Pollution Potential of Jaggery Industry: A Case Study

Dal Singh Kharat

Central Pollution Control Board, Shahdara, Delhi-110032, India.

Received:- 04 December 2022/ Revised:- 14 December 2022/ Accepted:- 21 December 2022/ Published: 31-12-2022
Copyright @ 2022 International Journal of Environmental and Agriculture Research
This is an Open-Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (https://creativecommons.org/licenses/by-nc/4.0) which permits unrestricted Non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract— *Jaggery industries are one of the agrobased cottage sectors in India. Jaggery production involves extraction of juice from the sugarcane and heating it to obtain a concentrate i.e. Jggery or Gur. Sugarcane bagasse and wood are used as fuel in the heating furnace, which is the main source of pollution. The pollution potential of the Jaggery industries was assessed in the present work that is based on the actual measurements at Jaggery industry sites. Two representative Jaggery industries were identified for detailed field studies including the stack emission monitoring. While selecting the representative industries, the production capacity and provisions of emissions monitoring were considered. Measurements were carried in respect particulate matters, sulthur dioxide, oxides of nitrogen and carbon monoxide. The particulate matter emissions were observed as 751.5 mg/Nm^3 in one industry and 682.5 mg/Nm^3 in other industry. It was also noted that the emission of gaseous pollutants namely, sulphur dioxide, oxides of nitrogen and carbon monoxide from both the industries were low.*

Keywords— Jaggery industry; Air pollution, Sugarcane; Gur; Kolhu.

I. INTRODUCTION

The Jaggery industries (also known as *Kolhus)* make Jaggery or *Gur* from the sugarcane juice and are one of the agrobased unorganized cottage sectors in India. The industries are owned and operated by farmers using knowledge and expertise gained over the generations. The Jaggeries are constructed using locally available resources such as bricks, soil, sand and mud. Sugarcane bagasse is used as fuel in the furnace. The consumption of sugarcane for Jaggery and *Khansari* production is given in Table 1 (SBI, 2016).

TABLE 1
DIFFERENT USAGES OF SUGARCANE IN INDIA

Year	Sugar (%)	Seed & feed (%)	Gaggery and *Khansari* (%)*
1971-72	30.2	12	57.8
1981-82	46-90	11.7	41.4
1991-92	53.7	11.8	36.8
2001.02	60.7	11.7	27.6
2011-12	71.2	11.9	16.9
2012-13	73.4	11.8	14.7

****Authentic data for separate Jaggery production is not available.***

It can be noticed from Table 1 that the production of Jaggery and *Khansari* show a decline trend over the decades. Emergence of sugar industries in large number, lack of hygiene, quality of products, changing food habits of population and the economics involve in the Jaggery production may be reasons for decrease in the Jaggery production (Dwivedi, 2010). However, these units are still popular in sugarcane growing states in India. The jaggery industries are seasonal and temporary in nature. Hence, their precise numbers and location are not available.

Jaggery is reported to have higher nutritional value as compared to the sugar. Jaggery preserves all the minerals and vitamins present in sugarcane juice such as calcium, iron and phosphorous (Jagannadha Rao et al. 2007; Kumar and Singh, 2020). Contrary to this, in sugar manufacturing, the valuable nutrients and minerals are discharged along with the molasses.

Most Jaggery industries are constructed using traditional knowhow. Inefficient burning of fuels and lack of adequate pollution control measures lead to significant air pollution. The present study seeks to present the pollution potential of Jaggery industries based on field studies and the measurement of emissions at site.

II. MATERIALS AND METHODS

The background information about Jaggery industries was collected from the available literatures and few preliminary visits at the Jaggery sites. Based on information received, two representative Jaggery industries were identified for the detailed field studies including the stack emission monitoring. While selecting the representative industries, types, sizes, technology adopted, locations and the provisions of pollution control devices were considered. At the Jaggery sites, the stack emissions were measured in respect of particulate matter, sulphur dioxide, oxides of nitrogen and the carbon monoxide. The chemicals, reagents, equipments and the method of measurements were followed as recommended by CPCB, 2012.

III. RESULTS AND DISCUSSIONS

3.1 Production process

A conventional Jaggery plant consists of sugarcane crusher and juice boiling pans. The crushers for extracting juice from sugarcane were found to have horizontal or vertical rollers. The sugarcane crusher use two rollers or three roller assembly. The top roller can be moved up or down by screw jack to adjust the pressure between top and bottom rollers as per the requirement. The crushers are locally available or can be fabricated by artisans or blacksmiths. It is driven by electric motor or diesel engine. The extraction of juice from sugarcane crusher is found in the range of 50 to 70% of total sugarcane crushed. After extraction of the juice, suspended matters are removed by cotton cloth or fine mesh screen before further processing.

The boiling pans are large shallow and thick vessels called '*Karahi*' that is positioned above furnace. The furnace is constructed using ordinary masonry bricks, cement, sand and clay. Depending on the production capacity, the furnace is designed to cater to one or more pans in series to make a counter current with the flow of hot flue gases. The sugarcane juice is added in the first pan only and the same is preheated with the heat contained in the flue gases. The preheated juice from the first pan is transferred to the second pan and from the second pan to next one. The last pan is positioned above the fuel combustion stage wherein actual boiling and evaporation take place. Heat transfer under this boiling pan is mainly through convection and radiation. Other pans installed downstream of the hot flue gas path also fetch heat through convection from the hot gases moving towards the stack (chimney) under a natural draft.

Even after filtration and sedimentation, the sugarcane juice contains colloidal matter, inorganic salts, fibers, various nitrogenous substances, lipids, gums, wax, organic acid, inorganic acid and pectin (Singh et al., 2007). The impurities have to be removed totally or partially by adding organic or inorganic clarificants in the juice contained in the pan. The organic clarificants are vegetable origin or inorganic clarificants. The vegetable origin clarificants are derived from roots, stem or seeds from certain plants.

The vegetables clarificants contain albumin that coagulates upon heating. This process agglomerate dehydrated colloids of juice that move to the surface in the form of scum. Chemical clarificants include lime, hydrous powder (sodium hydrosulphite), sodium carbonate and super phosphate.

After juice is taken in pan, firing starts slowly so that the dissolved air escapes and gummy, and colloidal substances get coagulated by the addition of clarificants as per the requirement. The juice with clarificants is continuously stirred during heating with the help of large ladles that avoid sticking of the juice at the bottom of the pan. The clarified impurities tend to rise to the juice surface that is known as scum that is removed continuously. In this process temperature requirement is 70-80 ºC. After certain consistency, the juice temperature is raised till it reaches about 100-105º C at which, the hot juice starts frothing. In order to suppress the froth formation, little quantity of cooking oil is added in the juice. The desired concentration is achieved by vigorous boiling and at this stage, the temperature of boiling mass is maintained about 110 ºC to 115 ºC that is

known as striking temperature. When a semi-fluid material (concentrate) is formed, it is transferred into molds and then allowed to cool to form a Jaggery. The schematic of production process is shown in Figure 1.

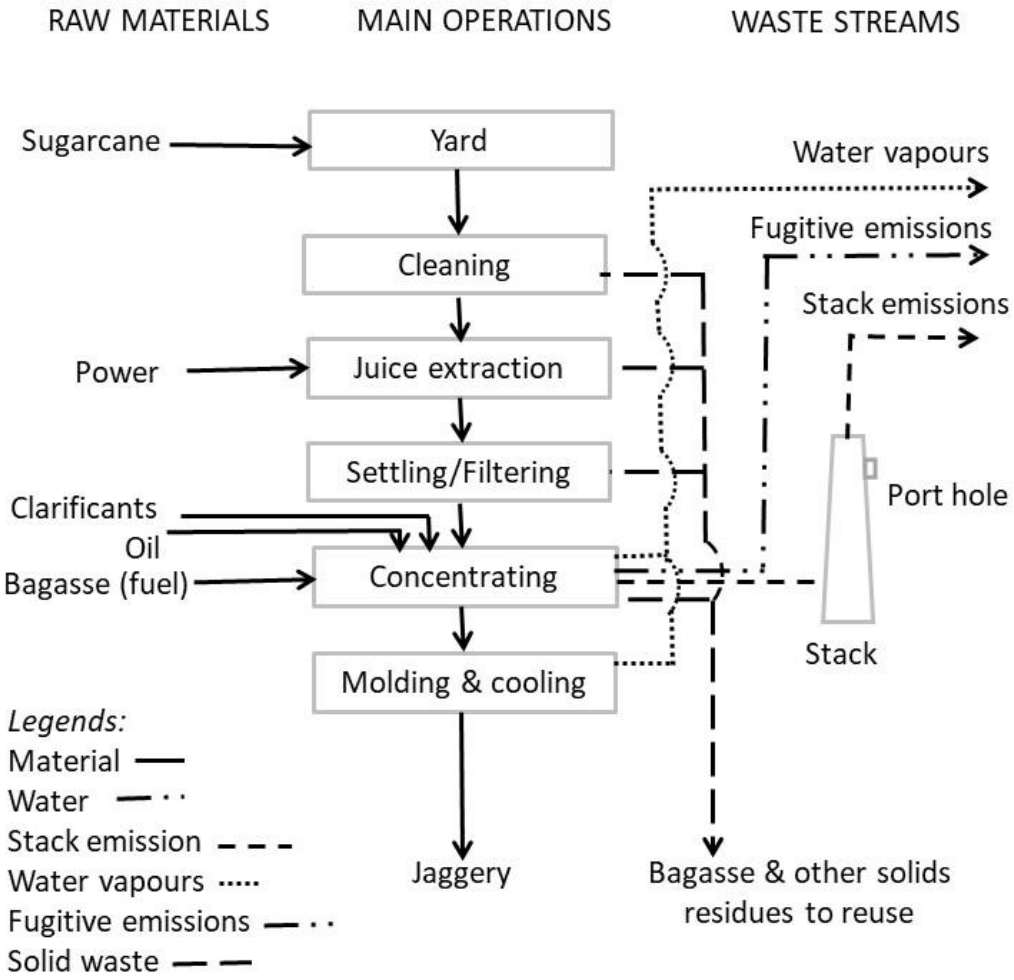

FIGURE 1: Process flow diagram and sources of pollution

3.2 Pollution generation

The stack is the main source of air pollution. Besides the stack emissions, fugitive emissions are also generated from the furnace. The stack emissions are let out at a certain height. The plume of flue gases floats with the wind stream and the pollutants get dispersed away from the jaggery plant location. The fugitive emissions, on the other hand, start getting dispersed near the furnace that affect work place environment. In case, diesel engine is employed to operate sugarcane crusher, its exhaust also a significant source of pollution. The solid residue discharged by the crusher is the bagasse that is mostly used as fuel in the furnace after drying. Addition of clarificants in juice form scum that is removed time to time. A little quantity of solid waste is also generated from the filtration and sedimentation of fresh sugarcane juice. The scum and wastes are burnt along with the sugarcane bagasse in furnace. Burning of bagasse generates ash which can be disposed to agriculture fields. Sources of pollution and waste generation are shown in Figure 1.

3.3 Air pollution monitoring

The emission monitoring was conducted during the routine and normal operation of Jaggery industries. The particulars of the jaggery industries identified for the study are given in Table 2. The wind direction was noticed East-West at the site. Measurements were conducted in respect of particulate matters, sulphur dioxide, oxides of nitrogen and carbon monoxide. The flue gas emission from stack did not show a definite plume shape. Besides the emission from stack, fugitive emissions were seen above the furnace. The stack emission monitoring results are shown in Table 3.

TABLE 2
PARTICULARS OF JAGGERIES

S. No.	Parameters	Industry A	Industry B
1	Production capacity (tons/d)	1.2	1
2	Pans in series (no.)	3	3
3	Diameter of stack (m)	0.64	0.61
4	Stack height (m)	5.2	6.1

TABLE 3
EMISSION MONITORING RESULTS

S. No.	Parameters	Industry A	Industry B
1	Ambient temperature (ºC)	28	30
2	Flue gas temperature (ºC)	310	290
3	Velocity of gases(m/sec)	10.04	9.26
4	Particulate matter (mg/Nm^3)	751.5	682.5
5	Sulphur dioxide (ppm)	9	7
6	Oxides of nitrogen (ppm)	0	0
7	Carbon monoxide (ppm)	4	3
8	Carbon dioxide (%)	0.12	0.11

It can be noticed from Table 3 that the emissions of particulate matters were observed as 751.5 mg/Nm^3 and 682.5 mg/Nm^3 in stacks of industry A and industry B, respectively. The high value of particulate matter may be due to the inefficient furnace structure and inadequate stack height. It was noticed that the emission levels of gaseous pollutants namely, sulphur dioxide, oxides of nitrogen and carbon were found low. Low carbon dioxide concentrations of 0.12 ppm and 0.11 ppm from industry A and industry B, respectively indicate excess supply of air in the furnace.

The furnaces employed by Jaggary industries were found constructed in a traditional manner that generate higher emissions of particulate matters. The industries were seen having open fuel feed hole. This may result in excess air flow of air in the furnace. There were no fire grates in the furnaces. Chimney was constructed using mud, soil etc., with inadequate height.

3.4 Material balance

Operation of Jaggery industries generate bagasse that is reused as fuel for heating and boiling the sugarcane juice. A little quantity of solid waste is also generated from the filtration and sedimentation of fresh sugarcane juice. The colloidal impurities are separated by addition of the clarificants in the hot juice and is removed as scum.

It was estimated that out of 100 kg of sugarcane crushed, 60 kg of the juice was measured to generate from the crusher. The sugarcane bagasse generation was measured as 40 kg. Of 60 kg of the sugarcane juice, the Jaggery production was measured to be 12 kg. During the process of heating, about 48 kg of water content of the juice was found to get evaporated. The quantity of sediments and scum were observed negligible and burnt along with bagasse as fuel in the furnace. The bagasse consumption in furnace is reported as 2.8 kg/kg of Jaggary produced with thermal efficiency of furnace 27.7% (Singh et al., 2021). However, the consumption of bagasse depends on moisture content. Similarly, the efficiency of furnace may vary depending on its structure and design.

IV. CONCLUSIONS

In the present study, two representative Gaggery industries were monitored to assess the pollution potential of these units. The particulate matter emissions were observed as 751.5 mg/Nm^3 in one industry and 682.5 mg/Nm^3 in other industry. Emissions of sulphur dioxide, oxides of nitrogen and carbon monoxide from both the industries were found low. The furnaces of the jaggery industries were seen constructed traditionally. As a result, significant heat loss is expected. The energy efficient furnace design with improved flue gas path and use of multi-pan heating arrangement can substantially reduce emission of pollutants

(Arya et al., 2013). In addition, provision of baffles in the flue gas path can reduce particulate matter in stack. Use of flap on fuel feed hole can properly control air flow. In addition, a fire grate, if proved, can ensure complete burning of fuel. These measure can reduce pollution problem besides improving process efficiency.

DECLARATIONS

Data availability

The information and data presented are based on the field studies and actual measurements at Jaggery sites. Interpretation of data are based on available literature and author's experience in the field.

Conflict of interest

The author declares no financial or non-financial conflict of interests.

REFERENCES

[1] Arya P.K., Kumar S. Jaiswal U.K. (2013), Design based improvement in a three pan Jaggery making plant for rural India. International Journal of Engineering Research 2(3): 264-268.

[2] Dwivedi A.K. (2010) An empirical study on *Gur* (Jaggery) industry (with special reference to operational efficiency & profitability measurement). Working paper no.2010-12-03, Indian Institute of Management, Ahmedabad, India.

[3] CPCB (2012) Guidelines on methodologies for source emission monitoring, Publication no. LATS/80/2013-14. Central Pollution Control Board, Delhi, India.

[4] Jagannadha Rao P.V.K, Das M. Das S.K. (2007) Jaggery- a traditional sweetener. Indian Journal Traditional Knowledge 6(1) 95-102.

[5] Kumar A., Singh S. (2020) The benefits of Indian Jaggery over sugar on human health. Chapter in: Dietary sugar, salt and fat in human health, Academic Press, 347-359.

[6] SBI (2016) Sugarcane statistics. Sugarcane Breading Institute, Indian Council Agriculture Research, Coimbatore, India.

[7] Singh A., Shahi H.N., Suman A. (2007) Improving sugarcane juice clarification for Jaggery manufacturing. Indian Journal of Food Science and Technology-Mysore 44(3) 315-318.

[8] Singh S., Kumar R., Kumar M. (2021) A case study on a traditional Jaggery making plant. Abstract in: Proceedings of International multidisciplinary conference-2021, Universal Group of Institutions, Chandigarh, India.