

# A Study on Leaching Potential of Bio-gasification Tar in Water

Hemantajeet Medhi<sup>1</sup>, M Ronghang<sup>2</sup>, B Chakrabarty<sup>3</sup> and A K Baruwa<sup>4</sup>

<sup>1</sup> Department of Chemical Engineering, Bineswar Brahma Engineering College, Kokrajhar, Assam 783370, India

<sup>2</sup> Department of Civil Engineering, Bineswar Brahma Engineering College, Kokrajhar, Assam 783370, India

<sup>3</sup> Department of Chemical Engineering, Assam Engineering College, Guwahati, Assam 781013, India

<sup>4</sup> NETES Institute of Technology & Science, Mirza, Assam 781125, India

E-mail: jeethemanta.medhi12@gmail.com

**Abstract.** Non-conventional energy sources based on biomass gasification for production of producer gas is a promising technique. However, the presence of unacceptable levels of bio-gasification tar waste puts the limit of its use. Although investigations are being carried out to study avenues for controlling the amount of tar produced during biomass gasification, the complete removal of this waste still remains a big challenge. Problems are severe when the waste comes to contact with water body leading to the leaching of components (pollutants) from tar into the environment. In this paper, we are reporting the study that has been carried out to investigate and evaluate the leaching properties of bio-gasification tar in water as a function of concentration levels, temperature and pH levels of the solvents.

## 1. Introduction

Development of non-conventional energy sources based on biomass gasification has the potential in fulfilling the requirement of modern world energy demands up to a large extent. Generated producer gas through biomass gasification has shown the potential to be used as an energy source. However, the by products, bio-gasification tar that come along with the production of producer gas have handling difficulties making the process unsuitable in commercializing the producer gas. There exist several ways to remove bio-gasification tar from the producer gas that mainly includes physical processes like filters, scrubbers, wet electrostatic precipitators and cooling tower, chemical processes like thermal cracking, catalytic cracking and catalytic reforming [1, 2, 3]. In a gasification system, bio-gasification tar draws the special attention which disposal is usually cumbersome and expensive. The amount of bio-gasification tar yield varies from 1 to 20% of the feed of biomass [4]. It mainly consists of water-soluble phenol and naphthalene that can easily pollute the water body on contact [5]. Moreover, the presence of carcinogenic compounds has to be treated properly before disposal fulfilling the health and environmental demands [6]. In recent years, there has been an increased focus on environmental issues. As all the industrial wastes eventually are dumped into the water bodies via drainage or direct dumping, there is a chance of bio-gasification tar come contact with water leading to the leaching of components (pollutants) from tar into the environment. This prompted us to study the leaching



behavior of bio-gasification tar in water at different concentration levels, at different working temperatures and at the solvents made of different pH levels.

## 2. Methodology

In the present investigation, bio-gasification tar from the rice husk based gasification unit is utilized for the evaluation of leaching property of it. The bio-gasification tar is collected from the Ankur make gasification system at NEBISCO industries Pvt. Ltd., situated in Tezpur, Assam, India that produces biscuits for consumption in the local market. In this study, the leaching property of bio-gasification tar in double distilled water (ddH<sub>2</sub>O) is measured. The electrical conductivity of the leached water is measured with the help of electrical conductivity (EC) meter at different interval of time at different experimental conditions. These experimental conditions are discussed below-

### 2.1. Weight of bio-gasification tar is varied

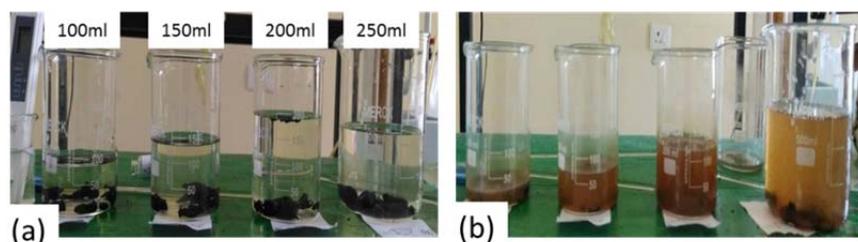
We take 1g, 2g, 3g, and 5g of bio-gasification tar (see figure 1 for the photograph) and 200 ml of double distilled water in beaker A, B, C & D respectively.



**Figure 1.** The weight of bio-gasification tar is varied. 1g, 2g, 3g, and 5g of bio-gasification tar is added in separate beakers A, B, C, and D respectively that contain 200 ml of ddH<sub>2</sub>O each.

### 2.2. Volume of distilled water is varied

In this given set of experiment, 100 ml, 150 ml, 200 ml and 250 ml of ddH<sub>2</sub>O is used in different beakers namely A, B, C and D as shown in figure 2(a), in which 5g of bio-gasification tar is added separately to each of them. We allowed the leaching process to continue until the EC reading of the beaker solutions saturates, leading to a stage similar to the one as shown in figure 2(b).



**Figure 2.** Leaching study of bio-gasification tar: 5g tar is added to each of the beakers containing ddH<sub>2</sub>O, of the volume of 100ml, 150ml, 200ml and 250ml respectively. (a) At the beginning, no leaching (b) leached, after 44hrs (see text).

### 2.3. Temperature of distilled water is varied

We pour 300 ml of double distilled water in each beaker and place each beaker on the hot plate of the magnetic stirrer, switch on the stirrer and adjust each beaker to a different starting temperature set at 40°C for beaker A, 50°C for beaker B, 45°C for beaker C & 55°C for beaker D. We take 5g of bio-gasification tar each for all the beakers for leaching. Experimental observations for the mentioned experiments are shown in figure 4, which is also explained in section 3.

### 2.4. pH of distilled water is varied

We place 6 beakers orderly manner and label them as A, B, C, D, E & F. In each beaker we pour 300 ml of distilled water. The pH in beaker A, B & C is maintained at pH 4, pH 5 & pH 6 by adding HCl

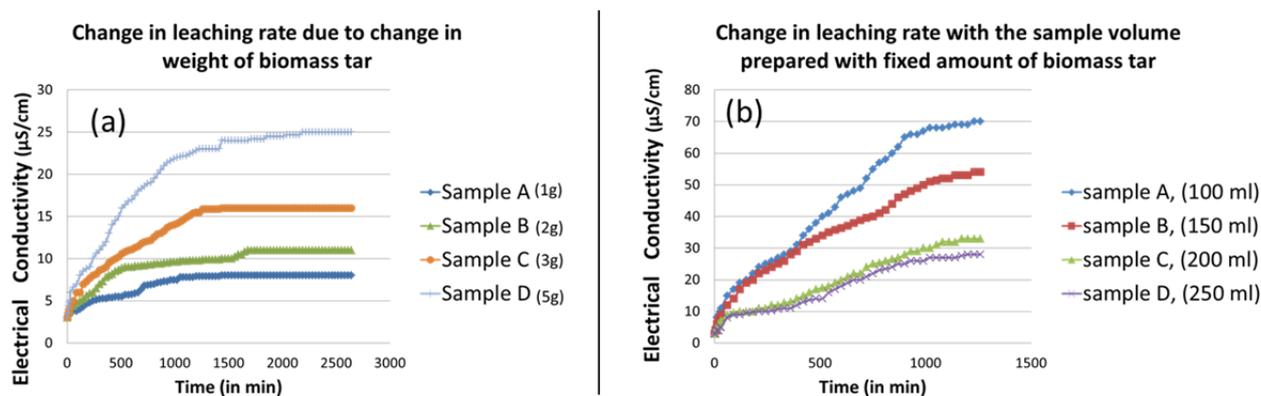
respectively. Similarly, the pH in beaker D, E & F is maintained pH 9, pH 10 & pH 11 by adding NaOH respectively. After setting the pH levels, 3g each of bio-gasification tar is added to the specified beakers for leaching.

### 3. Results & Discussion

Leaching rate at a particular experimental condition can be obtained with the help of the electrical conductivity (EC) measurements. To achieve this, for a given set of experiment, EC data (in  $\mu\text{S}/\text{cm}$ ) obtained at different time interval is plotted against time (in min), which are shown in figures 3-5. Calculated slope of a curve represents the leaching rate of that experiment. In another hand, biological oxygen demand (BOD) & chemical oxygen demand (COD) measurements of bio-gasification tar in distilled water are also carried out to determine its pollution in water at the District Level Water Testing Laboratory, Kokrajhar, Assam, India, which is tabulated in Table 1 and Table 2.

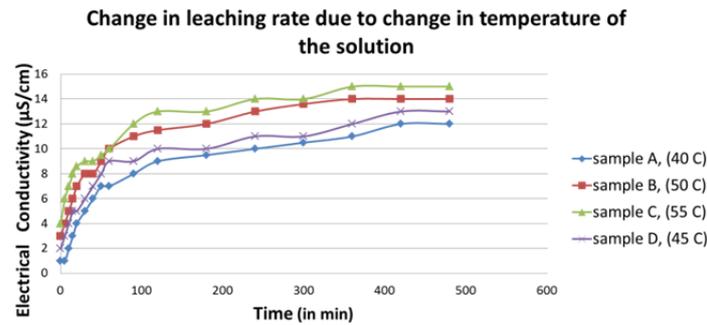
Experimentally measured EC data is plotted against time for measuring the leaching rate when the weight of bio-gasification tar is varied is shown in figure 3(a). It is clearly seen that the slope (hence the leaching rate) is high for the sample 5g, (represented as D, in figure 3(a)). Measured leaching rates from the graphs are  $0.00499 \text{ g}/\text{cm}^2\cdot\text{min}$  for 1g,  $0.00678 \text{ g}/\text{cm}^2\cdot\text{min}$  for 2g,  $0.01277 \text{ g}/\text{cm}^2\cdot\text{min}$  for 3g and  $0.02045 \text{ g}/\text{cm}^2\cdot\text{min}$  for 5g respectively.

In a different experimental setup as mentioned in section 2.2, the volume of ddH<sub>2</sub>O is varied (100 ml, 150 ml, 200 ml and 250 ml) keeping the weight of bio-gasification tar fixed at 5g for each of the samples. For obvious reason due to the high concentration of leached tar EC measurement is high for the sample prepared with 100ml. Measured leaching rates from the graphs of figure 3(b) are  $0.077 \text{ g}/\text{cm}^2\cdot\text{min}$  for 100ml,  $0.0618 \text{ g}/\text{cm}^2\cdot\text{min}$  for 150ml,  $0.02757 \text{ g}/\text{cm}^2\cdot\text{min}$  for 200ml and  $0.02665 \text{ g}/\text{cm}^2\cdot\text{min}$  for 250ml of solution respectively.



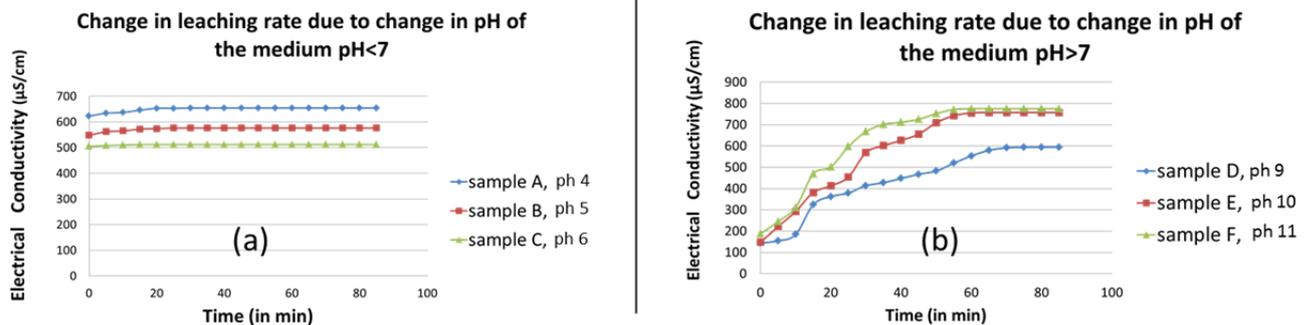
**Figure 3.** Graph representing change in EC (equivalently leaching rate) due to change in (a) weight of biomass tar vs. time and (b) volume of sample solution at fixed amount of biomass tar (5g) vs. time.

We repeat the experiments for the samples (5g biomass tar and 300ml of ddH<sub>2</sub>O) prepared at different temperatures, which has been discussed in section 2.3 in details. Experimentally measured electrical conductivity is plotted against time (see figure 4). Experimentally measured leaching rates of biomass tar calculated from the slopes of the plots are  $0.0483 \text{ g}/\text{cm}^2\cdot\text{min}$  for sample A at  $40^{\circ}\text{C}$ ,  $0.0548 \text{ g}/\text{cm}^2\cdot\text{min}$  for sample B at  $50^{\circ}\text{C}$ ,  $0.0574 \text{ g}/\text{cm}^2\cdot\text{min}$  for sample C at  $55^{\circ}\text{C}$  and  $0.05206 \text{ g}/\text{cm}^2\cdot\text{min}$  for sample D at  $45^{\circ}\text{C}$  respectively. In this case, sample kept at higher temperature ( $55^{\circ}\text{C}$ ) has high leaching rate.



**Figure 4.** Graph representing change in EC (equivalently leaching rate) due to change in temperature of sample solution (four samples of 5g biomass tar + 300ml of ddH<sub>2</sub>O each) vs. time.

In the final set of experiment pH of the ddH<sub>2</sub>O is changed which has been discussed already in section 2.4. When HCl is added, pH goes down making it acidic for which experimentally measured electrical conductivity with respect to time is shown in figure 5(a). Whereas for the case of NaOH addition to ddH<sub>2</sub>O (base solution), corresponding “EC vs Time” measurements for different pH levels are shown in figure 5(b). As before, from the EC vs Time graphs, leaching rate is calculated. Considering the experiments corresponds to pH values of 4, 5 and 6, the measured leaching rates of biomass tar are 0.8065 g/cm<sup>2</sup>.min, 0.648 g/cm<sup>2</sup>.min and 0.1594 g/cm<sup>2</sup>.min respectively. In case of experiments corresponds to pH value of 9, 10 and 11 obtained leaching rate of biomass tar are 16.15 g/cm<sup>2</sup>.min, 14.661 g/cm<sup>2</sup>.min and 9.37 g/cm<sup>2</sup>.min respectively.



**Figure 5.** Graph representing change in EC (equivalently leaching rate) due to change in pH of sample solution vs. time (a) when pH<7 (b) when pH>7.

From the BOD and COD collected data of the experimental samples, it is found that their values are at the peak on the 2<sup>nd</sup> day, that starts decreasing from 3<sup>rd</sup> day onwards vanishing on the 4<sup>th</sup> day.

**Table 1.** Biological oxygen demand (BOD) measurements for the sample of section 2.3

| Sl. no. | sample      | Temperature (°C) | Day 1 | Day 2 | Day3 | Day4 | Day 5 |
|---------|-------------|------------------|-------|-------|------|------|-------|
| 1.      | A (initial) | 40               | 1     | 4     | 1    | F    | F     |
| 2.      | A (final)   | 40               | 110   | 350   | 120  | F    | F     |
| 3.      | B (initial) | 50               | 1     | 4     | 1    | F    | F     |
| 4.      | B (final)   | 50               | 110   | 320   | 110  | F    | F     |
| 5.      | C (initial) | 55               | 1     | 4     | 1    | F    | F     |
| 6.      | C (final)   | 55               | 100   | 400   | 200  | F    | F     |
| 7.      | D (initial) | 45               | 1     | 4     | 1    | F    | F     |
| 8.      | D (final)   | 45               | 100   | 200   | 100  | F    | F     |

**Table 2.** Chemical oxygen demand (COD) measurements for the sample of section 2.3.

| Sl. no. | sample      | Temperature ( <sup>0</sup> C) | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |
|---------|-------------|-------------------------------|-------|-------|-------|-------|-------|
| 1.      | A (initial) | 40                            | 0.8   | 3.2   | 0.8   | F     | F     |
| 2.      | A (final)   | 40                            | 88    | 280   | 96    | F     | F     |
| 3.      | B (initial) | 50                            | 0.8   | 3.2   | 0.8   | F     | F     |
| 4.      | B (final)   | 50                            | 88    | 256   | 88    | F     | F     |
| 5.      | C (initial) | 55                            | 0.8   | 3.2   | 0.8   | F     | F     |
| 6.      | C (final)   | 55                            | 80    | 320   | 160   | F     | F     |
| 7.      | D (initial) | 45                            | 0.8   | 3.2   | 0.8   | F     | F     |
| 8.      | D (final)   | 45                            | 80    | 160   | 80    | F     | F     |

Note: F represents a value which cannot be measured by the instrument.

#### 4. Conclusions

The leaching behaviors (rates) of bio-gasification tar are experimentally measured for different experimental conditions. In which, the concentration of bio-gasification tar, the temperature of the medium, pH-level of the used medium are varied. The studies have shown the leaching rate of bio-gasification tar is proportional to the temperature and also increase with the decrease in pH-levels, which has been verified with the experiments conducted with ddH<sub>2</sub>O as a medium. For the used experimental conditions pH= 3 and T=55<sup>0</sup>C, it is observed that the contamination rate is very rapid that exceeds the permissible level of BOD and COD suggesting not to dump such byproducts directly into the environment. Favorable conditions for higher leaching rate of bio-gasification tar can easily pollute the environment affecting the livings including humans. Therefore, it is necessary to have thorough investigations of tar before dumping it into the environment.

#### 5. References

- [1] Stassen H.E.M., Prins W., Swaaij W.P.M., 2002 Thermal conversion of biomass into secondary products; the case of gasification and pyrolysis *12<sup>th</sup> European Biomass Conference, 17-21 June*, (Amsterdam:, The Netherlands) p 38-44
- [2] Milne T.A., Evans R.J. 1998 Biomass Gasifier Tars: Their Nature, Formation and Conversion *NREL/TP-570-25357*
- [3] Vivanpatarakij S., Assabumrungrat S., 2013 Thermodynamic analysis of combined unit of biomass gasifier and tar steam reformer for hydrogen production and tar removal *International Journal of Hydrogen Energy* 38, 3930- 3936
- [4] Stevans D.J., 2001 Hot gas conditioning: Recent Progress with large scale biomass gasification systems, update and summary of recent progress, National renewable energy laboratory, report NREL/SR-510-29952, August
- [5] Milne T.A., Evans, R.J. 1997 Developments in thermochemical biomass conversion, chemistry of tar formation and maturation in the thermochemical conversion of biomass. Blackie Academic and Professional
- [6] Bhler R., Nussbaumer T., Hasler P., 1997 Evaluation of gas cleaning technologies for small scale biomass gasifiers. Swiss Federal office of Energy and Swiss Federal Office for Education and Science, August