BAGASSE COMBUSTION FOR MOLASSES PROCESSING UNIT A CASE STUDY

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ABSTRACT

The main objective of the present work is to study direct combustion system used to heat a molasses processing units from the following points: environmental nature of traditional raw bagasse as a solid fuel. A case study on three different private processing factories in El Minia Governorate upper Egypt (El Roda and Dear Mawas village) in Malawy City, CO emmitted from the first, second and third factories were 4.5, 8.9 and 24 times that of the acceptable range stated by the Egyptian environmental rules (2016). Some bagasse producers used raw bagasse of moisture content ranged between 12 to 35 % wet basis. Higher moisture contents of bagasse fuel affect on the combustion efficiency in molasse processing units.

INTRODUCTION

Sugarcane bagasse is one of fibrous residues after extraction of juice from cane stem which can used as a source of roughages for ruminants. Utilization of sugarcane bagasse as fuel is limited due to their bulkiness that hinders their transport to areas of consumption. **FAO (2011).**

Pandey, et al. (2000) and **Manikandan,** & **Moganraj (2014**) reported that the sugarcane bagasse consists of approximately 50 % of cellulose, 25 % of hemicellulose is combustibles and 25 % of lignin is combustible **Monjeghtapeh** and **Kafilzadeh (2008**) reported that the sugar cane bagasse is a residue widely generated in high proportions in agro-industry. It is bulky and quite non uniform in particle size. The sugar cane residue bagasse is a material consists of two distinct cellular constituents: thick walled relatively long, fibrous fraction derived from the rind, fibro vascular bundles dispersed throughout the interior of the stalk, and a pith fraction derived from the thin walled cells of the ground tissue.

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Aigbodion, et al. (2010) reported that the utilized various industrial and agricultural waste products in the industry has been the focus of research for economic, environmental, and technical methods. Sugarcane bagasse is a fibrous waste-product of the sugarcane industry. This waste-product is already causing serious environmental pollution. **Anthony, et al. (2012)** added that the sugarcane bagasse is a residue that results from the crushing of sugarcane in the sugar industry. Among the various agricultural crop residues, sugarcane bagasse is the most abundant lignocellulose material in tropical countries such as South Africa. They also reported that the sugarcane bagasse storage in uncovered stock piles has the potential to result in adverse impacts on the environment and surrounding communities through hazards associated with nuisance dust. Groundwater sewage, spontaneous combustion and generation of contaminated leachates. Managing these hazards will assist in improved health and safety outcomes for factory staff and reduced potential environmental impacts on surrounding communities. **FAO (2012)** reported that the sugar cane is one of the important commercial crops grown in tropical regions. Bagasse is a fibrous residue after extraction of juice from sugar cane is an important co-product, generated in large quantities. Currently, a major part of bagasse is used as a source of fuel in the sugar production factories. It is also used as raw material in board and paper manufacture. **Hamed et.al. (2015)** reported that bagasse is a fibrous residues remaining after squeezing. Juicing of sugarcane which is about 22 to 30% of sugarcane weight. It is usually used as a solid biomass fuel. They also concluded that every about 4-5ton bagasse equal to about one ton of coal in calorific value. According to the annual report of Egypt sugar crops council **(2016)** sugarcane cropping pattern, number of molasses factories, cultivated areas, juiced sugarcane in tons, average productivity and amount of molasses produced in tons is depicted in Table (1). **Nakhla and El Haggar (2012)** mated that the low efficiency (60%) of bagasse is due to its low energy content per unit volume. They added that uncontrolled burning, approximately 30% of bagasse does not burn, and bulk is disposed in dumpsites instead of being utilized.

Table (1): Statistics annual report of Egypt sugar crops council 2016

Governorate	NO. of sugarcane traditional factories	Cultivated area in Fadans	Juiced sugarcane in tons	Avg. productivity Ton/ Fadan	Amounts of molasses in tons
El Menia	104	6123	288348	47.1	33472
Qena	173	5273	221080	41.9	19278
Total	277	11396	509428	44.7	52750

Janghathaikul and **Gheewala (2006)** reported that bagasse as energy source is friendly to global environment but affects local environment adversely as shown in table (2) and table(3) . Tables (2) and (3) summarize the interpretation and environmental problems of the bagasse power plant. The problem of high TSP emission can be addressed by installing dust control equipment such as ESP or bag filter in addition to the existing multi-cyclone. CO emissions might be reduced by pre-drying the bagasse using waste heat from the flue gas and also by improving the operation control. Thus, bagasse could become a sustainable and benign energy source.

Table (2): Interpretation summary of bagasse power plant

Category	**Effect on environment**	**Reasons**
Global warming (GW)	Positive	CO_2 emission is a part of the global carbon cycle.
Photochemical ozone Formation (PO)	Negative	High CO emission due to high moisture content and lack of adequate operation control.
Acidification (AC)	Positive	Low SO_2 and NO_2 emissions.
Nutrient enrichment (NE)	Positive	Low N as NO_2 emission to air and wastewater and ash do not have any N and P.
Solid waste to be landfilled (SL)	Positive	It is good for waste management in sugar industry to utilize bagasse rather than dumping to landfill.

***** Janghathaikul and Gheewala (2006).

Table (2): Problems from power generation using bagasse
***** Janghathaikul and Gheewala (2006).

Problems	Effect to environment	Reasons
High CO emission	Negative	Incomplete combustion because of the varying moisture content of bagasse and inadequate operation control.
High total suspended particulates (TSP) emission	Negative	Turbulent movement of gases during bagasse combustion and not sufficient flue gas treatment.

Permchart and **Kouprianov (2004)** listed the properties of ultimate and proximate analysis of biomass fuel included bagasse in Table (4).

Table (3): Properties of biomass fuels used in the experimental tests

Fuel	**Ultimate analysis (wt.%, daf)**					**Proximate analysis (wt.%)**	
	C	**H**	**O**	**N**	**S**	**W**	**A**
Sawdust	45.43	6.71	47.65	0.19	0.02	15.9	0.61
Rice husk	48.45	6.16	44.62	0.55	0.22	10.3	19.54
Bagasse [a]	42.00	6.58	51.00	0.26	0.16	14.4	1.84

[a] Pre-dried under room conditions from W = 48.8% (as-delivered) to W = 14.4%.

* W = moisture, A = ash, daf = dry and ash-free basis

The anticipated advantages of using agricultural residues for energy production are reduction in air emissions, especially CO2, NOx and SOx. Their utilization also contributes to waste management, reduction in electricity purchase at the generating facility (e.g. rice or sugar mills) and even profit from selling surplus electricity to the grid.

The problems are their low energy leading to increased transportation requirements if they are not utilized at the generation point, high moisture content leading to incomplete combustion and seasonal variability. **Premachart** and **Kouprianov (2004)** studied the effect of excess air on CO & NO emitted and tabulated the results in Table (5).
They concluded that when air increases CO emission decreased, while NO emission increased when using bagasse fuel.

Table (5): CO and NO emission as effected by excess air.

fuel fired	Excess air (vol%)	CO emission (vol%)	NO emission (vol%)
Bagasse	17.3	1.529	91
	60.7	0.312	116
	101.1	0.101	131

MATERIAL AND METHODS

Materials:

Row molasses is obtained by crushing, squeezing and sieving sugar cane. Juice is then clarified evaporated and concentrated by heating and then cooled to be a molasses. Solids remained after crushing and squeezing sugar cane was bagasse. In a molasses processing units solid raw bagasse is dried and usually used as a fuel for combustion process. Juice concentration process is performed in molasses oven. Fig. (1) shows a flow chart of molasses production. Molasses oven is a longitudinal oven of length, width and height of about 13 x 5 x 4 m built of bricks 40 cm thickness of thermal conductivity 0.2 W/m.K **Bergman and Incropera, (2011).** has one or two production lines, each line has three or four pans for molasses concentration process, as shown in Fig. (2).

The chimney emitted gases were measured by portable emission analyzer used for measuring O_2, CO, NO_X, SO_2, and ash, ambient temperatures, pressure, from the data obtained CO_2, efficiency, dew point and excess air, can be calculated Fig. (3).

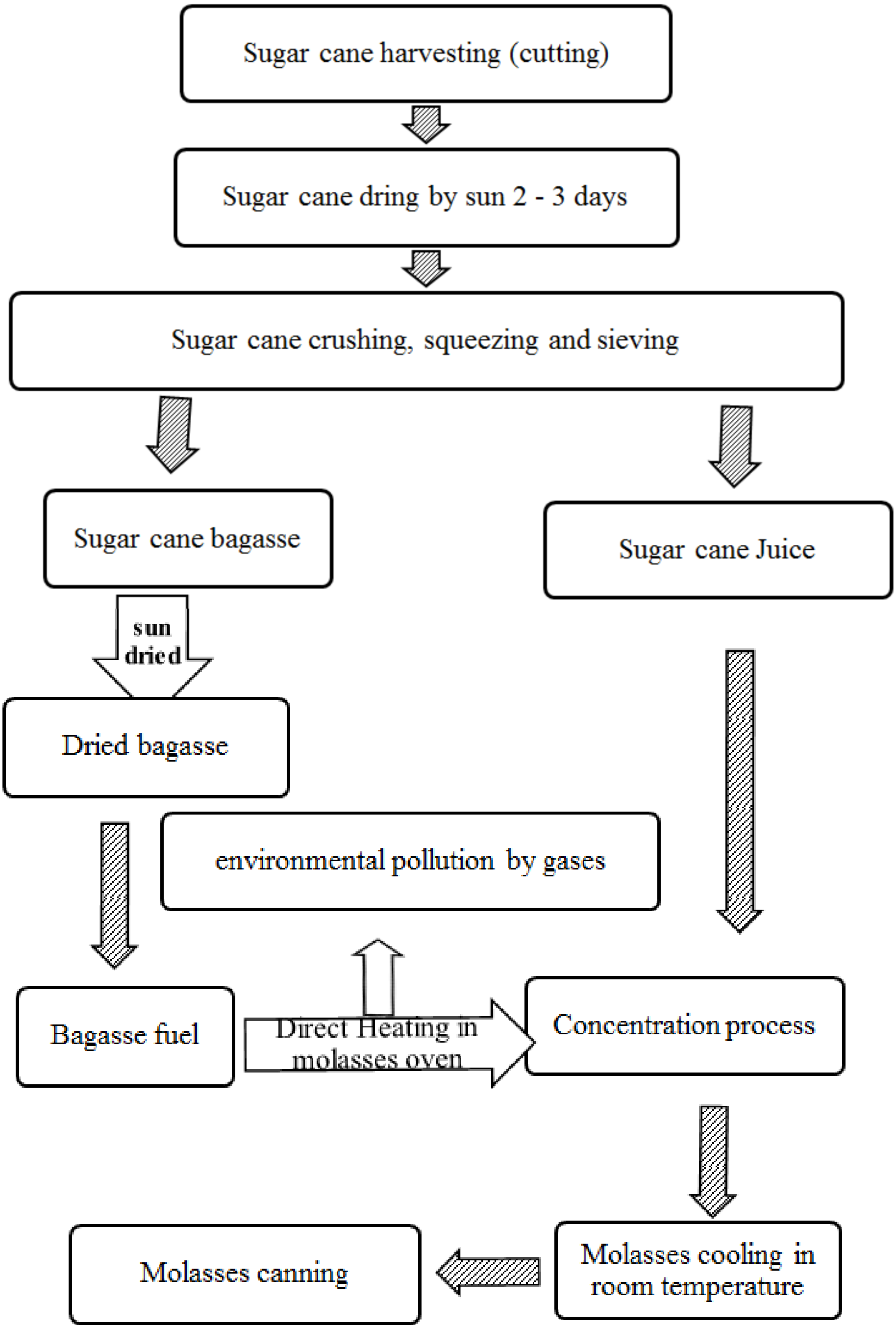
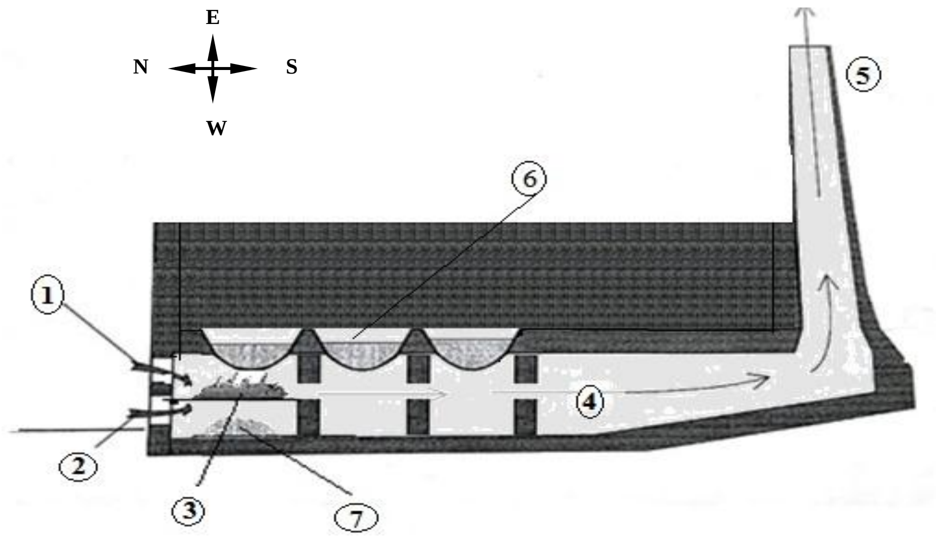


Fig. (1): Flow chart of classical methods for preparation of molasses production.



(1) Bagasse feed opening
(2) Air entry and ash exhausting
(3) Fire house
(4) Combustion gases out flam
(5) Chimney
(6) Pan made of copper
(7) Ash

Fig. (1): Elevation cross section of molasses factory

Fig. (3): Gases emission measuring device
(ECOM J2KN – made in Germany)

METHODS

The present work was carried out at several private factories in El Roda and Dear Maws villages in Malawi City, El Mina Governorate. Private small producers complained of lower combustion efficiency of bagasse.

1- Study the effect of combusting solid bagasse fuel in conventional molasses processing units.
2- Effect of manipulated additives on combustion process used at the private molasses processing factories.
3- Moisture contents required for complete combustion in molasses units and study the effect of combustion on environmental.
4- Is there enough air to complete the combustion process?

RESULTS AND DISCUSSION

In the present study environmental data were measured on different private bagasse processing factories in the sugar cane cultivation belt, El Roda and Dear Maws viltage in Malawi City, El Minia Governorate. Results showed that some molasses producers used raw bagasse of moisture content ranged between 12 to 35 % wet basis. Table (6) shown some physical characteristics of dried bagasse.

Table (6): Physical characteristics of sun dried bagasse

physical characteristics of bagasse		
	Bagasse	Dry bagasse
Particle size	Between 10 - 170 cm	Between 10 - 50 cm
Bulk density	120 - 145 kg/m^3	70 - 100 kg/m^3
Moisture content	50 - 59.5 %	12 - 35 %

High moisture contents of bagasse fuel affect on the combustion efficiency in molasse processing units. Some factories use automotive rubber tires, and others supplemented it with another fuel as fuel oil to enhance the burning efficiency for the continuity of flame firing which in turn reflected on the existence of huge amounts of SO_2 as presented in Figs. (4), (5) and (6). Fig. (7) shows a factory use bagasse only in combustion process. Table (7) summarized measurements of CO, NO_x and SO_2 emitted during molasses processing in the three factories. It is clear that CO for all factories and SO_2 for that factory use automotive tiers in combustion process were with the unacceptable ranges.

The CO emmitted from the first, second and third factories were 4.5, 8.9 and 24 times that of the acceptable range stated by the Egyptian environmental rules. It is also clear that the first and second factories in the case study has zero SO_2 emission compared in to 2689 mg/m^3 SO_2 of the third factory used automotive tiers. The portable emission analyzer were depicted in Fig. (8).

Table (7): Gases emitted from combustion of bagasse.

Ultimate analyses	Factories (a) Bagasse M.C = 12%	Factories (b) Bagasse M.C = 35%	Factories (c) Bagasse M.C= 28% & automotive rubber tires	Acceptable ranges according to Egyptian environmental rules	Notes
Co, mg/m^3.	1126	2246	6000	250	unacceptable
No_x, mg/m^3.	419	307	414	500	acceptable
So_2, mg/m^3.	--------	-------	2689	100	unacceptable

* ECOM J 2 K N Portable emission analyzer.

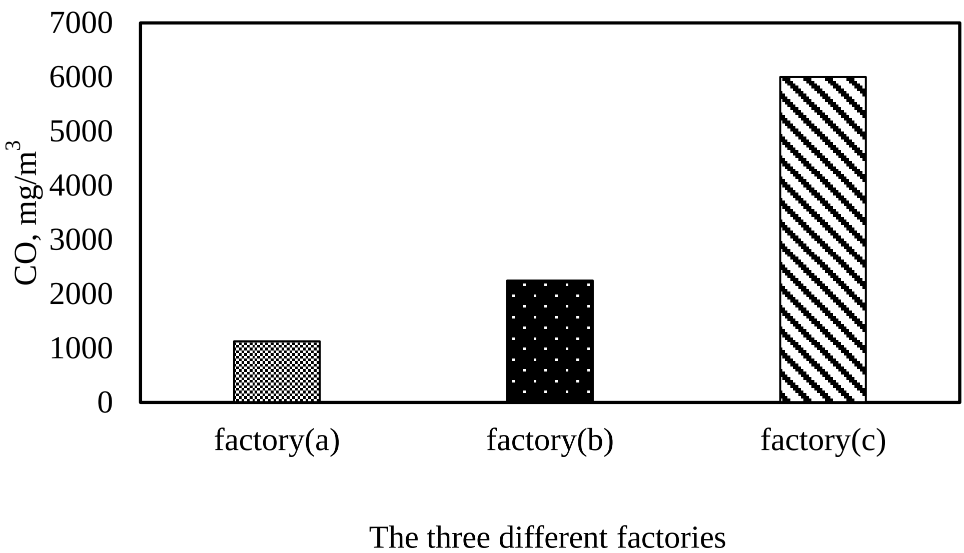


Fig. (4): CO emitted from the three molasses factories.

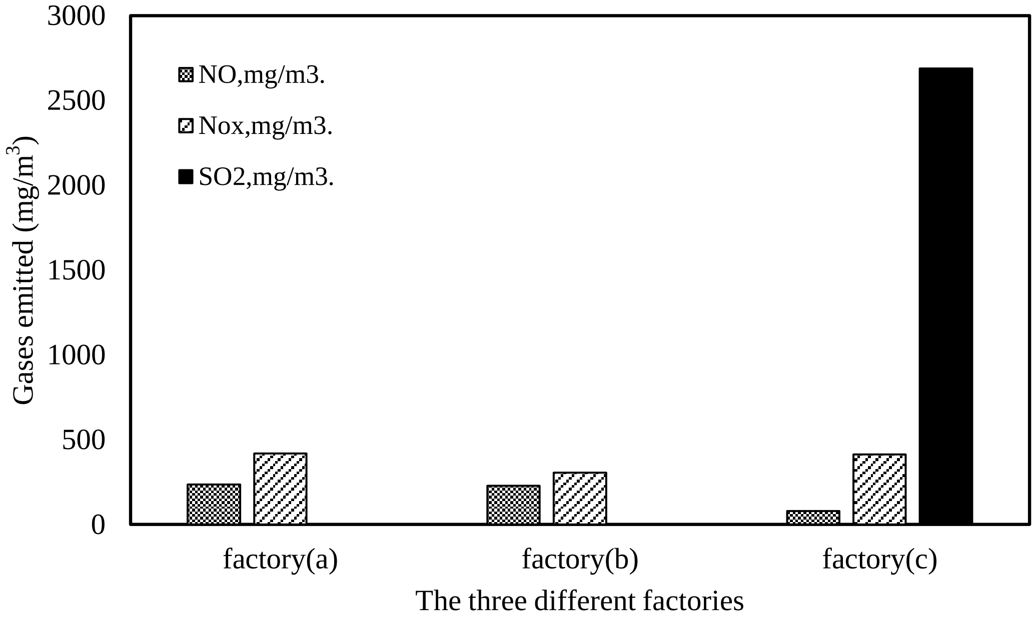
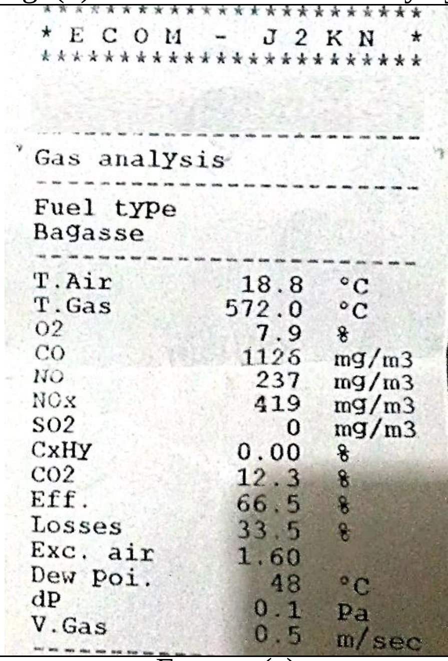


Fig. (5): Gases emitted from the three molasses factories.

Fig. (6): Smoke intensity from the chimney of factory (c) use bagasse & rubber.

Fig. (7): Smoke intensity from the chimney of factory (b) use bagasse in combustion process.

Fig. (8) Data sheets to case study by ECOM – J2KN



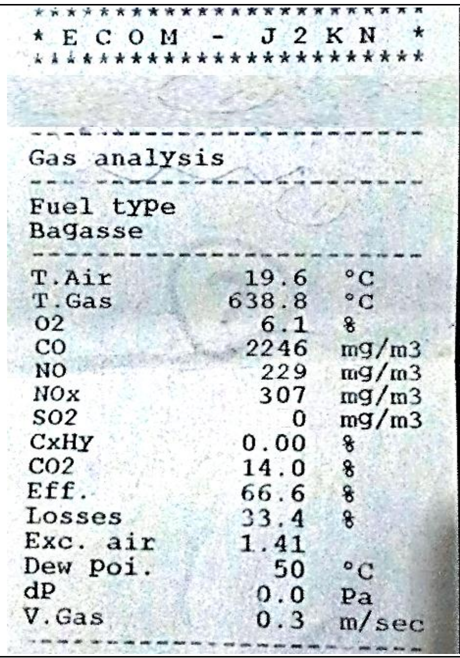
* E C O M - J 2 K N *

Gas analysis

Fuel type
Bagasse

T.Air	18.8	°C
T.Gas	572.0	°C
O2	7.9	%
CO	1126	mg/m3
NO	237	mg/m3
NOx	419	mg/m3
SO2	0	mg/m3
CxHy	0.00	%
CO2	12.3	%
Eff.	66.5	%
Losses	33.5	%
Exc. air	1.60	
Dew Poi.	48	°C
dP	0.1	Pa
V.Gas	0.5	m/sec

Factory (a)



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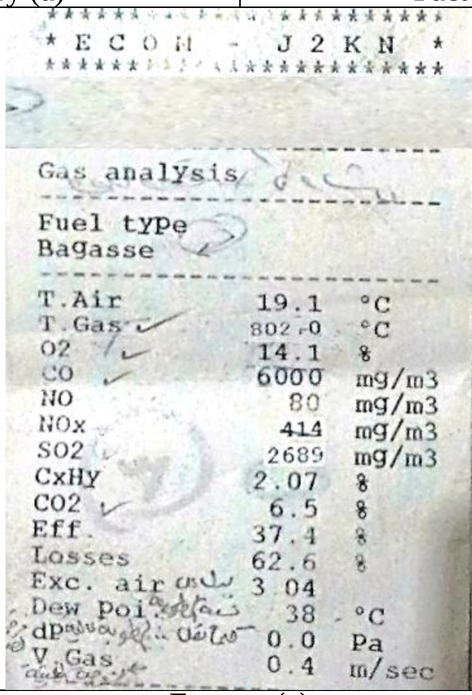
Gas analysis

Fuel type
Bagasse

T.Air	19.6	°C
T.Gas	638.8	°C
O2	6.1	%
CO	2246	mg/m3
NO	229	mg/m3
NOx	307	mg/m3
SO2	0	mg/m3
CxHy	0.00	%
CO2	14.0	%
Eff.	66.6	%
Losses	33.4	%
Exc. air	1.41	
Dew Poi.	50	°C
dP	0.0	Pa
V.Gas	0.3	m/sec

Factory (b)



* E C O M - J 2 K N *

Gas analysis

Fuel type
Bagasse

T.Air	19.1	°C
T.Gas	802.0	°C
O2	14.1	%
CO	6000	mg/m3
NO	80	mg/m3
NOx	414	mg/m3
SO2	2689	mg/m3
CxHy	2.07	%
CO2	6.5	%
Eff.	37.4	%
Losses	62.6	%
Exc. air	3.04	
Dew Poi.	38	°C
dP	0.0	Pa
V.Gas	0.4	m/sec

Factory (c)

CONCLUSION

The main objective of the present work is to study the direct combustion using bagasse system to heat a molasses processing units and estimation of different gases liberated from bagasse incineration in molasses oven. The results showed that some molasses producers used raw bagasse of moisture content ranged between 12 to 35 % wet basis. Some factories used automotive rubber tires, bagasse and others supplemented it with another fuel as fuel oil to enhance the burning efficiency as reported by **Nakhla and El Haggar (2012)** for the continuity of flame firing which in turn reflected on the existence of huge amounts of SO_2 in mg/m^3. It is clear that CO for all factories and SO_2 from third factories which used automotive tiers in combustion process were with the unacceptable ranges. The CO emitted from the first, second and third factories were 4.5, 8.9 and 24 times that of the acceptable range stated by the Egyptian environmental rules. It is also clear that the first and second factories has zero SO_2 emission compared to 2689 mg/m^3 SO_2 of the third factory used automotive tiers or their SO_2 emission is 26.89 times that determined by the Egyptian environmental rules.

Recommendations:

1- Using bagasse as a fuel for: -
   - a- Decreasing production costs of molasses.
   - b- Prevent of emittion of toxic gases to environment such as SO_2 emittion in rubber combustion.
   - c- Decreasing fibrous residues of bagasse amount resulting from sugar cane juice which prevents insects and putrefaction to protect human bean from infectious diseases.

2- Decreasing of bagasse moisture content before its combustion enhance the combustion process.

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الملخص العربي

إحتراق مخلف القصب (الباجاس) كوقود لوحدة تصنيع المولاس – دراسة حالة

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تنتشر وحدات تصنيع المولاس في جنوب مصر في مناطق زراعة القصب، ويصنع المولاس عن طريق تركيز عصير قصب السكر في قيزانات مفتوحة حيث يتم تسخين هذه القيزانات من أسفل عن طريق حرق مصاص القصب (الباجاس) الذي يتخلف عن عمليات العصير. ويهدف البحث إلي إجراء دراسة حالة في قريتي الروضة وديرمواس التابعتين لمركز ملوي داخل حزام القصب في الوجة القبلي لتحديد طبيعة الباجاس المحروق والتلوث الناتج من غازات عملية الحرق وبعض المؤشرات الهندسية لأفران تصنيع المولاس. وأوضحت التجارب أن نسبة تصاعد أول اكسيد الكربون تزيد في المصنع الأول والمصنع الثاني والمصنع الثالث بنسبة ٤.٥ ، ٨.٩ ، ٢٤ مرة علي الترتيب عن الحدود المسموح بها من قبل قوانين البيئة المصرية. كما اوضحت التجارب أيضا أن الباجاس المستخدم كوقود تتراوح نسب الرطوبة به ما بين ١٢ الي ٣٥% علي أساس رطب، وقد اتضح أن بعض المصانع تستخدم الإطارات المطاطية لتسخين ورفع كفاءة عملية الإحتراق مما يؤدي إلي زيادة التلوث وعلي الأخص غاز ثاني أكسيد الكبريت السام وخارج نطاق الحدود المسموح بها حسب قوانين البيئة المصرية.

التوصيات:

١- إستخدام الباجاس كمصدر للوقود لتصنيع المولاس يؤدي الي:-
أ- تقليل تكاليف الإنتاج.
ب- تقليل المخلفات الناتجة عن عصر القصب وتلافي تأثيرها علي البيئة حيث تعتبر مرتع جيد للذباب والحشرات الناقلة للأمراض الوبائية.
٢- تقليل نسبة الرطوبة في الباجاس قبل استخدامة في الحرق يحسن عملية الاحتراق.
٣- عدم إستخدام الإطارات في الإحتراق حتي لا ينبعث منها الغازات السامة وعلي الأخص غاز ثاني اكسيد الكبريت الذي يتحد مع الأكسوجين وبخار الماء الموجود في الهواء الجوي والأمطار ويكون حامض الكبريتيك الذي يؤثر علي النبات والمعادن والأقمشة والمباني.

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