Oxygen Management in Kerala

What made the state oxygen positive?

A CASE STUDY

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Published October 2021

Abbreviations

ASU	air separation unit
COVID	coronavirus disease
DPMSU	District Program Management Support Unit
GIS	Geographic Information System
IAS	Indian Administrative Services
KMML	Kerala Metals and Minerals Limited
KMSCL	Kerala Medical Services Corporation Limited
LMO	liquid medical oxygen
MGPS	medical gas pipeline system
MT	metric tons
PESO	Petroleum and Explosives Safety Organisation
PSA	pressure swing adsorption

Introduction

Kerala has the second-highest number of confirmed coronavirus disease 2019 (COVID-19) cases in India, a little over 4 million, and the highest test positivity rate of 18.2 percent.[a] In spite of it, the state also has the lowest case fatality rate in the country (0.5 percent).[b] During the second wave of COVID-19 between April and June 2021, when the unprecedented spike in demand for medical oxygen threw its supply into disarray in several parts of the country, Kerala reported a surplus of medical oxygen stock. Kerala was not only able to meet the oxygen demand in its health facilities but also supply it to other Indian states like Goa, Karnataka, and Tamil Nadu, which helped them meet the growing demand for medical oxygen in their hospitals, which were filling up with COVID-19 patients.

Amidst the rising COVID-19 cases and consequent oxygen crisis, the Kerala government was not only able to predict the demand for medical oxygen well in time but also put in place strategies to increase the production of liquid medical oxygen (LMO) and strengthen supply to health facilities. Due to the effective action taken by the state government and Petroleum and Explosives Safety Organisation (PESO), medical oxygen production and storage have significantly been ramped up in the state, with an increase in oxygen storage capacity from 99.39 metric tons (MT) in March 2020 to 219 MT in April 2021.[c] This case study documents the measures taken by the state government of Kerala to meet the COVID-19 induced demand for medical oxygen and draw lessons for possible replication in other states. In March 2020, the oxygen demand in Kerala was around 20-30 MT put together both public and private institutions, which went on to increase to 180 MT in the last week of May or first week of June.

The Oxygen Ecosystem in Kerala

As in September 2021, there is one liquid oxygen producing unit and 11 air separation units (ASUs), in addition to 17 re-fillers, and more than 100 public and private hospitals in Kerala. Before 2020, 40 percent of the oxygen produced in the state was industrial grade and transported to various industries. The remaining stock of oxygen was supplied as LMO to hospitals in the state. Till 2019, Kerala depended on Tamil Nadu and Karnataka for the regular supply of LMO. The onset of COVID-19 led to a turnaround.[d]

The PESO in Kerala along with the Health and Family Welfare Department, Government of Kerala provided leadership and guidance to the assessment of and meeting the demand for oxygen in the state ever since the pandemic hit the country in March 2020.

Kerala's Strategy to Enhance Medical Oxygen Availability

Strategic initiatives to increase gas cylinders to carry and supply medical oxygen

Kerala was able to predict the demand for medical oxygen and initiate actions very early into the COVID-19 pandemic. Its first strategic action was to rapidly increase the availability of gas cylinders to carry, store, and supply medical oxygen. It converted excessive industrial gas cylinders to medical oxygen gas cylinders.

By April 2020, within four months of the first case of COVID-19 in Kerala, PESO Kerala had informed the oxygen manufacturers in the state to convert excess industrial oxygen to medical oxygen and industrial

[a]Accessed from https://dashboard.kerala.gov.in/covid/ on September 16, 2021
[b]Ibid
[c]Report on Study on Optimal Allocation and Distribution of Liquefied Medical Oxygen in Kerala State, Motor Vehicle Department, Government of Kerala
[d]Accessed from https://www.indiatoday.in/coronavirus-outbreak/story/kerala-oxygen-crisis-covid-19-second-wave-1795603-2021-04-27 on September 10, 2021

oxygen cylinders and non-toxic and non-flammable gas cylinders (nitrogen, helium, and argon) to medical oxygen cylinders.[e]

Around the same time, the Department of Disaster Management, Kerala also issued an order informing all persons and entities holding industrial gas cylinders to hand them over to the District Collector, who is also the chairman of the District Disaster Management Authority, for conversion to medical oxygen cylinders.[f] Till then, Kerala had 7,000 type D cylinders with a cumulative storage capacity of 40-50 MT. By this single directive, Kerala mobilized additional 7,000 cylinders from industrial units and augmented its medical oxygen storage capacity.

Strategic actions to increase medical oxygen production in the state

Prior to COVID-19, Kerala had one major LMO producer catering to hospitals—INOX Air Products Private Limited. It produced around 50-60 MT of LMO every day. The state government, with support of the national government, put in measures to increase the production and storage capacity of LMO in the state.

In October 2020, the Department of Promotion of Industry and Internal Trade, under the Ministry of Commerce and Industries, Government of India, and the Central Medical Service Society, under the Ministry of Health and Family Welfare, jointly floated tenders for pressure swing adsorption (PSA) oxygen generation plants for the government hospitals to enable the public sector with captive oxygen generation capacity. Five of these PSA oxygen plants were set up in Kerala, namely the medical college and hospitals in Thiruvananthapuram, Pariyaram, Kottayam, Thrissur, and Ernakulam.[g] Through this initiative, the state added two additional suppliers of medical-grade oxygen—Praxair India Private Limited and Kerala Metals and Minerals Limited (KMML). These two entities delivered oxygen through PSA plants and were in addition to Inox, which was providing LMO to all the state's major hospitals including the medical college and hospitals.

The state government identified non-functional ASUs and made them functional by enhancing their capacity to produce gaseous oxygen. For example, when the pandemic began, the state government augmented KMML, which manufactures titanium dioxide, with a new 70 tons per day oxygen generation plant in October 2020. The gaseous industrial waste from the KMML factory was purified, liquefied, and separated into industrial gases such as oxygen and nitrogen at the plant. As a result, the plant produced 63 tons of industrial oxygen in gaseous form and 70 tons of nitrogen gas per day.[h]

At the time of writing this document, the Government of Kerala was procuring 35 PSA plants through Kerala Medical Services Corporation Limited to augment the existing oxygen generation capacity at the public health care institutions in the state[i] and has also instructed all private hospitals to install PSA oxygen generation plants of adequate quantity. The Kerala government aims to achieve 85 MT of medical oxygen production capacity per day within 30-40 days to meet peak requirements during the predicted surges and to purchase more cylinders to further improve the storage capacity.

Strategic approaches to improve storage capacity for medical oxygen

In addition to getting the industrial gas cylinders converted to medical oxygen gas cylinders, the state government provided licenses and support necessary for strengthening infrastructure to 32 large hospitals in the state for storage of liquid oxygen, adding an additional storage capacity of 420 MT. The state also identified the Bharat Petroleum Corporation Limited's Cochin Refinery, which had 20 MT of medical-grade oxygen on hand, as a source for emergency.

Based on the distance between production facility and supply units in the state, the state government also created three strategically located buffer storages – two at Kochi, which is situated in the central part of the

[e]SOP for conversion of industrial oxygen cylinders to medical oxygen cylinders
[f]Accessed from https://peso.gov.in/web/updates/monitoring-mechanism-medical-oxygen-supply on September 6, 2021
[g]Order issued to setting new PSA plants in Kerala (G.O.(Rt)No.1104/2021/H&FWD), accessed on August 29, 2021
[h]Ibid f
[i]Ibid g

state, and the third at the southern industrial part of the state. Put together, they added another 60 MT of medical oxygen storage capacity in the state. In addition, major private medical colleges and hospitals, which previously relied on daily oxygen supply, were identified and equipped with increased storage capacity.

These initiatives led to a combined storage capacity of 1,325 MT of liquid oxygen in the state, along with the Inox plant contributing 1,000 MT, the largest storage capacity in Kerala.[j]

Strategically strengthening infrastructure in hospitals to supply medical oxygen to patients' bedside

The state government in its audit of oxygen capacities in medical colleges and hospitals in September 2020 found that many of the health facilities in the state did not have adequate infrastructure to offer uninterrupted oxygen to their patients. The hospitals did not have the required copper pipeline for the medical gas pipeline system (MGPS) to connect and supply oxygen. Only the beds in the intensive care units and operation theaters were connected by MGPS. While medical oxygen supply was not an issue in the pre-COVID-19 scenario, these infrastructural gaps were identified for priority action at a time when the COVID-19 cases were rapidly rising in the state.

> In September 2020, the Thrissur Medical College and Hospital launched a crowdfunding campaign to install MGPS. The Prana Air for Care crowdfunding campaign successfully crowdsourced pipeline connections for 600 beds, costing Rs 12,000 per bed.[k]

Strategic supervision and supply chain enhancements to improve the availability of medical oxygen

Very early into the pandemic, the state government set up 24 x 7 oxygen war rooms in the state and in all the districts with a single nodal point for Oxygen monitoring at the State and District levels and ensure unrestricted supply of oxygen to the Government of Kerala. The state war room had representatives from nine departments—industries, health, revenue, disaster management, police, transport, PESO, finance, and information technology, with a 24 x 7 helpline and a clearly defined role for improved coordination.

The state created IT-enabled platforms to map and track oxygen demand for both government and private health institutions. The state's COVID-19 Jagratha portal has the Geographic Information System (GIS) mapping of liquid oxygen and gaseous oxygen production, distribution, and retail/filling units; number and type of oxygen cylinders; and other logistics in both public and private health facilities with oxygen beds. The state government collects real-time data analyzing daily oxygen usage and weekly usage history. This enables decision making to allocate requirement, assess wastage, and reconfigure stock situation.

The state government, working with the private transporters, ensured that all oxygen-carrying tankers are run at full capacity with no idling time for any tanker and that the running cost of oxygen tankers are subsidized by the state. To improve and optimize oxygen supply chain, the state reconfigured the supply flow by creating a hub-and-spoke model that mapped the hospitals to their nearest suppliers.

The State Oxygen War Room in Kerala[l]

[j]Ibid c

[k]Accessed from https://www.thehindu.com/news/national/kerala/prana-to-ensure-oxygen-to-in-patients-in-thrissur-mch/article34493903.ece on August 24, 2021

[l]G.O.(Rt)No.995/2021/H&FWD, Thiruvananthapuram, accessed on August 26, 2021

Kerala's state oxygen war room is responsible for monitoring the production, storage, transport, distribution, consumption, and supply chain monitoring of medical oxygen at the state level. It operates under the supervision of the Principal Secretary (Industries).

Industries Department	Overall coordination of production and distribution of oxygen from the producers to the storage units and hospitals Liaison with oxygen manufacturers and filling centers
Health Department	Compile and share information regarding infrastructure, such as the number of oxygen beds, daily occupancy status, oxygen consumption, and requirements, from both the government and private hospitals Ensure accuracy of data on occupancy status, oxygen consumption, and the projected oxygen requirement Representatives from the Directorate of Health Services, Directorate of Medical Education, State Health Authority, and Kerala Medical Services Corporation Limited (KMSCL) KMSCL is the nodal agency for monitoring the oxygen supply chain management within the Health Department
Disaster Management Authority	GIS mapping of liquid oxygen and gaseous oxygen production, distribution, and retail/filling units; number and type of oxygen cylinders; and other logistics in health facilities (public and private) with oxygen beds
Police and Transport Department	Ensure unhindered secure transport of oxygen containers across the state, including ensuring green corridors for a faster delivery
IT Department and NIC, Kozhikode	Ensure necessary technical support for implementing an 'Oxygen Logistics Module' on the COVID-19 Jagratha portal for real time capturing of all data pertaining to oxygen management
Petroleum and Explosives Safety Organisation	Regulation of oxygen production and supply
GST/Taxes Department	Implementation of financial and tax incentives, availability of finance for oxygen procurement and management

Dedicated 24 x 7 helpline numbers have been established to coordinate all activities and provide information to all stakeholders and the public. Five senior bureaucrats function as the heads of the Secretariat for the 24 x 7 state oxygen war room for oxygen monitoring and to liaison with line departments.

One of the senior Indian Administrative Services (IAS) officers posted as the overall head of the war room is available round-the-clock on call. From the deputy heads, two IAS officers are available at the war room round-the-clock overseeing the activities at the state and district war rooms.

One deputy head is responsible for the supply side, whereas the second deputy head is responsible for monitoring. Deputy heads call two review meetings daily—one in the morning and another in the evening—with all department representatives for coordination and resolving any escalation. The war room head as well as the deputy heads monitor all calls received at the war room and ensure that queries and complaints raised are resolved.

The state war room had also been asked to remain in constant touch with district war rooms. The district war rooms comprised the same representatives as the state war room. The district oxygen war room is attached to the District Program Management Support Unit (DPMSU) for COVID management. The nodal officer for the DPMSU is the nodal officer for the district oxygen war room.

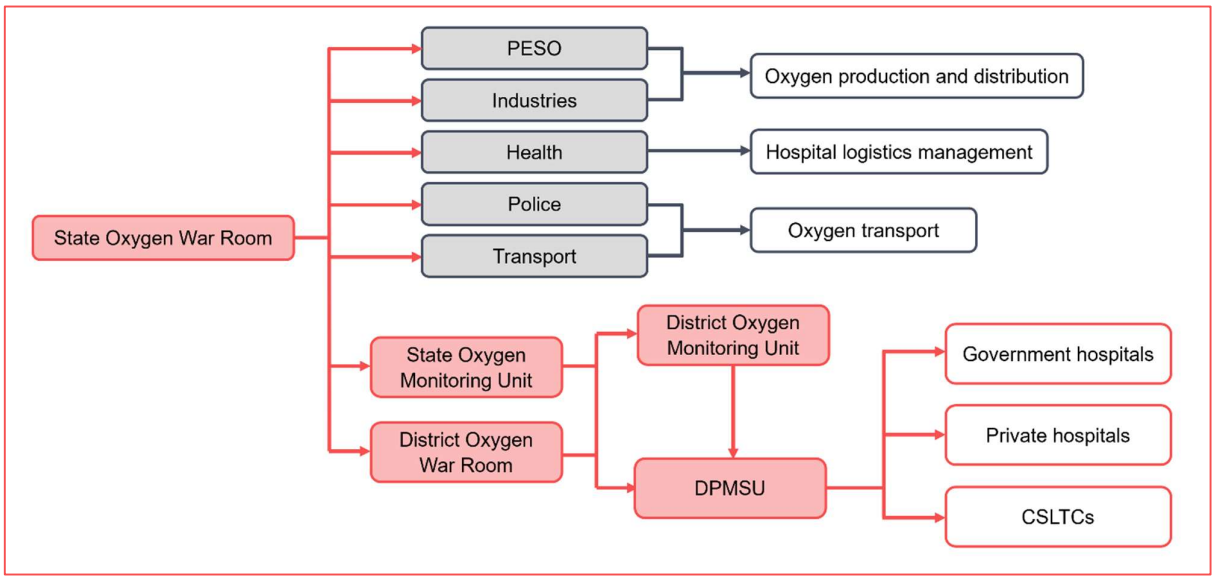

Figure 1. Oxygen management structure in Kerala

CSLTCs, COVID Second-Line Treatment Centers

Reducing oxygen wastage and rationalizing oxygen use in health facilities

The state government adopted an oxygen wastage reduction strategy to aid any acute increase in oxygen demands. As part of the strategy, the state government equipped 56 major hospitals with medical gas pipelines, which otherwise used cylinders.[m]

Since September 2020, all COVID-19 patients in the state are triaged depending on the severity and need for oxygen and classified into three categories, A, B, or C, based on the severity of the disease and referred to one of the three categories of hospitals—first-line treatment centers, the second-line treatment centers, and COVID-19 hospitals.

The state and district war rooms formed oxygen audit committees of anesthetists and biomedical engineers, who conducted regular oxygen audits in public and private hospitals. Based on the audit findings, the hospitals were asked to ensure that their systems are maintained properly arresting any leakage and that the health care providers were oriented and trained on the optimal use of high-flow nasal cannulas in patients with acute hypoxemic respiratory failure.

[m]Advisory on the rational use of oxygen by Covid-19 Outbreak Control and Prevention State Cell, Health & Family Welfare Department, Government of Kerala

Regulatory measures to strategically create a sustainable ecosystem for medical oxygen

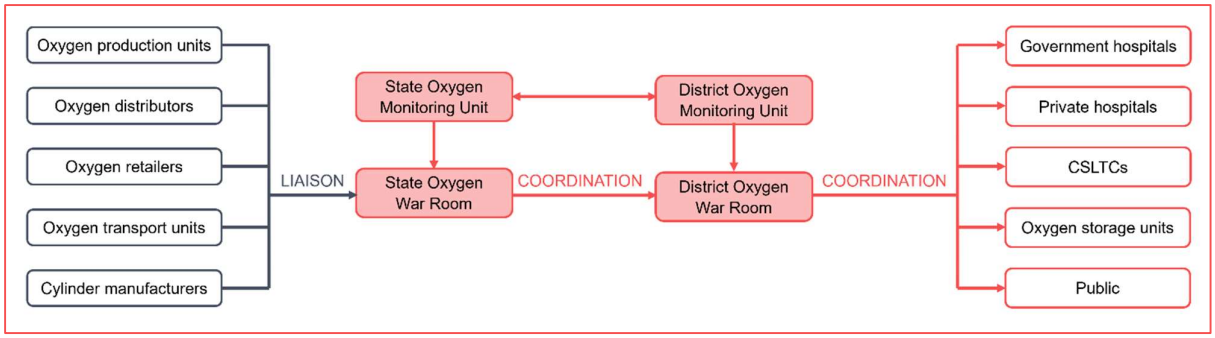

Figure 2. Coordination and liaison mechanism for oxygen management in Kerala

CSLTCs, COVID Second-Line Treatment Centers

The national government as well as the Kerala government put in place several key regulations to guide the production, storage, and distribution of medical oxygen. Measures such as the use of industrial oxygen producing units for the production of LMO by the Union government, diverting industrial oxygen cylinders for storage of medical oxygen, and stopping ASUs from supplying oxygen to industries and instead supply to medical facilities yielded the desired results in enhancing oxygen capacities in the state.

Regulatory measures to encourage private sector engagement in the production, storage, and transportation of medical oxygen, such as subsidized transportation charges, engaging government transporters for private manufacturers, and providing incentives for accelerating the installation of new oxygen production units contributed to the rapid upgrading of oxygen management capacities in the state.

Conclusion

Kerala's ability to treat COVID-19 cases is a result of the timely steps that the state government took to strengthen its medical oxygen capacities. Kerala's initiatives offer valuable insights into building a sustainable ecosystem for medical oxygen management. Key takeaways from Kerala's initiatives are:

- A convergent and synergistic approach, which involves and clearly defines the roles of all public and private stakeholders, is important to strengthen oxygen logistics and supply chain management.
- Capturing and updating day-to-day oxygen-related data, from production to delivery to patients in the hospitals and use of digital tools, helps in a data-driven supply of oxygen, which is essential for successfully overcoming shortages in oxygen supply.
- Regulation of oxygen ecosystem, such as converting industrial oxygen to medical-grade oxygen and diverting industrial gas cylinders to medical oxygen, can contribute to meeting immediate-term shortages in supply and give a window of opportunity to building a sustainable solution to medical oxygen requirement.
- It is important to build multiple sources of oxygen supply, such as LMO from existing ASUs, converting ASUs manufacturing industrial oxygen to generate medical-grade oxygen, captive oxygen capacity in key health facilities through PSA oxygen generation plant, and using innovations such as converting gaseous waste from industries into medical grade oxygen, to build a more reliable oxygen ecosystem.
- Other than increasing production capacity, expanding capacity to store medical oxygen at various nodes of the oxygen supply chain is also equally important. Creating strategic buffer storage capacities and realigning health facilities with the nearest supply points could help in further streamlining storage and demand-based supply of oxygen.

- It is important to build health facilities' capacity to deliver oxygen to patients with negligible loss of oxygen when transitioning from its storage units to patients.
- As oxygen management continues to be human driven, it is prudent to invest in building human resource capacities, as was shown in Kerala, where they oriented and trained their human resources for health in oxygen therapy and rational use of oxygen.

Kerala's approach demonstrates the significance of predictive analysis, proactive regulation with a scope for innovations, and a system-wide investment to establish a robust, responsive, and sustainable medical oxygen management system.

Additional Reference

1. India Today. *Why Kerala is not facing oxygen crisis in covid-19 second wave.* Published on April 27, 2021. https://www.indiatoday.in/coronavirus-outbreak/story/kerala-oxygen-crisis-covid-19-second-wave-1795603-2021-04-27
2. The News Minute. *How Kerala is managing its medical oxygen supply*. Published on April 21, 2021. https://www.thenewsminute.com/article/how-kerala-managing-its-medical-oxygen-supply-147579
3. The World Bank – PATH Webinar on Policy for Sustainable Medical Oxygen Supply: Lessons from early experiences in various states on September 03, 2021. Spotlight Address by Mr Balamurli D, IAS, Managing Director, Kerala Medical Services Corporation Limited. *Becoming Oxygen Surplus: Lessons from Kerala, the First Indian State to Become Oxygen Self-Sufficient*.