International Journal of Multidisciplinary Studies and Innovative Technologies

Volume : 1
Number: 1
Year: 2017
Pages: 21 - 23

Evaluation of Recovery of Aquatic Plants Used in Wastewater Treatment and Discharged as Waste†

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Abstract – In this study, the evaluation of the recovery of aquatic plants used in wastewater treatment and discharged as waste is discussed. There are studies in the literature about the removal of pollutants from wastewaters by using different treatment methods in wastewater treatment. Many treatment methods are used in wastewater treatment as biological processes, chemical treatment, membrane systems and so on. However, such treatment methods are not preferred because of high energy costs and high operating costs, which cannot be applied to all kinds of water bodies. Therefore, natural treatment systems, which do not require much human power, can be applied to almost any kind of water mass with low operating costs and energy costs, can be used for the disposal of pollutants. In natural treatment systems, treatment with aquatic plants is generally used. Because, treatment with aquatic plants are quite economical when compared with other advanced treatment methods. Harvested plants can be evaluated in biogas production and bioethanol production as an alternative fuel. In addition, harvested aquatic plants can be used in biopetrol and biochar production by subjecting to pyrolysis treatment, thus recovering of the discharged wastes can be ensured.

Keywords – Aquatic plant, treatment, waste, recovery

I. INTRODUCTION

Constructed wetland (CW) technology was developed in 1970s as an alternative ecological technology for wastewater treatment [1]. CW technology possess several advantages compared with conventional wastewater treatment plants, such as low investment, maintenance and operation cost, utilization of renewable energy sources (wind and solar energy), and tolerance over variation of wastewater volume and level [2], [3]. CWs have been applied for the treatment of industrial, municipal and aquaculture wastewaters, polluted surface water and groundwater, landfill leachate and storm water runoff [4-12] (Fig.1).

Fig.1. Aquatic plants in wastewater treatment

CWs can remove numerous types of pollutants [12], [13]. In CWs at the same time that pollutant removal from wastewater occurs, great quantities of biomass are produced which would be available for different uses. Proper methods of biomass disposal and/or utilization are required [14]. If they are not utilized immediately large amount of aquatic plant residues as biomass would decompose and decay. Then, this status can result in secondary pollution to water systems [15]. Different solutions have been proposed. Biomass can be transformed into raw material for the paper industry, fertilizers, compost or as a feed supplement for animals [16], [17]; and for fuel production [14].

II. DIFFERENT WAYS OF USING BIOMASS

Aquatic plants can be used for different purposes after harvesting. The uses include animal fodder, energy sector (i.e. biofuel, bioethanol, combustion), cellulosic derived bioproducts, construction of building materials and plant fiber/plastic composites, paper industry and biosourced biochemistry such as production of γ-valerolactone, Cu-ecocatalyst, potential fertilizers (compost, biochar, litter) [18-22].

The type of pollutants removed by the plants will be a crucial factor for the utilization of the biomass after harvest. In case of treating wastewater from animal farms, the plant biomass can be safely utilized as animal fodder. However, if hazardous pollutants are removed from the water and taken up by the plant, the biomass cannot be safely used as animal fodder, but only for bioenergy production [23].

† This is an extended version of a conference paper (ISMSIT2017).

Since the European Union has established the European Directive 2009/28/EC to increase the production of renewable energy sources and the biofuel proportion by at least 10% in each Member State by 2020 [24], processing of aquatic plants produced by phytotechnologies may be a suitable option [18], [22]. Aquatic plants provide a promising source of clean energy due to their high biomass yield and neutral CO_2 balance [14]. *Arundo donax* L. plant used in CWs displays many attractive characteristics for producing biomass [19]. It can be used for bioethanol production, direct combustion and other thermal transformations [22], [25-27]. Ciria et al. [14] studied the suitability of the macrophyte cattail (*Typha latifolia*) produced in a wetland as a fuel. *Typha latifolia* has high biomass yields (2·8 kg m^{-2} of dry matter, which is equivalent to 28 t ha^{-1} of dry matter). As a result, due to the high biomass yields obtained in the planted bed, and to the thermal behaviour of both cattail biomass and their ash (with a relatively high heating value of 19·6 MJ kg^{-1}), the utilization of cattail biomass as fuel in thermochemical conversion processes for the production of heat and/or electricity was recommended by Ciria et al. [14]. Pincam et al. [23] reported that Hybrid Napier grass (Pennisetum purpureum Schumach × *P. americanum* (L.) Leeke cv. Pakchong1) has the potential to be used in plant-based water treatment systems for removing contaminants from different types of polluted water while simultaneously producing qualified large amounts of plant biomass which has ease of propagation and harvesting for further utilization as e.g. bioenergy [23]. The plant has been considered as a suitable alternative lignocellulosic feedstock for biofuel production due to its high biomass production and high proportions of cellulose, hemicellulose, and lignin [28]. Hybrid Napier grass has been reported to produce 17.9 tons bioethanol $ha^{-1}year^{-1}$. Moreover, the biogas production potential is reported to be high, ranging from 0.24–0.27 m^3 CH_4kg^{-1} VS, depending on the digestive conditions and co-digestion materials [23], [28-30]. Jiang et al. [15] investigated the biogas production potential of aquatic plants. They reported the biogas yields of 7 species of aquatic plants as follows: *Typha orientalis Presl* 513.2 mL g^{-1} VS, *Hydrocotyle vulgaris* 539.1 mL g^{-1} VS, *Thalia dealbata* 578.0 mL g^{-1} VS, *Acorus calamus Linn* 508.9 mL g^{-1} VS, *Canna indica* 555.1 mL g^{-1} VS, *Colocasia tonoimo Nakai* 629.4 mL g^{-1} VS and *Pontederia cordata* 473.1 mL g^{-1} VS.

Harvested aquatic plants could be used for paper pulp production and construction of wooden build materials. Giant reed shoots could substitute hardwoods suitable in kraft pulp mills processing chain without major equipment changes [22], [31]. *Arundo donax* L. plant meets requirements for paper pulp production and construction of wooden build materials [19], [22], [32].

In CWs, *Arundo donax* L. plant removes contaminants such as trace elements mainly by immobilization in the rhizosphere and storage in the belowground biomass [33]. Based on this property, its use to rhizofiltrate Cu-contaminated effluents could provide both a belowground biomass with high Cu concentration. The Cu-rich belowground biomass may be used in biosourced (bio)chemistry as Cu-ecocatalyst [34]. Ecocatalysis is based on the plant ability to produce plant-borne metal species usable as key reactants to catalyze fine organic chemical reaction for the production of biorenewable transportation fuels, industrial chemicals and pharmaceuticals. Copper-based catalysts are promising candidates, as they are sustainable and cost-competitive catalyzers for the high yield production of next-generation biorefinery components [22], [35].

Composting is a natural way of recycling. It turns on organic materials into a farm resource enhancing soil fertility and soil quality that brings about increased agricultural productivity, improved soil biodiversity, reduced ecological risks and a better environment. Composting organic residues is a friendly to the environment alternative to producing fertilizer [36]. Therefore, harvested biomass of aquatic plants can be composted and then spreaded on farmland.

III. CONCLUSIONS

In the recent years, CWs have been gaining in popularity. Because CW technology is both a reduced cost technology and low maintenance technology for treating wastewater from different activities. Therefore, CW technology has been successfully applied to the treatment of various wastewaters (domestic, industrial, leachate, storm water runoff). After the wastewater treatment, large volumes of aquatic biomass are produced. The biomass harvested from the CWs can be used in different ways (paper pulp production, to get energy etc.). These routes of use will protect the natural resources.

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