Potential Application of Macrophytes Used in Phytoremediation

S. Dipu, Anju A. Kumar and V. Salom Gnana Thanga

Department of Environmental Sciences, University of Kerala, Kerala, India

Abstract: Phytoremediation is a technology designed to remove contaminants from wastewater employing ecological processes found in natural wetland ecosystems. The plants used for phytoremediation concentrate the pollutants in their biomass. For the removal of these pollutants from the plants, we had to reduce the size of the biomass. Biogasification was done to test for potential use and disposal of plants after treatment, which was observed as an added advantage. In the present study, five different concentrations of slurry were used for biogas production. These macrophytes were initially used for the phytoremediation process. We used wetland macrophytes like Typha sp., Eichhornia sp., Salvinia sp., Lemna sp., Azolla sp. and Pistia sp for the present study. Plant based biogas production, low in the initial days but increased with time. So a steady gas production can be obtained by mixing the cow dung slurry with plant biomass. Cow dung was used as the inoculum for the present study. The gas production by plant biomass is more than that of the traditional cow dung slurry in most of the treatments.

Key words: Constructed wetland · Biogasification · Cow dung · Biomass · Macrophytes

INTRODUCTION

Phytoremediation has gained considerable acceptance over the years and its place in the environmental technology market is steadily growing [1]. Despite its relatively slow rate of action and limitations related to environmental conditions necessary for plant growth, it is considered a low cost, environmentally sound technology that could in certain cases replace current engineering practices. A better understanding of soil properties and of physiochemical factors influencing the solubility of toxic compounds will likely allow the improvement of on-site plant performances in the future [2].

A major environmental concern due to dispersal of industrial and urban wastes generated by human activities is the contamination of soil. Controlled and uncontrolled disposal of waste, accidental and process spillage, mining and smelting of metalliferous ores, sewage sludge application to agricultural soils are responsible for the migration of contaminants into non-contaminated sites as dust or leachate and contribute towards contamination of our ecosystem. A wide range of inorganic and organic compounds cause contamination, these include heavy metals, combustible and putriscible substances, hazardous wastes, explosives and petroleum products. Major component of inorganic contaminates are heavy metals they present a different problem than organic contaminants.

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. In principle, all organic materials can ferment or digested. However, only homogenous and liquid substrates can be considered for simple biogas plants. The maximum of gas-production from a given amount of raw material depends on the type of substrate. Biogas is a mixture of gases that is composed chiefly of methane- 40 to 70 per cent volume; carbon dioxide- 30 to 60 per cent volume; hydrogen- 0 to 1 per cent volume; hydrogen sulfide- 0 to 3 per cent volume.

Biomass disposal problem and seasonal growth of aquatic macrophytes are some limitations in the transfer of phytoremediation technology from the laboratory to the field. However, the disposed biomass of macrophytes may be used for various fruitful applications [3]. Biomass is nothing but stored solar energy in plant mass; it is also termed as materials having combustible organic matter. The main constituents of any biomass material are lignin, hemicellulose, cellulose, mineral matter and ash. It possesses high moisture and volatile matter constituents, low bulk density and high calorific value.

Corresponding Author: Dr. S. Dipu, Senior Research Fellow, Department of Environmental Sciences, University of Kerala, Kariavattom Campus, Thiruvananthapuram, Kerala, India, Pin 695581. Tel: +919947142297, E-mail: dpsekn@yahoo.co.in.
Biogas production using anaerobic (oxygen free) digestion is a biological treatment process to reduce odor, produce energy and improve the storage and handling characteristics of manure. A biogas production system must be specially designed and requires regular attention by someone familiar with the needs and operation of the digester. The use of methane gas plants as a source of fuel and fertilizer is a practice only recently introduced in this century. Future experiments should concentrate on development of combustion system and methods to recycle different metals from ash. The process destroys organic matter, releasing metals as oxides. The major factors affecting biogas production was temperature, pH, volatile fatty acids, inoculum-substrate ratio, effect of microbial population etc [4-7]. Chanakya et al. [8] and Singhal and Rai [9] studied the biogas production using water hyacinth and attained promising results. Considering the other technologies for disposal this method is environment-friendly.

MATERIALS AND METHODS

Experimental Setup: In the present study, the plants used for phytoremediation were used for biogas production. The plants were cut into small pieces and macerated using distilled water. The cow dung slurry was used as inoculum. The treatments are the following. Five different concentrations of slurry were used for biogas production. In treatment one, 100 per cent cow dung slurry was used as the control. In treatment two, 75 per cent cow dung and 25 per cent plant slurry was used. In treatment three, cow dung and plant slurry were used in equal proportion i.e. 50 per cent each. In treatment four, 75 per cent plant slurry and 25 per cent cow dung slurry were used. In treatment five, 100 per cent plant slurry was used for gas production. The treatments were maintained in triplicates. The experiment was done in saline bottles, which were made airtight using rubber cork to ensure anaerobic condition. The slurry after biogas production was dried and powdered.

Estimation of Biogas: The amount of gas produced was measured from 24th hour by observing the volume of water displaced in inverted measuring cylinder containing water. The gas produced was measured in mL water displaced per 300 mL of plant slurry or cow dung slurry. The volume of methane gas produced is also calculated.

Statistical Analysis: For testing significant mean difference in different dilution with respect to different plants analysis of variance (ANOVA) was carried out. ANOVA showed significant difference in 100 per cent plant combinations. So Duncan’s multiple range tests were carried out for pair wise comparison.

RESULTS

Gas Production in Typha Sp. Based Slurry: The cow dung slurry showed a maximum of 60 mL of gas production on the fourth day of treatment and showed a decreasing trend towards the 9th day (5 mL). In 25 per cent Typha sp. slurry the maximum gas production was on 4th (50 mL) day, which decreased to 30 mL in the 6th day and further increased to 45 mL on the 7th day and again decreased to 5 mL on the 9th day. In 50 per cent Typha sp. slurry, gas production was maximum (50 mL) at 7th day and minimum at 9th day (20 mL). 75 per cent Typha sp. slurry showed a maximum of 45 mL gas production in 7th and 8th day and a minimum of 20 in the 4th day. When Typha sp. slurry was alone (100 per cent) used for gas production, the maximum (65 mL) on the 7th day and minimum at 5th day of treatment.

Gas Production in Pistia Sp. Based Slurry: In 25 per cent Pistia sp. based slurry, the maximum gas production was on 4th day (40mL) and decreased to 5mL on the 9th day. In 50 per cent Pistia sp. slurry, maximum (35mL) was on 4th and 7th day and minimum gas production was observed on 9th day (20 mL). 75 per cent Pistia sp. slurry showed a maximum gas production of 45 mL in 7th and a minimum of 20 mL on the 5th day. When the Pistia sp. slurry was used alone for gas production, the maximum gas production (50 mL) was observed on the 7th day and minimum (25 mL) at 5th day of treatment.

Gas Production in Eichhornia Sp. Based Slurry: In 25 per cent Eichhornia sp. slurry, the maximum gas production (35mL) was at 5th day and decreased to 10 mL in the 9th day. In 50 per cent Eichhornia sp. slurry, maximum (45 mL) was on 7th day and minimum on 5th and 9th day (20 mL). 75per cent Pistia sp. slurry showed a maximum of 45 mL on 7th and a minimum of 20 mL on 5th day. When the Eichhornia sp. slurry was used alone for gas production, the maximum value (40mL) was observed in the 8th day and minimum of 20 mL at 5th day.

Gas Production in Salvinia Sp. Based Slurry: In 25 per cent Salvinia sp. slurry the maximum gas production was on 4th (40 mL) day, which decreased to 5 mL on the 9th day. In 50 per cent Salvinia sp. slurry, maximum gas production was observed at 4th day and minimum at 9th day (10 mL). 75 per cent Salvinia sp. slurry showed a maximum of 20 mL in 6th and 7th day and a minimum of 5 mL in the 9th day. When Salvinia sp. slurry was used without
Gas Production in Azolla Sp. Based Slurry: In 75 per cent cow dung slurry i.e. 25 per cent Azolla sp. slurry, the maximum gas production (40 mL) was on the 4th day, which decreased to 10 mL on the 9th day. In 50 per cent Azolla sp. slurry, maximum (50 mL) gas production was on the 7th day and minimum on the 5th day (20 mL). 75 per cent Azolla sp. slurry showed a maximum of 45 mL on the 7th day and a minimum of 10 mL in the 4th day. When Azolla sp. slurry was used without the cow dung slurry i.e. 100 per cent Azolla sp., the maximum value (45 mL) was on the 8th day and minimum of 5 mL on the 4th day.

Gas Production in Lemna Sp. Based Slurry: Here also cow dung slurry (100 per cent) showed the same pattern as that of the above. 25 per cent Lemna sp. slurry showed a maximum of 40 mL on the 4th day and a minimum of 15 mL on the 9th day. In 50 per cent Lemna sp. slurry, maximum (40 mL) gas production was observed on the 7th day and minimum on the 5th day (20 mL). 75 per cent Lemna sp. slurry showed a maximum of 45 mL on the 7th day and a minimum of 15 mL on the 4th and 5th day. When Lemna sp. slurry was used without the cow dung slurry i.e. 100 per cent Lemna sp., there was an increasing trend from 5 to 45 mL from 4th to 8th day, which however decreased to 35 mL on the 9th day.

The total gas produced from different plant species in different combination with cow dung were shown in Table 1 and the percentage of methane gas in the total gas were shown in Table 2.

### DISCUSSION

It is essential to ensure safe disposal of plants used for phytoremediation. Several strategies have been reported earlier and in the present study, the plants were subjected to gas production under anaerobic condition. One of the principal objectives of anaerobic treatment of biomass is to reduce the bulk and mass. Anaerobic biodegradation of organic material proceeds in the absence of oxygen and in the presence of anaerobic microorganisms. It results in two products: biogas and a digested organic matter. Methane is produced by a group of bacteria called methane formers in two different pathways: either by means of cleavage of acetic acid molecules to generate carbon dioxide and methane, or by reduction of carbon dioxide with hydrogen. Methane production is higher from reduction of carbon dioxide but limited hydrogen concentration in digester results in that the acetate reaction is the primary path for methane [10].

Biogas conversion process is microbiological in nature and is affected by several factors like, temperature, pH, volatile fatty acids, inoculum-substrate ratio, effect of microbial population etc. Temperature is one of the most common factor affecting methanogenesis processes in a biogas digester [5]. pH is known to affect enzymatic activity owing to the fact that only a specific and a narrow pH range are often suitable for the maximum activity. A pH range between 6.7 and 7.4 is reported suitable for functioning of most methanogenic bacteria [7]. The long chain fatty acids were found to be inhibitory to the several kinds of essential reactions in the anaerobic digestion because of their toxicity to the bacteria [4]. Fernandez et al. [6] reported that the inoculum-substrate...
ratio variation had less impact on anaerobic degradability than on specific methane productivity and the microbial communities of biogas processes could respond quickly to changes in the feeding rate.

The total gas production from the cow dung slurry was 195 mL for six days i.e. from 4th day to 9th day. When 100 per cent Typha sp. slurry was used, the over all production of biogas was more than (205 mL) that of the cow dung slurry. The gas production in the 100 per cent Typha sp. based slurry was slow than other treatments. This may due to the time taken to degrade the biomass. It produced maximum gas in the seventh day. However, in the case of cow dung slurry, the production of biogas was high in the initial days and decreased as the day progressed. Chanakya et al. [8] evaluated the solid phase fermentation process to overcome problems in conventional slurry based reactors. Their experiment demonstrated the feasibility of solid waste conversion of biomass to biogas. The gas production in 75 per cent, 50 per cent and 25 per cent Typha sp. slurry was less than that of the 100 per cent cow dung slurry.

When 100 per cent Pistia sp. slurry was used, the over all production of biogas was more (205 mL) than that of the cow dung slurry. The gas production in the 100 per cent Pistia sp. based slurry had taken more than the cow dung slurry in gas production and this may due to the time taken to degrade the biomass [11]. It produced maximum gas in the seventh day. But in the case of cow dung slurry, the production of biogas was high in the initial days and decreased as the day progressed. The ultimate methane yields from aquatic macrophytes showed that methane yields were higher in shoots than roots [12]. The gas production in 75 per cent, 50 per cent and 25 per cent Pistia sp. slurry was less than that of the 100 per cent cow dung slurry.

Biogas production from water hyacinth was equal to that of the cow dung slurry (195 mL). The maximum production of biogas was on the 8th day (40mL). Singhal and Rai [9] employed water hyacinth (Eichhornia crassipes) and channel grass (Vallisneria spiralis) separately for phytoremediation of lignin and metal-rich pulp and paper mill and highly acidic distillery effluents. Chanakya et al. [8] reported that water hyacinth had good methane content of above 60% and utilized water hyacinth for biogas production, which showed 1.64L, 1.63L gas production and the utilization efficiency 16.6 per cent, 21 per cent respectively. The gas production in 75 per cent, 50 per cent Eichhornia sp. slurry was little less (170 mL) than that of the 100 per cent cow dung slurry. Köttner [13] used biomass such as grass, maize, fodder beets and other energy crops for energy production through anaerobic digestion and obtained biogas, which had high amount of methane than the cow dung slurry.

In case of 100 per cent Salvinia sp. (Fig. 6.4) and Lemna sp. based slurry, the gas production was less than that of the cow dung slurry. But when they were used in combination with cow dung, the gas production was increased to acceptable rates. Vituria et al. [14] reported 0.5 L biogas yield by using the two-phase digestion of fruit wastes mixtures. In case of Azolla sp. based slurry, a fairly good yield of biogas was obtained in all the combinations. Verma et al. [7] in his study, reported potentials of water hyacinth (Eichhornia crassipes) and water chestnut (Trapa bispinosa) employed for phytoremediation of toxic metal rich brass and electroplatting industry effluent, in terms of biogas generation. In previous work on banana peel [15] very high levels of biogas were produced, which suggests that this banana peel is good feedstock.

Table 1 show the total gas production in different plant combinations with cow dung slurry as the control. The table shows that 1:1 combination with plants in Typha, Eichhornia and Azolla showed higher gas production than the control cow dung slurry. This may be due to the degradation of plant material in the last stages of the treatment and there by increased gas production in the final days of the treatment. In 3:1 combination also observed higher gas production in Typha and Eichhornia based slurry.

The dried and powdered slurry after biogas production can be used as bio-ore. Future experiments should concentrate on development of combustion system and methods to recycle different metals from ash. The process destroys organic matter, releasing metals as oxides. The liberated metals remain in the slag; modern flue gas cleaning technology assures effective capture of the metal containing dust. Considering the other technologies for disposal this method is environment-friendly, access this article More than the biogas production, the plant mainly used for this study Typha sp. has other important uses such as silky cattail floss in homes as pillows, bedding and stuffing for furniture. It can also be spun like cotton to produce furniture or textile fabric. Dry floss makes excellent tinder to start fires.

Cattail leaves make a good pulp for papermaking. The fibers in cattail stems can be used as a substitute for jute and those of the leaves can be used for textile. Woven cattails were used in the production of rush-bottomed chairs. The leaves can be woven into commonly used items: sandals, hats, fans, flyswatters, awnings, baskets, partitions in homes and roof thatching are some
examples of ways cattail leaves made everyday life better. Cattail silk is buoyant and water repellent as well as a good insulator. Cattail has been used in many medicinal ways. Ash from the leaves has been used as antiseptic and antibiotic for wounds [16]. Poultices made from the mashed root were applied to cuts, stings and burns. Native Americans used the sticky excretion found at the base of the plant as an antiseptic for small wounds and toothaches. When this biomass after gas production was burnt in a heating plant, the ash can separated into highly contaminated fly ash and the bottom ash, which could be reused as fertilizer [17].

Statistical analysis by Duncan’s multiple range tests showed significant difference between 100 per cent plant slurry of *Typha* sp. and *Pistia* sp. All the other pairs did not show significant variation.

The biogas production in cow dung slurry was high in the initial days of treatment. But in plants, the gas production was low in the initial days and increased as the time increases. So a steady gas production can be obtained by mixing the cow dung slurry with plant biomass. The gas production by plant biomass is more than that of the traditional cow dung slurry in most of the treatment plants. Using the spent biomass after bioremediation, for the production of biogas is an added advantage.

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