water quality and bio energy : the case of sugar cane industries

(sugar cane mill and distillery).

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Summary

Sugar cane industries comprise sugar cane mill and distillery. In sugar mill, the production of one tonne of sugar releases about 50 cubic metres (m^3) of wastewater and 5 tonnes of solid wastes constituted by trash crops and bagasse. From the production of one cubic metre of alcohol the quantity of solid wastes is situated between 5 and 9 tonnes while the volume of slop is positioned in the interval between 10 and 15 m^3.

In these factories, significant progress is made to address their wastes produced. Liquid or solid wastes are often used to generate energy, returned to land in various forms as soil fertiliser or used as input for other product.

However, it is important to note that the proper disposal of sugar cane factories effluent, is not totally resolved and continuous to represent the biggest environmental problem. This situation grows at the same rhythm like the development of sugar cane production.

Decentralised wastewater treatment plant based on new scheme remains the key for liquid waste disposal. The new scheme aims to convert effluent into energy. According to the estimation, power generated from wastewater is more important than the one of solid waste.

Introduction

Sugar cane industries constituted by sugar cane mill and distillery, have made considerable progress in managing and utilizing their wastes produced. Liquid or solid wastes are often used to generate energy, returned to land in various forms as soil fertiliser or used as input for other product.

However, it is important to note that the proper disposal of sugar cane factories effluent, is not totally resolved and continuous to represent the biggest environmental problem. This situation grows at the same rhythm like the development of sugar cane production.

Water quality and bio energy will be the key to help sugar cane industries to meet the two most important challenges facing these factories, which are the protection of environment and the enhancement of the productive capacities and competitiveness.

The goal of this report are to: (i) define the use of water in sugar cane factories, (ii) determine the production of wastewater, (iii) to identify and characterise the effluents, (iv) the questions of liquid waste disposal in developing countries where most of the sugar cane grown, (v) define technical option which will be available for wastewater of sugar cane industries. This part focusing principally on wastewater treatment and reuse, aims to determine how to optimise bio energy production from liquid waste. (vi) compare the amount of energy produced by effluent and the one generated by solid wastes like bagasse and trash. Crops.

In order to support this analysis, many information sources are used. The cost effectiveness to improve water quality and to produce energy is not debate here. Sampling and measuring effluent from sugar industries are not conducted.

1. **the use of water in factory,**

The industry is one of the biggest users of water. Water is mainly used for the cooling of the machines, for feeding the boiler, in the various operation of manufacture, in the operations of cleanings of the devices and shops. Sugar cane mill consume huge volume of water evaluated to 200 m^3 for each tonne of sugar**[14]** . It is reported that only 1/10 of consumed water is lost in steam or enter in product manufactured while the remainder (9/10) are rejected after use **[2]**.

2. **wastewaters from sugar cane industries**

According to the type of factories, the characteristics of industrial wastewater are very variable. They also defer so much the domestic pollution by their concentration in the dismissals than the nature of the pollutants.
Several parameters are used to determine the level of wastewater pollution. Generally one uses the organic matters content as element of pollution comparison. This pollution can be expressed in equivalent inhabitant, permitting the approximate comparison thus between the industrial pollution and the domestic pollution. The organic load of wastewater can be expressed in chemical oxygen demand (COD) or in biochemical oxygen demand (BOD) or generally in BOD_5.

In industrial manufacture of sugar cane, wastewater are situated at several levels:

At the level of the cooling system:
This case is more observed in distillery. Here, the volumes of water are more important. The pollution is in thermal order. The growth of the temperature of wastewater rejected depends for a same circuit of manufacture, of the system of water circulation. In distillery the heated water is cooled by the natural air. On the other hand with the thermal machines of electricity production in sugar cane mill, the overheating of environment is made following a ratio of 10 or even 100. the pollution is not only thermal but sometimes chemical in fact to the addition of products in the water in order to avoid the deposits in the heat exchanger.

At the level of the boiler :
In order to avoid the deposits in the circuits of vaporization water is demineralised. On the other hand the waters of purge constituting the dismissals thus have a weak volume and contain some mineral and chemical elements.

A**t the level of washing:**
The waters of washing or transportation of the garbage are by nature of the important pollution sources. In fact their function is to drag various substances of which one wants to get rid. They always contain suspended solids (SS). In the case of these industries the pollutions are biodegradable and are estimated in organic load term (BOD, COD)**[2]**. Sugar cane stalks are generally washed, pesticide may present in sugar cane rinse liquid.

At the level of the product:
Water is called " waters of process ". they participate in the chemical reactions under manufacture or are incorporated in the product. Wastewater comes from the leakages and to the draining of the vats.

In sugar cane mill, wastewater is also constituted by the mud of juice clarification (250 kg by tonne of cane) and by the froths at the time of filtration (30 to 50 kg by tonne of cane)**[4]**. It is estimated that the volume of wastewater is 50 cubic meter (m3) by ton of sugar produced**[1]**. Its main sources of liquid waste are milling plant, weighing scales, boiler blowdown, lime plant, clarifier, filters, evaporator, storage tanks, equipment washwater, major spills, machine shop, sanitary convenience.

Table N°1: Wastewater characteristics of sugar cane factory

Parameter	unit	Values		
		maximum	mean	minimum
BOD5	Mg/l	15 000	5 400	2 000
Suspended solids (SS)	Mg/l	2 580	831	176
ph		11.4	6.2	4.7
temperature	Deg °.C	53	36	24
Total alkalinity	Mg/l	5.6	315	174

Source: Emru D. Millette – March 1991 – Industrial wastewater monitoring at a cane sugar factory – magazine of the UNEP Industry and Environment Vol. 14 No. 1 page 30-34

From the table N°1 above, in sugar cane mill Concentrated effluent typically contain SS in the range 831 mg/l (milligram per litre) , biochemical oxygen demand (BOD) in the range15,000 mg/l.

In distillery, the molasses, by-product of sugar cane mill, is used to produce rums and industrial alcohols. The garbage liquid from the manufacture of alcohol are largely constituted by the vinessa. The residual solution, vinessa, is variously called stillage or slops and contains 5 to 10% of dry matter. With one tonne of molasses 300 litres of pure alcohol (240 kg) and 3800 litres of vinessa can be achieved. With one ton of cane juice the production is on the other hand 70 litres of pure alcohol and 910 litres of vinessa**[4]**. The vinessa gets a very high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) compared with domestic waste, for which values average 250-1000 COD and 120-400 BOD. In comparison, the spent wash from an Indian distillery has a COD of 70,000-98,000 and BOD of 35,000-45,000 , the slops from a Caribbean rum distillery had a COD of 75,000-112,000 and BOD of 27,000-36,000**[6]**.

3. the question of wastewater disposal

In developing countries where most of sugar is presently grown**[11]**, the sugar cane industries are not connected to the municipal sewage network**[8] [12]**. Therefore, owing to the nature of liquid waste from sugar cane industries without their own wastewater treatment plant, much of its quantity is dumped into rivers or used as fertilizer.
Sugar cane industries, following the example of agro-food industries, their wastes are mainly biodegradable and not toxic. Noxious substance content is very weak**[2] [12] [14] [15]**. Nevertheless, high concentred or spilled in great quantity, they become harmful to environment.
The use of slops as fertilizer for sugar cane field has been quite successful. However, it is noted that the exclusive use of slops as fertilizer in poorer soils may result in a yearly deficit of 10.2 kg phosphorus **[3]**.
In rivers, owing to its high organic load, raw or insufficiently treated wastewater from sugar cane industries overload water resource with more organic material. The consequence is to affect the capacity of the aquatic environment to dilute and assimilate wastewater-borne pollutants. So it can affect animals respiration. Some form of treatment is necessary to prevent oxygen depletion of receiving water.
Natural decomposition of the organic matter gives off CO_2 and CH_4 belonging to the greenhouses gas. So, spreading raw or insufficiently treated effluent from sugar cane industries can contribute to increase greenhouses gas.

However concern for the environment is a growing international phenomenon and is becoming a feature of international trade pattern a key to accessing foreign markets and funding. So environmental legislation and regulation is the broader picture of sustainable development and consumption. This view is shared and sustained by international opinions (E U, USA , Canada, financial institutions like World Bank and IMF, and international labour pressures. For example the E U is a leading player in developing environmental law, and the governments of the USA and the Canada have had significant influence in international development**[10]**.

Cleaner production approaches can be very good for business as they focus the attention on maximising output, minimising wasted resources of any kind, and recycling and reusing all by-product. Technology change is only one aspect of this approach and cause better managed if it is part of a voluntary programme than if it is dictated by legislation.

In order to protect environment and to save water resource, many actions can be undertaken such as environmental policies framework, and the minimisation of pollution.
The goal of environmental policies framework is to reduce environmental degradation at the lowest possible costs. A wide range of potential mechanisms and individual instruments are applied to improve environmental quality. In the field of water pollution, market-based instruments mainly used are pollution charge, waste fees and levies, eco-labeling…etc. In many countries, when sugar cane factories is allowed to connect to the municipal sewage network or to dump their liquid waste into river or other surface water , pre-treatment may be required or wastewater discharge fees are imposed by the municipality on effluent volume, on suspended solid and BOD loads[1]. The debate about environmental policies framework is not the purpose of this paper.
Concerning the minimisation of water pollution by reducing liquid waste in sugar cane factories two ways can be operated.
In upstream, it is important to adopt technology aimed to minimize liquid waste production. The upgrading of processing technology aims not only to decrease wastewater discharges of BOD and volume of effluent but leads in term to reduce costs production and to save resource, without forgetting its effects on the costs to repair damage and polluted sites. This position is not the purpose of this paper.
In downstream, effluent is treated advantageously with regard to environment. The requirement imposed to sugar cane industries to pre-treat their effluent, the wastewater discharge fees and the optimisation of production by reusing all by-products may encourage sugar cane factories to install their own treatment plant. The type of decentralised wastewater treatment plant proposed here, combines the treatment of effluent with energy generation from liquid waste. The next paragraph focuses about the scheme which leads to treat and reuse effluent. The last paragraph give a comparison between the energy generated from wastewater and the one produced from solid waste like bagasse and trash.

4. Wastewaters treatment

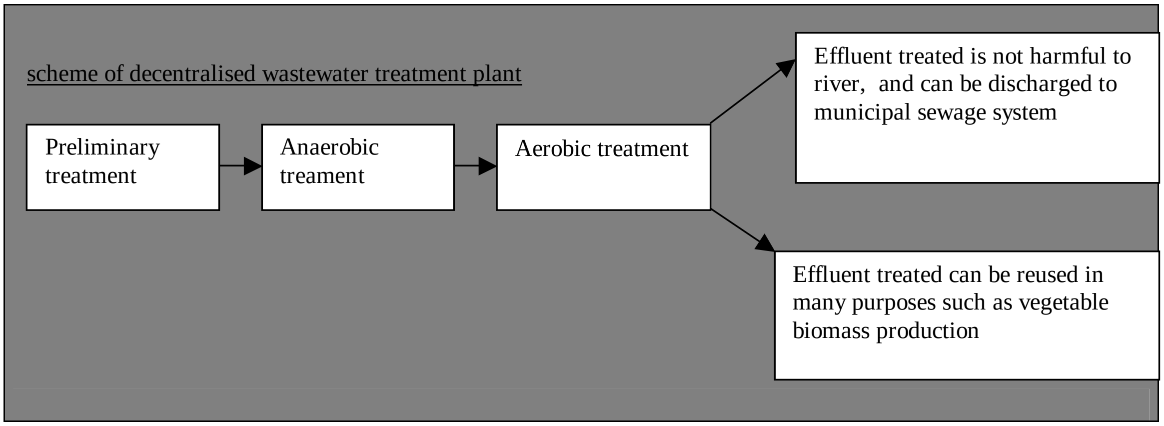
liquid waste from sugar cane industries is a valuable resource for biogas production owing to its characteristics described above. The table below illustrates the results about the experiences done for this purpose.

Table N° 2: results of experience about biogas production from effluent of sugar cane factories

Type of substrates	*Temperature (°C)*	*Loading rate volatile solids kg/m3/day*	*Retention time days*	*Gas yield per kg of COD m3/kg*
sugar-refining waste	**35**	**1.5**	**5.1**	**0.76**
Molasses stillage	**35**			**0.35**
	37	**2.2**	**10**	**0.12**
		5.4	**4.1**	**0.04**
		7.5	**3**	**0.02**
Rum Distillery waste	**35**	**10.4**	**12_ 15**	**0.28_ 0.29**
		8.8	**8_10**	**0.27_0.29**

[1] For example in Brazil one of countries biggest sugar producer, the state of Sao Paulo is responsible for more than 60% of the production of sugar cane, sugar and ethanol **[9]**. In this state where majority of the sugar cane sector equipment manufacturers are located, industrial sewage tariff based on pollution content is partially implemented since 1981 for cost recovery of sewage treatment station **[17]**.

Fermentation of wastewater from sugar factories integrated in system of sewage treatment is well developed. However, conventional wastewater treatment plant widely used in developing countries is different with an anaerobic system of liquid waste treatment.
A scheme of decentralised wastewater treatment plant is presented below:



The approach to reduce water pollution is :

- to know wastewater characteristics such as flow, physical, chemical and biological parameters;
- to define the objective to treat and reuse water effluent;
- to define the reduction necessary;
- to develop option for reduction.

Wastewater characteristics is developed above. The objective to treat or reuse effluent is to discharge to surface water effluent without no damage to environment, to discharge to municipal sewage system or to reuse for irrigation.

The new scheme comprises a series of steps notably preliminary treatment, anaerobic treatment, aerobic treatment and the destination of wastewater treated by decentralised wastewater treatment plant.
The goal of preliminary treatment is to adjust ph, and temperature after flow equalization and to remove large and heavy solids by collecting ,screening and degritting. In anaerobic treatment where effluent is fermented, about 85 percent of suspended solids and BOD/COD are removed. At this level the digester widely used is called UASB (Upflow Anaerobic Sludge Blanket) reactor which is applied successfully in municipal and industrial sector. With aerobic treatment, organic loads continues to decrease, nutrients like nitrogen and phosphorus are removed. Aerobic treatment system is generally constituted by one or three oxidation ponds.
After these treatment, wastewater is not harmful to environment and can be discharged to Municipal sewage system with lowest cost for industry, if the capacity exists, with the approval of relevant authority.
It is important to note that in the field of wastewater treatment, the first step is called primary treatment and the combination of anaerobic an aerobic treatment is known as secondary treatment.
An advanced or tertiary treatment can be applied to liquid waste disposal. Natural system for wastewater treatment such as constructed wetlands may be used for tertiary treatment. Constructed wetlands regarded as an emerging technology for industrial effluent are designed to treat wastewater by using emergent plant such as cattails (*Typha spp*), reeds (*Phragmites spp*) and rushes (*Juncus spp*). Natural system can provide a huge quantity of vegetable biomass which can be burned additionally for electricity generation in sugar cane mill at the same level like solid waste constituted by bagasse and cane trash.

5. comparison between energy generation from solid waste constituted by bagasse and trash (leaves and straw) and from effluent.

Sugar cane industries comprise the sugar cane mill and distillery. These factories produce a great deal of wastes in solid and liquid form. It was established that for each tonne of sugar cane stalks:

- between 250 and 300 kg of bagasse can be obtained, **[4] [9]**
- 140 kg of dry residues called cane trash can be recovered. Trash crop includes leaves and straws. With using green harvesting the potential of trash will be almost doubled**[9]**.
- Between 70 kg and 100 kg of sugar cane**[10]**

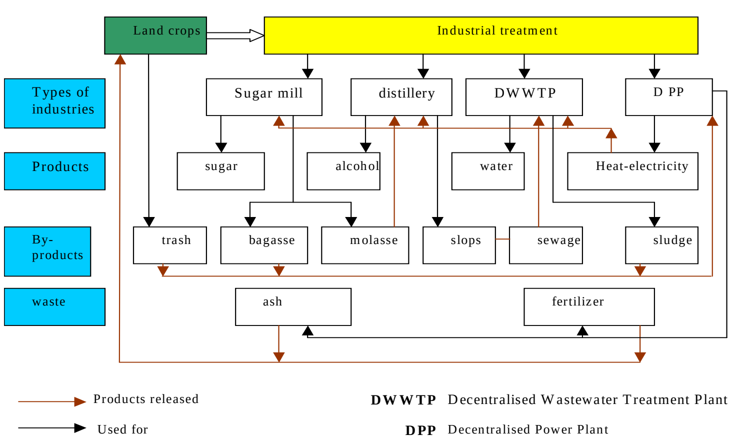
It is estimated that the volume of wastewater is 50 cubic meter (m^3) per ton of sugar produced**[1]**. With one tonne of cane juice, the production is 70 litres of pure alcohol and 910 litres of slops**[4]**.

Nowadays, in sugar cane factory, a large proportion of self generated energy is derived from the solid wastes constituted by cane trash and bagasse as by-product of production. Large amounts of energy are required for steam and electricity production to power mill processes. The energy generated during the burning of these residues is more the adequate to meet the energy demands of the factory, excess electricity is generally exported**[18] [9]**. In distillery, on other hand, the great majority of its energy is supplied by external power.
Liquid waste can be used advantageously to satisfy part or all of energy needed for any purposes. It is noted that anaerobic treatment of wastewater released by sugar cane factory can generate power, bio methane. The table below give a comparison between energy produced from solid waste and the one from the treatment of effluent. than bagasse from one tonne of sugar produced.

	Sugar Cane Mill		**Distillery**	
	Wastewater	**Solid wastes**	**Wastewater**	**Solid wastes**
Quantity of wastes released from one tonne of sugar produced	**50 m^3**	**5 tonnes**	**10 m^3 of slops**	**6 tonnes**
Treatment required	**anaerobic**	**no**	**anaerobic**	**no**
Type of fuel	**biogas**	**Bagasse and trash crops as fuel**	**biogas**	**Bagasse and trash crops as fuel**
Quantity of fuel from one tonne of sugar	**1543 m^3 of CH_4**	**5 tonnes**	**58,800 m^3 of CH_4**	**6 tonnes**
Calorifiques Value	**9122 Kcal/m3**	**2000 Kcal/kg**	**9122 Kcal/m3**	**2000 Kcal/kg**
Quantity of energy generated	**14,073,349 Kcal**	**10,000,000 Kcal**	**536,373,600 Kcal**	**11,264,285 Kcal**

Source : see annexe 1 & 2

In a conventional sugar cane mill, the production of one tonne of sugar releases about 50 m^3 of wastewater and 5 tonnes of solid wastes constituted by bagasse and cane trash. This volume of effluent treated can generate 1543 m^3 of methane (CH_4). From the table above , in sugar cane mill, energy produced from wastewater is superior than the one obtained from solid waste.
In distillery, with direct use of cane juice for alcohol production, the production of one cubic metre of alcohol cane provide 10 m^3 of slops and 6 tonnes of solid wastes. The digestion of its effluent can provide around 60 000 m^3 of methane. This power is more important than the one generated from solid waste.



A decentralised wastewater treatment based on scheme developed above allows us to present a new diagram for sugar cane industries.

From this diagram sugar cane factories provide products such as sugar, alcohol, heat/electricity . liquid waste is a valuable by-products like bagasse, molasses. Fly ash and other waste may be used as fertiliser to land crops. Power generated from liquid waste may be used to satisfy part of energy needed for any purpose. This case is advantageous to distillery where the great majority of its energy were supplied by external power.

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ANNEXE 1:
Energy Generation from Waste in Sugar Cane Mill

Energy generation from solid waste of tonne of sugar cane production

	Calculation	Unit	Values		
			Min,	**Med.**	**Max.**
Sugar cane yield production from 1 tonne of sugar cane stalk	**a**[4]	kg	70	90	100
Quantity of sugar cane stalk to produce 1 tonne of sugar cane	**b**= 1000/a	tonne	14..29	11.11	10
Bagasse production per tonne of sugar cane stalks	**c**[4] [18]	kg	250	275	300
Weigh of bagasse from 1 tonne of sugar cane production	**d**= (c b)/1000	tonne	3.57	3.06	3.00
Cane trash production per tonne of sugar cane stalks	**e**[4] [18]	kg	100	140	300
Weigh of cane trash from 1 tonne of sugar cane production	**f**= (eb)/1000	tonne	1.43	1.56	3.00
Quantity of solid waste to produce 1 tonne of sugar cane	**g**= f+d	tonne	5.0015	4.61065	6
Calorific value of solid waste from sugar cane production	**h[**[4] [3]	Kcal/kg	1500	1800	2000
Energy generation from solid waste of tonne of sugar cane production	**i** = hg1000	Kcal	7 502 250	8 299 170	12 000 000

ENERGY GENERATION FROM WASTEWATER OF 1 TONNE OF SUGAR PRODUCTION

	Calculation	Unity	Values		
			Min.	Med.	Max.
Biogas production depending on concentration of COD	**a**[5] [1]	l/kg	240	300	330
Methane content	**b**[5]	% CH4	70	80	85
Organic load of wastewater (concentration of COD)	**c**[2] [12]	mg/l	50 000	75 000	110 000
Gas production	**d** = (ac)/1000	l/m^3	12 000	22 500	36 300
Methane production from 1 cubic metre ($m^{3)}$ of wastewater	**e** = (bd)/100	l/m^3	8 400	18 000	30 855
Volume of wastewater from one tonne of sugar cane	**f**[1]	m^3	40	45	50
Methane generation from wastewater of 1 t of sugar produced	**g** = (ef)/1000	m^3	336	810	1542,75
calorific value of methane	h[3]	kj/m^3	20900	31350	38131
	h/4,18	$kcal/m^3$	5000	7500	9122
total energy	I = hg	Kcal	**1 680 000**	**6 075 000**	**14 073 349**

ANNEXE 2:
Energy Generation from Waste in Distillery

Energy Generation from solid waste of 1 m^3 of alcohol production

	Calculation	Unity	Min	Med	Max
Alcohol yield production from 1 tonne of sugar cane	**a**[4] [18]	litre	70	70	80
Quantity of sugar cane to produce 1m3 of Alcohol	**b**= 1000/a	tonne	14,.9	14.29	15
Bagasse production per tonne of sugar cane stalks	**c**[4] [18]	kg	250	275	300
Weight of bagasse from 1 m3 of alcohol production	**d**= (bc)/1000	tonne	3.57	3.93	4.5
Cane trash production per tonne of sugar cane stalks	**e**[9]	kg		140	300
Weight of trash crops from 1 m3 of alcohol production	**f**= (be)/1000	tonne	0	2	4,5
Quantity of solid wastes to produce 1m3 of Alcohol	**g**=d+ f	tonne	3.57	5.93	9
Calorifique value of solid waste	**h**[4] [3]	Kcal/kg	2000	2000	2000
Energy Generation from solid waste of 1 m3 of alcohol production	**i**=(gh)1000	Kcal	7, 142, 857	11 ,857, 143	18, 000, 000

ENERGY PRODUCTION FROM LIQUID WASTE OF 1M^3 ALCOHOL PRODUCTION

			Values		
		Unity	Min.	Med.	Max.
Production of slops from 1m^3 of alcohol	a[4] [3]	m^3	10	12	15
Organic load of slops(concentration of COD)	b[6] [12]	mg/l	50 000	75 000	110 000
Ratio of biogas production from COD removal	c[1] [7]	l/kg	240	300	340
yield of methane from biogas	d[5]	% CH4	70	80	85
COD reduction	e[8] [5]	%	70	85	98
Total digested COD	f=(bae)/100	kg	350000	765000	1617000
Biogas production	g=(fc)/1000	m^3	84000	229500	549780
Methane production	h=(gd)/100	m^3	58800	183600	467313
calorific value of methane	**i**[3]	kj/m^3			38 131
	[4]	Kcal/m^3	9 122	9 122	9 122
total energy		Kcal	536 373 600	1 674 799 200	4 262 829 186