

Effect of Biomass Gasification on Environment

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Abstract

Biomass gasification is a proficient technology able to convert any kind of biomass into valuable products and can contribute extensively to renewable energy generation. Gasification is a form of thermal breakdown of biomass feed stocks, carried out at high temperature result in a gas known as producer gas which can be used for numerous purposes. Apart from all the advantages this technologies have some drawback related to process and products which results environmental pollutions, occupational health and safety hazards. The producer gas is needs to be cool before use depending upon the application and some byproducts are also released such as tar, ash, char, oils etc., which create specific problem in the environment require suitable treatment before discharged. The present study gives a review of health, safety and environmental issues with process and products of biomass gasification plant.

Keywords; Biomass Gasification, Tar, Environment, Health & Safety impact

Introduction

Biomass is the term used to describe all biologically produced matter and it is the name given to all earth's living matter [1]. Bio-mass is the plant-based products, wastes and residues, derived from agriculture, forestry and industry and are biodegradable in nature. Biomass feed stocks can be converted into several forms of useful energy including liquid biofuels for transport and solid biomass for heat and electricity generation [2]. It is increasingly recognized globally that plant-based raw materials will play an important role in providing alternatives to fossil fuel as feedstock for industrial production for both the

energy and non-energy areas[3]. Gasification technology enhances the worth to low or negative value feedstock by converting them to marketable fuels and yields [4].

The biomass resource can be considered as organic matter, in which the energy of sunlight driving photosynthesis is stored. Once the bonds between adjacent carbon, oxygen and hydrogen molecules are broken by decomposition or digestion, combustion, these substances release their stored, chemical energy [5]. Conversion of biomass to energy is undertaken using different process technologies i.e., thermo-chemical, bio-chemical, and physio-chemical. Thermochemical conversion includes the four main process are combustion, gasification, pyrolysis and liquefaction [6].

Gasification is a century old technology that succeeded properly before and during the Second World War, the technology disappeared soon after the Second World War, when liquid fuel became easily available. Today, because of increased fuel prices and environmental concerns, there is renewed interest in this century old technology [7]. Gasification technology is the conversion of biomass into a new energy carrier (in the form of a combustible gas mixture) by the incomplete oxidation of biomass at high temperatures, usually in the range 800– 900°C [8-11]. An oxygen-containing gasification medium such as air or oxygen is applied to the biomass in a gasification reactor [12]. The organic substances are broken down into combustible compounds such as CO, H₂, CO₂ and CH₄ [13, 14]. Gasification techniques can be used to turn low heat values or negative value feed stocks such as agricultural waste, crop residues, wood and woody waste into valuable products such as substitute natural gas, electricity, fuel and chemicals [15]. Biomass gasification is a comparatively new technology capable to convert any kind of biomass. The main advantages of this process are the low investment, the nimble arrangement, the reliable techniques used, the low costs, and the overall compact structure [16].

According to Demirbas[17] the technology of gasification afford the opportunity to transform renewable biomass into clean fuel gases. If biomass is gasified efficiently it can generate a high yield of clean product gas which called as synthesis gas (CO + H₂) or syngas. Biomass gasification is an efficient power generation technology that can produce electricity deprived of any increase of CO₂ concentration in the atmosphere [18, 19].

Every technologies have some limitations similarly biomass gasification technology also have some problem related to process and product. The biomass gasification plant consequence in environmental pollution, occupational health and safety hazards unless adequate and effective preventive measures are taken and continuously enforced [20]. Producer gas in its raw form tends to be enormously polluted, containing major quantities of tars, soot and ash [21, 22]. Producer gas also contents trace amounts of higher hydrocarbons and water vapour, nitrogen (if air is used as the oxidizing agent) and several impurities such as tar, ash, oils and char particles[4, 23]. In this report emphasis are given on environmental aspect of gasification technology.

Environmental impacts of gasification process

Lata *et al.* [24], reported that each part of the plant creates specific occupational, health and safety hazards. Gasification facilities share the environmental problems as similar to those associated with mass burn incinerators, including: water pollution, air pollution, disposal of ash and other by-products. Gasification process involves huge amounts of water for cooling purposes and also include health, safety, and odour problems. The final major environmental impact of biomass energy may be that of loss of biodiversity. Environmental aspects of gasification technology and related hazards are tabulated in Table 1. Major problem associated with biomass gasification is formed during the process [25, 26].

Table1: Environmental aspects of gasification and associated hazards

Process activity	Fuel preparation	Fuel feeding system	Gasifier	Gas cleaning system	Gas utilization
Environmental concern					
Dust	*	*		*	
Noise	*	*	*	*	*
Odour	*		*	*	
Wastewater				*	*
Tar				*	*
Fly ash				*	
Exhaust gases					*
Hazards					
Fire	*	*	*	*	*
Dust explosion	*	*	*		
Mechanical Hazard	*	*	*		*
Gas poisoning		*	*	*	*
Skin burns			*	*	*
Gas explosion			*	*	*
Gas leak			*	*	*

Source: [20, 24].

During gasification, tars, alkaline compounds, halogens and heavy metals are released and can cause environmental and operational troubles [27]. According to [28] the power generation through biomass gasification encompasses different type of environmental impact and hazards such as, toxic, fire, explosion and environmental hazards.

Air pollution

During the process of gasification, different byproducts are released in environment as air pollutants like dust, biomass ash, fly ash/char and gaseous emission that leads to adversely affect both environment and human health.

Dust

Dust is generated during feedstock preparation, storage and handling, feeding, and fly ash removal [29]. The handling of solid materials is a notorious source of airborne particles, especially when the solids are dry and friable. Some types of gasifiers may produce hot particles as a consequence of malfunction or equipment faults. These may ignite flammable materials and cause a fire [20]. Lata *et al.* [24] reported that dust can cause lung damage, irritation of skin and eyes and may form explosive mixture with air. The gasifier should not generate more than 2–6 g/m³ of dust [30].

Biomass ash

The ash which remains after gasification, 8% to 15% of the original volume, is toxic and presents special problems because of the acidic, or low pH, conditions in landfills [31].

From an occupational health viewpoint, dust particles of the in-between size range 0.2 – 5 µm is the most dangerous; Shape and composition of some materials are known to cause lung damage, for example silica (fibrosis) may arise from fluid bed materials. The dispersion of gasifier dust leads to air pollution [24].

Fly ash and char

Biomass gasification can outcomes in a high production of gaseous product and small of char and ash [32, 33]. [34],investigated that essentially, two types of particles existed in fly ash from gasification i.e., irregular— mostly unburned carbon (char) particles and mineral substances, and spherical particles— formed by volatilization and condensation. Generally, the size of spherical particles were noted lesser than 10 µm in geometric diameter. Fly ash and char shows the similar issues as dust and biomass ash. The fly ash may also cause risk of fire which illustrate that it must be stored in moist and closed condition. Disposal of this wetted mixture presents its specific environmental problems [24].

Gaseous emissions

According to [35] if we use the non-woody biomass as a raw material in gasification then relatively a high amount of sulphur, chlorine and ash was produced, compared with the gasification of woody biomass. Sulphur and chlorine have the several negative impact on environment. [36] investigated that Nitrogen and sulphur are present in many of the by-products and the corresponding oxides are produced during combustion of the fuel gas; these oxides (NO_x and SO_x) can have a negative environmental impact.

Carbon monoxide poisoning

The report of [20] specified that the leading product of gasification process is carbon monoxide (CO) and undoubtedly, is the most common cause of gas poisoning. Due to the absence of color or smell it is particularly noxious. Carboxyhaemoglobin (COHb) formed as 80-90% of absorbed CO binds with haemoglobin, which is a specific biomarker of exposure in blood. Hemoglobin affinity for CO is 200-250 times that for oxygen. Epidemiological and clinical data indicate that CO from smoking and occupational exposures environmental may give to cardiovascular mortality and myocardial infarction.

Water pollution

According to [37] waste water as an effluent is produced during the process of cooling and cleaning of producer gas. Cleaning of producer gas is an important component of any biomass gasification plant and uses water for cleaning the contaminants also [21]. Phenolic and terry components are presents in wastewater released from gasifier based power plant. Disposal of this contaminated liquid effluents generates environmental problems and needs adequate pretreatment before its discharge into natural stream. Discarding of such effluent can lead to contamination of drinking water, fish kills and other negative impacts [24].

According to Department of water and Environmental Engineering, Denmark, wastewater generated from four different gasifier units' viz., updraft, downdraft, two stage and open top downdraft gasifier. The wastewater from the up-draft gasifier was found about one time more toxic than open top downdraft gasifier, two time more toxic than the downdraft gasifier and about three times more toxic than the wastewater from the two stage gasifier. Depending on the different gasification technology, the type of gas treatment and the operating parameters the waste water can contain different organic and inorganic substances [24].

Producer gas obtained from biomass gasification is often cooled before use in gas engines to increase the energy density of the gas [38]. However, during the cooling process some hydrocarbons are condensed with the water vapor out of the gas resulting in a condensate contaminated with organic compounds. Organic gaseous pollutants such as polycyclic aromatic hydrocarbons (PAH) and BTEX (benzene, toluene, ethyl benzene and xylene) from this condensate are carcinogenic and highly toxic leading to a risk of water pollution, adverse health and environmental effects and the emission concentration of both (BTEX, PAH) increases with time [39, 40].

Hazards of gasifier operation

Combustible gases and vapours

CPCB [20] report inspected that when a flammable mixture of gas and air is formed, detonation may occur when the mixture is ignited. Ignition may occur from static electricity, sparking equipment, or

contact with a hot surface. The main components of producer gas, hydrogen and carbon monoxide are explosive gases, thus they must be prevented.

Combustible dusts

Combustible solids such as wood and coal dust are very minor particles but can also form explosive mixtures with air [24].

Fire risks

As stated by [20, 24] that the main fire risks in gasifier systems are associated with:

- Fuel storage
- Fuel drying
- Combustible dusts formed in fuel preparation
- Ignition procedure
- The product gas

Tar yield as an environmental problem

According to [41, 42] biomass gasification process has the disadvantage of generating a high amount of tar, which vary from 0.5-150g/Nm³, depending upon the design of gasifier. The byproducts generated from gasification plants, “tars” stand the leading problem to end users [43, 44]. According to [45] biomass tar is referred to as condensable organics in the producer gas produced in the gasification process of biomass, and it is assumed to be largely aromatic. Elliot, 1998, [40, 46] classified tars into three primary categories based on the reaction temperature ranges in which they form. Thermochemical conversion process generates hundred or even thousands of tar species [47]. Effect of tar on human health and environment are summarized in Table 2. Gasifier should put out less than 1 g/m³ of tar [48, 49].

Table 2. Health and environmental effects associated with selected aromatic hydrocarbons (tar).

Aromatic hydrocarbon	Effect on human	Effect on environment	Reference
Naphthalene (Tertiary tar)	Hemolytic anemia, Hemolysis	depletion of pulmonary glutathione and dose- dependent bronchiolar epithelial cell necrosis	Haddon <i>et al.</i> , 1998 [50], Richieri <i>et al.</i> , 1988 [51]
Benzene (Secondary/tertiary tar)	Anemia, drowsiness, dizziness, headaches, tremors, confusion	Benzene in soil or water decomposes with the presence of oxygen, contaminate groundwater	ANZECC,1992 [52]
Toluene (Secondary tar)	headaches to intoxication, convulsions, narcosis, and death	toxic to both fish and other small organisms	US EPA, 1994 [53], Environment Canada, 1984 [54]
Xylene (Secondary tar)	irritation of the skin, eyes, nose, and throat, difficulty in breathing, headache, lack of muscle coordination, dizziness, confusion	bio accumulate, in fish, high acute toxicity to aquatic life,	United States Public Health Service, 1995 [55], Environment Australia, 2001 [56]
Ethyl benzene (Secondary/tertiary tar)	paralysis, trouble breathing, liver damage and death, drinking water contaminated	high acute toxicity to aquatic life causing death of animals, birds, or fish	United States Public Health Service, 1990 [57], ANZECC, 1992 [52]

Trace impurities:

The other trace gases like N₂, S, Cl and some other trace elements volatilized from the biomass during gasification, which is typically required for maximum end-uses of the gas. Nitrogen compounds are present in the form of ammonia, with hydrogen cyanide being likely and cannot be removed by filtration that requires wet scrubbing with aqueous solutions, which cool down the gas to nearby 50°C [59].

Conclusion:

Based on the study on effect of Biomass gasification on environment, the following conclusion are drawn:

- Biomass gasification is a promising and energy efficient technology that can contribute significantly to renewable energy generation.
- Gasification technology is able to convert any kind of biomass energy with lower heat values to valuable products.
- But at the same time biomass gasification process produce solid, liquid, and gaseous wastes, depending on type of gasifier and solid fuel used for gasification.

- Gasification plant consequence in environmental pollution, occupational health and safety hazards unless adequate and effective preventive measures are taken and continuously enforced.
- The producer gas needs to clean before use and cleaning process generates enormous amount of liquid effluents and needs to treat properly before discharge into natural stream.

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