BUILDING SUSTAINABLE MEDICAL OXYGEN SYSTEMS:

Experiences and lessons from India's COVID-19 response

A compendium of audience questions and expert responses

PATH

15th Floor, Gopal Das Building
Fire Brigade Lane
New Barakhamba Rd, Barakhamba
New Delhi, Delhi 110001
www.path.org

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Questions on Oxygen Policy and Program

Question 1:

Why did India face such an acute oxygen crisis during second wave even when it claimed to sufficient oxygen in the country?

Expert response:

During the second wave, India faced shortage of medical oxygen due to challenges at various stages of manufacturing, transporting and storing medical oxygen, in addition to lack of coordination among the relevant players. For example, nearly 80 percent of the Oxygen demand during the second wave was being met by liquid medical oxygen (LMO). Most of the LMO manufacturers are based in the eastern states of India, due to steel manufacturing, whereas the high demand of medical Oxygen was in the northern and western states.

As a result of this uneven distribution of LMO manufacturers, the health systems faced issues with oxygen transportation, as the LMO tankers had to travel up to 1000 kms to deliver Oxygen but move at the max speed limit of 25 km/hr, which took the trucks about 3-5 days for a return journey. Moreover, India only had about 1200 LMO tankers which were not sufficient to transport the daily demand of 10,000 MT.

While LMO supply was experiencing challenges, it was also observed during the second wave that many hospitals in India did not have LMO tanks, which led to the storage and decanting issues. Finally, due to unprecedented spike in demand, it took for all stakeholders like the manufacturers, suppliers and consumers/ hospitals to establish seamless coordination for oxygen distribution, which further perpetuated the oxygen crisis.

Question 2:

How does oxygen generation translate into availability of O2 at bed level? Can we create a guidance for positioning different O2 generating devices as broader health system strengthening going beyond COVID-19? As per ISO7396-1-2016, each hospital must have three resources of oxygen as primary and secondary options. Can we make policies to have this system replicated across all hospitals in India?

Expert response:

There is already a policy guidance on health facilities having different sources of oxygen as primary, secondary and reserve could be developed. It is recommended that all hospitals should classify their oxygen sources into three categories –

- Primary sources: PSA plant, LMO tanks (when PSA plant is not available) and oxygen cylinders (when both PSA plant and LMO tank are not available) should be considered as the primary source of delivering oxygen to patients
- Secondary sources: All health facilities should have a back-up secondary source. LMO tanks, where PSA plant is available and oxygen cylinders, where PSA and/or LMO tanks is available, is recommended as the secondary source.
- Reserve sources: It is recommended that health facilities use cylinders (to deliver any flow rate) or concentrators (only to deliver flow rates of up to 10 LPM) as its reserve sources for oxygen supply.

To estimate the demand of oxygen for each hospital, the Government of India recommends demand projection on basis of 10 LPM for each oxygen supported beds and 30 LPM for each ICU bed. Non-government hospitals in India are encouraged to use this formula when calculating their oxygen demand. Please note that the recommended formula may vary by country. One is advised to consult the in-country guidelines when calculating oxygen demand.

A policy on minimum stock of oxygen and oxygen therapy related commodities and consumables based on the facility bed capacity could be developed, to strengthen oxygen inventory management practices at the level of health facilities.

Question 3:

Are there any plans to develop technical guidance to set-up oxygen generation equipment at medical facilities as a broader health system strengthening initiative which is not just limited to COVID-19 but also addresses medical conditions such as COPDs?

Expert response:

Training modules have been developed for running and maintaining PSA plants, concentrators and cylinders. However, we could explore developing guidance for typical flow rates of oxygen that would be required to treat a specific disease and the sources of oxygen that could deliver those flow rates. Other than COVID-19, there are multiple other conditions such as pneumonia, chronic obstructive pulmonary disease (COPD), heart failure, asthma, bronchopulmonary dysplasia, cystic fibrosis, sleep apnea, etc. that require oxygen therapy to treat hypoxemia.

Question 4:

Could you elaborate on how states with limited resources learn from a state like Kerala, and take precautions for the anticipated third wave? What were some of the challenges faced and how did the state overcome them?

Expert response:

Despite of the high disease burden, Kerala saw a case fatality rate of only 0.5% with a seropositivity of 43%. Mr. Balamurali D. provided insights on the measures taken by Government of Kerala to address the surge in the demand met with limited resources in a short span.

Kerala adopted the oxygen wastage reduction strategy

The state government equipped 56 major hospitals with medical gas pipelines which otherwise used cylinders. Patients were triaged depending on severity and need for oxygen. Patients were categorized into three categories based on severity of disease as A, B and C. Hospitals were categorized as first line treatment centers, second line treatment centers, and COVID-19 hospitals.

Oxygen audit committees were formed which consist of anesthetists and biomedical engineers. Audits were done before the second wave, which helped in identifying and correcting wastage at the local level. Kerala also developed and disseminated guidelines on rational use of oxygen.

Regulation of oxygen production and storage by the government

Regulations such as the use of industrial oxygen producing units for production of liquid medical oxygen, were imposed by the national government. There is one major LMO producer in Kerala which previously produced about 50 to 60 MT of oxygen per day. The oxygen production increased to 180 MT by the first week of June.

National Disaster Management Authority also issued directive of diverting industrial oxygen cylinders for storage of medical oxygen.

Improving oxygen storage capacity across the state

Three buffer storages were created at strategic locations based on the distance between production and supply units in the state. For example, two buffer zones at Kochi which is towards central part of the state, and one at the southern industrial area were established for emergency which together accounted for 60 MT.

Private hospitals complied with the government's advice on increasing storage capacity. Major private medical colleges which previously relied on daily oxygen supply were identified and equipped with increased storage capacity.

Strengthened supply chain management of oxygen

In Kerala, there was one liquid oxygen producing unit, 11 air separation units, 17 re-fillers, and 100+ hospitals including public and private sector. Some of these hospitals purchased oxygen from states like Karnataka and Tamil Nadu through existing contracts and supply chains. A command system called state war room and district-level war room was established. It was one-stop platform for management of all the oxygen-related demands.

IT platforms were created to map the demand for government and private health institutions. These mapped the capacity of patient bed; patient load; storage capacity; oxygen production; and major suppliers like dealers, gaseous generation units, manufacturers, re-fillers, etc.

Data collection of 24-hour oxygen usage pattern, weekly usage history etc. aided in evaluating allocation requirement, wastage and overstocking that further helped in prudent decision-making.

Transportation was subsidized and several rules were introduced such as tankers to be run at full capacity with no idling time for any tanker.

Hub and Spoke model were created that mapped the nearest suppliers to the institution in need and optimized the oxygen supply chain and evacuation capacity of LMO.

Upgradation of oxygen production capacity

The state government identified non-functional air separation units and made them functional by adding more production in gaseous oxygen.

The state also increased the bed capacity surrounding places nearby industries that were producing other gases along with gaseous oxygen as a byproduct like KMML (public sector unit) and a refinery in Kochi.

Incentives to private sector for oxygen supply and management

Economic incentive was provided such as subsidized transportation charges for private sector and government funded transportation means.

Regulatory incentives for speeding up installation of new oxygen production units by relaxation on the legal clearance helped in increasing oxygen production.

Preparation for subsequent waves of the pandemic

The government is focusing on investing in PSA plants since establishing liquid oxygen production units is a time-consuming practice. The aim is to achieve 85 MT of capacity per day, to meet peak requirements during the predicted surges and purchasing more cylinders to further improve the storage capacity. The state government is also increasing the storage capacity for LMO.

For more information, kindly refer to “Oxygen Management in Kerala: What made the state oxygen positive? A Case Study” in the Resource Centre.

Question 5:

What are some of the initiatives and ways the Government of India is planning on increasing oxygen production for the anticipated third wave?

Expert response:

The government of India has already taken several steps in preparation for the third wave. Some of the steps taken to meet immediate and medium-term demands are –

- Accelerating the production of Liquid Medical Oxygen (LMO) at both public and private sector establishments, including industrial units like steel and petroleum refineries. The Drug Controller General of India advised the industrial oxygen manufacturers in April 2020 to produce medical-grade oxygen.
- Increasing the storage capacity for liquid oxygen across all major health facilities by installation of LMO tanks.

- Releasing excess stocks of liquid oxygen, for example, safety stock in storage tanks of the steel plants was brought down to a requirement of 2.5 days from about 3.5 days, thereby increasing the availability of liquid medical oxygen from the stocks for medical use.
- Acknowledging that the oxygen burden is always not constant across all the states, the government classified the states and districts geographically as high burden, moderate burden, and low burden areas, and used formula-based oxygen demand-supply gap estimation to plan and allocate oxygen using a dynamic framework.
- India has developed a nationwide supply plan, matching with the production centers, and sharing the oxygen sources between states.
- During the second wave, when demand for oxygen was peaking, the Government of India brought in the services of Indian Air Force and Indian Railways to expedite the mobilization of LMO tankers. For the first time, liquid medical oxygen was transported on rail.
- During the second wave, the oxygen allocation plan was reviewed every alternate day and allocations were made in consultations with the state governments facilitated by the health ministry.
- Government also restricted supply of oxygen for industrial use to only 9 industries which included ampoules & vials, pharmaceutical, petroleum refineries, steel plants, nuclear energy facilities, oxygen cylinder manufacturers, wastewater treatment plants, food and water purification, and process industries that require uninterrupted supply of Oxygen as approved by respective State governments.
- During the second wave, GoI also imported PSA plants, LMO, LMO tankers, concentrators and cylinders from other countries to augment its manufacturing, storage and transportation capacity for medical oxygen.
- Around 800 liquid nitrogen and argon tankers were converted into LMO tankers with the help of PESO certification to enhance the movement of LMO in the country. This led to a total of about 2000 LMO tankers during the peak of pandemic.
- Multiple defunct LMO manufacturing units were also revived.

The long-term systems strengthening for medical oxygen, includes –

- Establishment of over 4500 PSA plants at public health facilities, along with procurement and distribution of over 100,000 concentrators to the states. In addition, India is also in process of procuring 100 new LMO tankers and over 100,000 cylinders.
- Development of web portals, such as oxygen demand aggregation system (ODAS) to capture oxygen shortage data, and oxygen demand tracking system is enabling timely response to oxygen demand and supply. A similar portal tracks distribution of oxygen concentrators in the country.
- The Ministry of Skills Development and Entrepreneurship has launched short-term courses on operation and management of respiratory equipment and operation and management of PSA plants, with the Indian Institute of Technology, Kanpur, which is now being rolled out through Regional Directorate for Skills Development and Entrepreneurship (RDSDEs) across the country. This initiative is aimed at reducing the skills gap in managing operation and maintenance of respiratory care equipment by training semi-skilled workers and developing them as multi-task technicians.

For more insights, kindly listen to the video recording of the webinars in this series where several representatives from the government of India have shared the country's experience in building a resilient oxygen ecosystem. The videos are available in the Resource Centre of the webinar platform.

Question 6:

Which regulatory body in India certifies and approves the performance of devices, like HFNC, CPAP machine, BIPAP machine, ICU ventilators, etc.?

Expert response:

Cylinder and LMO installation and refilling of cylinders: PESO (Petroleum and Explosives Safety Organization) is the regulatory body in India. The BIPAP system has to be tested and certified for safety and performance of NABL accredited agencies. Following the production and performance criteria and standards to follow, only certification is mandatory.

Quality Council of India (QCI), India's apex quality facilitation and national accreditation body, and the Association of Indian Medical Device Industry (AIMED) develop and operate voluntary certification programmes for Medical Devices in order to enable medical device industry to demonstrate adherence to the best international standards and enhance its credibility in the world market. Moreover, Indian Public Health Standards (IPHS) are a set of uniform standards envisaged to improve the quality of health care delivery in the country by ensuring necessary public health care infrastructure planning and up-gradation.

Question 7:

Which regulatory body in India regulates the quality and quantity of oxygen generated by oxygen equipment?

Expert response:

The Petroleum and Explosives Safety Organization (PESO) serves as a nodal agency for regulating safety of hazardous substances such as explosives, compressed gases and petroleum. PESO primarily was responsible for approving the conversion of liquid argon and nitrogen tankers into liquid oxygen tankers. Moreover, PESO also monitored the conversion of liquid nitrogen cylinders into liquid oxygen cylinders.

Moreover, Central Pollution Control Board was tasked with a responsibility of converting nitrogen plants based on PSA technology into oxygen PSA plants to enhance availability of medical Oxygen. National Pharmaceuticals Pricing Authority (NPPA) was tasked with the responsibility of capping prices of Oxygen concentrators whereas Central Drugs Standard Control Organization (CDSCO) was tasked with issuing advisory regarding Oxygen concentrators suitable in a home setting. Furthermore, DPCO capped the price of LMO as well gaseous oxygen and Controller FDA at the State level monitored the overall supply and quality of medical oxygen.

Question 8:

What are some ways to reduce the misuse of oxygen in a health facility?

Expert response:

The health facility (if private) or the state or district health authority should develop comprehensive guidelines on rational use of oxygen.

Some of the practices that can contribute to ensure rational use of oxygen are provided in the table below. These are only indicative in nature. Please consult your medical experts before applying them.

Do's	Don'ts
Target SpO_2: 92-94%	Don't use HFNC with high Oxygen flow
Target PaO_2: Around 60 mm Hg	Don't allow leakages from NIV mask
Never exceed oxygen flow (litres per minute – LPM) of - • 14 LPM on NRBM • 8 LPM on simple mask	Don't keep central oxygen pipeline connected when ventilator is not in use

• 6 LPM on nasal prongs	
Titrate use of IPAP to achieve Tidal Volume of 6-7 ml/kg only	Don't keep flow meter connected when not in use
Use only EPAP/CPAP for better oxygenation	Don't keep ventilator SWITCHED ON when not in use
Encourage awake proning for all. Lateral position is favoured for those who do not tolerate prone position, in obese and pregnant patients.	Don't use leaky or faulty flow meters
Use Oxygen concentrator (with different capacity and dual flowmeter)	Don't keep humidifier bottle full of water in flow meter

Besides these, ensure regular maintenance and calibration of oxygen delivery devices such as concentrators, cylinders, flow meters, manifold systems, oxygen outlets, etc., and regularly train and upgrade skill of the ICU staff and staff managing oxygen beds on clinical practices and equipment management.

Question 9:

What is the difference between production and effective delivery of medical oxygen?

Expert response:

Production of medical oxygen refers to generation of oxygen either using pressure swing adsorption technology (PSA plants or concentrators) or using cryogenic distillation (LMO).

Effective delivery of oxygen is about ensuring timely delivery of medical grade oxygen (90% purity or above) to the patient at a desired flow rate and for desired amount of time with correct regulatory (flowmeters), conditioning (humidifiers), monitoring devices (oxygen analyzers, POx) and delivery devices (nasal cannula, catheter, venturi masks, etc.), and under the supervision of qualified healthcare staff.

Question 10:

How many patients can a ton of oxygen serve every day?

Expert response:

One metric ton (or a 1000 kgs) of medical oxygen in gaseous form can serve about 50 oxygen beds (at 10 LPM) or about 16 ICU beds (at 30 LPM) for a single day.

Question 11:

What has been the preparation for the third wave in terms of storage augmentation?

Expert response:

Storage of oxygen can be augmented by procuring more oxygen cylinders and cryogenic tanks (including micro cylinders). Moreover, oxygen storage can be indirectly augmented by generating oxygen on site through PSA plants or oxygen concentrators, which can reduce the dependence on oxygen cylinders.

During the first wave in May 2020, Government of India procured 102,400 oxygen cylinders and distributed them to various states to augment oxygen storage capacity. During the second wave in April 2021, the Indian government placed orders for additional 127,000 cylinders (54,000 D-type and 73,000 B-type) of which 33,404 were delivered by the end of July 2021.

To generate oxygen at the health facility level and to reduce dependence on oxygen cylinders and LMO, about 4500 PSA plants are being established in hospitals, especially in far-flung areas. This will enable hospitals in difficult-to-reach areas to become self-sufficient in the generation of oxygen for their needs. Furthermore, the Government of India has allocated more than 100,000 oxygen concentrators to various states to fast-track the availability of medical oxygen in rural and peri-urban areas.

Question 12:

What are the preparations among private hospitals for the third wave in terms of storage augmentation? Is there any state support, like subsidies, to private hospitals for storage augmentation?

Expert response:

There has been a systematic approach for ensuring the medical oxygen systems for managing COVID-19 case load at private hospitals. The following steps have been taken to ensure the same:

- Constitution of a Paediatric COVID-19 expert group and development of guidelines for Paediatric COVID-19 case management
- Operational readiness assessments have been initiated and are being carried out. However, as far as including setting up oxygen generator plants on premises is concerned, it is yet to start and is in progress
- Needs assessment for Paediatric and adult medicines and supplies volumes are being carried out in discussion with supply chain teams and suppliers
- Mock drills are being conducted at major hospitals to assess readiness of emergency and other departments to handle surge in cases; gaps identified are being closed
- Vaccination of all employees has been done and their family members are being encouraged to complete their vaccination
- Learning of first and second wave have been documented to serve as ready reference
- Daily report of COVID-19 admissions and discharges are being documented so that any change in trend can be picked up early and preparations are made accordingly

Besides this, the hospital teams are in regular contact with health authorities, and there are so far no roadblocks in terms of storage capacities.

Question 13:

What benefits can one expect from using Internet of Things (IoT) technology to operationally connect oxygen concentration units to dashboards, like the e-upkarn system?

Expert response:

Any digital automation which helps in real time data collection and monitoring which helps in proactive decision making is certainly going to be immensely helpful in public health specifically when it comes to effective pandemic response. IoT based interventions to monitor O2 availability and consumption should be an integral part of the O2 Management Ecosystem and OCs are not an exception. There have been few efforts going on by the Government at the PSA Plant level and PATH has also been actively exploring the space at both the PSA Plant as well as the O2 Cylinder levels.

Question 14:

What is the technical guidance on use oxygen generation and storage devices beyond COVID-19 and have a system wide approach for sustainable oxygen systems in public health?

Expert response:

The Government of India is planning to make the PSA plants the primary source of medical oxygen in health facilities, which would be connected to the MGPS and reduce heavy reliance on jumbo cylinders, as was the case in many health facilities. Moreover, LMO tanks, cylinders and concentrators would be either the secondary or reserve supply depending on their availability. The health facilities in India are being advised to adopt the following approach –

- If all four sources are present, then PSA would be primary, LMO would be secondary, and cylinders and concentrators would be reserve supply.
- If PSA, cylinders, and concentrators are present, PSA would be primary, cylinders secondary and concentrators would be reserve supply.

In addition, as PSA plants consume large amount of electricity, the government is exploring viability of solarisation of PSA plants through pilots. The government may also investigate installation of filling stations at PSA plant sites to function as a hub for cylinder refilling and distribution to nearby facilities, as spoke, thus adopting a hub-and-spoke approach. Finally, as qualified personnel is required to run the PSA plant, the government is ensuring trainings of several thousands of technicians to ensure their regular functioning, upkeep, and maintenance.

Question 15:

Availability of continuous electricity at the level of SC/PHCs is one of the any challenges. What steps are being taken to address this challenge and ensure that oxygen concentrators work uninterrupted?

Expert response:

The oxygen concentrator can be directly plugged in to the power line (220 V AC/50 Hz) with an average power consumption of ranging from 300W to 550 W. Appropriate plugs and sockets for the same need to be identified and ensured along with a voltage stabilizer to avoid any damage to the system and drop in oxygen supply.

It is desirable to have continuous uninterrupted power supply at the health facility and a power back-up through DG Set / heavy duty invertor. UPS/Inverter/DG Set is recommended. Reserve back-up oxygen cylinders are necessary in case of equipment breakdown/failure and also for patient transport for referral.

Question 16:

How frequently should zeolite be changed? Is India now producing zeolite now? If so, who are the leading manufacturers and suppliers of zeolite in India?

Expert response:

Ideally zeolite should last over 10 years easily, but it is dedicated by the quality and quantity of zeolite filled. For more information, please refer to PATH's Technical Brief on 'Zeolite Molecular Sieve: Application, Availability and Accessibility for Medical Oxygen Concentration' available in the Resource Center on the webinar platform.

Question 17:

While preparing for the anticipated third wave, what are the few things that should be kept in mind to ensure effective supply chain management?

Expert response:

Drawing from the learnings of the first two waves, health experts have suggested following measures to ensure effective oxygen supply chain management:

- Three critical parameters, such as the size of the hospital, geographical location, and electricity supply reliability, are paramount while ensuring effective medical oxygen supply chain management.
- Based on the experience of last 18–20 months, it is mandatorily advised to have a minimum of two (maximum three) oxygen supply modes out of the available options such as oxygen concentrator (OC), pressure swing adsorption (PSA) oxygen generator, oxygen booster compressor with cylinder filling system (downstream of PSA), oxygen cylinders, and liquid medical oxygen (LMO) tank system.
- It is advisable for hospitals with more than 50 beds capacity to have a centralized pipeline network (MGPS).

The following examples further illustrate the measures mentioned above:

<u>Example 1</u>: Considering a 200-bed (or bigger) hospital located within a distance of 200 km of an LMO source having a reliable electricity supply, the supply chain management model should be as follows:

a. LMO tank system (as a primary source): 60%
b. PSA generator along with booster and cylinder filling system (as a secondary source): 40%
c. Oxygen cylinders
d. MGPS network
e. OC (as standby)

<u>Example 2</u>: Considering a hospital located at a far-off distance above 400 km from an LMO source having a reliable electricity supply, the supply chain management model should be as follows:

a. PSA generator along with booster and cylinder filling system (as a primary source): 80%
b. Cylinder manifold system (as a secondary source): 20%
c. Oxygen cylinders
d. MGPS network
e. OC (as standby)

<u>Example 3:</u> Considering a health center located at a far-off distance from an LMO source having an unreliable electricity supply, the supply chain model should be as follows:

a. PSA generator along with booster and cylinder filling system (as a primary source): 60%
b. OC (as a secondary source): 40%
c. Oxygen cylinders
d. MGPS network
e. Cylinder manifold system (as standby)
f. Suitable-size truck (in-house) for cylinder transportation
g. DG power source + Solar power source + UPS

<u>In addition, some of the other important points to note here are as follows:</u>

- The supply reliability of all equipment should be maintained round the clock.
- For all above supply systems, the minimum operational reliability of 98% should be ensured.
- AMC or equipment maintenance schedule should be ensured to avoid any breakdown or downtime.
- The stock of spare parts should be maintained mandatorily.

- The O&M training of in-house personnel should be organized.
- The oxygen consumption data should be recorded and maintained on a daily log sheet.
- The inspection and audit of oxygen supply system should be conducted on a fortnightly basis.

Question 18:

What is being done in India to make the medical oxygen supply flexible enough to meet a spike in the oxygen demand in the future?

Expert response:

A multilayered strategy is being adopted to ensure an adequate supply of medical oxygen to meet a spike in the demand in the future. This includes a combination of captive production at large public health facilities and enhanced access to LMO through improved storage and use of digital technology for better demand forecast and logistics management, First, over 3,500 PSA plants are being procured under various government and private sector programs, and more than half have already been installed. Second, solutions to demand and supply of medical oxygen have been developed across India through mechanisms such as ODAS and ODTS. These digital tools enable real-time collection of both demand and movement of medical oxygen across India. Third, LMO storage facilities are being set up across major cities and districts of India to enable the services to more areas through LMO supplies in case of a third wave. Last, the method of transporting LMO in bulk through railways is now well established, and operating procedures are institutionalized to respond to a spike in the oxygen demand in the future.

Question 19:

Where did Meghalaya source its oxygen-filled cylinders from, given that there were no LMO and PSA plants within the state?

Expert response:

Meghalaya sourced oxygen cylinders from Assam. The Premier Cryogenics Ltd. (Assam) is the primary supplier of oxygen to Meghalaya. Earlier, it used to supply refilled cylinders to Meghalaya as it doesn’t have the storage capacity for LMO. However, after the commissioning of two cryogenic mega tanks in Meghalaya in August/September 2021, the major portion of oxygen will be supplied as LMO from this company. These two mega cryogenic tanks are installed at Umsawli (13 kl), Shillong and Jengjal (20 kl), Tura. The company has two LMO production plants and one mega cryogenic tank in Assam. All three locations will be used to supply LMO or filled cylinders to Meghalaya.

Another supplier called Meghalaya Oxygen Pvt. Ltd., which is located at Amingaon (Assam), also supplies gaseous oxygen to Meghalaya (refilling cylinders only). In addition, Byrnihat is another gaseous oxygen plant in Meghalaya run by Byrnihat Oxygen Pvt. Ltd., which offers refilled cylinders to Meghalaya. This will also continue to supply oxygen to Khasi hills as per need

Questions on PSA Oxygen Generation Plant

Question 20:

What are the differences in performance outcomes between PSA/VSA system and VIE, regarding costs and efficiency?

Expert response:

Technology

Adsorption is defined as the affinity of a fluid for a solid surface. Using the differential affinities of various components of a gas mixture (such as air) it is possible to separate the various components. That, essentially, is the principle used by a PSA/VSA oxygen plant to supply oxygen via medical gas pipeline system. PSA plant performance is susceptible to humid environments and higher altitudes unlike VSA plant.

On the other hand, a vacuum insulated evaporator (VIE) is a form of pressure vessel that allows the bulk storage of cryogenic liquids including oxygen, nitrogen and argon. LMO tank is one such pressure vessel. Together with vaporizers, valves, piping, and a pressure control and pressure relief system, the VIE can supply oxygen via a medical gas pipeline system in a medical facility and is often leased from the medical gas supplier. Additionally, they are also installed at industrial units (also referred to as refilling stations) to fill Oxygen cylinders.

Operations

PSA/VSA plants operate at room temperature and require power source for onsite generation of Oxygen. A diesel generator (DG) set is required as a power backup source. Moreover, the plant site requires continuous manning for monitoring and operations purposes. On the other hand, VIEs do not require electricity to operate, however, its monitoring systems such as alarms, and other safety features do require power/battery source. Additionally, VIEs at industrial units have refilling systems such as compressor-booster systems that require power source to fill Oxygen cylinders. As oxygen is not produced by VIEs and they only act as storage devices for liquid Oxygen, they require specialized bulk road cryogenic tankers for transport of LMO from cryogenic air separation units (ASUs) to VIEs. As LMO is stored at about at -180 degrees Celsius, they require careful handling.

Costs

PSA oxygen plants have an initial set-up cost, which depends on the capacity of the plant. The set-up cost of a small PSA plant of 0.036 MT/day (18 LPM or 4 D type cylinders/day) capacity is about Rs 11 lacs (~USD 15,000) plus the annual CMC cost of around Rs 62,500 (~USD 800). The set-up cost of a large PSA plant of 2.75 MT/day (approx. 1400 LPM or 300 D type cylinders/day) capacity is about Rs 1.6 crore (~USD 215,000) plus the annual CMC cost of around Rs 862,500 (~USD 11,500). On the other hand, the cost of VIEs vary from Rs 7.5 lacs (~ USD 10,000) to Rs 15 lacs (~USD 20,000) for 1 kL (1.25 MT) and 10 kL (12.5 MT) tank, respectively. Please note that the costs mentioned for both PSAs and VIEs do not include costs of installation, and running costs such as electricity, labour and license fee wherever applicable. However, the running costs of VIE are lower than the PSA plant running costs when no compressor-booster systems are involved.

Question 21:

How can one ensure that purity of above 95% at output in PSA plants is consistently maintained?

Expert response:

The purity of above 95% at output in PSA plants is consistently maintained by following the steps below:

- Firstly, it is important to have a functional oxygen concentration monitoring device such as oxygen analyzer installed that is calibrated on a weekly basis. This is done to ensure the readings of oxygen concentrations are accurate
- Secondly, it should be ensured that the zeolite beds are replaced when the PSA plant fails to maintain concentration above at least 90%. To have 95% purity all the time would be a challenging and it would increase the cost of maintenance
- Thirdly, there should be adequate ventilation in the room
- Lastly, regular upkeep and maintenance of the plant is critical

Question 22:

What factors affects the quality and quantity of oxygen at production in the PSA plant and delivered to the patients?

Expert response:

Multiple regulation, conditioning and monitoring devices are used to monitor the flow rates, pressure of oxygen both at the PSA plant site and at the patient bedside. The pressures and flow rates that are generated at the PSA plant site are much higher than what are delivered to the patient.

Moreover, oxygen that is produced and delivered to patients is dry; therefore, humidifiers are used to add moisture to the air before the patient inhales the oxygen. It is important to note that the dry air causes irritation if inhaled.

Regular maintenance such as replacement of filters (air filter, oil particle filter & bacterial filter), and zeolite beds ensure good quality of oxygen. Quantity of oxygen may be adversely affected by high temperature, humidity, and altitude as well as lack of proper ventilation. Any leakages can affect both the quantity and quality of oxygen.

Question 23:

How to calibrate PSA oxygen plant analyzer? With calibration gas or refer to atmospheric air? How often do we need to calibrate PSA oxygen plants analyzer?

Expert response:

- Calibrate the Oxygen Analyzer before each use; and also while replacing the oxygen sensor or the batteries.
- To ensure accuracy, the precision medical Oxygen Analyzer should only be calibrated using 100% oxygen. Using any other concentration will result in possible inaccurate readings. Air calibration is not recommended unless the sensor can be exposed to a known source of clean air. Hospital room air is often enriched with excess oxygen by staff.
- Calibrate the Oxygen Analyzer at a pressure and flow similar to your application.
- Before calibrating the Oxygen Analyzer, the oxygen concentration readout should be stable and not drifting more than 0.2%.
- DO NOT calibrate the Oxygen Analyzer in humidified gas.
- Calibration gas flow to the Oxygen Analyzer of two liters per minute or more is recommended to minimize the possibility of obtaining a “false” calibration value.
- Allow the oxygen to saturate the sensor. Although a stable value is usually observed within 30 seconds, allow at least two minutes to ensure that the sensor is completely saturated with the calibration gas.

Question 24:

Should we also install another analyzer at manifold or in hospital to monitor quality of oxygen once it leaves the PSA plant?

Expert response:

Yes, oxygen manifold systems could have an Oxygen Analyzer to monitor the quality of oxygen. Sometimes, the patient breathing circuits also have Oxygen Analyzers to monitor the oxygen concentration being delivered to the patient.

Question 25:

What is the procedure of oxygen testing for PSA? Which labs are authorised for oxygen quality testing on western Uttar Pradesh? [While the question is specific to western UP, we should give the detailed list of authorised labs].

Expert response:

In India, it is mandatory that the oxygen generated from PSA plant is collected from the installed unit by the vendor and sent only to the NABL accredited labs before commissioning. Until a satisfactory analysis result is received, the medical oxygen is not supplied to the hospital.

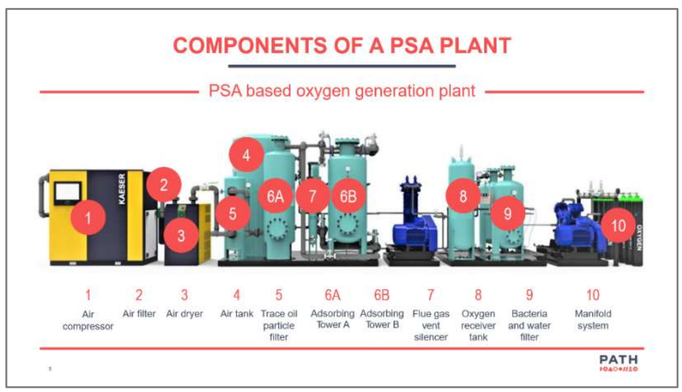
Following link provides the list of NABL accredited labs for oxygen quality testing across India: https://nabl-india.org/wp-content/uploads/2020/04/Testing-directory-as-on-31.03.2020.pdf

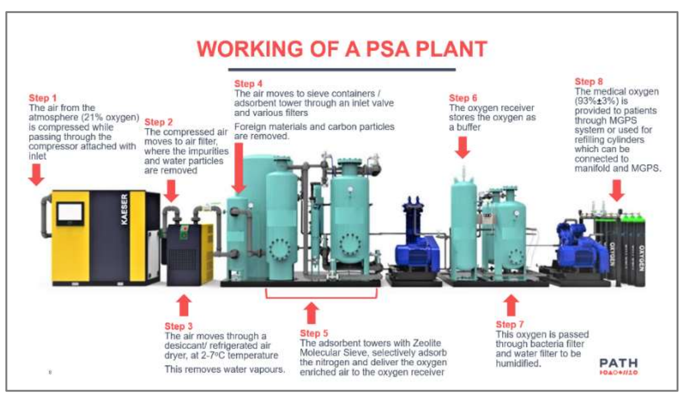
Question 26:

What are the different parts of a PSA plant and its significance? Please give us names of all the filters used in a PSA oxygen plant and its role in the oxygen production chain?

Expert response:

A PSA based oxygen generation plant typically consists of an air compressor, dryer, filters, dual separation chambers, a reservoir, and controls. The main installation parts are an Air Compressor, an Air Filter, an Air Dryer, an Air Buffer Tank, Trace Oil Particle Filter or a Coal Tower, an Air Buffer for pneumatic valves, a 2-Column (or 3-Column or X-version) PSA generator combined with internal piping and electric cabinet and an Oxygen buffer tank, all connected to either an Oxygen Storage Tank or a manifold, with many oxygen cylinders, or directly connected to a medical gas pipeline system. However, there can be some minor modifications in the components from one manufacturer to another.





The working of each component of PSA plant is explained in Figure 2.

Filters in a PSA plant

The electric motor of the PSA plant's compressor should have dry paper type suction air filter with silencer. The refrigerant in the PSA plant has capillary filter and tube.

Each PSA plant has a filter assembly, which has a pre-filter (>5 micron), a coalescing filter (0.1 micron) and a coal filter (coal tower, alternatively activated carbon filter). The compressed air flows through the filter assembly before the air enters the adsorber vessels. The particulate filter or pre-filter removes condensed water, oil, dirt, scale, etc. from the feed air, and then, a separate coalescing filter (mounted on most of the models) removes condensed water, oil vapor, and other contaminants from the feed air before the air enters the adsorbers.

The PSA plant also has a pair of molecular sieves to permit continuous generation of oxygen. In some models, they are coal filters, with activate carbon filters. In other models, the molecular sieves of a high-performing chemically produced zeolite.

The oxygen tank (receiver/buffer tank) has a bacterial outlet filter.

However, the number and type of filters vary from model to model. Kindly check with the original equipment manufacturer on the filter before procuring the device.

Question 27:

Where can one access training manuals on operation and maintenance of the PSA oxygen plants? Can these trainings be done online? Are the trainings on operation and maintenance of PSA plant available for participants from countries other than India? If so, please provide detail.

Expert response:

PATH has developed a resource of training materials on operations and maintenance of PSA oxygen generation plants. PATH is currently engaged in building capacity of technicians in public health facilities in its project locations across India, where the PSA oxygen generating plants are being installed. This training is largely virtual with some components delivered through classroom training.

The Ministry of Skills Development and Entrepreneurship, Government of India has trained master trainers associated with Regional Directorate of Skills Development and Entrepreneurship (RDSDEs) across India on operations and management of PSA oxygen plants. They, in turn, conduct a 180-hour training for qualified plant operators using materials from this course. More information on this training is available on https://nqr.gov.in/qualification-title?nid=5520

Other than PATH and the Government of India, the Indian Institute of Technology, Kanpur in India has designed a short-term course for master trainers who will eventually train technicians working on the PSA Oxygen Generating Plants, which are being installed throughout the country. The course outlines the fundamentals behind the plant operation, generic layout of such plants, maintenance issues and troubleshooting aspects. For more information, please contact Dr. Sameer Khandekar, Professor, Department of Mechanical Engineering, IIT Kanpur at samkhan@iitk.ac.in

Question 28:

How far from the hospital building should one establish the PSA plant?

Expert response:

While there is no documented guidance on the distance between the PSA plant and the hospital building, it is recommended that the site for the PSA plant should be within 20 meters from the existing manifold or MGPS.

Question 29:

How can the PSA plants be used to fill oxygen cylinders for nearby smaller hospitals that do not have regular or adequate oxygen supply?

Expert response:

It can be done by supplemental booster compressor and by attaching a manifold to the plant.

Question 30:

What is the approximate cost of one PSA plant? [Approximate cost by capacity (LPM)]

Expert response:

Cost the PSA oxygen generation plant varies based on the plant capacity in Litres Per Minute (LPM) specifications and vendor to vendor, plant capacity starts from 50 LPM to up to 5000 LPM. The costing can be referred from vendors websites/GeM Portal.

Question 31:

Are the required spare parts for the PSA plant available in India? Which spare parts of a PSA plant can be sourced from India?

Expert response:

PSA Oxygen Generation Plant (OGP) should be maintained by the vendor for at least till 10 years of installation. One SHOULD get the spares for PSA GP only from its OEM or its authorized vendors only.

Question 32:

We are aware that PSA plants need uninterrupted power supply, but the power downtime are inevitable. Considering such situations, what kind of down time level is assumed at any PSA installation so that backups are adequately planned?

Expert response:

PSA plants need uninterrupted power supply for functioning, in case of power downtime, there should be secondary source of oxygen source to support during downtime.

- In case of power downtime, PSA plant needs 15-20 minutes to attain the oxygen purity of 93% ± 3%. To avoid the gap of 15-20 minutes, it is recommended to have DG power back up with auto change over system, so that power interruption is not there for PSA Plant functioning
- During PSA plants breakdown to avoid interruptions, each health facility where a PSA plant is installed should also have a back-up source of at least 2-3 days stock of filled oxygen cylinders. These filled oxygen cylinder banks should be connected to the manifold at all times. In case of any interruption of oxygen flow from the PSA plant, the oxygen supply is to automatically switch over to these cylinder banks.

Questions on Oxygen Concentrators

Question 33:

During the second wave of COVID-19 in India, I noticed patients requiring oxygen therapy were being supported by concentrators instead of cylinders, which worsened their condition. What are the advantages/ disadvantages of providing an oxygen concentrator vs an oxygen cylinder to patient in need of oxygen therapy?

Expert response:

Adequate availability of sources of medical oxygen and supportive respiratory care is a critical lifesaving intervention in cases where a patient experiences hypoxia due to COVID-19. An oxygen concentrator is an alternative to using oxygen cylinders, both of which are used in the process of oxygen therapy to help people who fail to get suitable oxygen to breathe and for the proper functioning of the body.

Oxygen concentrators work in a similar way as oxygen cylinders in delivering oxygen (with maximum flow rate of up to 10 LPM) to hypoxemic patients with the use of a cannula, oxygen masks or nasal tubes. However, while oxygen cylinders work for a finite amount of time (since they contain a limited supply of oxygen), oxygen concentrators use pressure swing adsorption (PSA) technology to deliver oxygen with a concentration of 93+/-3%. Concentrators extract the ambient air, compress it, remove nitrogen and deliver the purified and concentrated Oxygen. Such a process cuts down the need for constant replacements or refilling, which are needed with LMO tanks or cylinders. Concentrators are available in with single vs dual outlet and in capacities of 3, 5 and 10 LPM flow rates.

Some of the reported problems while using an oxygen concentrator: Oxygen concentrators may fail to produce therapeutic levels of oxygen because of common problems involving the air-intake system, malfunctioning sieve-control valves, and contaminated sieve materials. Water vapors in room air can compromise the adsorption of nitrogen in the sieve beds by entering through small leaks in the internal tubing; if sufficient water vapors contaminate the sieve beds, the gas delivered will not be of requisite purity. Moreover, oxygen concentrators are not suitable for highly critical or ICU patients on ventilator support who require flow rates over 10 LPM. Additionally, they require regular calibration, maintenance and delicate handling. As they require power source for operation, a reserve supply of oxygen cylinders is required in case of power or equipment failure.

Advantages of using oxygen concentrators over cylinders: They are much less dangerous than oxygen cylinders, which can, if ruptured or leaking, cause or increase the combustion rate of a fire. Oxygen concentrators, on the other hand, pose no such danger. The other main benefit is they are portable and increase the ability to be mobile with oxygen. Although cylinders may be portal, they are heavier and require additional equipment for relocation. Moreover, concentrators have inbuilt humidifier bottle, flowmeter and sometimes pulse oximeter to monitor the oxygen delivery process, which is not the case with cylinders.

Question 34:

How do we decide which facilities should be given 5 LPM oxygen concentrators and which ones will get 10 LPM oxygen concentrators?

Expert response:

Most of the oxygen concentrators supplied in India are of 5 LPM, 8LPM and 10 LPM capacity. The oxygen concentrators are also available in 3 LPM capacity. They are portable units, but not much in supply in India.

In the public health systems in India, the primary facilities such as the Health and Wellness Centers, the Primary Healthcare Centers (PHC) and the Community Healthcare Centers (CHC) are being equipped with two to three 5 or 10 LPM capacity oxygen concentrators per 10 beds. However, for higher caseload CHCs, Referral and District Hospital or Tertiary level facilities, 10 LPM capacity is recommended. A 10 LPM oxygen concentrator is suitable to manage mild and moderate hypoxemia cases. It can service usually up to two l beds with the use of a flowmeter stand to split output flow.

Question 35:

Are the oxygen banks currently active for non-COVID-19 cases? What are the guidelines from the Government of India regarding oxygen banks?

Expert response:

Currently, there are no oxygen concentrators' bank that are offering its services to meet the needs of non-COVID-19 cases. A few districts and states started this initiative as an emergency response when there was crisis of oxygen and oxygen concentrators, especially for home use, were in low supply. After the supply of Oxygen Concentrators was augmented by PMCARES and other CSR and philanthropic organizations, there is a case of over-availability of oxygen concentrators, which are now being kept in state and district warehouses or in the facilities as reserve resource.

Although, an Oxygen Concentrator Bank at district level can be boon for home quarantine, COVID-19 centers and for cases such as emergency triage, neonatal resuscitation, MCH unit and for the referral, there are no guidelines from the government of India on the operation or regulation of Oxygen Concentrator banks.

Question 36:

At what level of oxygen, should a patient be administered oxygen via oxygen concentrator? What are the indicators for use of oxygen concentrators during oxygen therapy?

Expert response:

Indications for the use of oxygen concentrators during oxygen therapy are as follows:

- Any COVID patient with oxygen saturation less than or equal to 94%.
- Oxygen supplementation is required when respiration rate is more than 25 per minute and SpO2 is less than 94%.
- It is advisable to take doctor consultation and measure SpO2 by pulse oximeter every 2 hrs.
- When the range of SpO2 is dropping from 94% to 92 %, one should start oxygen either through cylinder or concentrator at 5L per minute.
- The management of these patients should be on guidance from doctors and aligned with the National guidelines.

Question 37:

If humidifier is not an active part in the purification of oxygen, why it is necessary to change water in humidifier regularly?

Expert response:

Water used in the humidifier is exposed to high levels of oxygen (and of course moisture), which can lead to rapid microbial growth. These microbes are then aerosolized by the water and inhaled by the patient, which can increase the risk of infection.

Question 38:

Can the oxygen concentrators start up immediately once power returns after a brief interruption? If not, what is the duration of down time for oxygen concentrators?

Expert response:

It is not certain that this is an issue for concentrators, but it is best advised that to be completely safe there should be a wait until the oxygen flow stops (around 30 seconds depending on model) before restarting.

Please refer to the use guidance from the Oxygen Concentrator manufacturers for more input on this aspect.

Question 39:

In low resource setting with erratic electricity supply, what are the options one can consider to power oxygen concentrators at scale?

Expert response:

Devices such as surge suppressors, voltage cut off devices, and voltage stabilizers can help protect oxygen concentrators from unstable electricity conditions. For more information, please refer to chapter 6 of the PATH electricity planning guide for more details about these devices; www.path.org/resource/electricity-planning-guide.

Question 40:

Does the OCMIS portal also collect information on oxygen concentrators mobilized through development partners, CSR resources etc.?

Expert response:

OC-MIS Portal, currently captures the details of oxygen concentrators allocated, distributed and installed under PMCARES. There is a provision to capture the details of oxygen concentrators mobilized through other sources such as CSR etc. The state government can capture this information in the OC-MIS in coordination with the team from the Government of India.

Question 41:

What precautions should be taken by the health staff during generation of oxygen?

Expert response:

Following precautions should be taken by health staff while working with oxygen concentrators:

- In case of oxygen concentrators, distance of OC from any electric panel should be at least 1.5 meters and the distance from any heat source should be at least three meters.
- It should not be placed close to the wall to allow for continuous suction of air.
- Using of sanitizers while using OC should be avoided as a preventive measure for fire hazards.
- Any fire related activity is strictly prohibited in the vicinity of OC usage.
- Staff should make patients aware that they should not use any cosmetic creams, deodorants, lip balms etc. these cosmetics support combustion.
- Filters of OC should be checked prior to its usage.

When working with PSA oxygen generation plants, following precautions should be taken:

- In the plant room smoking and fire related activity is strictly prohibited.
- Plant room flooring should not be made up of combustible material like carpets, wooden floor, PVC sheets.
- Sound absorbers should be avoided as they are made up of combustible material.
- Venting of oxygen should not be done towards electric panels.

- Everyday walk around task should be made to check for leakages from joints.
- ABC fire extinguishers should be places in plant room in a functional state.
- PSA plant parts and sub-assemblies should be observed for faults and if any level 2 troubleshooting is required then it is necessary to contact vendor of PSA plant. Any component should not be repaired without instructions from vendors.
- The PSA plant site should be well-ventilated and be protected from direct sunlight, rains and flooding.

Question 42:

What level of flexibility and approvals in administration acted as an enabler for procurement of oxygen concentrators? How does RMSCL plan to manage inventory for oxygen concentrators to meet demand for spares and replacements?

Expert response:

Based on the experiences of first wave, the state had decided to procure OCs before the second wave itself. There was buying from the highest level for ensuring OCs till the Panchayat level. Considering the need of the hour, process of procurement by floating tenders was also avoided by the state. RMSCL directly got in touch with major vendors and negotiated the price for the OCs.

OCs have been included in E-upkaran. All the equipment entered in E-upkaran are under maintenance contract with Kirloskar Technical Private Limited (KTPL) ando OCs have been part of it from day 1. The state is also in discussion with major vendors to establish their units/branches in Rajasthan which will happen in the near future. . Once established, the OCs will be serviced by them including meeting their demand for spares and replacements.

Question 43:

How can we get more information on the features and functionality of the e-upkarn portal - the web-based repair and maintenance portal for OCs in Rajasthan, if we'd like to replicate it?

Expert response:

All the information related in E-Upkaran is available at the link: http://nrhmrajasthan.nic.in/E-Upkaran.htm. In case of further information, the State Nodal Officer can be reached at stateinventorycell02@gmail.com

Questions on Liquid Medical Oxygen and MGPS

Question 44:

What were best practices in operations and management of oxygen devices, medical gas pipeline system (MGPS) and manifold in practice that private hospitals can replicate?

Expert response:

Some of the best practices in operations and management of oxygen devices, medical gas pipeline system (MGPS) are as follows:

Development of clinical case management guidelines

Clinical case management guidelines have been developed by a COVID-19 expert group of senior clinicians. This guideline includes information on the following:

- Defining target oxygen saturation based on clinical condition rather than blindly following oxygen flow rate
- Use of awake prone ventilation

Efficient use of oxygen at patient bed side

This can be ensured by the following:

- Role of 'Oxygen Nurse' – ward rounds to see target saturation, flow rate etc.
- Ensure flow meters are off when patient does not need oxygen or mask is removed – e.g. while having meals, visiting the washroom, etc.

Maintenance of leak free Oxygen delivery

This can be ensured by –

- Regular round by engineering and maintenance team to identify and fix sources of oxygen leaks
- Check MGPS (including terminal outlets) and cylinders for any loose connections, cracks etc. – from leakage and fire hazard perspective

Management Support

This can be done by the following steps:

- Formation of oxygen committee to monitor and ensure correct use of medical oxygen
- Round the clock availability of maintenance team and supervisor for early response and rectification

Question 45:

What fundamental principles should be kept in mind when setting up the MGPS? Which technical guidelines should we refer to for MGPS?

Expert response:

The control panel should fulfil all requirements of EN ISO 7396 – 1: 2007/ HTM-02-01, to withstand the pressure at every different section of the oxygen piping system and have and other relevant international standards. Oxygen pipeline in India is colored in yellow paint.

Oxygen pipeline system should gradually taper, with its diameter systematically reducing from the oxygen plant to the delivery point. The oxygen flow pressure through the MGPS near the LMO tank or oxygen plant should be more than 15 bars, at the wards and zones should be between 5 to 7 bars, and at the point of delivery should be 4 to 5 bars.

When constructing the MGPS, one must ensure that the pipeline system is divided into different zones, and there are pressure gauges to show pressure in the zones. The MGPS must have a master alarm and zonal alarms to alert if there is a drop in pressure.

Pressure reducers should be flame proofed by an authorized certification agency and specially certified for medical gases such as oxygen and nitrous oxide. It should have a safety certificate from a competent authority CE issued by a notified body registered in European Commission and all the regulators should be adiabatic certified.

Question 46:

What should be the MGPS central line pressure? Should we ask the vendor to supply pressure regulator if it is below 4.2 bar?

Expert response:

Inform the vendor to fix the issue. The pressure drop may be due to multiple reasons.

Gas	US	Pressure	HTM/ ISO	Pressure
Oxygen		50-59 psi		4 Bar (400 kPa)
Nitrous oxide		50-59 psi		4 Bar (400 kPa)
Medical air		50-59 psi		4 Bar (400 kPa)
Surgical air		100-120 psi		7 Bar (700 kPa)
Medical Vacuum		-650 to -450 mmHg		-650 to -450 mmHg
Carbon dioxide		50-59 psi		4 Bar (400 kPa)
Outlet shall be equipped with a primary and secondary check valve and the secondary check valve shall be rated at minimum pressure of 200 psi.				

US, United States; psi, pounds per square inch; HTM, Health Technical Memorandum; ISO, International Organization for Standardization

Question 47:

Can a PSA reticulation system be used for cryogenic tank supply, or is there any need for new reticulation?

Expert response:

The manifold system or medical gas pipeline system that is required to deliver medical oxygen to patients' bedside is the same for both PSA and LMO (cryogenic tank with the vaporizer). Both PSA and LMO tanks could be connected to the manifold system, with one source being the primary supply and the other being the secondary or reserve supply. As the purity of the oxygen from PSA (about 93%) and LMO tank (about 99%) is different, the monitoring devices (for pressure, temperature, and alarm systems) and ventilators may have to be recalibrated each time the source of oxygen is switched between PSA and LMO.

Questions on Oxygen Logistics

Question 48:

How did the bordering districts rely on neighboring states and manage their oxygen supply? Were the suppliers from neighboring states able to honor their existing contracts?

Expert response:

During the second wave of the pandemic, an oxygen task force was formed by the central government that was assigned the responsibility of allocating and distributing LMO to all the states of India. Based on the oxygen requirements, the states were allocated LMO. This was irrespective of whether any state had an LMO manufacturing plant within its boundaries or not.

The task force did take cognizance of earlier existing MoUs in allocating oxygen to bordering districts of the state having LMO manufacturing within their geography. For example, Meghalaya managed all its oxygen supplies from Assam during the first wave and the same arrangement continued for the second wave.

Question 49:

What is the lead time you generally keep from the time demand is generated till it is delivered?

Expert response:

- This depends on the geography and the availability of producers/refillers.
- Usually, the lead time for oxygen cylinder was almost 5–6 hours, which has been increased substantially during the second wave peak.

Question 50:

What is the Ro-Ro movement?

Expert response:

Ro-Ro stands for Roll On Roll Off. Under this scheme, trucks are driven onto a specially designed wagon (Roll-On). The truck is then secured on the wagon. The drivers of the truck are accommodated in a passenger coach of the train. The train which carries these trucks then travels to its destination where the truck is driven out of the wagon (Roll-Off). For the movement of trucks onto and out of the wagon, special ramps are used. From a railway's perspective, an important consideration for Ro-Ro operations is to ensure that the truck's height and breadth once loaded on the wagons do not infringe with elements along the railway track such as bridges, platforms, overhead electrical wire, signals, and tunnels. Therefore, the route on which the Ro-Ro train movement is permitted has to be carefully planned.

Question 51:

Was there a centralized dashboard to monitor the movement of these special oxygen trains?

Expert response:

Yes, there was a centralized dashboard to monitor oxygen trains. Indian Railways uses its online Freight Operations Information System (FOIS) to monitor all freight train movements. The FOIS platform and its dashboard were used to monitor the movement of oxygen trains. For more information on online Freight Operations Information System (FOIS) to monitor all freight train movements, please refer the link: https://www.fois.indianrail.gov.in/RailSAHAY/pages/TLMORakes.jsp

Question 52:

Were LMO tankers in any state given the status of an ambulance to allow their continuous movement to cut down delays?

Expert response:

Yes. On April 23, 2021, a letter was issued by the Ministry of Home Affairs to chief secretaries of all the states, which directed states to provide adequate security to oxygen-transporting vehicles and make provision for exclusive corridors for such transportation, treating these vehicles as ambulances. For more information on details provided to states for providing security to oxygen tankers and making green corridor, please refer to the link : https://covid19.india.gov.in/document/states-for-providing-security-to-oxygen-tankers-and-making-green-corridor/

Miscellaneous Questions

Question 53:

Is the simulator integrated with GoI ODTS and ODAS?

Expert response:

Online digital solutions, such as the oxygen demand aggregation system (ODAS) and oxygen digital tracking system (ODTS), have been developed to ascertain the demand for medical oxygen from all medical facilities and track their transportation.

The Simulator is designed to be integrated to complement the ODAS and ODTS systems through API links. Although these API links are not yet in place, this is an option that is available to the Government, and the team can facilitate this.

Question 54:

What is the result of using industrial oxygen for medical purposes?

Expert response:

Medical oxygen can only be generated by medical air compressors. The medical oxygen generators or compressors usually are in oil-free or oil-less varieties. Industrial oxygen can be generated by oil-lubricated, oil-less, or oil-free compressors. Strict regulations and set parameters pertaining to tank cleanliness is a must to eliminate the possibility of any potentially harmful contaminants and infections. Industrial oxygen is not regulated as strictly as it is used to accelerate or support some sort of industrial function. This also means that there may be some level of contamination in the tank that can be administered for such industrial purposes. Industrial oxygen should never be used for medical purposes unless strict parameters are applied. Conversion of Industrial gas cylinders into medical oxygen cylinders shall have a risk of contamination and infection. This needs to be addressed immediately because of the current crisis.

Question 55:

There were news bytes that the usage of industrial oxygen has exacerbated the black fungus situation. Is that the case?

Expert response:

The Press Release 1 dated May 24, 2021, from the Ministry of Health and Family Welfare states, “no definite link between oxygen therapy and catching the infection” and “90%–95% of mucormycosis patients are diabetic and/or taking steroids.”

Mucormycosis, also known as black fungus disease, is not uncommon in India. The disease is caused by a group of molds called mucoromycetes which are present naturally in air, water, and even food. It is prevalent mostly in soil and decaying organic matter like leaves, compost, and piles. People catch mucormycosis by coming in contact with the fungal spores in the environment. It can also develop on the skin after the fungus enters the skin through a cut, scrape, burn, or other types of skin trauma.

COVID-19-associated mucormycosis is being seen in patients who are either recovering or have recovered from COVID-19. Dr. Randeep Guleria1, Director, AIIMS says, "Earlier, mucormycosis was commonly spotted in people suffering from diabetes mellitus, a condition where one's blood sugar (glucose) levels are abnormally high. Cancer patients undergoing chemotherapy, those who have had a transplant, and people taking immune suppressants (medications that weaken the immune system) also used to get it. But now due to COVID-19 and its treatment, an increase in number of cases is being witnessed."

It was noted by medical practitioners2 that COVID-19 infection and medicines used in treating COVID-19 tend to bring down the count of lymphocytes that defends our body against disease-causing pathogens such as bacteria, viruses, and parasites. The reduced count of lymphocytes puts patients of COVID-19 at a higher risk of contracting the black fungus infection. Comorbid COVID-19 positive patients having uncontrolled diabetes were also advised to monitor steroid usage and blood sugar levels, as steroids can affect the immune system3, resulting in secondary infections such as mucormycosis.

According to an advisory issued by the Indian Council of Medical Research4, the following conditions in COVID-19 patients increase the risk of mucormycosis infection:

- Uncontrolled diabetes
- Weakening of immune system due to use of steroids
- Prolonged ICU/hospital stay
- Comorbidities/post-organ transplant/cancer

For further information on mucormycosis, please refer to the Government of India press release available in the links: https://pib.gov.in/PressReleasePage.aspx?PRID=1721312;
https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1720551;
https://pib.gov.in/PressReleasePage.aspx?PRID=1724044;
https://pib.gov.in/PressReleseDetailm.aspx?PRID=1718501;
https://www.pib.gov.in/PressReleasePage.aspx?PRID=1720669.