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Electricity Generation and Removal of Heavy Metal Ions from Laboratory Effluent by Rice Husk

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Abstract- *Rice hulls, the largest milling byproduct of rice, constitute one fifth of the paddy by weight. The hulls which can be obtained at relatively low cost are in abundant supply in most developing countries, particularly in the Asian region. Rice husk, which is considered a waste, has a high level of silicon. This paper investigates the use of grounded and carbonized rice husk in water purification and electricity production by rice husk gasification. The rapid growth of industries has not only enhanced the productivity but also resulted in the release of toxic substances into the environment, creating health hazards and hampering the normal activity of flora and fauna. Here, adsorption technique has been applied for the removal of heavy metals such as Cu, Zn and Pb from water. Rice husk is a highly efficient adsorption material that shows nearly 95- 100% removal of heavy metals from water. The purpose of this paper is to make available an idea of electricity generation from rice husk & removal of heavy metal ions from industrial wastewater. The rice husk based small and medium power plants are very much useful to generate and supply electricity in the rural areas. Rice husk is preferred to any other materials because of its abundant availability in India since rice production in India is very high and its cost is quite lower than other materials.*

Keywords: Silica, Grounded, Carbonized, Effluent, homogenized, gasification.

Introduction

Rice is the dominated crop of India. In 2017-18 the rice production of India was 111 m tonnes which produced 20 m tonnes of husk of which usually 90% is burnt in open air or discharged into rivers or oceans causing air or water pollution respectively. By using this huge amount of rice husk, we may generate a good amount of electricity & can distribute it to the rural areas at a cheaper rate. This rice husk can also be used for the removal of heavy metal ions like Cu, Zn, and Pb from water. Rice hull contains lignin (9 % - 20%), cellulose (28% - 30%), proteins (2%-3%), fat (0.5% - 1 %), and other nutrients (9.3% - 9.5%) like carbon, haematite, MgO, TiO, K_2O and approximately 20% silica by weight and, on combustion, yields a porous ash having a silica content of approximately 90 %.

The characteristics of rice husk compared with other solid fuels can be summarized as follows:

- Its high silica content causes excessive wear to parts of processing machines, such as conveyors or grinders, and hampers digestibility in livestock. The content of volatile matter in the rice husk is higher than in wood and much higher than in coal; whereas,

fixed carbon is much lower than in coal. Ash content in the rice husk is much higher than in wood and coal, which causes barriers in energy conversion.
- The high content of ash, alkali, and potassium causes agglomeration, fouling, and melting of the parts of combustors or boilers.

Material & Methods
Procedure to remove heavy metals from laboratory effluent
Reagents and Sample

Sample-A: Grounded rice husk
Rice husk is obtained from rice mills. To prepare the powdered husks, they are initially ground and homogenized using a food blender with steel blades for 10 min. Particle sizes <355µm is obtained by passing the milled material through a steel sieve. Afterwards, the ground husks are stored in polyethylene bottles (high density) and used without any other physical or chemical treatment. The experiments are to be carried out in conical flask (1). The wastewater used is prepared synthetically in laboratory by taking 100 ml solution of Cu, Pb, Zn with varying concentration from 1ppm to 20 ppm and, finally, solutions of metals used for calibration procedures in atomic absorption spectrometry.

Figure 1.1 355 µm sieve, used for sieving sample (powdered rice husk)

Sample-B: Carbonized rice husk
Rice husk is washed 3-4 times with de-ionized water to remove all dirt in its original particle size followed by filtration and oven dried at 100°C. The cleaned and dried rice husk is then kept inside the muffle furnace (shown in fig.1.2) at 500°C for 3 hours. The burned rice husk is soaked in 0.6M of citric acid for two hours at 20 degree temperature. The acid slurry is then oven dried at 50 degree and then the product is cleaned and dried and used without any other further treatment. It is called Carbonized Rice Husks (CRH) as shown in fig 1.3.

Figure 1.2 Muffle furnaceFigure

Figure 1.3 Carbonized Rice Husk

Procedure to remove heavy metals from laboratory effluent

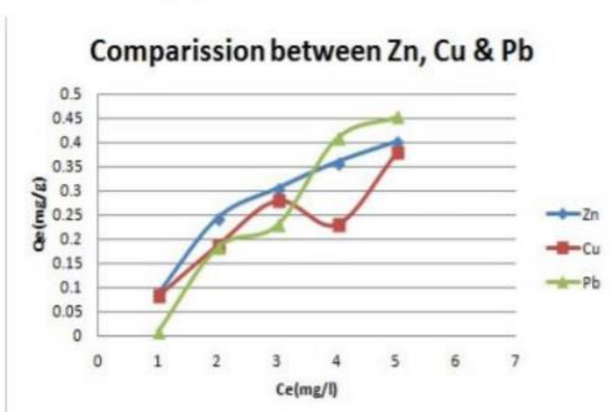
For these experiments 100 ml of a solution containing Cu(II), Zn(II), and Pb(II) at 1ppm to 20ppm concentrations is to be added with the adsorbent and stirred continuously at 250 rpm speed in a electromagnetic stirrer (shown in fig 1.5) for 24 hours at 40 degree constant temperature. Then the sample is allowed for settlement till clear water is seen on the surface, in the sample the filtered and final concentration of metals is measured from the analysis using a Perkin Elmer Model Analyst 200 atomic adsorption spectrometer (shown in fig.4). The experimental parameters affecting the bioaccumulation of Cu (II), Zn and Pb (II) species are examined. Then the effect of pH on the ability of rice husks to adsorb metal ions is investigated. For this purpose, the pH values of the Cu (II), Zn and Pb (II) solution are varied from 2 to 6.

Figure 1.4 Perkin-Elmer Model Analyst 200atomic adsorption spectroscopy

Figure 1.5 Electromagnetic stirrer

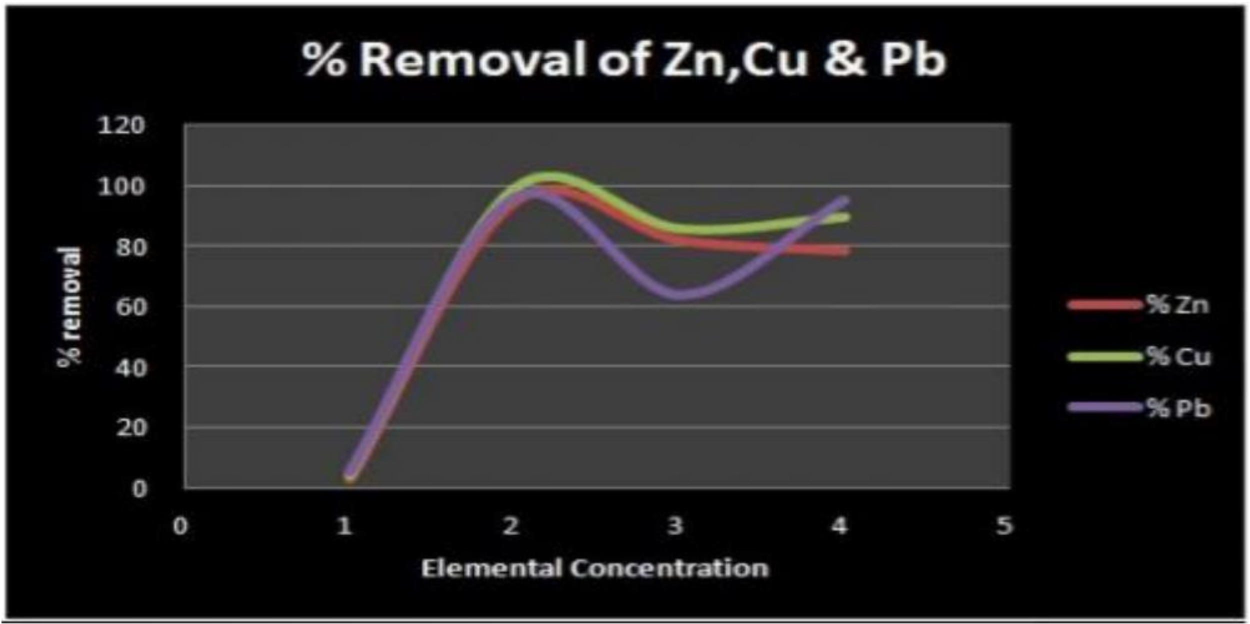
Results

The graphs show comparison among the adsorption capacity and % removal of metals Zn, Cu and Pb by grounded and carbonated rice husk.



Initial conc(mg/l)	Qe(mg/g) Zn	Qe(mg/g) Cu	Qe(mg/g) Pb
1	0.089	0.083	0.0086
2	0.2445	0.188	0.184
3	0.3051	0.280	0.230
4	0.359	0.2312	0.4095
5	0.4005	0.3793	0.4531

Figure 1.6(a). Effect of initial concentration of metals Zn, Cu, Pb on the adsorption capacity of grounded rice husks (particle size <355 micron)



Initial conc. (mg/l)	% removal Zn	% removal Cu	% removal Pb
1	86.90	93.25	48.04
2	93.39	82.02	78.35
3	99.00	85.65	89.00
4	95.29	64.02	95.25
5	84.02	78.65	97.52

Figure 1.6(b). Graph between initial concentration of metals of the Zn, Cu, Pb and their respective % removal by grounded rice husk.

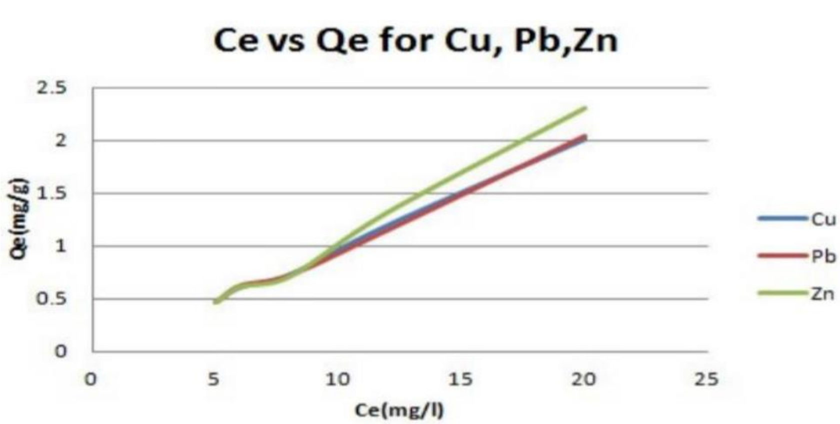


Figure 1.7(a). Effect of initial concentration of metals Zn, Cu, Pb on the adsorption capacity of carbonated rice husk (particle size < 355 micron)

Initial Conc (mg/l)	%Removal	%Removal	%Removal
5	87.16	86.55	87.91
7	89.85	89.22	89.61
9	90.78	90.68	90.62
14	94.03	9404	94.43
20	96.45	96.31	96.64

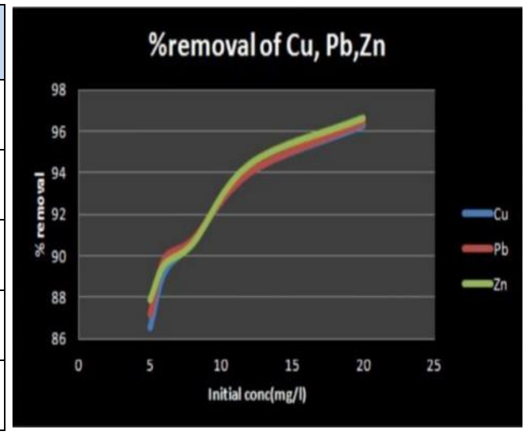


Figure 1.7(b). Graph between initial concentration of metals of the Zn, Cu, Pb and their respective % removal by carbonated rice husk.

The adsorption capacity of the material decreases in order of Zn>Pb>Cu. The adsorption capacity increases with increase in initial concentration of heavy metal present in the solution and is true for each metal.

Procedure of Electricity Generation from Rice Husk

There are several methods of generating electricity from rice husk. Among some effective ways, here power generation by rice husk gasification is discussed and the system is designed in such a greener way so that the system evolves absolute zero emission. For the process to discuss elaborately a basic block diagram is shown in Figure1.8.

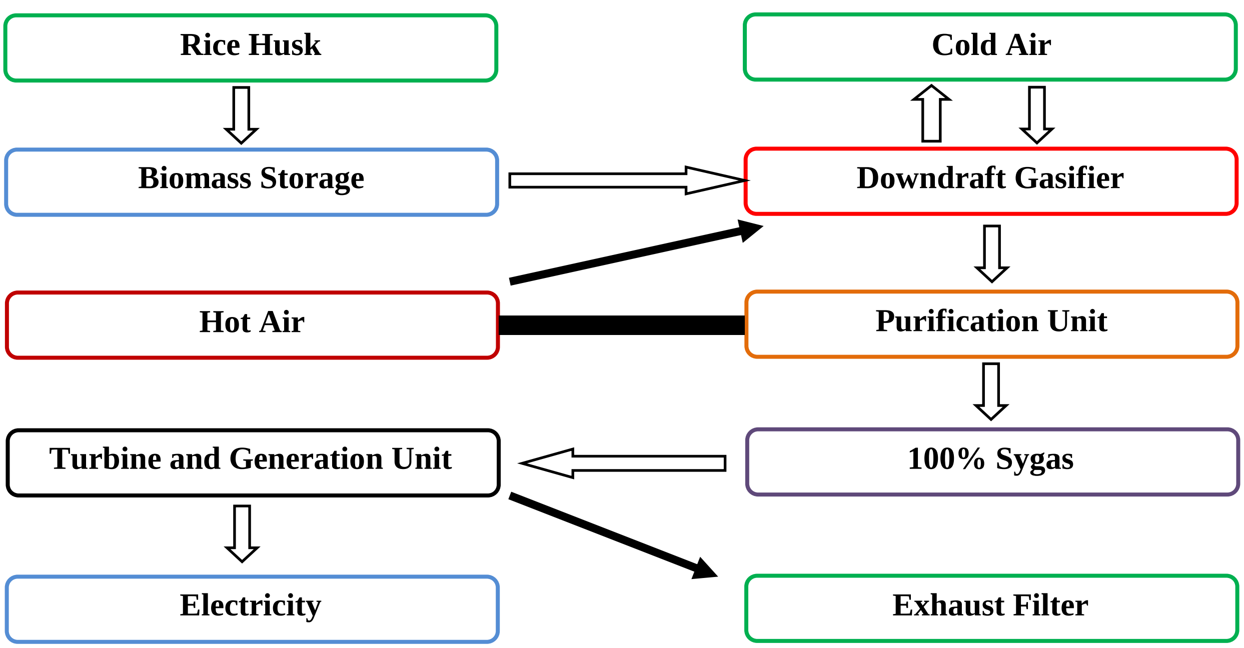


Figure 1.8 Block diagram of rice husk electricity production unit

From the figure it is clear that the process starts from the biomass storage where the rice husk is put for the process. It is nothing but a reservoir of rice husk. After preserving there, the rice husk is conveyed to the gasifier where it goes through some certain chemical reactions to produce syngas. There are a few types of gasifiers present in the market which have different sets of pros and cons, such as fixed bed updraft and downdraft gasifier, twin fire fixed bed gasifier, fluidized bed gasifier and bubbling bed gasifier. However, the cheapest among these gasifiers is downdraft gasifier and this gasification chamber produces a product gas with very low tar content. So for utilizing this benefit, for small scale rice husk biomass plant fixed-bed downdraft gasifier is ideal. Here, biomass fuel is fed at the top of the reactor/gasifier. Then as the fuel moves downward, it reacts with air (the gasification agent). The suction of a blower or an engine supplies the air needed for the reaction and then the air is converted into combustible producer gas through a complex series of reactions like oxidation, reduction, and pyrolysis (Waewsak and et al, 2017). The major processes are described further below.

Downdraft Gasification

A downdraft gasifier is a chamber in which both the gas and the solids flow in the sane downward direction. Due to the downward flow this type of gasifier produces cleaner gas than any other method like updraft gasification chamber. It is because in downdraft gasifier all the produced tar is secondary whereas updraft gasifier produces primary tars. Moreover, the downdraft nature also allows for grater conversion rates as gravity forces the material to flow through the entire gasification chamber (Abedin and Das, 2014). It has also some limitations on controllability for large diameters or power output. Due to the formation of preferential channel being at the fuel bed, it prevents the tar rich stream to move from the pyrolysis region to enter the combustion region. By using slow-rotating paddles, uniform distribution of particles in the bed is provided and thus this problem is extinguished. A schematic diagram of a downdraft gasifier is given in Figure 1.9.

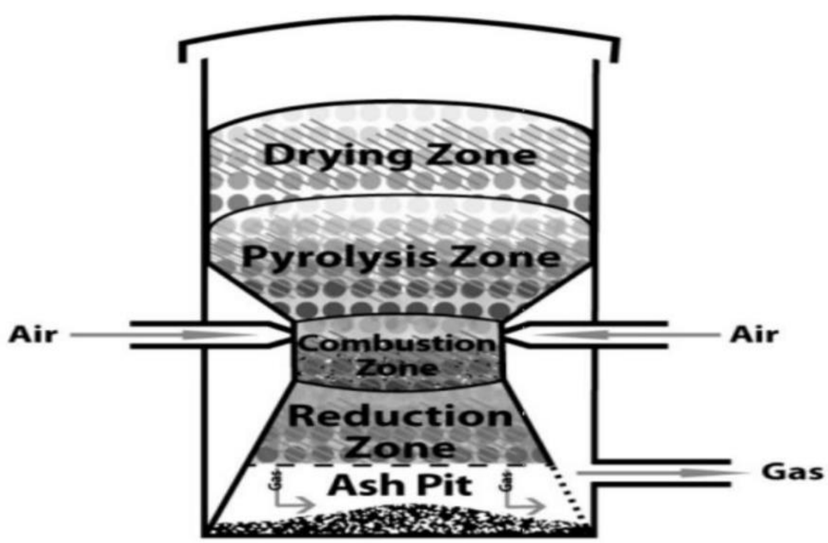


Figure 1.9 Downdraft gasifier

From the figure it is clear that rice husk is entered in the system from the top of the unit and the process progresses as it descends. The actions involved in the full process are drying, pyrolysis also known as de-volatilization and combustion also known as gasification. In the drying process the rice husk is dried at high temperature, which results steam. This steam is later mixed with gas flow and creates some water gas chemical reaction if the temperature is sufficiently high. Now the next step is pyrolysis, where cracking and burning of most of the primary tar (made of oxygenated organic compounds) content is done. It is also called flaming pyrolysis or de-volatilization. In this zone the temperature is around 200-300 degree Celsius and char is produced by burning process. The char is then forwarded to the combustion zone where it undergoes gasification reactions with steam produced in the drying process and air. The basic reactions which occur in the entire process are given below.

(a) $C + O_2 \leftrightarrow CO_2$ $\Delta H = -393.5$ kJ/mol
(b) $C + H_2O \leftrightarrow H_2 + CO$ $\Delta H = -131.3$ kJ/mol
(c) $CO + H_2O \leftrightarrow CO_2 + H_2$ $\Delta H = -41.1$ kJ/mol
(d) $4CO + 2H_2O \rightarrow CH_4 + 3CO_2$ $\Delta H = -520$ kJ/mol

While the char and volatile products reacts with air, Carbon dioxide and a small amount of Carbon monoxide is produced in reaction (a) and the reaction emits heat which helps the subsequent gasification reaction. Then again the Carbon from char and steam reacts and produces carbon monoxide and hydrogen. As this reaction (b) is a reversible one, after a certain time the amount of carbon, steam, carbon monoxide and hydrogen becomes equal and the reaction reaches equilibrium condition. Then a limited amount of air is introduced in the system which forwards the burning process and produces some more carbon which again restarts the reaction (b) and produces more carbon monoxide and energy. Then the reaction (c) takes place and produces hydrogen and carbon dioxide. Further reactions (d) produce methane and excess carbon dioxide from residual water and carbon monoxide. And this final reaction increases the resident time of the reactive gases and organic materials as well as heat and pressure (Bhavanam and Sastry, 2011). In the model (Fig 1.9) it is seen that below the combustion zone there is a reduction zone from where the gas is collected out of the gasification chamber. There is an ash pit where the ash of rice husk is accumulated and is ready for disposal.

Purification Unit

To make the purification system more environmental friendly here it is suggested to use the dry type purification unit. Commonly used gasification system uses a wet type purification unit which follows the method of direct washing. It washes the producer gas with direct water to get rid of particulates, tar etc. It works as the cooling system for the producer gas at the same time. This type of purification unit requires a large amount of water and it also pollutes water as water come direct contact with the gas. The tar mixes with the water and usually no precaution is taken to purify the water. Moreover, this water may be used repeatedly, so after a certain time it becomes completely contaminated. So an extra water purification system is necessary for this kind of units. As the water cools the gas, it becomes hot and it emits vapour which contains

PAHs (polycyclic Aromatic Hydrocarbons) and ammonia. Also this kind of systems does not have heat recovery option, so efficiency is less. To eliminate these barriers, this exclusive dry gas purification unit is introduced. This system excludes all the limitations of the wet type purification unit. It does not need any water to purify the gas, so no water pollution is present here also the gas processing happens in the chamber so there is no foul smell in the air of the plant area. No liquid tars, no evaporation of contaminated water with ammonia and other gases makes this system air as well as the environment pollution free. The maintenance needed of this type of purification system is minimum as there is no slug production is present and the efficiency is maximum as the heat from the producer gas is recoverable and it can be reused for drying the rice husk or heating the gasifier. This type of purification unit is more reliable as it allows a smooth operation of the turbine to generate electricity. Below is the specification of purified gas from the system.

Average CV > 1100 - 1200 kcal/Nm^3
Tar content < 5 - 10 mg/Nm^3
Particulates < 5 – 10 mg/Nm^3

The dusts are removed in dry format from the ESP, so dust processing is convenient. The ammonia removing process from gas is dissolution and it produces small amount of residue (condensate) to handle. From the residue ammonium salt can be recovered and can be used as good fertilizer (Nguyen and Ha-Duong, 2014). The process shows clearly the steps to purify the syngas received from the downdraft gasifier. The produced gas coming from the gasifier usually contains contaminants including dust, ash, coke, tar etc. The contaminants are removed from the gas by the purification system to ensure normal operation of the turbine in which it will be fed next.

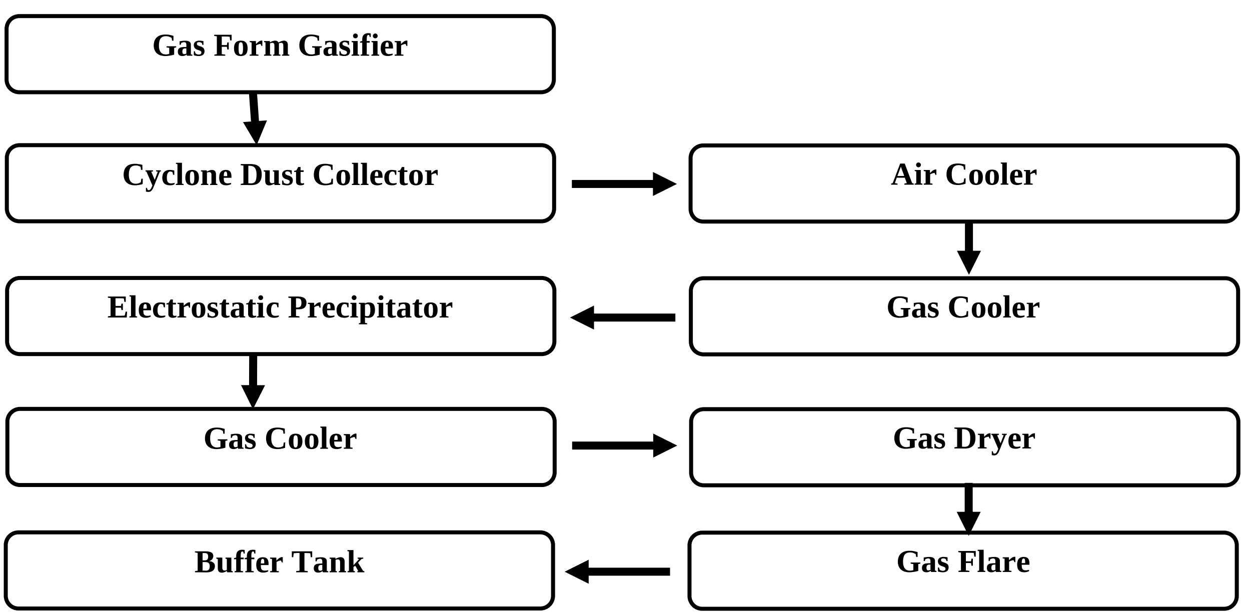


Figure 1.10 Block diagram of purification unit

Turbine and Generation Unit

This unit is the power generation section of the system. Here the syngas collected from the purification system is used to generate electricity. Here two types of turbines can be used: gas turbine or steam turbine. If steam turbine is to be used, it will require a boiler where water will be heated and made steam using syngas and the efficiency will not be so high. So here it is best to use gas turbines. The efficiency of gas turbine is far better than the previous process (Bohr and et al, 2014). Here in this process, the syngas is taken into the combustion chamber, mixed with air and then combusted. It produces flu gas, which is flown through the blades of the turbine. The turbine absorbs energy from the high pressurized hot gas and rotates. As a result, the gas becomes low pressure which will be exhausted. Now this exhausted gas will be passed through a chimney which includes a high featured filter and ejected into air. The turbine shaft is connected with a generator which generates electricity while the turbine rotates. The fig 1.11 below shows the diagram of electricity generation unit. In most of the implemented projects there is no focus on the exhaust system. Here it is suggested to use a smart exhaust filter system which will downsize the emission of CO2 and other component in the air.

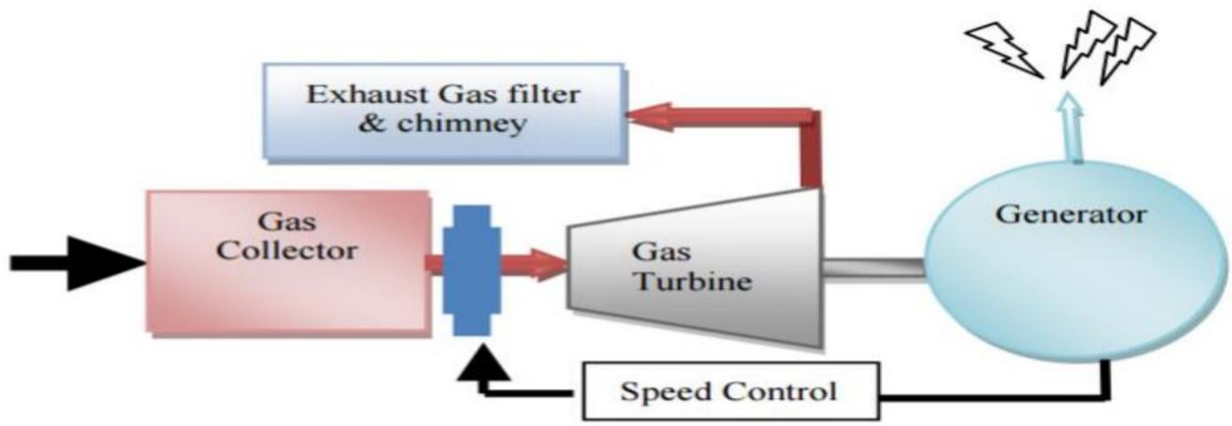


Figure 1.11 Generation unit

Conclusion

The conventional energy sources are decreasing day by day. So now it is high time we should take the renewable energy sources in action. Electricity generation from rice husk can be a better alternative of conventional energy sources in India. It is comparatively cheaper to install, easy to handle.

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