

# OPTIMUM UTILISATION OF WASTE OIL FOR IMPROVED THERMAL EFFICIENCY OF BAGASSE

B.V.Babu<sup>1#</sup> and V. Ramakrishna<sup>2</sup>

## ABSTRACT

*A combination of bagasse and waste oil, which is usually recovered in the industry from the effluent drains or at the machinery sections, is studied to generate a high CV fuel relative to the low CV bagasse fuel alone. The associated technical aspects such as excess steam generation, stack height requirements, economical returns due to the fuel mix are theoretically assessed in the present study.*

**Key words:** *Calorific Value, Utilization of waste oil, Recovery of bagasse, Energy improvement, Occupational health hazards, Economics of waste utilization.*

## NEED AND IMPORTANCE OF RESOURCE UTILISATION

Rapid industrialization and urbanization in the last few decades has resulted in the heavier demand for the natural resources. Much is being said about conservation of natural resources but most of the proposals are either being caught in a controversy or moving only on papers. The need for the resources like fuel, water, food grains etc. is ever increasing due to the varied needs of the human beings. Indiscriminate use of the resources without supplementing its equivalent recharge will lead to a huge deficit for the supply of resources. For example, in India, against a power requirement of 57,530 million watts (in 1994-95), the supply deficit is around 16.5% while the energy deficit is around 7.1% against a demand of 352,260 million kilo watt hours<sup>1</sup>.

Industry is one of the prime users of the natural resources for its increased and effective production of their stream of products (Table 1). However, industrial sectors are now going for captive power plants, since power supply is under deficit whereas industry needs continuous power supply for its operation. Industrial groups like paper and pulp units usually require huge quantities of water<sup>2</sup> for their plant operations (Table 2) and are often located on the banks of rivers for the same purpose. The treated wastewater can be utilised for various purposes

varying from - green belt development, floor and reactor washings to other plant purposes depending on the degree of treatment.

Industrial effluent streams are characterised by the presence of different pollutants depending upon the industrial group. Some of these pollutants can be recovered and appropriately utilised saving revenue for the user, reducing pollution load on to the environment thereby adopting an effective resources management. Such techniques reduce the demand for the particular material from the resource banks and hence increase the effective life of the resource banks.

Technologies are available for recovery of materials like oil and grease, heavy metals, metals, dust (metal) particulates, gaseous streams etc. from the waste streams.

## OBJECTIVE OF THE STUDY

In many industries, the raw materials at the processing stage need to be heated either directly or indirectly. The indirect heating needs to be provided to avoid contamination of raw materials due to contact with the heating media. The most suitably and commonly adopted heating media is steam, either for direct heating or indirect heating, being in purest form and ease in its generation. The process steam is generated through boilers, which are operated with fuels like coal, fuel oil or locally available cheaper agro-residues like bagasse, husk, briquettes, wood etc.<sup>3</sup>

In many industrial operations, oil is used for lubrication and maintenance operations. The discarded oil is often recovered from the wastewater drains. It is either stored in drums and sometimes mixed with boiler ash to fill the

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1 Professor of Chemical Engineering & Head of Engineering Technology Department

#Corresponding author:

Email: [bvbabu@bits-pilani.ac.in](mailto:bvbabu@bits-pilani.ac.in);

Homepage: <http://bvbabu.50megs.com>

2 Lecturer, Civil Engineering Group; Email: [vrama@bits-pilani.ac.in](mailto:vrama@bits-pilani.ac.in)

low-lying areas or simply spreaded on the ground forming oil mud pools. Such pools encourage mosquito breeding. The surface (rain) water percolated through the pools will be rich in oil content and forms a thick layer obstructing the sun rays and creating anaerobic conditions when enters any water course or effluent drain.

The objective of the present study is many-fold and is oriented towards: finding the heat efficiency of the bagasse + oil fuel mix, making use of high energy content of waste oil; optimum mix of oil and bagasse for the stack height for the emissions from the fuel mix not to exceed 30m; financial savings from the fuel mix; and reiterating the thrust towards waste minimization and resource management.

### WHY BAGASSE?

Bagasse is a by-product during the manufacture of sugar cane. It contains about 50-55% moisture, 2% ash<sup>4</sup> and a heating value<sup>2</sup> of 1917 kcal/kg. In India, there are about 391 Sugar units operating and falling under the 17 categories of industrial groups classified by Ministry of Environment and Forests (MEF), with a potential for pollution<sup>1</sup>. Sugar cane consists of 25-30% bagasse whereas sugar recovered by the industry is about 10%. Table 3 shows the sugar cane yield and production in India.

The likely bagasse generation during 1994-95 is 67.8 (@ 25%) to 81.36 (@ 30%) million tonnes, if all the 271.2 million tonnes of sugar cane is converted to sugar. Bagasse is also used as a raw material for paper making due to its fibrous content and about 0.3 tonnes of paper can be made from one tonne of bagasse<sup>2</sup>. Hence, recovery of bagasse is useful in terms of:

- energy production
- revenue inputs for its value as a raw material in paper industry

Because of its low heating value (1917 Kcal/kg), huge quantities of bagasse need to be fired to get the required heat output. The present study is aimed at reducing the bagasse input by mixing it with waste oil, which has a comparatively high heating value<sup>5</sup> (10,163 Kcal/kg) in an optimum ratio so that, the stack height will not be altered. It may be noted that, according to the regulatory standards, the minimum stack height for any boiler is fixed at 30m under Air Act<sup>2</sup> 1981 and the stack height depends upon the particulate and SO<sub>2</sub> emissions.

Some of the sugar industries may have already been practicing the mix of oil and bagasse without being aware of the technical aspects involved in the operation. It is these technical aspects on which the present study is aimed at to enlighten the various technical concepts involved in the operation.

### APPROACH TO THE STUDY

Considering the objective and the aspects covered under the present study, the following approach is adopted:

- Conducting literature survey for the properties of bagasse and oil, regulatory standards for disposal of emissions into atmosphere, cost factors for bagasse etc.
- Finding out the ratios of bagasse to oil for which the stack height for the emissions do not exceed the stipulated minimum stack height 30m calculated by the formula
- $H = 74 (Q_p)^{0.27}$  ---- (1)  
Where, Q<sub>p</sub> = suspended particulate emission in tonnes/hour
- $H = 14 (Q_{se})^{0.3}$  ----- (2)  
Where, Q<sub>se</sub> = sulphur-di-oxide emission in kg/hour
- Computing the net heat value of the fuel mix for the mix ratios whose emissions does not exceed the stipulated minimum stack height requirement of 30m for effective disposal
- Selecting the mix with the highest ratio
- Finding out the steam generation with the net heat value
- Calculating the excess steam generation due to the fuel mix instead of bagasse alone
- Assessing the economic returns for the industry

It can be visualized that, the higher the steam generation, the increase will be its use for plant operations, resulting in increased product manufacturing rates leading to high economy returns.

### POLLUTANT EMISSIONS

Using equation (1) and (2), the minimum value of Q<sub>p</sub> and Q<sub>se</sub> are worked out and presented in Tables 4 and 5. It is assumed that:

- no control equipment is needed for minimum stack height of 30m whereas, installing a control equipment facilities the bagasse input increase since very less pollutant load

(1 - efficiency) will leave from the stack into the atmosphere.

- three cases are considered for particulate emissions, viz. direct emissions; with cyclone at 80% efficiency; and a combination of cyclone (80%) and bagfilter (90%) efficiencies respectively.
- flyash generation is assumed to be 75% of bagasse ash.
- Bagasse ash is @2% and for working period is 23 hrs per day for operation of utilities like boiler.

## RESULTS AND DISCUSSION

A computer programme has been developed in C language<sup>8</sup> and executed for finding out the ratios of bagasse to waste oil for which the stack heights of the emissions computed by equations (1) and (2) are below 30m. Table 6 presents the typical values of the result. It can be seen from the table that, for the ratios  $Q_b/Q_s$  greater than or equal to 4, the stack height of the mix is below 30m. Hence, it can be concluded that, if the bagasse and oil are mixed in the ratio greater than or equal to 4, the emissions from the mix are satisfying the minimum stack height condition of 30m.

Now, the values computed in Tables 4 and 5 are tried with result to find out the ratios. But, it is observed that, it is the ratio  $Q_b/Q_s$  that matters but not the individual values of the parameters. The computer programme was re-executed for a wide range of  $Q_b/Q_s$  values from 0.1 to 10.0 and it was strikingly similar for the ratio to be 4:1 as the deciding factor for choosing the fuel mix satisfying the objective.

The heat value of the mixture (4:1) was worked out to be 3568 kcal/kg. The net heat increment is 1651 kcal/kg, which is about 186% of the heat output with bagasse alone. Fig. 1 shows the variation of  $Q_b/Q_s$  with stack height for bagasse and oil respectively.

## STEAM GENERATION

The steam generation with the net heat output of the fuel mix was computed and given in Table 7. From the table, it can be seen that, the higher the heat value of the fuel mix, the higher will be the steam generation. For the  $Q_b/Q_s$  ratio of 4, the steam generation is 5.8 kg/kg of fuel and is greater than the steam generated for the next ratio of  $Q_b/Q_s = 5$  i.e., 5.37 kg/kg of fuel. The steam

generated for the bagasse alone work out to 3.11 kg/kg of fuel. The higher ratios of  $Q_b/Q_s$  result in increase of steam production, which is an encouraging factor for, the availability of waste oil at the site in the required quantity (1:4) is often a practical limitation. However, the increased  $Q_b/Q_s$  ratios will reduce the net increment in steam generation due to mixing of bagasse and oil.

## ECONOMICS

It may be recalled that, the objective of the study is to increase the heat value of the fuel by reducing the bagasse input, since bagasse is one of the valuable raw material for paper making. The economic benefits that can be availed as a result of the present study can be summarized as direct and indirect benefits.

### Direct benefits

- About 86% excess steam generation (weight mix ratio 4:1)
- Minimization of bagasse input
- Economic returns for the excess bagasse minimized
- Reduction of cost for oil waste management
- No increase in stack height
- No likely infrastructural changes due to the fuel mix (It is assumed that, the efficiency factors for steam generation and utilisation when bagasse alone is used as fuel will prevail)

The monetary returns due to the fuel mix can be mathematically calculated by the following expression:

$$\text{Net monetary savings (NMS)} = \text{Steam utility} + \text{Sale of bagasse} - \text{Cost of oil disposal} \text{ ----- (3)}$$

Let,  $S_1$ ,  $B_1$ ,  $C_1$  and  $S_2$ ,  $B_2$ ,  $C_2$  are the factors for the steam generation, sale of bagasse and cost of oil disposal for bagasse alone and for fuel mix respectively. The monetary savings can be calculated as follows.

*for bagasse alone*

$$\text{NMS}_1 = S_1 + B_1 - C_1$$

$$\text{or NMS}_1 = S_1 - C_1 \text{ ----- (4)}$$

since, bagasse is not recovered and hence no sale value

*for fuel mix (4:1)*

$$\text{NMS}_2 = S_2 + B_2 - C_2 \text{ ----- (5)}$$

from Table 7, for  $Q_b/Q_s = 4$ ,  $S_2 = 5.8$

hence,  $S_2/S_1 = 5.8/3.11 = 1.86$

Eqn (5) can be written as,

$$NMS_2 = 1.86 S_1 + B_2 - C_2 \text{ ----- (6)}$$

Now, bagasse saved = 20% or oil utilised = 20% (fuel mix 4:1)

$$B_2 = 0.2 B$$

$$\text{and } C_2 = 0.8 C_1$$

where B and  $C_1$  are the cost factors for bagasse sale and waste oil disposal respectively

Eqn (6) now becomes,

$$NMS_2 = 1.86 S_1 + 0.2 B - 0.8 C_1 \text{ ----- (7)}$$

Net monetary savings due to the fuel mix =  $NMS_2 - NMS_1$

$$\text{i.e., } 0.86 S_1 + 0.2 B + 0.2 C_1 \text{ ----- (8)}$$

i.e., a cost savings or profit of 86% excess steam utilisation value, sale value of bagasse saved (20% at 4:1 ratio) and 20% reduction in cost for oil waste disposal - per unit of fuel mix.

Considering 100 tonnes of fuel input with 20 tonnes oil (4:1 mix), the steam utilisation rate at 2.5 US \$ (Rs. 87.5 @ Rs. 35 per US \$) per tonne<sup>6</sup> and cost of bagasse at Rs. 150 per tonne, the NMS works out to (from eqn (8)):

$$NMS = 0.86 \times 100 \times 87.5 + 0.2 \times 100 \times 150 + 0.2 C$$

$$\text{or } NMS = \text{Rs. } 10,525 + 0.2 C$$

$$NMS \text{ per tonne of fuel mix} = \text{Rs. } 10,525/100 = \text{Rs. } 105.25$$

i.e., a saving of approximately Rs. 105 for every tonne of fuel mix (4:1), **excluding** savings in the cost of waste oil disposal.

### Indirect benefits

The indirect benefits that can be availed are:

- Reduced ash handling
- Increased process efficiency and better control over the operating parameters
- Improved aesthetic appearance
- Paper production @ 0.3 tonnes per tonne of bagasse, if the industry has an ancillary paper unit
- Supplementation of more energy
- Improved production efficiency due to better aesthetic environment
- Awareness among the workers towards waste minimization and recovery

### LIMITATIONS AND REMEDIES

Besides the various benefits that can be availed due to the present study, there are also few limitations as observed from the present study for

which some possible remedies are suggested as follows:

**Increased storage space:** The reduction in bagasse input necessitates an increased storage space. This can be overcome by compressing the bagasse into bales to increase its density. It can facilitate increase in storage quantity in a lesser area, while the material is disposed by sale to outside parties.

**Increased incidence of Occupational health hazards (OHH):** The fine fibers of bagasse when inhaled, give rise to bagassosis, an occupational disease<sup>4</sup>. The more the bagasse to be handled the more will be the potential for the incidence of OHH. However, this will be experienced mainly due to the poor handling of the bagasse at the storage yard and can be controlled taking precautionary measures like employing protective equipment like masks, nose strips etc.

**Low waste oil availability:** This limitation is mostly due to the poor recovery of waste oil. It can be overcome by employing proper collection mechanisms for oil recovery at the source of generation or at the collection/treatment system. Indiscriminate disposal hitherto practiced can be avoided. Inventorisation of oil consumption and usage will bring open many interesting aspects pertaining to waste oil generation.

### SUMMARY AND CONCLUSIONS

The natural resources are being consumed at a faster rate due to the varied needs of the human beings especially since the last few decades. Energy is becoming one of the dependable and important requirement in our daily life, while energy generation is mostly associated with pollutant generation due to the various activities involved in the process. Striking a balance among the fuel, heat/energy generation and pollutant emission is the need of the hour. The present study is a pointer towards that direction.

An attempt has been made to find out theoretically, the variation of inter-related parameters using low calorific value bagasse (1917 Kcal/kg) and high calorific value waste oil (10,163 Kcal/kg) mix. It was found that, for the ratio of quantities of bagasse to oil ( $Q_b/Q_s$ ) greater than or equal to 4, the emissions from the fuel mix are satisfying the minimum stack height condition stipulated by MEF. The net heat value works out to be 3568 kcal/kg i.e., 1651 kcal/kg in

excess. Considering the material value, the steam utilisation and the stack height condition, it is concluded that, the ratio of Qb/Qs should be kept at 4 for higher economic savings / profits. The present study emphasizes the utility value of waste oil which is recovered as waste material from various operational and maintenance activities in the industry.

For the ratio of Qb/Qs = 4, the economic savings work out to be approximately Rs. 105 per tonne of fuel fired excluding the cost saved for disposal of waste oil.

### **PRACTICAL SIGNIFICANCE OF THE STUDY**

Industry is one of the prime users of the natural resources for its increased and effective production of their stream of products. Striking a balance between production and conservation of natural resources is the need of the hour. The salient features of the present study towards this objective and the significance of the study can be summarized as:

- Unlike the high CV fuels, some of the low CV fuels such as bagasse, rice husk etc. that, are derived mostly as by-products have an additional advantage of exploiting their utility as recoverable materials for their use in downstream industries.
- It is be noted that bagasse can be used as a raw material for paper making and about 0.3 tonne of paper can be made from one tonne of bagasse.
- From the present study, it was observed that, for the ratio of Qb/Qs =4, the economic savings work out to be approximately Rs. 105 per tonne of fuel fired excluding the cost saved for disposal of waste oil.

### **REFERENCES**

1. *Teri Energy Data Directory & Yearbook, 1996/97*, Tata Energy Research Institute, New Delhi, 1996, pp. 121; 196-198; 202-203.
2. *Industrial safety and pollution control handbook*, A joint publication of National Safety Council & Associate (Data) Publishers (Pvt) Ltd., Hyderabad, 2<sup>nd</sup> edition, 1995, (2<sup>nd</sup> print 1996), pp. 267-269, 430.
3. Patil M.A., Industrial pollution urban area and possible solutions – a case study of boilers. *Energy Environment and Monitor*, Vol.12, No. 2, Tata Energy Research Institute, New Delhi, September, 1996, pp. 79-87.
4. Kirk Raymond Eller and Orthmond Donald Frederick, *Encyclopedia of Chemical Technology*, 3<sup>rd</sup> edition, A Wiley Interscience publications, John Wiley & Sons, New York, Vol. 3 (1978), pp. 434-437; Vol. 21 (1983), pp. 878-890.
5. Robert H. Perry and Don Green, *Perry's Chemical Engineers' Handbook*, McGraw Hill International editions, Chemical Engineering Series, 6<sup>th</sup> edition, McGraw Hill Book Company, New York, 1984, (50<sup>th</sup> Anniversary edition), pp. 9-18.
6. James M. Douglas, *Conceptual design of chemical processes*, McGraw Hill Book Company, New York, 1988 (International edition), pp. 36-37.
7. Max S. Peters, Klaus D. Timmerhaus, *Plant design and economics for Chemical Engineers*, 3<sup>rd</sup> edition, ISE, McGraw Hill International Book Company, Tokyo, 1981(3<sup>rd</sup> printing), pp. 160-161.
8. Stephen C. Kochan, *Programming in C*, CBS Publishers & Distributors, Delhi, First Indian edition, 1987, (Reprint 1991).

**Table-1 Utility wise Power Consumption (%)<sup>1</sup>**

Sector	1980-81	1985-86	1990-91	1991-92	1992-93	1993-94
Domestic	11.2	14.0	16.5	17.3	18.0	18.2
Commercial	5.7	5.9	5.9	5.8	5.7	5.9
Industrial	58.4	54.5	44.2	42.0	40.9	39.6
Railways	2.7	2.5	2.2	2.2	2.3	2.3
Agriculture	17.8	19.1	26.4	28.2	28.7	29.6
Others	4.4	4.0	4.5	4.5	4.4	4.3

**Table-2 Water Consumption and wastewater generation from selected Industrial Groups<sup>2</sup>**

Industrial group	Water consumption	Wastewater generation
Automobiles	40 KL per vehicle	40 KL per vehicle
Fertilizer	300 KL per tonne	200 KL per tonne
Leather tanning	75 KL per tonne of raw hide	40 KL per tonne of raw hide
Kraft paper	900 KL per tonne of dry pulp	400 KL per tonne of dry pulp
Sugar	2-4 KL per tonne of sugar cane crushed	1-2 KL per tonne of sugar cane crushed
Petroleum refinery	10-30 KL per tonne of crude petroleum	2-3 KL per tonne of crude petroleum
Cotton textile	10-300 KL per tonne	150-200 KL per tonne
Straw board	100 KL per tonne of dry pulp	75-100 KL per tonne of dry pulp
Finished steel	300 KL per tonne	200-250 KL per tonne

KL: kilo liter

**Table-3 Sugar cane production and yield in India<sup>1</sup>**

Year	Sugar cane production, Million tonnes	Sugar cane yield, tonnes/hectare
1970-71	126.4	48.322
1975-76	140.6	50.903
1980-81	154.2	57.844
1985-86	170.7	59.889
1986-87	186.1	60.444
1987-88	196.7	60.006
1988-89	203.0	60.992
1989-90	225.6	65.612
1990-91	241.0	65.395
1991-92	254.0	66.069
1992-93	228.0	63.843
1993-94	229.7	67.000
1994-95	271.2	71.099

**Table-4 Particulate emissions from Bagasse**

Parameter	Qp, TPH	Qp, TPD	Bagasse, TPD
For direct emissions	0.0353	0.84	56
With cyclone (80% efficiency)	0.23	5.3	353
With Cyclone (80% efficiency) & Bagfilter (90% efficiency)	1.76	40.5	2700

TPH: Tonnes per hour; TPD: Tonnes per day

**Table-5 SO<sub>2</sub> emissions from waste oil**

Parameter	Qs, TPH	Qs, TPD
For direct emissions	0.01269	0.292

**Table-6 Effect of bagasse and oil mix on stack height**

Qb/Qs	1	2	3	4	5	6	7	8	9	10
<b>Hb</b>	19.75	21.34	22.03	22.42	22.66	22.84	22.96	23.06	23.14	23.20
<b>Hs</b>	38.84	34.40	31.55	29.50	27.94	26.67	25.62	24.73	23.96	23.29

Qb, Qs = quantities of bagasse and waste oil in the mix;

Hb = stack height computed for particulate emissions due to mix

Hs = stack height computed for sulphurdioxide emissions due to mix

**Table-7 Variation of steam and heat generation with Qb/Qs**

Qb/Qs	1	2	3	4	5	6	7	8	9	10
<b>Heat, kcal/kg</b>	6040	4666	3978	3568	3291	3095	2948	2833	2742	2667
<b>Steam, kg/kg of fuel</b>	9.82	7.6	6.48	5.8	5.37	5.04	4.8	4.62	4.49	4.34