Batch digestion of aquatic weeds in tropical countries

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Introduction

Sewage from most urban areas in tropical countries is discharged untreated in rivers and lakes. This leads to eutrofication. Fast growing aquatic weeds use the nutrients and form thick mats hindering fishing and navigation. Lake Victoria is a prime example. Biological control of the waterweeds is seen as one method to reduce the problems, but does not address the root cause of eutrofication. Controlling of one type of waterweed will give others the opportunity to become a pest. There are a number of instances where aquatic weeds are used as an organic fertilizer (Jandl 2010), but this practice is not wide spread. This may be due to a lack of understanding of its value as fertilizer or to the amount of manpower required to collect, transport and apply aquatic weeds.

Harvesting of aquatic weeds is expensive. Antunuassi et al. (2002) calculate a cost of 15 000 €/ha or 0.15 €/kg VS. Veitch et al. (2007) suggest significant cost reductions using outboard motor powered launches with a rake and a land based backhoe.

Backhoes with a rake as they are used to clean ditches in the Netherlands mounted on a barge will be quite efficient.

Anaerobic digestion produces a biofuel for cooking and use in stationary engines, while retaining the fertilizer value in the digestate. The process is promoted on the basis of animal manure in India, China and south-east Asia. There are only a few instances where aquqtic weeds are used on a regular basis. (Luzira prison Kampala, Uganda; Lindsay et al. 2000; and at the Songai agricultural training centre in Porto Novo Benin; Jandl 2011)

Aquatic weeds are bulky. Loading large quantities of aquatic weeds into a “closed” digester requires a lot of manpower.

My proposal is to digest whole aquatic weed plants in a batch mode in foil lined basins. The basins are covered after loading is completed.

Tests with chopped water hyacinth

Anaerobic digestion of whole plants is not common. There are a number of tests with chopped (0.01 - 0.06 m) water hyacinth available in the literature.

Table I Properties of water hyacinth used in tests

Author	VS/TS	C/N ratio
Wolverton 1975		17
Vaidyanathan et al. 1985	0.75	29
Moorhead et al. 1992	0.85	13
Almoustapha et al. 2008	0.70	
Ofoefule et al. 2009	0.40	18

Table II Test conditions

Author	T °C	VS Kg/m³	seed	Test duration d	Gas yield l/kg VS
Wolverton 1975	25		Information not available	125	350
Vaidyanathan et al. 1985	29	30	Digested Water hyacinth	90	440
Moorhead et al. 1992	35	5	Swine manure	60	120
Oosterkamp 2002		10	Compost		
Almoustapha et al. 2008	30 - 40	10	Fresh rumen residue	65	460
Almoustapha et al. 2008	20 - 30	10	Fresh rumen residue	95	370
Ofoefule et al. 2009	25 – 35	20	Information not available	30	32

The original publication of Wolverton is not available. Gas yields are high for the experiments of Wolverton, Vaidyanathan et al, and Almoustapha et al. Swine manure is not well suited as a seed for water hyacinth digestion and this explains the low yield of Moorhead et al. (1992). Duration of the tests by Ofoefule et al. is low.

Moorhead et al. (1993) have done tests with ground (1.6 mm) water hyacinth and chopped water hyacinth (12.6 mm), resulting in a 15 % lower gas yield for the chopped water hyacinth. The results for the digestion of whole plants will be also lower than for ground water hyacinth. Longer digestion times will compensate for this.

The data on anaerobic digestion of chopped water hyacinth suggest that around 4 m^3 methane per m^3 digester volume and batch can be obtained. There is no data available what happens when water hyacinth plants are stacked to five meters high. My expectation is that around 10 m^3 methane per m^3 digester volume and batch is possible.

Storage possibilities

Rijsenbeek (2011) suggest that in some countries aquatic weeds can only be harvested during a few month per year. The weeds have to be stored in order to have gas production during the whole year.

Open air storage near riverbank

Experience in Bangladesh indicates that open air storage is not viable as the plants are aerobically and an-aerobically digested during the dry season and the plants disappear after a few months.

Foil covered storage near riverbank

Foil coverage will create an anaerobic atmosphere. This will retard the digestion. Part of the water hyacinth will become juice and will be lost as a feed to a biogas plant if it is allowed to run off into the river.

Foil covered storage after drying

Drying of the water hyacinth requires space and extra manpower. This may be a viable option if space and manpower are available. Drying will result in some loss of volatile solids and nitrogen. The VS/TS ratio goes from 0.38 to .30. The C/N ratio increases from 18 to 28 (Ofoefule et al. 2009). Dried water hyacinth from Bangladesh has a C/N ratio of 50 and needs supplemental nitrogen.

Wet storage in basins and anaerobic filter

Wet storage in foil lined basins does preserve volatile solids and nitrogen. Available sugars will turn into acids and prevent further decay. A large volume is required. The density of volatile solids is estimated at 10 kg/m^3. Part of the water hyacinth plants will not be submerged as the plants have large air pockets and are designed to float. Wolverton (1979) describes a system for the rapid digestion of water hyacinth. Juice is pumped from the storage basin to a gravel filter seeded with a bacterial solution from an ongoing anaerobic digester. The filtrate is recycled to the storage basin. The methane yield was 200 l/kg TS (about 220 l/kg VS) in 30 days.

Semi dry storage and anaerobic filter

Aquatic weeds can be stored in foil lined and covered basins with little extra water. The density of the volatile solids can be higher than during wet storage. Part of the water hyacinth will become juice and can be processed similar to the wet storage. Water can be added during the year in order to treat most of the aquatic weeds.

Storage and digestion

The semi dry storage can be simplified by seeding the lower part of the basins. After digestion the remaining digestate will occupy a smaller volume than the plants and new material will come into contact with the seeded fluid. During the year water can be added, so as to digest most of the plants.

Semi dry storage with anaerobic filter seems to me the most practical option. Gas production can be kept constant during the year by varying the flow through the filter.

Storage and digestion in the same basin is simpler but gas production can only be regulated by the liquid level in the basin. Some extra diesel fuel is necessary to keep the generator at the required capacity.

The gas production of whole aquatic weed plants in batches needs to be confirmed. The same holds for the density of volatile solids in stacks of 7 meters high of aquatic weeds.

Ghana

Jandl (2010) proposed biogas from aquatic weeds for cooking and fuelling a 25 kW generator in a village of 600 inhabitants. He estimates that about 22 000 m^3/a (12 000 m^3/ methane) is required. The ratio between annual methane production and storage volume is estimated at 10 and a storage volume of 1 200 m^3 is necessary. This is three times more than the digester suggested by Jandl. Total project investment costs will be 10% higher using basin type storage with a depth of 3.5 m, a height of 3.5 m and a width of 7 m and length around 20 m. Manpower requirements are 30 % lower. There are a number of variations possible, depending on the local conditions (transporting 1 m by 1 m pieces, drying for a week, one week collecting, next week loading, the use of discarded banan trees in the off season).

Jandl (2010) reports, that a water treatment plant, using water hyacinth, in Tema was abandoned due to bad smell. This project could be revived by installing an anaerobic filter before the water is discharged into the basins.

Benin

The Songaï project in Porto Novo is set up as an agricultural training centre and works according to the “Zero emission research initiative”. Here a test could be done on the batch digestion of whole aquatic weed plants, as they already digest ground water hyacinth. A bag digester could be filled to 30% with diluted cow dung or fresh rumen residue as the existing plant works at 55 °C. The whole should be filled with water hyacinth dried for a few days, if space for drying is available. The resulting biogas needs to be pressurized to 0.23 bar by a pump.

Bangladesh

In the period 1999 – 2002 some digestion test on water hyacinth were performed by the author (Oosterkamp 2002). Following these tests two brick digesters were built. After some time they were abandoned due to excessive gas leakage. Plastic water tanks are cost effective (100 €/m^3). Bag digesters cost only 35 €/m^3, but these can not easily be filled with water hyacinth. Ravindranath et al. 1997 estimates that a family of six requires around 500 m^3 per year of biogas. In Bangladesh four batches per year are possible and about 12 m^3 of digester volume are required. I propose that a test is made with one 5 m^3 water tank. Filled at first with 30 % diluted cow dung and then completely filled with water hyacinth dried for one week. The water tank is sealed except for one connection to a gas storage system, consisting of a 0.5 m^3 water tank in a 1 m^3 water tank. Gas production can be measured at various intervals using the gas storage system. It may be necessary to add nitrogen in order to have a high gas yield. Completely dried water hyacinth from Bangladesh had only a C/N ratio of 50.

A first test could be done using an existing 3.5 m³ brick digester after repair. Up to 2009 this digester was regularly filled with cow dung. The easiest is to fill this digester with fresh water hyacinth and observe the gas production.

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