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An Energy Generation Opportunity from Face Mask by Thermochemical Gasification Techniques

Waste management with Energy generation Approach

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Abstract : Effective tool for control on spreading COVID-19 disease, face mask used. Uses of face mask equipment containing plastic and other derivatives of plastics create enormous instability in medical waste treatment and recycling result as global socio economic environmental challenges. Such medical waste challenges not only quantitative aspects but also need to look qualitative aspects for environmental sustainable management. This paper examines the various healthcare solid waste management systems used in various nations, the issues encountered during this management, and potential solutions for addressing these challenges. It also gives valuable insights into hospital solid waste management issues during the COVID-19 epidemic, as well as a viable path ahead. This paper review give view on thermochemical techniques and process as sustainable solution for overcoming Covid-19 medical wastes management. Thermochemical techniques for producing gaseous fuel from waste to ward bioenergy production. One of the need of plastics waste mainly contains polypropylene, polyethylene, polyethylene terephthalate, nylon and polystyrene diversify in to source of energy. Thermochemical gasification techniques use for producing char, oil, and syngas as environmental friendly and sustainable method of energy conversion. Produced of thermochemical techniques can be used for power generation application as well as process heating.

Keywords: Personal Protection Equipment (PPE), Face Mask, wastes management, thermochemical techniques, Energy Generation

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I. Introduction

The World Health Organization (WHO) declared the current situation to be a pandemic in March 2020 because the viral infection was spreading rapidly and infecting the majority of the world's inhabitants. It killed out millions of people globally, leaving more than 100 million individuals afflicted with the fatal virus (exact statistics - 100,455,529 confirmed cases of COVID-19 as of January 29, 2021) [1]. Figure 1 shows various plastics wastes resources [2]. Although the use of plastic polymers has several social benefits, microplastic (MP) particles associated with the plastic age pose health and environmental concerns. This problem is caused by incorrect treatment of plastic garbage as part of solid waste. Mismanagement of plastic solid waste, along with the large manufacturing capacity of plastic items, raises a prosperity research that proves that MP has now universally invaded the aquatic habitat. MP ingestion by aquaticbiotas has grown as a result of the massive plastic solid wastes generated in littering as well as aquatic bodies. Surprisingly, plastic trash in the aquatic system originates from solid waste, but it might also be from municipal effluents and runoff from littering in cities [3].

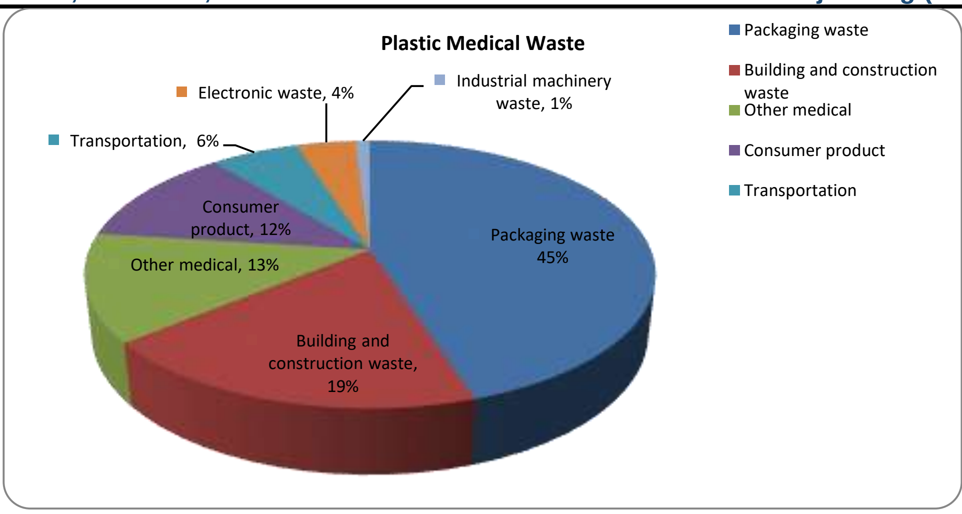


Fig 1. Various types of plastic wastes generated from the packaging, medical and other plastic waste sources

BMW generated, during this period, inflated the CBWTFs of India. In India, BMW is managed as per BMW legislation, 2016 and according to this legislation, there are four categories of the BMW i.e., red, yellow, white and blue. Among these categories of BMW, yellow BMW (Y-BMW) is treated using incinerators. As per latest report of Central Pollution Control Board (CPCB), India, there are 198 CBWTFs with installed incineration capacity of 782 T/d, with additional capacity of 72 T/d from captive incineration. The problem is still worse in poor nations for COVID-19 waste handlers since they are not properly outfitted with PPE. In underdeveloped nations, rag and casual garbage collectors are more likely to become sick with virus-laden waste. The critical actions that must be taken to solve the pandemic crisis will be the establishment of an adequate treatment facility and the safe disposal of CMW, which will control and prevent the spread of the virus [4]. Figure 2 Shows various medical waste generation.

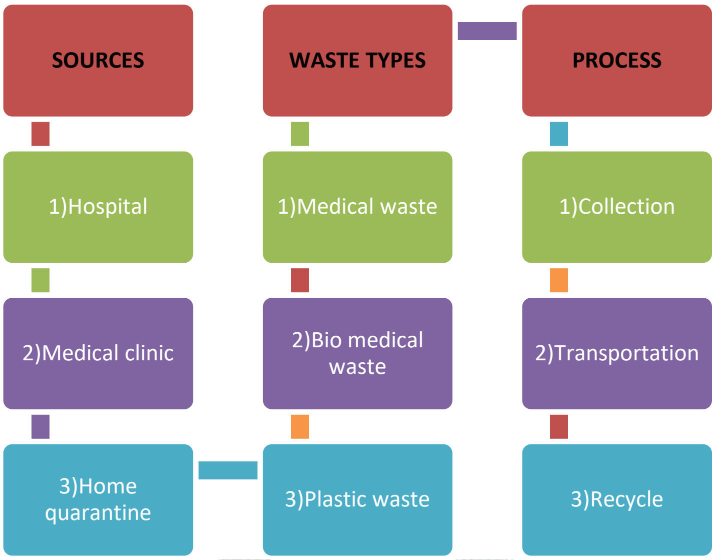


Fig. 2 Sources of medical wastes

This biomedical waste can be handles by thermochemical gasification. Thermochemical gasification in which any feedstock is partly oxidized by using one of the substance like O_2, Atmospheric air, water vapor (steam) and CO_2 to derive produced gases for using in various applications. The overall efficiency of gasification (45-50 percent) is higher compared to standard direct combustion (25-35 percent)[5]. Biomass Producer of gas with a mixture of CO, CO_2, H, CH_4, H_2O in water vapor, N_2 (with the possibility of the air imported as oxidizer substance) along with various different harmful substance like ash, little char, tar as well as oil. Gasification with air generate syngas with LHV for motor, boiler as well as turbine operation (4-7 MJ/Nm^3 HHV). Owing to its low energy density, pipeline transport cannot be used. Medium heating gas of 9-18 MJ/Nm^2 and higher heating value for restricted distribution of the pipeline and as a synthesis gas for conversion by gasification by O_2 [6].

During Covid-19 plenty of face mask used for protecting against spreading of virus. The massive use of face masks by the emergency of COVID-19 gives evidence on the environmental disorder both in the terrestrial and aquatic environment and that the global pandemic has not reduced the challenge of increasing plastic pollution in the environment.

II. FACE MASK MATERIAL OBSERVATION

. Use and through polymeric (polystyrene, polypropylene etc) materials have been identified so far as a significant source of macroplastics and microplastic particulate pollution in the environment [7].

The 3-ply surgical mask is commonly used in the COVID-19 pandemic. Figure 3 shows surgical mask image. The 3-layer surgical mask is made up of 3 different layers of nonwoven fabric with each layer having a specific function, as shown in Figure 4 The outermost layer (typically blue) is waterproof and helps to repel fluids such as mucosalivary droplets. The middle piece is the filter, which prevents particles or pathogens above a certain size from penetrating in either direction. The innermost layer is made of absorbent materials to trap mucosalivary droplets from the user. This layer also absorbs the moisture from exhaled air, thus improving comfort. Together, these 3 layers effectively protect both the user and the surrounding people by limiting the penetration of particles and pathogens in both directions. These polymeric compounds will enter aquatic bodies through a variety of means, including leaching, floods, and wind. Similarly, disposable face masks made of polymeric materials have been found in the environment, initially as a result of dumping in landfills and dumpsites or littering in public places, and later as a new developing source of microplastic fibers in freshwater and seas. With varied environmental circumstances (temperature, humidity, salinity) these face masks degrade/fragment into particles that are typically smaller than 5 mm in size [8].

2.1 Face Mask FTIR Spectral analysis observation

Three layers of the surgical facial mask were shrunk down and crushed with potassium bromide (KBr) powder using mortar-pestle mechanical pressing. The phenyl vibration absorption is attributed to the peak at 611 cm-1 for the outer and inner layers, not the center [9]. However, the bands at 886 cm-1 for just the inner and outer regions of the face mask are caused by carbonyl functional group stretching [10]. The peaks about 1100 cm-1 are assigned to the three portions of the face mask's glucose rings extending in the fiber. The outer and inner layer characteristics for the CeO stretches have maxima at 1253 cm-1 region. The outside (non-woven), inner (pure polystyrene), and middle layers all have two distinct peaks about 1454 and 1380 cm-1, which are attributed to the symmetry distortion of methyl (–CH2–) groups [9]. The methyl deformation and others are assigned to the tiny spectral peaks at 1369, 1338, and 1319 cm-1 respectively on the outer and inner layers, respectively. FTIR spectrum properties of PS/non-woven, pure polystyrene, and non-woven textiles were reported in a comparable manner [11].

2.2 Face Mask Thermogravimetri analysis observation

The three (inner, middle, and outer) layers were heated from 25 to 600 °C with a heating rate of 15 °C/min in the atmosphere control at a sampling cycle. A 6.3 mg mass was used for the three layers. The empty crucible used as a reference. The complete thermal analysis was 38 min. The endothermic phase transition heat flows and peak temperatures of low-density polymeric plastics are different. The phase transition flow value of polyethylene, polypropylene, polyethylene terephthalate, polyester, polyamide, polyvinyl chloride, and polyurethane are around 100 °C, 160 °C, 250 °C, 216 °C, 260 °C, 270 °C, and 290 °C, respectively [12]. TGA/DTA thermograms reveal mass loss and an endothermic event as an endothermic (negative) peak. The current author hypothesizes that the three layers' negative thermal maxima would have occurred. Figure 5 shows the inner, middle, and outer layers of the face mask have 130, 125, and 175 °C endothermic peak temperatures, respectively [13].

Fig 3. 3-layer surgical mask

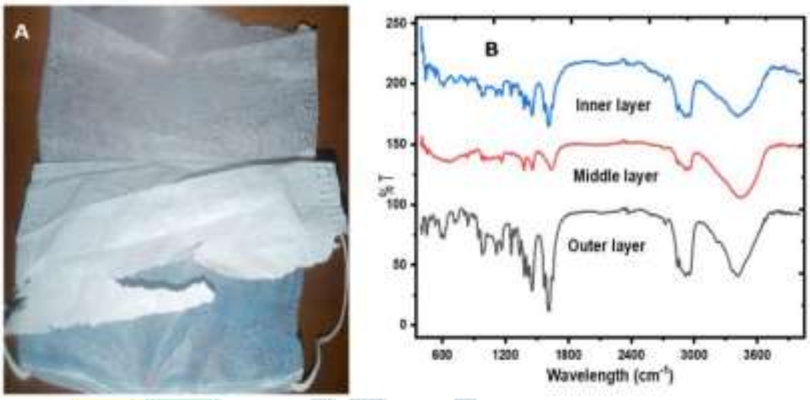


Fig. 4 Unwrapped Three-layer face mask (A) and FTIR spectra corresponding (B)[13]

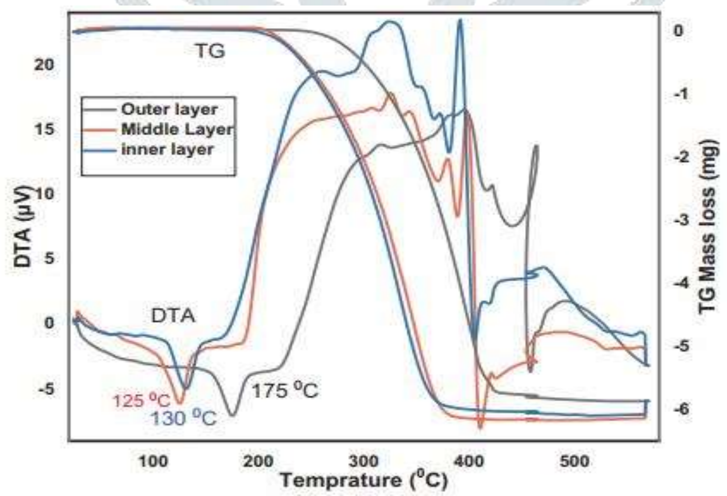


Fig. 5 GA/differential thermal analysis of the three layers surgical face mask [13]

This indicates that the surgical face masks are made of polypropylene (PP) plastic polymers, which is consistent with research on the microplastic characteristics of various polymers [12]. The other endothermic and exothermic peaks seen after temperatures ranging from 300 to 450 °C might represent the deformational or melt agglomerate transition phase. Furthermore, the ash content that remained after thermogravimetric analysis was evaluated in order to compute the organic matter degraded. It was observed that 94 percent of the degraded organics (remaining ash = 6%) were stable at 600 °C. That is, 5.9 mg of mass was lost out of the initial 6.3 mg masses [13].

III. Socio Economy and Environment impact of Face Mask waste

Toxic compounds such as phthalate, organotin, nonylphenol, polybrominated biphenyl ether, and triclosan are used as additives in microplastics. These hazardous compounds can be released into the environment through the chemical or biological decomposition of plastic polymers. In general, the environment's fauna and plants suffer as a result. Some of the delights involve aquatic life, such as fish, which play an important role in the human food web. Fish consume microplastics on purpose or unintentionally, which can wind up in meals intended for human consumption, increasing concerns about global food safety and resulting in food scarcity [14]. Another substantial aspect of environmental decline and degradation, all the way up to climate change. The presence of plastics and plastic particles in the environment will contribute to drought, and disaster risk management will become tougher as a result of global warming caused by carbon emissions [15-16]. Figure 6 A Land base face mask pollution, B in Sea Face mask pollutions [13]. Microplastics are becoming a huge concern as a niche for microorganisms and growing biofilms. When compared to the natural freely dwelling microbe communities in the surrounding aquatic environment, the microbial components may be considerably different [17]. The research incentives to increase understanding of the microplastic persistence in the open water system and develop controlling and/or remediation plans for generation energy from this wastages. The State Economic and Trade Commission (SETC) issued a proclamation prohibiting the manufacture and use of disposable foam plastic tableware [18].

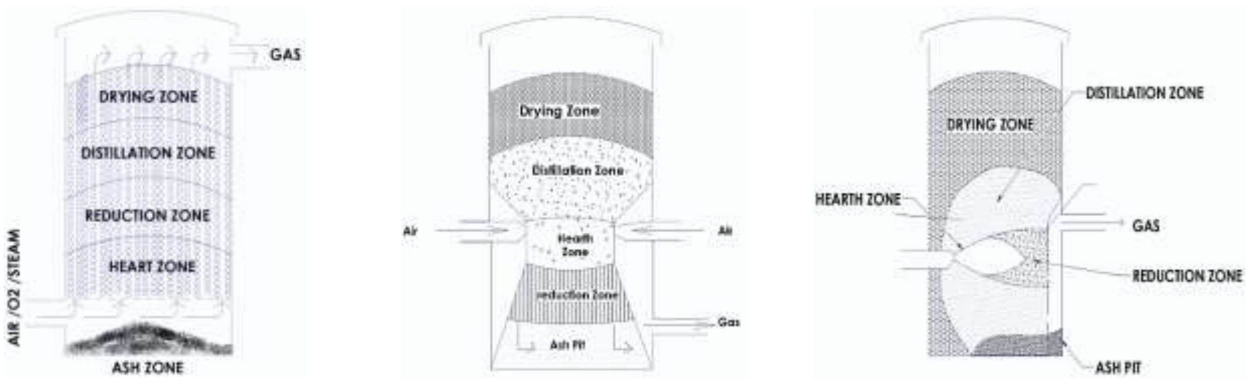
Fig. 6 A Land base face mask pollution, B in Sea Face mask pollutions[13]

III. Thermochemical Gasifier techniques (TGT)

Processes of thermochemical and biochemical conversion convert solid degradable wastage into bio-power and bio-fuel. Bioenergy is an energy available from biological sources from natural materials. There are various thermochemical gasification techniques implements for face mask gasification.

3.1 Fixed Bed Thermochemical Gasification Techniques

Fixed bed gasifiers are defined as the basis of a fuel and oxygen (air/steam) path that is either concurrently or counterflow. Because of the simple mechanism, biomass gasification using fixed bed type gasifier is advantageous. Biomass can be feed by pushing into or moving as a plug, with gases flowing between particles[19]. In both updraft and downdraft fixed-bed gasifiers, feedstock is a feed from the top of the gasifier reactor. Gasifier agents such as O_2 or ambient air rise and pass from the heated reaction zone to the gasifier base in the opposite direction of solid raw material advancement[20]. The produced gas contains tar components, and it must be cleaned out; otherwise, it destroys a substantial portion of the gasifier. Fixed bed gasifiers require well-defined fuel qualities due to the inflexibility of feedstock. [21]. Figure 7 shows (a) Updraft (b) Down Draft (c) Crossdraft types Fixed Bed Gasifier.



(a) (b) (c)

Fig. 7 shows (a) Updraft (b) Down Draft (c) Crossdraft types Fixed Bed Gasifier [22]

3.2 Fluidized Bed Thermochemical Gasification Techniques

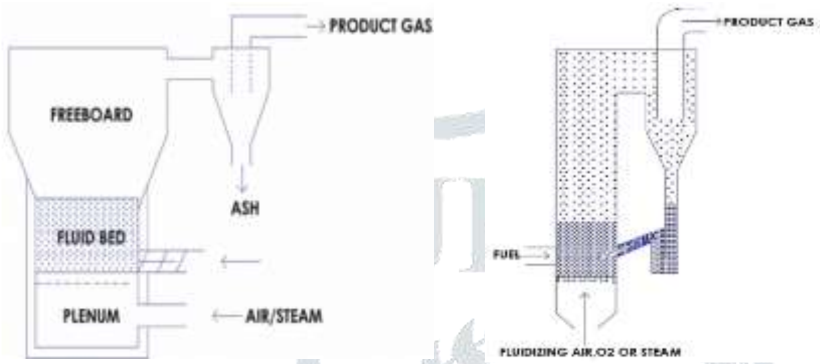
The gas flow entering the reactor (air, oxidant, steam, and reused syngas) must be adequate, but not too heavy to float feedstock particles onto the bed. The reactor will get lighter and smaller as the feedstock particles are gasified. To minimize particle agglomeration, the bed temperature must be kept between 800-1000 C lower than the initial ash fusion temperature of the biomass. Such features are present in FBG type reactors[23]. When pyrolysis products come into contact with hot solids, they disintegrate into non-condensable gases. FBG has a flexible biomass fuel supply, a constant fuel combination, equal biomass heating, and a variety of reactive gasify mediums such as atmospheric air, steam, O_2, and CO_2[24]. FBG reactors are classed according on their medium fluidization velocity. BFB normally operates at low gas speeds of less than 1 m/s, whereas CFB operates at higher gas speeds of 3-10 m/s.

3.2.1 Bubbling Fluidized Bed Gasifier (BFBG)

In BFBG, the feedstock is heated to a high temperature before being introduced into the bed. To ensure efficient heat transmission. Inert bed materials include sand, ash, and char. Figure 8 (a) displays a schematic diagram of the BFB gasifierAir, O2, or steam is forced through the bed's inert material until friction forces between feedstock materials and gas counterbalance. Gas velocity at which minimal fluidization occurs and bed material bubbling begins, with the objective that feedstock elements remain in gasifier chamber and seem to be nearing boiling state. Through allowing heat transfer through the reactor to be successful, feedstock particles separate by fluidization from the bed. Imported bad material reacts as a catalyst or as a gas cleansing procedure[22].

3.2.2 Circular Fluidized Bed Gasifier (CFBG)

CFBG functions at a greater gas velocity than the needed fluidization stage and exhibits feedstock element dissipation with the generated syngas stream. Figure 8 (b) displays a schematic diagram of the CFB gasifier[22]. The cyclone separator removes dissipated particles from generated gas as it exits the reactor's top and returns to the reactor's bed. Continues the process of recirculating fugitive feedstock elements to bed until it is light and tiny enough to occur with the generated gas leaving the cyclone separator[22].



(a) (b)

Fig. 8 schematic diagram of (a) BFB gasifier (b)CFB gasifier [22]

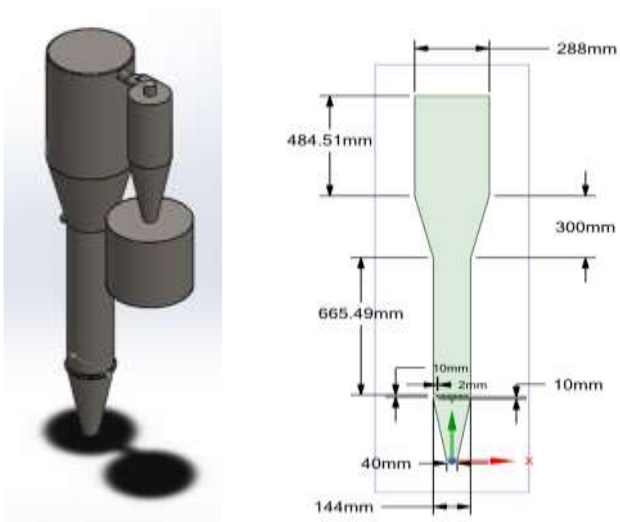
Fig. 9 Plasma gasifier [22]

3.3 Plasma Thermochemical Gasification Techniques

Two ways can produce the plasma stage “thermal or equilibrium” by atmospheric pressure along with “cold or non-equilibrium” by negative (vacuum) pressure. By plasma gasification, thermal way produced gas with components like Ar, N_2, H_2, H_2O vapor or mixture of gases has a temperature of 4700˚C-20000˚C. This method benefits non-ionizing radiation, high energy density, high intensity, and high temperature[25-27]. Figure 9 Shows a schematic working diagram of a plasma gasifier[22]. Biomedical waste with radioactive compounds gasify in a plasma gasifier at high temperatures. A high-temperature plasma gasifier working environment of about 1500K removes highly toxic dioxins, benzopyrene, furans and destroys thermally stable bacteria with no harmful impurities. Plasma gasifier is economically disadvantaged as an electricity source that contributes to high building, operating, and maintenance costs [28,29].

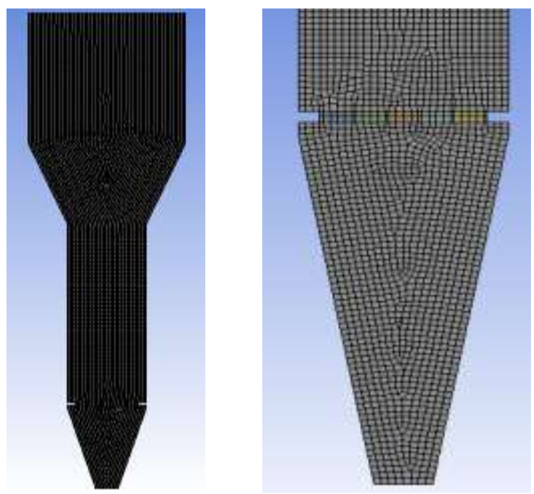
IV. FACE MASK GASIFICATION USING BUBBLING FLUIDIZED BED GASIFIER

BFBG System for face mask 10 kg/hr feed stock rate designed and developed. CAD model analyses for three different velocities 0.19, 0.22 and 0.30 m/s air velocity. Figure 10 (a) (b) shows CAD model based on designed BFBG calculation. Figure 11 (a) and (b) shows mesh geometry distribution. Table 4.1 shows analysis messing details. Analyses carried out in ANSYS FLUENT software[30]. Table 4.2 Sand and Face mask physical properties



(a) (b)

Fig. 10 Designed CAD BFBG Model[30]



(a) (b)

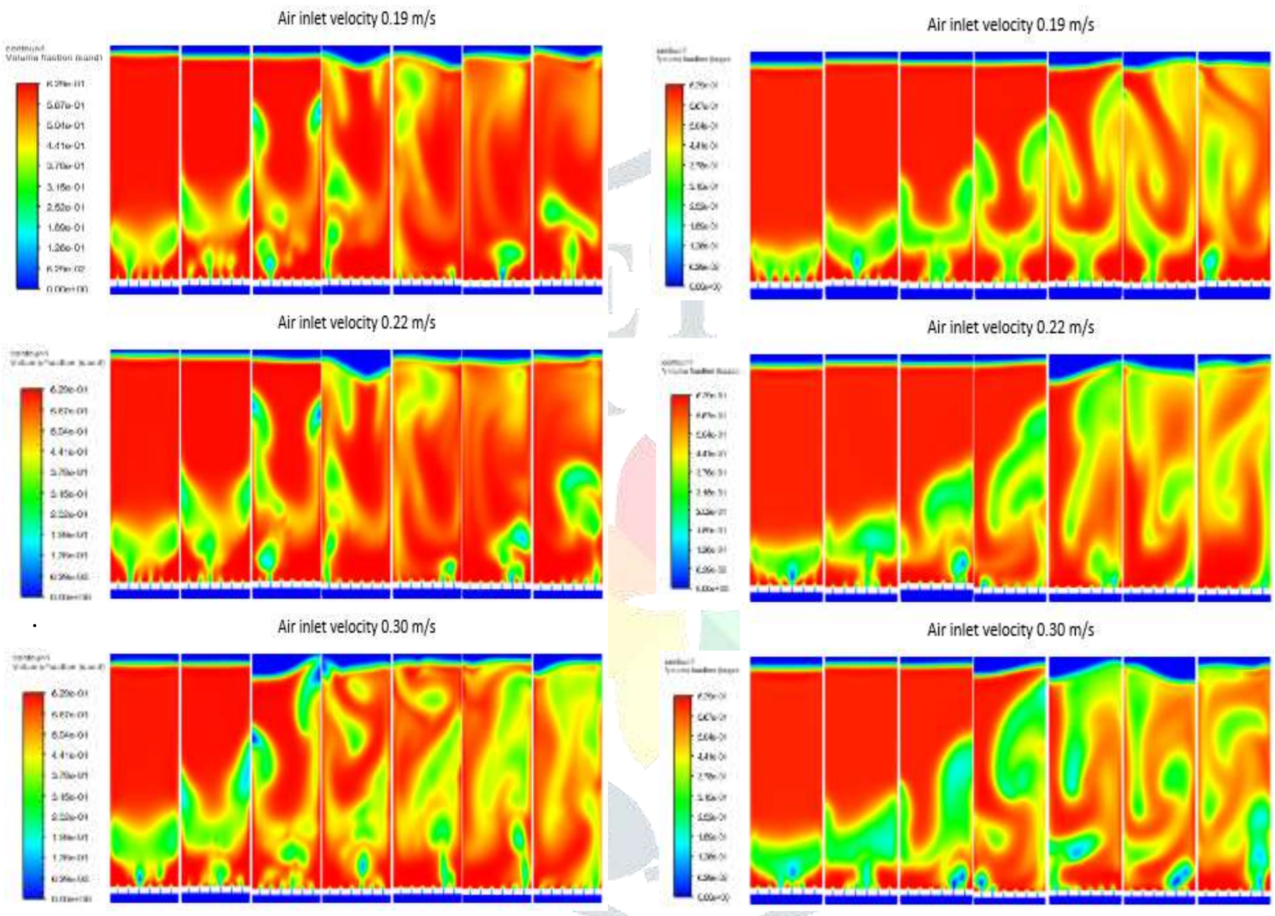
Fig. 11 Mesh geometry and Closer View[30]

Table 4.1. Mesh Details[30]

Element Size (mm)	5
Number of Elements	13430
Number of Nodes	13880

Table 4.2 Sand and Face mask physical properties

Property	Sand	Face Mask
Particle Size (μm)	385	2230
Density (kg/m^3)	2650	128
Porosity (ε)	0.46	0.82
Sphericity (ø)	0.78	0.43



0.5s 0.75s 1s 1.25s 1.5s 1.75s 2s 0.5s 0.75s 1s 1.25s 1.5s 1.75s 2s

(a) (b)

Fig 12. Volume fraction distribution for (a) the Sand (b) Face Mask Particles using the Syamlal and O'Brien drag model with three inlet velocities 0.19 m/s, 0.22 m/s and 0.30 m/s [30]

Figure 12 shows sand as bed material and Face mask as Feed stock material particle distribution during three inlet velocities 0.19 m/s, 0.22 m/s and 0.30 m/s using the Syamlal and O'Brien drag model. Face mask particles were predominantly found in the middle and upper regions of the bed, according to BFBG profiles. The sand particles accumulated in the center and bottom region of the bed. This distribution was shown to be highly correlated with the component's density and particle size. Lighter facemask particles isolated to the top of the bed, larger particles showed stronger mixing behavior due to their density being closer to that of sand. As a result of being so close to the size of sand particles, smaller facemask particles indicated a more uniform mixing. Furthermore, it was observed that increasing air velocity enhanced binary mixing. The majority of face mask movement over the bed was upwards at the reactor's center-line and downwards regions of the wall Pressure across the bed height going down because of sand and facemask particles interacts with air. Small temperature variation occur because simulation time was 2s only. In next study will built a lab-scale model of BFBG according to design parameters and perform experiments and compare the result with CFD data[30].

V. EXPERIMENTAL ON BFBG FOR FACE MASK GASIFICATION

Figure 13 shows schematic diagram of Face mask to syngas conversion methodology.

5.1 Experimental Procedure:

For experimental work following procedure are followed

- Collection of Face mask, Bacteria removing processes in UV chamber

- Sizing of face mask as per feed stock size requirement
- Fluidized bed preparation by sizing on sand by messing process and feed it in to BFBG reactor
- Start Supply of Air as gasify agent at 0.5 m/s speed as per 0.30 Equivalent Ratio requirement
- Reach BFBG Reactor Temperature up to 650-700 ºC
- Feed Face mask in to the reactor, Produced syngas leave reactor from top portion of the BFBG reactor
- Face mask Particle leave with syngas separated at Cyclone separator
- Syngas go to Cleaning and cooling device for separation of further particles and cooling of syngas.
- Syngas come out from the burner by proving spark at burner, ignition of flame can be observed

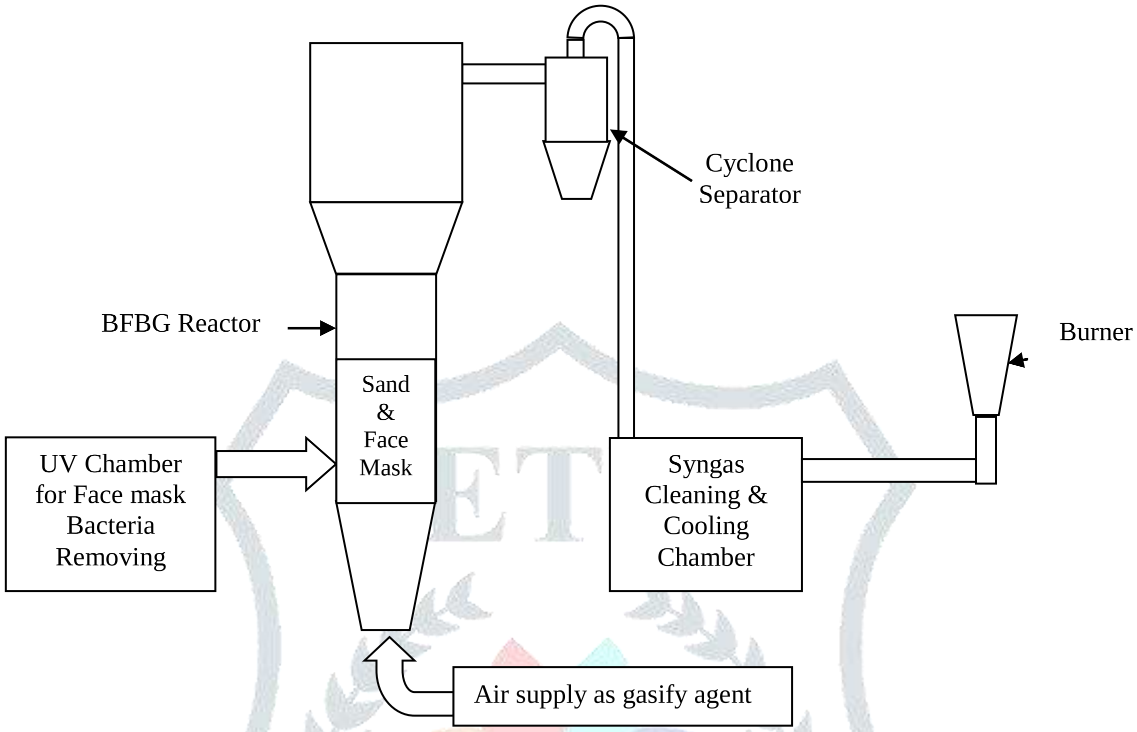


Fig. 13 Experimental Setup Schematic Diagram

VI. RESULTS AND DISCUSSION

6.1 Results of Feed Stock Material

Table 6.1: Proximate analysis of Face Mask

Feed Stock Material	Moisture %	Volatile Matters %	Ash %	Fixed Carbon %	Sulfur %	Calorific Value Kcal/kg
Face Mask	0.8	95.6	2.7	0.3	0.6	8467

Table 6.2: Ultimate Analysis of Face Mask

Feed Stock Material	C%	H%	N%	S%	O%
Face Mask	58.8	13.4	0.28	0.3	27.22

Table 6.1 displayed face mask Proximate analysis face mask used for feed stock material for gasification, which shows content of Moisture, Volatile matters with maximum content of 95.6 %, Ash, Fixed Carbon and Sulfure contents. Calorific value of the face mask shows the value of 8467 Kcal/kg which is high as compared to solid fuels like coal and different woddy based biomass.
Table 6.2 displayed Ultimate analysis which shows Carbon, Hydrogen, Nitrogen, Sulfur and Oxygen content present in selected face mask feed stock material.

6.2 Discussion on Experiment work

By observing flame of syngas generated from face mask gasification, it can say that flame can be used for thermal or heating applications. Analysis of the produced syngas will be carried out by testing it in laboratory.

CONCLUSION

The COVID-19 epidemic has been causing severe harm to people all across the world. The pandemic of COVID-19 has resulted in a rise in the vast volume of plastic garbage. When these non-renewable polymers are pyrolyzed, syngas, HCs, and H2 gas are produced. To address the COVID-19 waste accumulation scenario, effective waste management at the same level of public health and safety must be implemented. Thermochemical Gasification Techniques (TGT) may also be an ecologically friendly and cost-effective method of dealing with COVID-19 plastic waste while also creating value-added goods. TGT makes it easier and greener to convert waste into energy products like ready-to-use fuels. Experiment work was done with a face mask as the feed stock material, sand as the bed material, and air as the gasify agent. The syngas produced by the BFBG reactor is used to generate heating flame. As thermal applications, this syngas flame was noticed. Produced Syngas lab tests can be done to identify other properties. Waste generated by TGT COVID-19 might be viewed as energy generating waste. TGT might become waste management with the use of an energy generating approach.

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