CHAPTER 5
STUDIES ON THE EFFLUENT TREATMENT FROM THE GASIFIER

5.1 Introduction

Trouble-free operation of an internal combustion engine using producer gas requires an acceptable low level of contaminants. Gas streams from biomass gasification contain very small carbon containing particles like tar mist, acids, hydrogen chloride, sulfur gases (very less amount), ammonia and nitrogen compounds, solid dust particles, alkali metals and heavy metals. It is very difficult to remove these impurities by common filters. In such a system the particulates can not be reduced to less than 5-30 g/Nm$^3$ [1]. The tar imposes serious constrain in the use of producer gas. This is caused due to occurrence of fouling at the downstream of the process equipment. This led to higher rate of wear and increase in maintenance cost.

The level of contamination depends on the gasification parameters i.e., pressure, temperature, and residence time etc., types and properties of the biomass, moisture content, particle size etc.; and lastly the type of the gasifier. By far, tar removal is the most complex one. Thus, for the successful implementation of gasification technology for internal combustion engine it is imperative to have an effective and efficient tar removal or conversion system to prevent corrosion and environmental hazards in equipment downstream of the system.

In the last few years, it has become clear that the tar plays an important – but negative – role in wastewater management. In a conventional water-based gas cleaning systems tar is dissolved in water and this leads to an extensive water treatment situation. The presence of tar in syngas causes the major obstacle in the smooth functioning in biomass gasification process.

Tar aerosols and deposits lead to more frequent maintenance and repair of especially gas cleaning equipment. This results in lower plant use factor. This leads to a decrease in revenues. Furthermore, the removal of tar from the process wastewater requires considerable investments for its machineries and that can even be dramatic as some tar components show poisoning behavior in biological wastewater systems (e.g. phenol).
Several measures for tar removal have been studied and the processes investigated. These measures are divided in two categories: (i) primary measures i.e., measures inside the gasifier, (ii) secondary measures i.e., measures in the downstream of the gasifier. Majority of our work for such a gasification system is mainly concentrated towards the primary control of the tar reduction. However, for a smooth functioning of a system it is imperative to have a close understanding and control of tar in the secondary process. Although tar reducing measures taken inside the gasifier may be fundamentally more ideal, but they are yet to reach a satisfactory solution. Some of the primary measures do result in low tar emissions, but suffer from disadvantages related to limits in feedstock flexibility and scale-up. In the process of tar removal the tar in the gaseous state when condensed by flowing water, the heat due to the tar content in the syngas is removed. This gives rise in outlet cooling water temperature. Thus these individual subsystems lead to a complex gasifier construction and results in higher cost. Although primary measures can reduce the tar content considerably, it is foreseen that complete removal is not feasible without applying secondary measures.

Secondary measures that have been investigated till now, exhibit similar deficiencies. The measures are either not effective enough or too expensive or the tar removal problem is shifted towards the treatment of wastewater. However, a secondary measure can be feasible without implementing primary measures. This becomes an important factor in case of wastewater treatment. A secondary measure should therefore form the basis for tar removal from syngas and primary measures could possibly be used for its optimization.

5.2 Solubility of tar

The solvent chosen depends on the components of the tar. Hopefully, the types of components likely to be present in the tar were determined before this analysis was initiated. The tar is a mixture of highly polar compounds consisting essentially of phenol and methoxy-type compounds and to a lesser extent polynuclear aromatic hydrocarbon. The more one knows about a sample (suspected components, boiling range and structures etc.) the easier it is to select the proper solvent and condition of various parameters like temperature, time etc. For an efficient removal, the solvent required should be similar in chemical structure to the components of the tar. Basically tar is a mixture of higher
hydrocarbons whose molecular weight is greater than benzene (boiling point 80.1°C) [2]. Thus tar can be effectively dissolved in hydrocarbon solvent. The polar compounds can be dissolved in polar solvents like phenols; and saturated hydrocarbons (non-polar) act as non-polar solvent.

Water is known to be a polar solvent and very commonly utilized and it functions effectively. Some experiments were also conducted by dissolving synthetic tar in various organic solvents to study its solubility characteristics in these solvents. Table 5.1 presented different types of solvent and the percentage of tar dissolve in that particular solvent.

Table 5.1: Solubility characteristics of tar in different solvents

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Solubility (wt. %)</th>
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<tbody>
<tr>
<td>Benzene</td>
<td>59.19</td>
</tr>
<tr>
<td>Chloroform</td>
<td>65.30</td>
</tr>
<tr>
<td>Methanol</td>
<td>53.00</td>
</tr>
<tr>
<td>Anisole (Methyl Benzene)</td>
<td>36.86</td>
</tr>
<tr>
<td>Glacial acetic acid</td>
<td>41.18</td>
</tr>
<tr>
<td>Petroleum ether</td>
<td>10.06</td>
</tr>
<tr>
<td>NN-Dimethyl formamide</td>
<td>30.00</td>
</tr>
<tr>
<td>Acetone</td>
<td>07.13</td>
</tr>
<tr>
<td>o- Xylene</td>
<td>47.00</td>
</tr>
<tr>
<td>p- Xylene</td>
<td>08.17</td>
</tr>
<tr>
<td>Methanol, NN-Dimethyl formamide, Benzene in1:1:1</td>
<td>72.50</td>
</tr>
<tr>
<td>Kerosene</td>
<td>45.21</td>
</tr>
<tr>
<td>Diesel</td>
<td>31.88</td>
</tr>
</tbody>
</table>
From the Table 5.1 it is seen that the maximum solubility (72.5%) of tar is in the mixture of equal amount of methanol, NN-dimethyl formamide and benzene [3]. These solvents are of higher cost and thus lead to a non-economical solution. Thus a mixture of less costly items was formulated. The solubility of tar in the new solvents was studied in details. From the Figure 5.1 it is seen that the solubility of tar in 4:1 :: kerosene: benzene mixture is more effective than that of 4:1 :: diesel: benzene mixture.

![Graph showing solubility of tar in different solvents](image)

**Figure 5.1: Weight of precipitated tar in different solvents.**

### 5.3 Design of a filter

Much has been written and assumed about the effectiveness and performance of tar removing filters. But these systems cannot be substantiated for biomass based systems. This is probably the least developed aspect of the entire system. There is no long term or large scale operating experience of tar removing filters. A careful evaluation is required
for effective use of these filters and also to understand the consequences of failure of such devices.

To remove the tar and particulates from the syngas after gasification of wood, rice husk as well as gas from the immature paddy, it generally requires special type of filtering system as mentioned earlier. With this in mind a filter has been conceived and designed for effective removal of tar. The filter contained a series of metallic jet placed in a concentric manner in a cylindrical vessel. The gas with tar and particulates are allowed to enter through the bottom of the system. The solution of proposed combination of kerosene and benzene was allowed to sprinkle from the jets. The gas with tar and particulates interacts with the mixture of kerosene, benzene and ultimately deposits at the bottom of the vessel. The basic elements of the filter are shown schematically in Figure 5.2. The liquid was then filtered and allowed to spread over the jet repeatedly.

By this arrangement a major part of the tar and particulates has been removed. This type of filtering arrangement suits quite well in the rice husk gasifier system.

5.4 Waste water treatment

During water scrubbing, the gasifier plant discharges large quantities of acidic water as effluent with high chemical oxygen demand (COD), high total solids, total dissolved solids (TDS), total suspended solids (TSS), and turbidity and therefore this causes environmental hazards. Sometimes the plant discharges the water repeatedly over a localized area where the released water stagnates and emits an off-odor. The characteristic off-odor develops in the stagnant wastewater due to fermentative change [4] and the water discharged from the plants showed a relatively higher population of total aerobic bacteria, staphylococci, lactic acid bacteria and yeast than the other

![Figure 5.2: Schematic diagram of a tar filter.](image)
methods. It exhibited a smaller microbial population and showed higher concentrations of sugar, amino nitrogen and total phenolic compounds, and hence higher chemical oxygen demand [5]. However, the wastewater from various gasifier plants has been investigated but its treatment process has not been explored. The steps used in treating raw water flowing out of a gasifier for the safe and desirable reuse may vary widely in different gasifier plants. This is due to the wide variation of raw water and various filtering techniques. The different steps for the treatment of wastewater containing large amounts of impurities are in seriatim.

5.4.1 Aeration

The first step for water purification is aeration. The raw water discharged from the gasifier unit is first sent to an aeration tank where large quantities of air are injected into and bubble through the raw water in which COD (chemical oxygen demand) is reduced to a certain level. The color of the water changes from tan to black. Aeration improves the taste and odor and oxidizes soluble iron.

5.4.2 Flash mixing

The next step after aeration is flash mixing. One or more chemicals are mixed into the raw water to neutralize or reduce specific impurities found in this raw water. The types and amount of chemicals added depend on the type and concentrations of impurities found in the raw water. This raw water and chemicals are mixed by agitation in flash mixing chamber to allow instantaneous mixing. A pinch of alum is added to clear the cloudy, sediment-laden water and activated charcoal is added to sweeten, soften and purify the water and also removes unpleasant odor. It also increases the pH levels of water. However, the time required to settle down the impurities is at least 12 hours. The relatively clear water is then decanted into another water storage tank.

5.4.3 Filtration

The final step in the purification process is filtration through rapid sand filters. These filters consist of four different beds; graded gravel is positioned at the top, next a layer of activated charcoal added with alum, and then sand and finally a layer of rice husk char. Filtration of the semi clear water through activated charcoal mixed with alum and also through sand removes fine suspended particles. This filtration process would clear and to
a large extent, purify the water. During filtration the impurities would be adsorbed and adhere to the surfaces of the sand particles. The sand particles acquire a sheath of floc. As a result, the filtering capacity of the columns reduces.

To reactivate this filter, it is cleaned by shutting off the flow of partially treated water and then forcing the purified water upwards through the sand bed, in a reverse flow direction. The water used for cleaning is then disposed of and the sand is allowed to settle down. The sand filter is then ready for reuse.

### 5.4.4 Additives

Additional chemicals may be mixed in the water before it leaves the water treatment plant. Liquid chlorine bleach is used to kill the harmful bacteria, yeast and viruses and reducing the pollution load. Eight drops of chlorine bleach per gallon of water is added and it is kept undisturbed for 30 minutes. Anhydrous ammonia is added shortly thereafter, producing chloramine. It is a compound produced by reacting free chlorine with ammonia, and is used for residual disinfections.

Chloraminated water then enters large secondary settling basins, allowing additional settling time for suspended particles and the process disinfections is completed. The major advantages of chloramine are:

(i) To provide a more stable and persistent disinfectant throughout the water distribution system.

(ii) To help in reducing the levels of disinfections by-products such as trihalomethanes in the water and

(iii) To reduce the chlorine taste and odor in treated water.
The flow diagram for the wastewater treatment is given in the following Figure.

Figure 5.4: Different stages of waste water purification.

**5.5 Conclusion**

The solubility of tar in different solvents is studied. It has been observed that kerosene and benzene mixture (at a volume ratio of 4:1) is the most effective solvent to dissolve the tar. A filter is designed for effective removal of tar. This type of filter is very much suitable for rice husk gasifier system. Moreover, the mixture is also quite cost effective.

Different methods for the treatment of affluent that is generated during gas cleaning by water scrubbing method is of utter importance. The suggested treatment system involves aeration, flash mixing, filtration and disinfection. The effectiveness of the system increases with the rate and duration of aeration. A pinch of alum clears cloudy, sediment-laden water. Activated charcoal purifies the wastewater and along with that removes the unpleasant odor. Chloramine helps in disinfection.
References


