondary products the case of gasification and pyrolysis. In: Palz W, Spitzer J, Maniatis K, Kwant K, Helm P, Grassi A, editors. Proceedings of the 12th European conference on biomass for energy, industry and climate protection, Amsterdam, pp. 38-44. Epidemiol 14(S1):S110–S117. doi:10.1038/sj.jea.7500365

The Bureau of State Statistics (1997). Statistical, Brussels Yearbook of China. Beijing, China.

Vinod M, Kirk RS, Robert DR (2005). Smoke and environmental tobacco smoke on acute respiratory infections in young Indian children. Popul. Environ., 26(5): 375-396. doi:10.1007/s11111-005-0005-y.

Wu C, Xu, B, Yin X, Luo Z (1997a). The current state of rice hulls gasification and power generation in China. In: China–EU Renewable Energy Technology Conference, September 1997, Beijing, China.

Wu C, Zheng S, Luo Z, Yin, X (1999). The status and future of biomass gasification and power generation system. In: China–EU Renewable Energy Technology Conference, March 1999, Brussels.