Oxygen Production in Sugar & Ethanol Units- Opportunities & Challenges

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Abstract**:** India has been hit by a huge second coronavirus wave as surge in infections began around mid-March and increased rapidly, reaching a peak of more than 400,000 recorded daily cases on Friday, 30 April 2021. During the last week of May 2021 members of the national Covid-19 task force said hospital data shows that a significant 54.5% of hospital admissions during the second wave required supplemental oxygen during treatment. The sudden rise in supplementary oxygen demand resulted in appreciable shortage and thus to mitigate the crisis, various options including production of oxygen in sugar and ethanol units were considered and this aspect has been detailed in the present paper.

Key words: Corona, Oxygen, Distillation, Cryogenic.

I. INTRODUCTION:

Shortness of breath occurs because of the way Covid-19 affects the patient's respiratory system. The lungs enable the body to absorb oxygen from the air and expel carbon dioxide. When a person inhales, the tiny air sacs in the lungs — alveoli — expand to capture this oxygen, which is then transferred to blood vessels and transported through the rest of the body. Respiratory epithelial cells line the respiratory tract. Their primary function is to protect the airway tract from pathogens and infections, and also facilitate gas exchange and the SARS-CoV-2 coronavirus can infect these epithelial cells. Data with the National Clinical Registry for Covid-19 shows a new emerging trend during the second wave: shortness of breath is the most common clinical feature among symptomatic hospitalized patients at 47.5%, compared to 41.7% during the first wave.1

Oxygen export data from the Department of Commerce showed that the country exported twice as much oxygen to the world during the first 10 months of FY21 in comparison to the previous financial year. India had exported 9,301 metric tonnes of oxygen across the world between April 2020 and January 2021. In comparison, the country had exported only 4,502 metric tonnes of oxygen in FY20. The oxygen supplied was in liquid form and can be used for both industrial and medical use. However, the demand for oxygen in India was not as high during the aforementioned period. During the first wave, the demand for liquid medical oxygen (LMO) increased from 700 metric tonnes per day (MTPD) to 2,800 MTPD. But during the second wave, it has skyrocketed to 5,000 MTPD. It was only in the second week of April when demand for medical oxygen in India witnessed a five-fold jump, according to Crisil.

While many are blaming the government over India's FY21 oxygen exports, the fact that the country produces over 7,000 metric tonnes of liquid oxygen per day indicates that the problem lies somewhere else. Demand for medical oxygen skyrocketed in India soon after Maharashtra started witnessing a sharper of Covid-19 cases since February. The situation worsened as the second Covid wave hit with blistering force in March.2 Initially, the sugar mills in Maharashtra, the worst hit state decided to come forward to produce and supply oxygen at their plants in the wake of rising Covid-19 cases and severe shortage of oxygen being faced by hospitals in several states and then a serious debate was started on feasibility of producing oxygen in distilleries (ethanol units) attached to sugar factories with co-generation facilities.

The present paper discusses medical grade oxygen production methodologies and feasibility of its production in sugar industry.

II. METHODS OF PRODUCTION OF OXYGEN

Two types of technologies are used for large scale production of Oxygen:

1. Fractional Distillation Technology or Cryogenic Method
2. PSA/VPSA Technology

Cryogenic Method is used generally for plant capacities above 100 Nm3/h, whereas, PSA/VPSA Technology is generally for plant capacities below 200 Nm3/h. Apart from these large scale production methods, there are small units called Oxygen Concentrators of 0.3 - 0.6 Nm3/h capacity in use by the individual patients in home and hospitals. However, the technology used in these concentrators is also PSA Technology.

In both the methods, Oxygen is produced by separating Nitrogen, Argon and other impure gases from Air. So air is the raw material for large scale production of Oxygen. The oxygen obtained as the result of the separation, has a purity to the extent of 99.77 % in cryogenic method, whereas in the PSA method, it is 90-95 %.

Besides plant and machinery and other infrastructural facilities, the other requirement is of utilities i.e. electrical power and of manpower. 75-80 % of the cost of production is power cost and the rest is manpower and the overheads. The cost of production varies from Rs. 7/- to Rs, 12/- per Nm3 depending mainly on the power cost, the scale of production, the technology adopted and the supply system. The sale price for medical grade Oxygen is fixed by National Pharmaceutical Pricing Authority and the present rates are as Rs. 15.22 per Nm3 for liquid Oxygen and Rs. 25.71 per Nm3 for Oxygen in Cylinders. (The Gazette of India no. CG-DL-E-26092020-222006 dated 25-09-2020).

Major uses of Oxygen are medical use and industrial use. For the inhalation purpose, i.e. medical grade, the purity required is 90 + % whereas for industrial purpose, the requirement of purity level is above 99.5 %. In both the uses, the supply may be directly to the oxygen manifold available at the site or through pressure vessels. In case of cryogenic method, the oxygen produced is in liquid form and is filled in pressurized containers for the purpose of transportation. It is then filled into the cylinders at a pressure of about 140-150 bar g in a filling station for end use. In case of PSA method, the oxygen is produced in gaseous form and is filled directly into the cylinders at a pressure of about 140-150 bar g in the filling station.

Two types of cylinders are generally used for the purpose of medical grade Oxygen, D-type having water volume of 46.7 liters carrying 7 Nm3 or 10.02 kg of Oxygen at 150 bar g, and B-type having water volume of 10.2 liters carrying 1.53 Nm3 or 2.18 kg of Oxygen at 150 bar g.

For a moderate capacity sugar factory (5000 TCD), the requirement of Oxygen is only 1000 cylinders per annum which is equivalent to 7000 Nm3/year or say 20 Nm3/day or say 1 Nm3/h. Hence, the installation of an oxygen production unit in a sugar factory does not stand justified. Even for a group of 10-12 factories, it is not justified taking into account the low requirement, the purity of Oxygen and the cost of transportation. However, the two methods in vogue are as follows:

A. Oxygen Production by Cryogenics Method

Oxygen production by cryogenic method is meant for higher capacity plants and the output purity above 99.5%. In this plant, not only liquid oxygen, but liquid nitrogen and for very high capacity plants, even liquid argon are the coproducts. The oxygen produced from such units can be used both as medical oxygen and industrial oxygen. The cost of production is lower because of the coproducts. If only oxygen is produced using this method, then the cost of production will be much higher as the power requirement of such plants are much higher. The CAPEX for such plants is 4 to 5 times than the other method. No sugar factory / distillery shall be interested for such units investing such high capital and having uncertainty of return as the demand of oxygen is not so during normalcy.

B. Oxygen Production by PSA/VPSA Technology

In this method oxygen is produced from air after separation of nitrogen and argon gas by following Pressure Swing Adsorption (PSA) Technology. Vacuum is used for regeneration of the adsorption columns. No other coproduct gas is produced in this method. oxygen produced is 90-93 % pure and is suitable for inhalation as per medical standards. The CAPEX is lower but OPEX is higher due to no other coproduct and low plant capacity. Schematic diagram of a PSA plant displaying major equipment of the system is shown below in fig.1:

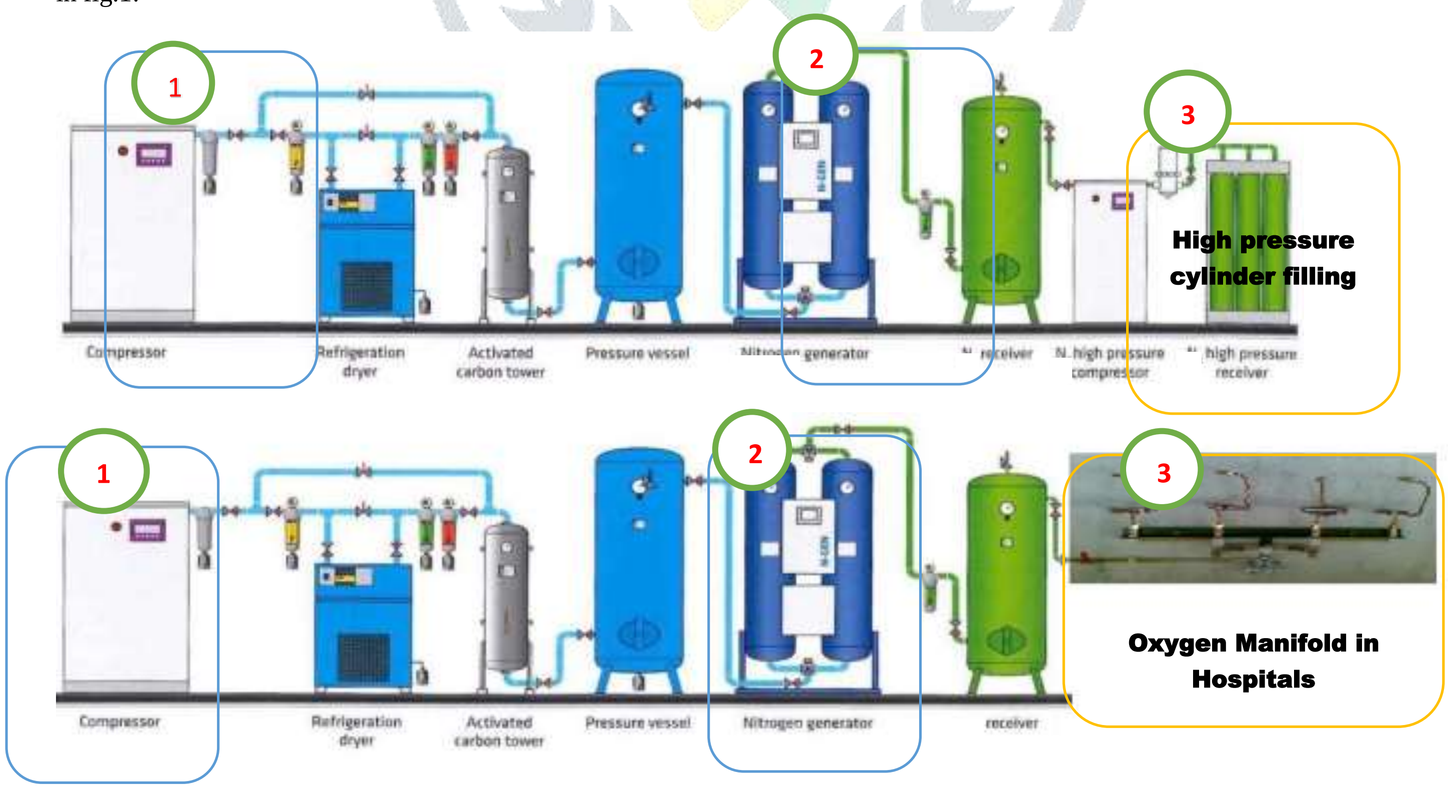

Fig.1: Schematic diagram of PSA plant

Two ways of oxygen supply are followed; one as shown at the top in the figure and the other at the bottom in the figure. The intake air to the system is through a compressor where 7-8 bar pressure is the output pressure and the oxygen is produced at a pressure of 4.5 - 5 bar pressure and stored in the receiver. In the 1st system a high pressure booster compressor is used to boost up the pressure up to 150 bar and the oxygen is filled through the filling station in the cylinders at 150 bar pressure. In the 2nd system the Oxygen at 4 – 4.5 bar pressure is directly connected to the oxygen manifold available in the hospitals. So it is obvious that the 2nd System has to be installed directly in the hospitals where as the 1st system can be installed at any place and the oxygen cylinders can be transported to the hospitals and connected to the oxygen manifold.

The major parts of the PSA plant are as follows:

1. Air Compressor
2. Adsorption twin tower/generator
3. High pressure Compressor with filling station
4. Surge tanks/buffer tanks/ pipe lines/ dryer/ valves/filters
5. Control system with software
6. Civil Constructions

III. PROJECT ECONOMICS:

The economics of a 50 Nm3/h plant is considered. Cost of Plant and machinery of the project (Oxygen generating plant with PSA technology) is given below in table no. 1 & 2:

Table no. 1: Cost components of plant & machinery

S. No	Plant and Machinery	HP Filling Station (Cost in Lakh Rupees)	Direct to Manifold (Cost in Lakh Rupees)
1	Air Compressor	12	12
2	Adsorption twin tower/generator	15	15
3	High pressure Compressor with filling station	20	0
4	Surge tanks/buffer tanks/ pipe lines/ dryer/ valves/filters	12	12
5	Control system with software	10	10
6	Civil Constructions	8	5
7	Empty Cylinders 200 Nos	15	0
	Total	92	54

Table no. 2: Returns on Investment

S. No	Particulars	UOM	With Boosting	Without Boosting
1	Capital Investment	Rs	8700000	4900000
2	Plant Capacity	Nm3/h	50	50
3	Oxygen per cylinder	Nm3	7	7
4	No of Cylinders per day	No	171	171
5	Say	No	170	170
6	Cost of production	Rs/Nm3	10	10
7	OPEX per day	Rs/day	12000	12000
8	Price of Oxygen	Rs/Nm3	25.71	26.71
9	Sales realization per day	Rs/day	30852	32052

10	Profit per day	Rs	18852	20052
11	No of working days/year	No	310	310
12	Profit per year	Rs	5844120	6216120
13	Interest on capital @5% on reduced balance	Rs/year	435000	245000
14	ROI	years	1.61	0.82

As per the extant guide lines from Govt. of India, oxygen production units may get free electricity. Under this condition, the ROI for the plant will be 1 year and 6 months respectively for the plants with booster and without booster compressor.

It may be mentioned that in case of retrofitting, reference table no.1 out of the 7 items that cost Rs. 92 lakhs, serial no. 1 and 6 are available which cost Rs.20 lakhs. Item at serial no. 2 i.e. adsorption tower, only the structure is usable. The molecular sieves which cost half of the cost of the tower need to be replaced by different type of zeolite. Also, the existing sieves will be of no use once it is taken out and comes in contact with air which adds to the cost of replacement. Hence, the retrofitting will cost about Rs.92-27.5 = 64.5 lakh for a 50 Nm3/h plant or 175 lakhs for a 160 nm3/h plant i.e. 70 % of the new project cost (expenses to the extent of 20-22 % on plant and machinery and about 8-10 % on civil works are saved).

IV. Project Feasibility

Keeping in view the possible third wave of COVID-19 pandemic, it seems that there will be demand of oxygen at the present rate for the next one year or so also. Hence, there is feasibility of PSA based Plants in both the arrangements of with boosting and without boosting. However, in case of normalcy, the ROI period may increase.

V. Project Implementation Schedule

The lead time for the project is more for the system with booster compressor as the compressor used in the system are usually imported. The schedule of implementation of the project is given in the table below:

Table no. 3: Timelines of the projects

		Plant without Booster Compressor										Plant with Booster Compressor												
	Week -------->	1	2	3	4	5	6	7	8	9		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Planning of the project with DPR Preparation																							
2	Tendering & Placing of the order																							
3	Drawing and Civil work																							
4	Supply of Plant and Machinery																							
5	Electrical Layout & Supply																							
6	Plant Commissioning																							

Retrofitting of the PSA unit with Distillery

Oxygen may be produced by PSA technology in a sugar factory having a sugar factory with attached ethanol unit during idle season by using some of the available plant and machinery of both the units and adding the other equipment as detailed below.

1. Every distillery with ethanol production facility has a MSDH unit based on PSA technology. So the adsorption unit may be utilized as the adsorption tower for the oxygen production unit.
2. Pipe lines of the adsorption tower may or may not be suitable for the oxygen unit, hence it is considered to be provided.

3. Every sugar factory and distillery has got compressors used for instrumentation and control which work at 7-8 bar which are suitable for oxygen production unit using PSA technology. The above mentioned compressors have air filters attached with it which may be used.

4. Shaded area of 20’ x 20’ or larger is generally available surrounding the PSA unit of distillery which may be utilized for oxygen unit.

5. The manpower of the distillery unit may be used for oxygen plant as they will be idle when there is no production of ethanol.

6. The cables and MCC available in the MSDH Unit may be utilized for the oxygen unit.

Apart from the above equipment, the following new plant and machinery are to be added as retrofit on foot mounted pattern with the PSA unit for production of oxygen.

1. Refrigeration Dryer for drying of Air
2. Various Filters like Oil and Grease Filters, Bio-filters, Micron Filters etc.
3. Buffer tanks, Surge tanks and Receiver tanks are to be added which are pressure vessels.
4. Booster Air Compressor which is a high pressure compressor and is a high cost imported item.
5. Oxygen Filling station
6. Empty Oxygen Cylinders of appropriate number as per the capacity of the plant.
7. Vacuum pump for cleaning of the Cylinders.
8. Control System with software.

Addition of the above said plant and machinery will make the PSA unit suitable for production of oxygen in the Distillery.

It has been reported that these modifications and additions have been incorporated in one of the closed distillery in Maharashtra the “Dharashiv Sakhar Karkhana, Chorakhali, Osmanabad District”. The factory has utilized the closed 60 KLPD distillery MSDH unit for production of Oxygen @ 160 Nm3/h. The project could be managed to operate with a lead time of more than one month withsupport of state govt. in logistics arrangement like importing the booster compressors and the molecular sieve.

Though “Dharashiv” distillery started Oxygen production in the retrofit unit, it is running at 80 % of its capacity because of sodium discharged 13X zeolite molecular sieve used in the adsorption tower. The plant may operate at full capacity when Lithium discharged X type zeolite molecular sieve will be used.

VI. CHALLENGES OF RETROFIT WITH THE MSDH UNIT OF DISTILLERY

No other distillery/sugar factory even in Maharastra have followed the Dharashiv model as it does not seem to be economical and productive as desired. The challenges faced are as follows:

1. The 3A type molecular sieves are to be replaced by Lithium discharged X type zeolite sieves. The cost of the zeolite is almost half of the cost of the PSA tower.

2. The 3A type molecular sieves taken out may be of no use as they become inactive when come in contact with air and moisture. Replacement of these sieves when the MSDH unit will run for ethanol production will cost the rest of the half of the cost of the tower. That means, in terms of the sieves replacement, the total tower can be added as a new one.

3. In ethanol operation, the tower feed is from top whereas in oxygen production the feed is to be from bottom. That requires change in the pipe line layout. Also other pipe lines are to be replaced by suitable size as the density of air and ethanol is different.

4. The control system and the software needs to be new as modified use will require re-modification for running on ethanol.

5. The cost saving is only to the extent of 20-22 % in terms of plant and machinery.

6. Ethanol production is to be stopped during oxygen production. The plant will require extra storage tank for storage of rectified spirit produced during that period.

7. There may be no saving of time of installation in case of retrofitting.

8. Excise Commissioner approval is required for any modification in distillery PD-2 license area.

VII. OTHER OPTIONS

Low Cost Oxygen Concentrators of 5-10 l/m capacity may be fabricated and assembled in sugar factories utilizing their engineering strength. Transfer of technology for such concentrators are provided by ISRO and is available on their website.

CONCLUSION

1. Keeping in view the challenges, minor saving of cost and almost no saving in installation time, it is advisable not to go for the retrofitting of the oxygen Plant in the MSDH unit of the distilleries/ethanol units.
2. Sugar factories may go for PSA based plants either in their factory area or in the nearby hospitals.
3. Keeping in view the high demand of oxygen at present and in near future and the short period of ROI due to free electricity by Govt., installation of PSA based units may be economical and remunerative.
4. Sugar groups may go for Cryogenic Units keeping in view their own demand of oxygen and sale to the nearby units.
5. CSR fund may be used for installing low cost, low capacity units in the nearby hospitals directly connecting them to their oxygen manifold. The table below shows the capacity of plant and the number of patients which may be supplied Oxygen:

Table 4: Oxygen plant capacity and number of patients which may be supplied oxygen

Plant Capacity in Nm^3/h	Supply to No of Patients
5	10
10	20
15	30
20	45
25	55
30	65
50	105
100	215

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