International Journal of Allied Medical Sciences and Clinical Research (IJAMSCR)

ISSN:2347-6567

IJAMSCR | Volume 9 | Issue 2 | Apr - Jun - 2021
www.ijamscr.com

Research Study *Medical research*

A Critical Evaluation of the COVID-19 Second-Wave Oxygen Crisis in India

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ABSTRACT

The devastation that we see around us today caused by the second wave of COVID-19 within the country, isn't simply because of the rates of contagion and therefore the virulence of the disease, but also — and maybe, more significantly — due to the crunch in life-saving resources. Especially something we've always taken without any consideration — Oxygen. Although oxygen is that the element primarily liable for sustaining life on planet Earth and constitutes 21% of the atmosphere, oxygen during a purer state is required for variety of applications which may be broadly grouped into two categories. Industrial uses – Oxygen purified to 80% and over finds application in multiple industries starting from steel manufacturing to cutting torches and fabrication. Medical uses – Oxygen purified to 90% and above may be a vital a part of hospital infrastructure and finds application in multiple medical situations to enhance oxygenation in tissues, assist inhaling patients etc. Various estimates put the pre-COVID total oxygen usage at approximately 75% -80% industrial and 20-25% medical. India had, at the time of writing, a production capacity of roughly 7200 MT. However the assembly capacity isn't spread evenly. Eight states, Maharashtra, Gujarat, Jharkhand, Odisha, TamilNadu, Karnataka, Kerala and West Bengal account for nearly 80% of India's total oxygen production. The primary manufacturing method used for extracting oxygen from air is liquefaction and fractionation. Of late, oxygen concentrators are deployed to supply oxygen for medical purposes, but oxygen concentrators haven't demonstrated their capacity to be scaled up to large quantities.

Keywords: COVID-19, Oxygen, Maharashtra, Gujarat, Jharkhand, Odisha, TamilNadu, Karnataka, Kerala and West Bengal.

INTRODUCTION

The devastation that we see around us today caused by the second wave of COVID-19 within the country, isn't simply because of the rates of contagion and therefore the virulence of the disease, but also — and maybe, more significantly — due to the crunch in life-saving resources. Especially something we've always taken without any consideration — Oxygen. Although oxygen is that the element primarily liable for sustaining life on planet Earth and constitutes 21% of the atmosphere, oxygen during a purer state is required for variety of applications which may be broadly grouped into two categories. Industrial uses – Oxygen purified to 80% and over finds application in multiple industries starting from steel manufacturing to cutting torches and fabrication. Medical uses – Oxygen purified to 90% and above may be a vital a part of hospital infrastructure and finds application in multiple medical situations to enhance oxygenation in tissues, assist inhaling patients etc. Various estimates put the pre-COVID total oxygen usage at approximately 75% -80% industrial and 20-25% medical. India had, at the time of writing, a production capacity of roughly 7200 MT. However the assembly capacity isn't spread evenly. Eight states, Maharashtra, Gujarat, Jharkhand, Odisha, TamilNadu, Karnataka, Kerala and West Bengal account for nearly 80% of India's total oxygen production. The primary manufacturing method used for extracting oxygen from air is liquefaction and fractionation. Of late, oxygen concentrators are deployed to supply oxygen for medical purposes, but oxygen concentrators haven't demonstrated their capacity to be scaled up to large quantities.

TOTAL BREAKUP OF INDUSTRIAL vs MEDICAL OXYGEN (PRE-COVID 19)	
INDUSTRIAL	78.00%
MEDICAL	22.00%

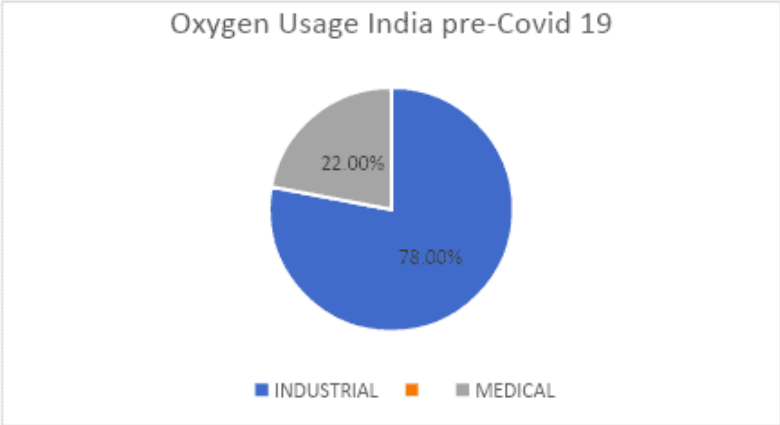

Figure 1 Alternative uses of oxygen pre-COVID

The primary manufacturing method used for extracting oxygen from air is liquefaction and fractional distillation. Of late, oxygen concentrators have been deployed to provide oxygen for medical purposes, but oxygen concentrators have not demonstrated their capacity to be scaled up to large quantities.

Core industrial usage and medical requirements (Pre-COVID & post)

In a recent hearing, the central government had made certain submissions before the Delhi High Court. On that basis, it is possible to group together the pre-COVID and post-COVID scenario into the single table that shows where things stood on April 22nd.

Industrial Usage – Core Industrial Usage and Medical Requirements (Pre-Covid & post)

CAPACTIY	PRE-COVID SCENARIO		POST-COVID SCENARIO		ASSUMPTIONS
TOTAL PRODUCTION CAPACITY	7200	MT	7200	MT	Data from submissions to Delhi HC
NEW CAPACITY ADDED *			3300	MT	Statement of PMO on 22-Apr 2021
TOTAL CAPACITY	7200	MT	10500	MT	
INDUSTRIAL USAGE					
(a) 'Core' Industries identified	2500	MT	2500	MT	Data from submissions to Delhi HC
(b) 'Non-core' Industries	1790	MT	700	MT	Impossible to stop fully other usage
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Total Industrial	4290	MT	3200	MT	
MEDICAL USAGE					
a) Non-Covid usage	1210	MT	1210	MT	
b) Covid usage	0	MT	6790	MT	
Total Medical	1210	MT	8000	MT	Data from submissions to Delhi HC
Excess/ Short Capacity	1700	MT	-700	MT	
Available Buffer stock at April 1	50000	MT			

But there are several problems with this data and the assumptions that have gone into it:

1. From the data above, it is clear that oxygen will run out within around 71 days from April 1st without further measures.
2. The exploding number of COVID-19 cases would mean that the total COVID-related medical oxygen usage would probably climb quite drastically and the usage figure shown – of 6790 MT – may already be quite out of date when you read this.
3. Enhancement of oxygen manufacturing capacity does not translate into seamless availability of oxygen at the locations required because of the poor

infrastructure available at hospitals, transport systems etc.

Medical oxygen is that the single most vital intervention for moderate and severe cases of COVID-19. Without it, patients can suffocate and die. In India, within the past one and a half years of the pandemic, both hospitals that treat COVID-19, and people that don't, suffered a shortage of medical oxygen. the matter was noted during the height of the primary wave in September 2020, and recurred on a way larger scale during the height of the second wave, in April and should 2021. Some trackers have estimated that as many as 512 lives were lost across the country thanks to oxygen shortage or denial.[1] the rationale isn't a scarcity of medical oxygen, per se, but the inadequacy of the distribution network of tankers to move LOX from the purpose of manufacture, to the hospitals.

Indeed, the distribution of medical oxygen may be a complex endeavour. Large hospitals are usually supplied directly by manufacturers that use tankers to move the oxygen. Meanwhile, medium and little hospitals, also as nursing homes, rely totally on intermediaries: the manufacturers supply LOX to filling stations, again via tankers; gas agencies, who own cylinders, then get them filled in filling stations and thereafter supply them to the nursing homes either via "jumbo cylinders" (gaseous oxygen) or "dura cylinders" (containing LOX that expands 860 times to gaseous form).

This entire supply chain was severely disrupted at multiple levels thanks to the steep and sudden rise in demand across the country—from 3,842 MT per day on 12 April 2021 to eight, 400 MT per day by 25 April, and further up to 11,000 MT per day by the start of May—before gradually reducing because the number of fresh cases declined.[2] At the time of scripting this report, the demand has gone right down to normal levels and supplies are adequate once more.

Responding to the Surge

In April 2021, when the demand for medical oxygen suddenly increased, more tankers needed to be pressed into service. However, India only had around 1,200 cryogenic oxygen tankers across the country—the number is insufficient for servicing the wants. to unravel the matter, some state governments like that of Uttar Pradesh repurposed tankers used for other liquid gases to service the transportation of medical oxygen; they utilized technology, too, and tagged tankers to urge real-time data on their location.[3] Several large corporations including Reliance, Adani Group, and Tata Companies, stepped in to divert industrial oxygen from their plants to hospitals across the country.[a] The Central government airlifted tankers from other countries[4,5] and has been running Oxygen Express trains to affected areas for the rapid transport of LOX from large industrial plants.[6, 7] The Delhi government announced within the last week of April that they might import cryogenic tankers from Bangkok, also as oxygen plants from France.[8]The Central government also flew in ready-to-use plants for installation at several government hospitals. As per the central government, the amount of oxygen tankers stands currently in more than 2,000 amounting to about 30,000 MT of LOX. This, too, would probably be inadequate within the event of an outsized third wave if daily consumption again rises to 11,000 MT per day or more, because the average turnaround for a tanker is five to seven days.

In what has been widely described as reciprocity for India's own vaccine outreach during the primary wave in 2020, different countries sent donations of oxygen concentrators, oxygen plants, and tankers to India beginning within the last week of April when the country's massive battle with the steep surges in cases was being highlighted within the international media.[9]The question remains: Why was India caught unprepared for the sudden rise in demand for medical oxygen?

How the simplest Laid Plans Came to Naught

In the start of 2020, the Ministry of Commerce's Department of Promotion of Industry and Industrial Trade formed an 'oxygen monitoring committee' and held several rounds of discussions with oxygen manufacturers' associations on the augmentation of capacity supported potential requirements.[10]State governments were apprised of the necessity to line up oxygen plants at the larger hospitals in their jurisdictions, and funds were allocated for 162 oxygen plants from PM CARES Fund for this purpose in January 2021.[11]By that point, however, it appeared that the primary wave of the pandemic was ebbing, and therefore the sense of urgency was lost. Most states didn't proceed to fixing the oxygen plants—and they might land into extreme difficulties during the second wave.

Only a couple of states, like Assam and Uttar Pradesh, found out oxygen plants at key hospitals.[12, 13] Kerala, too, augmented its capacity and claimed to be oxygen-surplus; soon, however, they requested for extra oxygen allocation because the situation within the state began to deteriorate.[14, 15] The state of Odisha, which was recording relatively lower infection rates within the beginning of the second wave, stepped in to provide 345 tankers of oxygen to severely affected states because it has several large industrial plants producing massive quantities of oxygen.[16]The state was ready to comfortably manage its own requirements.

During the primary wave, some parts of the country like Mumbai and other cities of Maharashtra, faced shortages in oxygen but quickly overcame the gaps by diverting oxygen tankers from states that had more. The second wave brought a severe challenge, however, as several large states across the country suffered massive increases in cases during a very short time. This exposed the sheer inadequacy of the distribution network for medical oxygen. Manufacturers were unable to deliver even to the massive hospitals. Smaller hospitals ran out of supply, sometimes resulting in catastrophic consequences.[17]To manage things; these smaller hospitals lent one another a couple of cylinders that helped for a couple of hours, until their own supplies arrived. Suppliers' vehicles would often spend several hours waiting in queue for refilling of oxygen cylinders, only to be turned back as stocks were quickly exhausted.

Compounding Issues

The Black Market

The cost of medical oxygen rose rapidly to the maximum amount as ten times that before the pandemic. Cylinders quickly disappeared from circulation, as individuals and black-marketers alike began to hoard supplies.[18]Black-marketing, though rampant across most of North, West and

Central India, occurred on a way lesser scale in states like Kerala, Tamil Nadu, and Karnataka, as far fewer patients may are on home oxygen thanks to better public health infrastructure. Moreover, the height of the second wave in some Southern states like Karnataka and Tamil Nadu (in the second week of May 2021) happened fortnight later than that in states like Maharashtra and Delhi (in the third week of April 2021)—by which era a big a part of the availability problem had been sorted out. Small portable cylinders like those employed by mountaineers, were selling at over INR 25,000/- each in Delhi; the particular cost wouldn't be quite INR 1,000. In some states like Maharashtra, the govt stepped in to place a cap on the worth of oxygen per cylinder. This proved completely ineffective, though, as dealers billed separately for transportation and logistics, leaving internet cost to hospitals virtually unchanged. The black marketplace for oxygen cylinders continued to flourish across several states as hospital beds became scarce and residential care was the sole option for thousands of patients.[19]Oxygen concentrators quickly flew off the shelves and their asking price shot up from INR 35,000 to 40,0000 pre-COVID-19, to over INR 100,000 in April and May 2021.

Oxygen Rationing

Because the situation turned dire, the central and state governments turned to oxygen rationing. The concept isn't unique to India. Hospitals within the us (US) and therefore the uk (UK) resorted to implicit or explicit rationing of medical services including oxygen during the height of the pandemic in their respective countries.[20]However, the way during which rationing is completed is different in each country. In India, the Central government collected data on oxygen beds and ICU beds from all COVID-19 hospitals in each state and allocated a particular quantity of oxygen to the state, consistent with the quantity that was deemed necessary for the treatment of each patient. For instance, 5 lit/min was allocated for an oxygen bed, and 20-24 lit/min for an ICU bed. In turn, each state allocated a quota to every district, and every district to the hospitals under their jurisdiction. Moreover, the utilization of High-Flow Nasal Cannula (HFNC) was strongly discouraged by several state governments like Maharashtra and Karnataka as unnecessary wastage of oxygen.[21, 22] HFNC may be a commonly used treatment modality for COVID-19 patients that push during a high flow of oxygen at up to 100 lit/min to severely ill patients. It's known to scale back the necessity for ventilatory support by over 50 percent. Several other measures have also been introduced. Hospitals are directed to appoint a nurse whose sole responsibility are going to be to watch and control oxygen wastage, from leaking oxygen lines to patients not turning off their oxygen on visits to the washroom.[23, 24]In Maharashtra, the government has found out 'control rooms' that make sure that the availability chain is maintained, albeit the value of oxygen for the hospitals is extremely high. Municipal officials, and infrequently top officials like the collector of the district, take rounds in COVID-19 hospitals and means ways during which oxygen wastage are often curbed. At some places, this has gone to extremes, with doctors making allegations about officials turning off some patients' oxygen supply, twiddling with ventilator settings, and reprimanding treating teams for wasting oxygen if the patient's oxygen saturation doesn't fall without it.[25]Though on the face of it, these measures could be ready to ensure equitable distribution of a highly valuable resource, it'll only be counter-productive due to the subsequent essential facts:

1. Patients' requirements aren't static. They'll change from minute to minute, and from 2 lit/min to fifteen lit/min within a matter of hours. It takes for much longer for requirements to fall than it takes for them to rise, and thus, even attempting to average the wants might not work well.
2. ICU requirements of oxygen are much above 20 lit/min. because the fundamental treatment modality in COVID-19 is non-invasive ventilation (NIV) or BiPap, [b] the typical consumption is 30-40 lit/min.
3. Vendors can under-fill the oxygen cylinders, sometimes intentionally, or others thanks to lapses within the filling process. Therefore, there's no guarantee that the allotted quota contains the claimed amount of oxygen.
4. If supply of oxygen goes to be fixed at a particular level with no possibility for compensation if a patient with higher requirements were to wish treatment, it's almost inevitable that hospitals would attempt to accommodate only those patients it can manage within that allotted quota, and avoid those that have higher requirements. This translates to patients with less severe cases getting adequate treatment in hospital, and therefore the more severe ones are left unable to seek out a single bed.

While "oxygen rationing", therefore, ensured that hospitals get a minimum of some regular supply of oxygen, it indirectly discouraged these facilities from admitting more critically ill patients with the very best requirements for an ICU bed, for fear of being unable to treat other patients properly thanks to limited supplies of oxygen. This will translate to higher mortality. Oxygen rationing, though unavoidable in many respects under this situation, is way from a perfect solution. If the wants are to be calculated, they ought to get on the idea of maximum and not minimum consumption. For instance, rather than telling hospitals to not use HFNC, the need must be considered during calculations for procurement. At the state level, the oxygen crisis led to allegations of political favouritism. The difficulty reached the chambers of the Supreme Court, where the state of Delhi and therefore the Centre made allegations and counter-allegations on one another regarding oxygen supplies to Delhi.[26]While the Delhi government claimed that supplies were deliberately delayed by the Centre; it refused an oxygen audit to determine its actual requirements. The central government, for its part, insisted that the oxygen supplies to Delhi were adequate, but still maintained that additional allocations couldn't be avoided compromising on supplies to other states. Some states seized oxygen tankers meant for other states[27]and diverted them to their own hospitals, resulting in conflicts between states. Oxygen tankers have now been given security and escorts to make sure that they reach their destinations without disruption.[28]At the time of scripting this report, the second wave has abated with daily numbers of fresh cases across India dropping to around 50,000, from the height of over 400,000 per day recorded on 4 May 2021.[29]The conflicts

regarding oxygen supply, too, appear to possess been resolved, a minimum of for now.

Towards Long-term Solutions

The Central government in June 2021 launched "Project O2 for India"[30] under the direct command of the office of Principal Scientific Advisor. A National Consortium of Oxygen consisting of corporations, Indian Institutes of Technology (IITs), and various non-profit organizations helps the govt in build up the
Availability chain of critical materials and parts of oxygen plants. Funding for plants is being arranged through PM CARES, [c] also as corporate sponsorships via CSR funding. The execution of permanent solutions like fixing oxygen plants and procuring adequate numbers of cryogenic tankers also got to be completed in an urgent manner. There are today reasonably good solutions available: for instance, Pressure Swing Adsorption (PSA) plants are often found out within a matter of a couple of days in small areas of up to 200 square foot, as compared to the normal cryogenic plants that take six months or more and wish an outsized area of a couple of acres, at least. Most oxygen plants that are being installed in hospitals are PSA plants. The matter for the overwhelming majority of nursing homes and little and medium-sized hospitals is that the capital investment needed to put in PSA plants. Some states like Madhya Pradesh and Maharashtra are offering incentives to non-public companies for the fixing of cryogenic oxygen plants and manufacturing cryogenic containers.[31, 32]Other states are prioritizing building oxygen plants within government hospitals and over 1,200 oxygen plants are sanctioned at government hospitals with PM CARES funds.[33]of those, 551 plants were approved for district hospitals.[34]Tenders were involved 162 plants in October 2020. The method saw problems because the companies that won the tender were unable to deliver the plants.[35]However; several corporations like Coal India, Maruti Suzuki, and Tata Group have stepped in, offering to create plants at various hospitals. Several plants are commissioned in UP, Haryana, Kerala, Assam, Nagaland, Gujarat, Maharashtra and other states either through state and central government funding, or by corporate support. As there are 734 district hospitals within the country, it are often reasonably assumed that the majority of them would have a functional oxygen plant in situ within subsequent few months, provided the local authorities expedite the installations. Consistent with the government's data presented before the Supreme Court, 33 plants funded through PM CARES are already functional and 80 are in various stages of construction.[36]
Corporate-sponsored PSA plants are being commissioned almost on a day to day across the country.[37,38,39,40,[41],[42],[43],[44],[45],[46]]

Company	State	Number of plants
Maruti Suzuki	J&K, Haryana & others	22
HCL	Delhi	17
IGL	Delhi	1
Tata Sons and DRDO	Multiple	500
Oil PSUs	Multiple	100
DCM Shriram	Gujarat	2
Tech Mahindra	Multiple	50
Northern Coalfields	Madhya Pradesh	5
Western Coalfields	Maharashtra	2
Powergrid Corporation	Rajasthan	3

Table 1

Maharashtra Health Minister Rajesh Tope has declared that it might be made mandatory for all private hospitals to possess in-house oxygen plants.[47] The Haryana Government has also asked all hospitals with over-50 bed capacity to form their own arrangements for oxygen.[48]Some oxygen plants that were lying in disuse are recommissioned and restarted. Police raids are conducted on black-marketers and large numbers of cylinders and oxygen concentrators are recovered.[49, 50]

RECOMMENDATIONS AND CONCLUSION

Private hospitals also are being mandated to put in oxygen plants. However, most small nursing homes and medium-sized hospitals don't have the specified resources. Hospitals without medical care setups can manage with oxygen concentrators and cylinders, and plants shouldn't be insisted upon. For medium and bigger hospitals, some support is required to melt the value implications of oxygen plants within the short term. The Central government has made provisions for soft loans to hospitals[51] and nursing homes for fixing oxygen plants, for a maximum of INR 2 crores and rate of interest for the loan has been capped at 7.5 percent once a year. Several NGOs and non secular organizations have also offered to line up oxygen plants at government facilities.[52, 53] However, the drive to put in oxygen plants is facing resistance from administrators of the many government hospitals, as they claim lack of space and permissions as obstacles in fixing the plants.[54]An "iron fist in velvet glove" approach are going to be needed to beat such bureaucratic hurdles. Some additional obstacles are expected thereafter. Many government hospitals indeed had their own oxygen plants but that they had fallen into disuse. Repairs weren't done and instead, large LOX tanks were

installed that made the hospital hooked in to transport network and suppliers. An identical situation must be pre-empted and methods formulated to stop the newly built plants from falling into disuse. This becomes especially important as many of those plants are being donated by well-meaning organizations and their maintenance will eventually need to be managed by the recipients. Hospitals will save significant financial resources on oxygen thanks to these plants and a few a parts of these resources would wish to be diverted towards maintenance. Regular functioning audits of the plants would also got to be conducted and capacity augmentation done as required.

Endnotes

[a] Industrial and medical oxygen are the same. The difference between the two is that for medical oxygen, the chambers, cylinders, and transport tanks need to be cleaned regularly.

[b] NIV – non-invasive ventilation, in which the patient is on a conventional ventilator but without a breathing tube placed in the throat. Ventilatory support is provided through a specialized face mask. 30 – 40Lit/min can be delivered through NIV. Consumption of oxygen is higher due to leaks around the mask.

Invasive ventilation: in which ventilator is connected to the patient with a breathing ('endotracheal') tube placed in the throat. Generally requires around 10-12 Lit/min to maintain oxygen levels but mortality is much higher in COVID patients who are on invasive ventilation.

BIPAP – a positive pressure machine that delivers oxygen under pressure through a face mask. It is less effective than ventilation and consumes upto 30 Lit/min of oxygen.

High Flow Nasal Cannula – a specialized device that delivers very high flows of oxygen upto 100 Lit/min. It is known to reduce the need for invasive ventilation by as much as 50%.

[c] The Prime Minister's Citizen Assistance and Relief in Emergency Situations Fund (or PM CARES) were created on 27 March 2020, as the first wave of the COVID-19 pandemic swept through India.

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How to cite this article: R Darla. A Critical Evaluation of the COVID-19 Second-Wave Oxygen Crisis in India. Int J of Allied Med Sci and Clin Res 2021; 9(2): 342-348.

Source of Support: Nil**. Conflict of Interest:** None declared.