Medical Oxygen Ecosystem Gap Assessment for Maharashtra

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PATH

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The work described in this report was carried out as part of the Strengthening Oxygen Utilization and Respiratory Care Ecosystems (SOURCE) project, an initiative led by PATH to improve equitable access to high-quality respiratory care services at all levels of the health care system and, ultimately, reduce maternal, child, and overall mortality from hypoxemia-related causes. Working closely with global and country stakeholders, the initiative supports governments and partners in focus geographies to advance efforts to reinforce oxygen and respiratory care systems as essential components of national health care systems, pandemic preparedness, and global health architecture.

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Abbreviations

BiPAP	bilevel positive airway pressure
COVID-19	coronavirus disease 2019
CPAP	continuous positive airway pressure
ICU	intensive care unit
LOX	liquid oxygen
PSA	pressure swing adsorption
SNCU	special newborn care unit

Executive summary

Medical oxygen is an essential medicine. Despite the critical role that it plays in treating hypoxemia across numerous disease areas, many facilities still lack access to this lifesaving treatment. Therefore, it is important to assess the availability of different sources of oxygen—including the production, delivery, and use of medical oxygen systems—so that resources can be prioritized and allocated to meet the demand for oxygen therapy. PATH, in collaboration with the Maharashtra Department of Health and Family Welfare, conducted a biomedical equipment survey in health facilities across the state in January 2024. This initiative was carried out as part of the Strengthening Oxygen Utilization and Respiratory Care Ecosysthems (SOURCE) project to support country decision-makers in the development and execution of a comprehensive respiratory care plan to ensure long-term access to medical oxygen and resilient systems for future pandemic response efforts. The project also is pursuing strategies to help prioritize and improve access to oxygen therapy and other essential equipment involved in respiratory care as an integral part of health systems strengthening.

This report analyzes data collected through facility assessments to provide a snapshot of the medical oxygen ecosystem of 34 health facilities in 27 of Maharashtra's 36 districts. The purpose of this work is to quantify existing oxygen delivery and production equipment, consumables for administering oxygen therapy, bed capacity, and facility infrastructure characteristics. The survey included level 3 facilities/hospitals that, per Maharashtra's standards, should provide respiratory care.

The availability of oxygen services and respiratory care equipment was shown to be highly variable in Maharashtra. Of the 34 facilities surveyed, 32 (94%) had pulse oximeters, but in most cases the quantity was proportionally too low for the number of beds. Additionally, 26 facilities (76%) reported possessing on-site pressure swing adsorption plants for continuous and reliable oxygen delivery to patients. Most facilities that provide services with high oxygen demand (maternity, surgical, and intensive care wards) also possessed oxygen concentrators and cylinders to maintain a reliable supply. The quantity of small equipment and delivery devices, such as flowmeters and cannulas, varies considerably across facilities and limits the accessibility of available oxygen supply to patients.

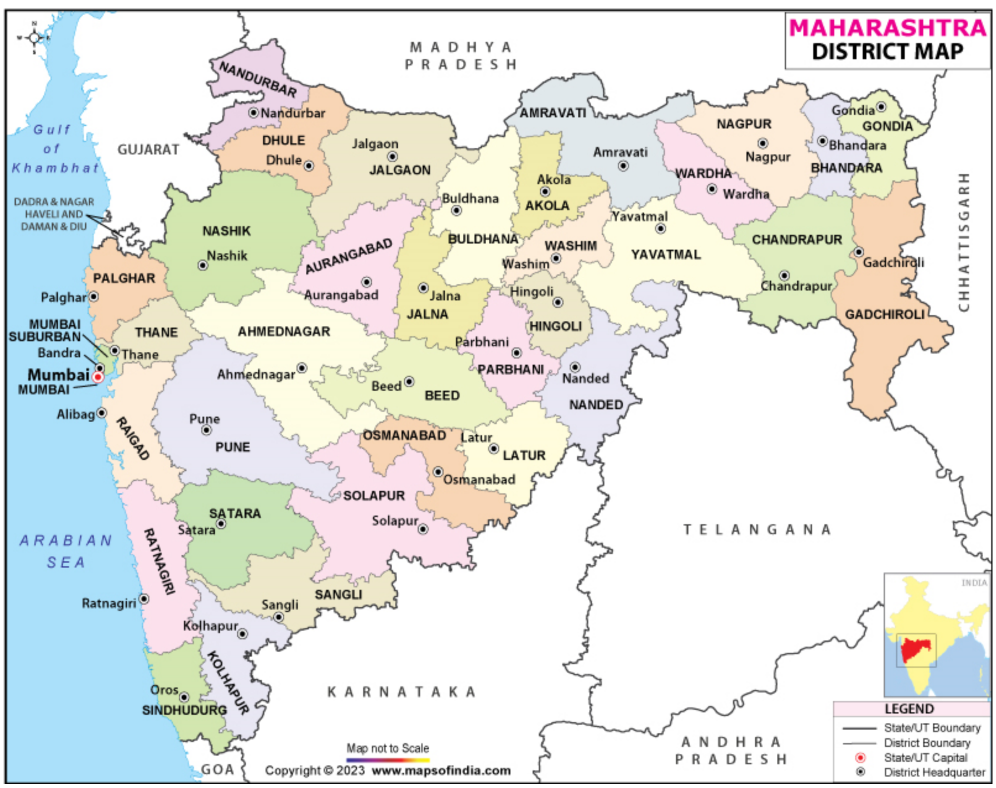
Intensive care treatment capacity is critical to providing respiratory care to patients with respiratory illnesses across disease areas. Data from these facility assessments show that critical services are available, with 58% of health care facilities equipped with intensive care unit beds.

Survey data will inform equitable allocation and redistribution of equipment to ensure that it is placed in facilities where it can be maximally utilized.

Background

Geography and demographics

Maharashtra, located in the western region of India, is one of the most economically and demographically significant states in the country. It shares borders with the states of Goa, Gujarat, Chhattisgarh, Madhya Pradesh, Telangana, and Karnataka. The state spans an area of 307,711 km^2 (approximately 118,808 square miles), making it geographically the third largest state in India. It comprises 35 districts divided into five major regions (Vidarbha, Marathwada, Konkan, Khandeshi, and Western Maharashtra) and it also has six revenue divisions for administrative purposes (Konkan, Pune, Nashik, Aurangabad, Amravati, and Nagpur). The state is home to several ethnic and linguistic groups, primarily Marathi-speaking people. Per the 2021 census, Maharashtra is the second most densely populated state in India, with an estimated population of over 124 million and with an estimated projected growth rate of 0.8%. Nearly half (48.5%) of the population resides in urban areas, which is higher than the national average.



Photos: www.mapsofindia.com

Health indicators

According to the *National Health Profile 2019* report for Indian states, Maharashtra ranked sixth among all states and union territories for health outcomes.[1] The state had a gross state domestic product of approximately US$435 billion in 2022/23, making it the largest economy in India.[2] Per the National Institution for Transforming India Aayog's National Multidimensional Poverty Index 2023 report, the state's index was measured at 0.033 for 2019–21.[3] Additionally, per the Sample Registration System 2020 report, the infant mortality rate reported was 16 per 1,000 live births, and life expectancy at birth in Maharashtra was estimated at 72 years of age.[4]

Organization of the health system

Maharashtra health infrastructure is one of the most extensive in the country, encompassing a wide spectrum of facilities delivering primary, secondary, tertiary, and super-specialist care. The state has 42 government medical colleges and teaching hospitals, which serve as hubs for medical education, advanced diagnostics, and specialized treatment. Under the public health division, 19 district hospitals, 22 women's hospitals, and 101 subdistrict hospitals provide secondary care and referrals.

For community-level services:

- There are 367 rural hospitals / community health centers and 1,909 primary health centers that function as key providers of outpatient and limited inpatient care, as well as delivery points.
- The system is further supported by 10,627 Ayushman Arogya health care workers, ensuring timely primary health care access in rural and tribal areas.
- First referral units are designated to manage obstetrics emergencies and other referral cases.
- To support newborn and child health, 53 special newborn care units and 203 newborn stabilization units operate across government-owned hospitals.
- To address malnutrition, 42 nutritional rehabilitation centers deliver intensive nutritional support and monitor for severe acute malnutrition in children.

This layered and decentralized health care architecture reinforces Maharashtra's commitment to equitable health care access across urban, rural, and tribal regions.

State medical oxygen strategic plan

In response to the oxygen crisis during the COVID-19 pandemic, Maharashtra has launched a comprehensive strategy to ensure safe, timely, and equitable access to medical oxygen across all health care levels. The strategy's key objectives are to:

- Strengthen oxygen infrastructure by ensuring availability of pressure swing adsorption (PSA) plants, liquid oxygen (LOX) tanks, and oxygen concentrators in 100% of medical colleges, district hospitals, district women hospitals, and specialist hospitals and 75% of subdistrict/rural hospitals.
- Promote rational oxygen use by training health care workers on oxygen stewardship and clinical protocols across the state.
- Expand access in peripheral areas by equipping 100% of primary and community health centers with oxygen concentrators and oxygen cylinders by hub-and-spoke supply models in remote regions.
- Build technical capacity by establishing two divisional oxygen skill labs to train oxygen handlers (nurses, ward boys, biomedical engineers and/or technicians)
- Establish optimal use of data-driven systems for real-time oxygen dashboards to monitor production, consumption, and facility readiness.

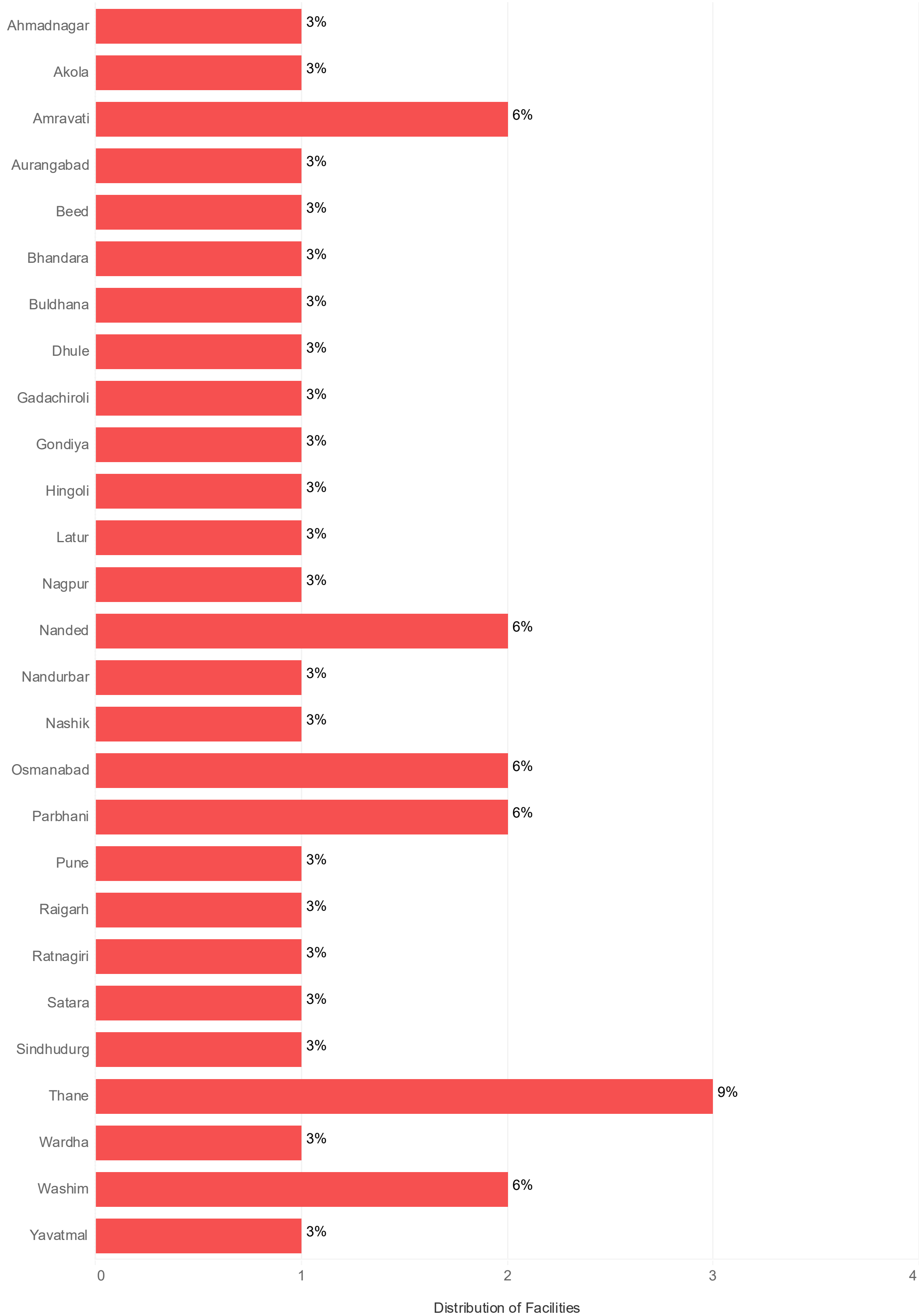
- Foster and promote oxygen-related innovations, such as boosting the number of PSA plants, working toward solarization, and providing oxygen concentrators in ambulances.
- Strengthen governance and coordination by setting up a State Oxygen Task Force and district committees for intersectoral collaboration.
- Mobilize sustainable financing by using government funds and private partnerships to maintain systems and ensure long-term resilience.

Survey scope and site selection

A cross-sectional study of respiratory care equipment was conducted in 34 publicly managed level 3 hospitals in 27of 36 districts of Maharashtra. The sample consisted of level 2 and level 3 hospitals. These hospitals were selected based on budget, Ministry of Health and Family Welfare priorities, and the fact that PATH provides technical assistance for oxygen in these areas. The distribution of health facilities by district was weighted by the total number of facilities in each district.

Figure 1 characterizes the health facilities in the dataset by subnational distribution.

Figure 1. Health facilities surveyed by subnational distribution.



Data collection methods

The biomedical equipment survey data collection tool was adapted by PATH for use in Maharashtra with support from the Ministry of Health and Family Welfare. The survey questions were partly based on the World Health Organization list of priority medical devices for COVID-19 case management.[5]

The instrument was hosted on the SurveyCTO platform, and data generated from it were used to develop this report.

PATH completed data collection in partnership with the contracted enumerator firm IQVIA. Data collection was conducted over a two-month period in Maharashtra by teams of five field investigators, covering all 34 facilities.

Results

This section describes the scope of the facility assessments, key characteristics observed (e.g., intensive care unit [ICU] bed counts), and a discussion of other factors that could constrain respiratory care treatment capacity. Observations on the current availability of oxygen delivery equipment, oxygen production equipment, and consumables within health facilities are highlighted throughout the report. Other devices described include ventilators, pulse oximeters, oxygen concentrators, PSA plants, and various types of oxygen masks and airways.

Facility characteristics

Services

Services available at the level 3 facilities surveyed are detailed in **Table 1**. Critical care services for respiratory care include emergency rooms, ICUs, neonate and maternity wards, high-dependency units, and surgical wards.

Table 1. Percentage of level 3 health facilities reporting specific service wards.

Ward/unit type	% of facilities
Emergency	82%
Intensive care	65%
Maternity/labor	71%
Special newborn care	74%
Pediatric	59%
Surgery (male)	53%
Surgery (female)	65%
Tuberculosis	29%
Adult high dependency	15%
Pediatric high dependency	12%

Bed capacity for surveyed level 3 facilities

Treatment capacity can be greatly constrained by the number of available beds (for both general and ICU patients). Intensive care beds are especially important for the treatment of severe and critical illnesses with high rates of hypoxemia, as they are needed to provide consistent oxygen therapy at higher flow rates. Intensive care bed requirements are not standardized globally, and health care worker perceptions about what constitutes an intensive care bed can vary. In this survey, it was defined as a bed capable of providing mechanical ventilation and/or sustained oxygen for severe acute respiratory illness. It is critical to note that, even if a bed may be capable of providing mechanical ventilation and/or sustained oxygen, a facility may not have sufficient ventilators and/or oxygen supply to provide those services to patients.

The total number of beds across all 34 facilities surveyed was 7,882. **Table 2** provides summary statistics for the beds, by facility type.

Table 2. Summary statistics for bed capacity across 34 surveyed level 3 facilities.

Count type	Capacity
Total bed capacity	7,882
Minimum bed capacity	30
Maximum bed capacity	600
Average bed capacity	232

There is significant variation in the facility bed count, as evidenced by the relatively large range between minimum and maximum number of beds in a facility. For instance, the largest facility, DH Nashik, reported 600 beds, whereas the smallest hospital, WH Washim, reported 30. Of the 7,882 total beds in surveyed facilities, 5,125 were identified as intensive care beds (**Table 3**).

Table 3. Summary statistics for intensive care bed capacity in surveyed facilities, by unit type.

	ICU	Pediatric ICU	SNCU
Total bed capacity	2,659	336	706
Average # beds	295	336	23

Abbreviations: ICU, intensive care unit; SNCU, special newborn care unit.

Infrastructure

While bed counts are essential for evaluating health facility treatment capacity, additional characteristics can impact effective provision of care, such as the type of electricity source used and the variety and number of clinical staff. Where constraints in these two areas are an issue, it is important to have alternative oxygen sources and medical devices readily available, such as bedside cylinders, ventilators, and oxygen concentrators.

Primary sources of electricity

All the 34 surveyed facilities reported that their primary power source is the central electricity grid (**Table 4**).

Table 4. Primary electricity sources of surveyed health facilities.

	# of facilities	% of facilities
Central electricity grid	34	100%
Power generator	0	0%
Grand Total	**34**	**100%**

Staffing (health care and biomedical engineering)

Among the surveyed facilities, 18% reported having biomedical engineers and/or technicians available for the maintenance of medical devices, including respiratory care equipment. **Table 5** outlines the availability of biomedical engineers in level 3 facilities.

Table 5. Availability of biomedical engineers and/or technicians in level 3 facilities.

Facilities with biomedical engineers and/or technicians		Facilities without biomedical engineers and/or technicians	
# of facilities	% of reporting facilities	# of facilities	% of reporting facilities
6	18%	28	82%

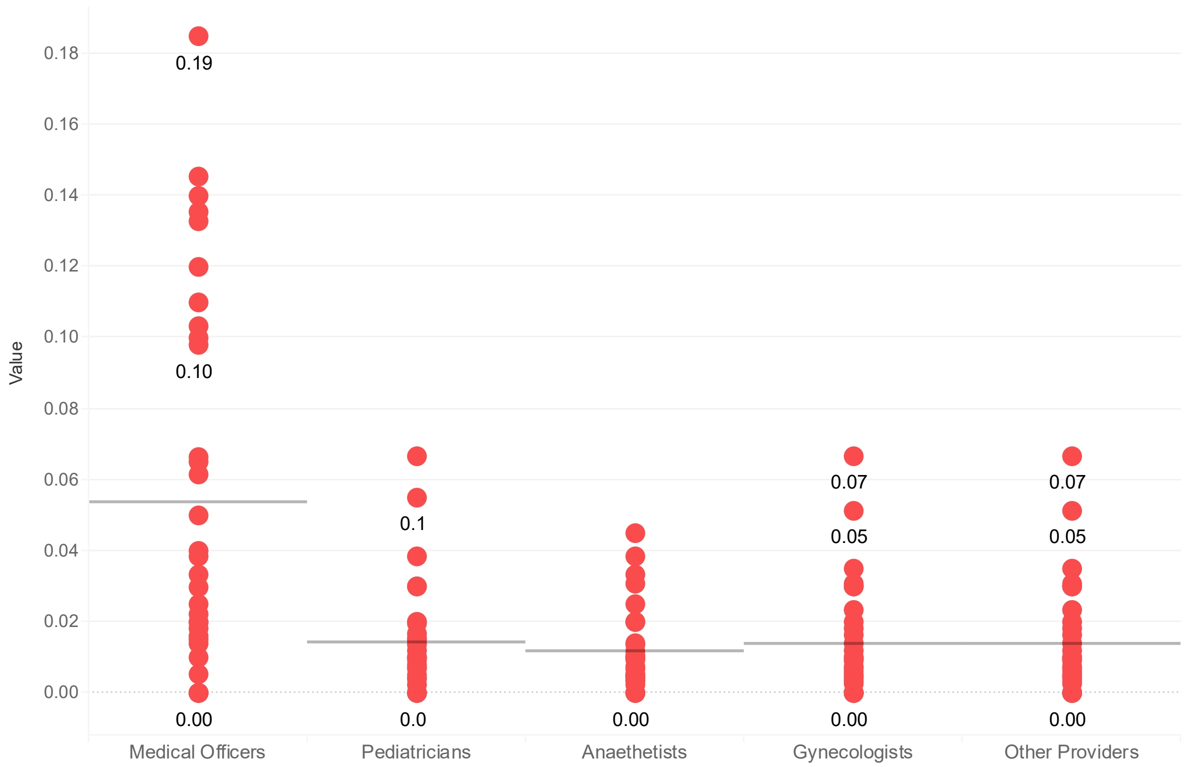
Clinical staffing numbers vary across facilities. Not all clinical staff within the same health cadre are trained specifically to provide respiratory care. **Table 6** outlines the availability of staff trained in respiratory care in level 3 facilities.

Table 6. Average numbers of clinical staffing in surveyed level 3 facilities.

Human resource	Average per facility
Medical officers	13
Anesthetists	2
Gynecologists	2
Pediatricians	2

A comparison of available staffing to the number of beds within a facility is presented in **Figure 2**. Looking at the most resourced health cadres, there is an average of 0.06 medical officers per bed, 0.01 anesthetists per bed, and 0.01 other providers (gynecologists and pediatricians) per bed.

Figure 2. Staff-to-bed ratios, by clinical cadre.



Respiratory care capacity

The provision of oxygen varies by district and facility. There are multiple components of a medical oxygen ecosystem involved in delivering respiratory care, including having an adequate and reliable supply and the necessary equipment to deliver oxygen to patients.

Oxygen can be supplied to a facility through bulk oxygen resources—such as oxygen production plants, LOX tanks, and cylinder manifolds—or through bedside resources such as cylinders and concentrators (see "Hypoxemia Treatment" section for more information).

Bulk oxygen production and supply

All of the 34 facilities surveyed had access to a bulk oxygen source, including either a PSA oxygen generation plant or a bulk oxygen storage source like a cylinder manifold or LOX tank, or a combination of both. **Table 7** summarizes the mix of bulk oxygen production and storage sources across surveyed facilities.

Table 7. Surveyed level 3 facilities with a bulk oxygen source.

Type of bulk oxygen	# of facilities
None	0
PSA plant only	0
Manifold only	7
PSA plant + manifold	1
LOX only	1
PSA + LOX	10
PSA + LOX + manifold	15
Grand total	**34**

Abbreviations: LOX, liquid oxygen; PSA, pressure swing adsorption.

Pressure swing adsorption (PSA) plants

PSA oxygen-generating plants are a source of medical-grade oxygen. A PSA oxygen generator plant is a unit designed to concentrate oxygen from ambient air at scale, with output capacity varying according to calculated oxygen demand, typically ranging from 2 Nm^3/hour to 200 Nm^3/hour (or 2,000 to 200,000 liters per minute). For distribution of oxygen produced from PSA plants, oxygen can be either piped directly to the wards or further compressed to fill cylinders using a supplemental booster compressor and a filling ramp or manifold.[6]

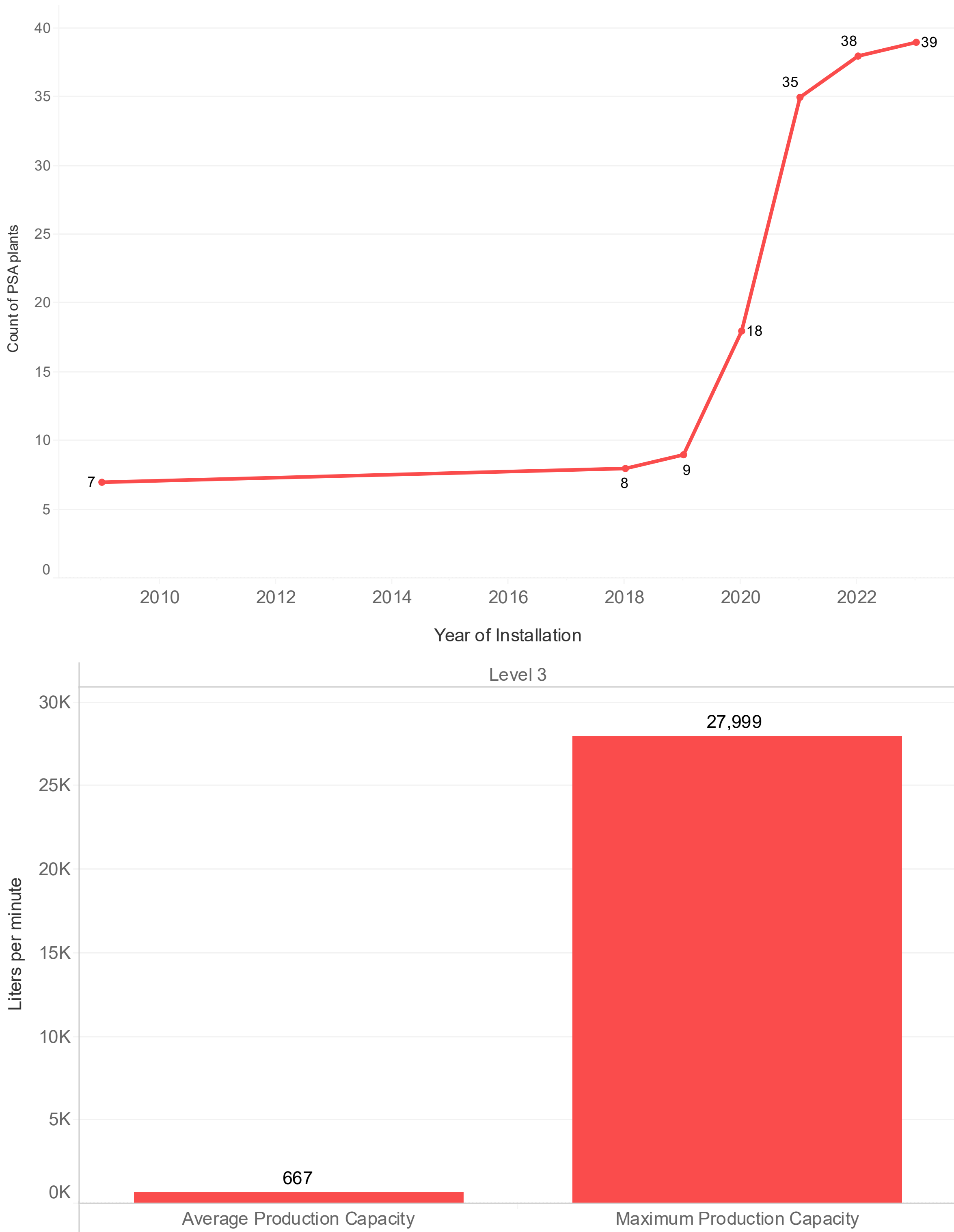
Of the 34 facilities surveyed, 30 had a PSA plant, or approximately 88% of facilities. Some facilities had more than one PSA plant for a total of 44 PSA plants (**Table 8**).

Table 8. Availability of pressure swing adsorption plants in surveyed facilities.

# of facilities with PSA plant		# of facilities without PSA plant	
% of entire sample	Total # of facilities	% of entire sample	Total # of facilities
88%	30	12%	4

Most oxygen production plants have been installed since the onset of the COVID-19 pandemic in 2020. A summary of PSA production capacity is illustrated in **Figure 3**.

Figure 3. Total number of pressure swing adsorption plants by year of installation and average production capacity.



PSA plants in Maharashtra have an average production capacity of 667 liters per minute. The data on hours of operation were not collected for all PSA plants, but about 33% of plants operate year-round.

LOX tanks

LOX tanks hold cryogenic liquid oxygen, which is vaporized into gaseous oxygen for medical use.[7] Of the 27 districts surveyed, 17 had an LOX tank installed at one Level 3 facility per district with a storage capacity ranging from 2 to 120 liters (**Table 10**).

Table 9. Surveyed level 3 facilities with liquid oxygen tank capacity, by district.

	Facility	Capacity (L)
Ahmadnagar	District Hospital Ahmednagar; SNCU	N/A
Akola	Lady Hardin Women Hospital; SNCU District Women Hospital	13,000
Amravati	District Hospital Amravati	10,000
Aurangabad	District Hospital Aurangabad; SNCU	13,000
Beed	District Hospital Beed; SNCU Subdistrict Hospital Beed	13,000
Bhandara	District Hospital Bhandara; SNCU	23,000
Buldhana	District Hospital Buldhana; SNCU	40,000
Dhule	District Hospital Dhule; District Women Hospital	23,000
Hingoli	District Hospital Hingoli	20,000
Latur	Latur Women Hospital; SNCU	10,000
Nagpur	Daga Women Hospital; SNCU	20,000
Nanded	Guru govind Memorial District Hospital	N/A
Nandurbar	District Hospital Nandurbar; SNCU	17,000
Nashik	District Hospital Nashik; SNCU	36,000
Osmanabad	District Hospital Osmanabad	33,000
Parbhani	District Hospital Parbhani	40,000
Pune	District Hospital Aundh, Pune; SNCU	22,000
Raigad	District Hospital Alibag; SNCU	16,000
Ratnagiri	District Hospital Ratnagiri; SNCU	N/A
Satara	Lt Karntisigh Nana Patil Civil Hospital; SNCU District Hospital Satara	51,000
Thane	District Hospital Thane; SNCU	23,000

Abbreviations: SNCU, special newborn care unit.

Cylinder manifolds and filling stations

Cylinder manifolds allow oxygen to be piped to various wards. They can hold multiple cylinders and switch from depleted to full cylinders to maintain a steady oxygen flow.[8] An oxygen cylinder filling station is a facility or equipment setup designed to refill empty oxygen cylinders. All the 34 facilities surveyed had a cylinder manifold or filling station (**Table 11**). Emergency rooms, surgical wards, and maternity wards were most likely to be connected to a cylinder manifold.

Table 10. Summary of facilities with or without cylinder manifold / filling station.

Availability status	# of facilities
Has manifold or filling station	34
Does not have manifold or filling station	0
Total	**34**

The availability of cylinder manifolds and filling stations varies, with 10 of 27 districts having at least one facility with a cylinder manifold and/or filling station (**Table 12**).

Table 11. Number and percentage of cylinder manifolds, by district.

	# of facilities with cylinder manifold		# of facilities without cylinder manifold	
	# of facilities	% of facilities within district	# of facilities	% of facilities within district
Ahmadnagar	1	100%	0	0%
Akola	1	100%	0	0%
Amravati	2	100%	0	0%
Aurangabad	1	100%	0	0%
Beed	1	100%	0	0%
Bhandara	1	100%	0	0%
Buldhana	1	100%	0	0%
Dhule	1	100%	0	0%
Gadchiroli	1	100%	0	0%
Hingoli	1	100%	0	0%
Latur	1	100%	0	0%

	# of facilities with cylinder manifold		# of facilities without cylinder manifold	
	# of facilities	% of facilities within district	# of facilities	% of facilities within district
Nagpur	1	100%	0	0%
Nanded	2	100%	0	0%
Nandurbar	1	100%	0	0%
Nashik	1	100%	0	0%
Osmanabad	2	100%	0	0%
Parbhani	2	100%	0	0%
Pune	1	100%	0	0%
Raigad	1	100%	0	0%
Ratnagiri	1	100%	0	0%
Satara	1	100%	0	0%
Sindhudurg	1	100%	0	0%
Thane	3	100%	0	0%
Wardha	1	100%	0	0%
Washim	2	100%	0	0%
Yavatmal	1	100%	0	0%

Piping

Piping for medical oxygen is needed only when a bulk oxygen source (PSA, cylinder manifold, or LOX tank) is available to efficiently distribute oxygen in a health facility. Of the surveyed facilities, 53% (18/34) reported on the availability of piping at facilities. Of those 18 facilities, all had an associated bulk oxygen source (**Table 13**).

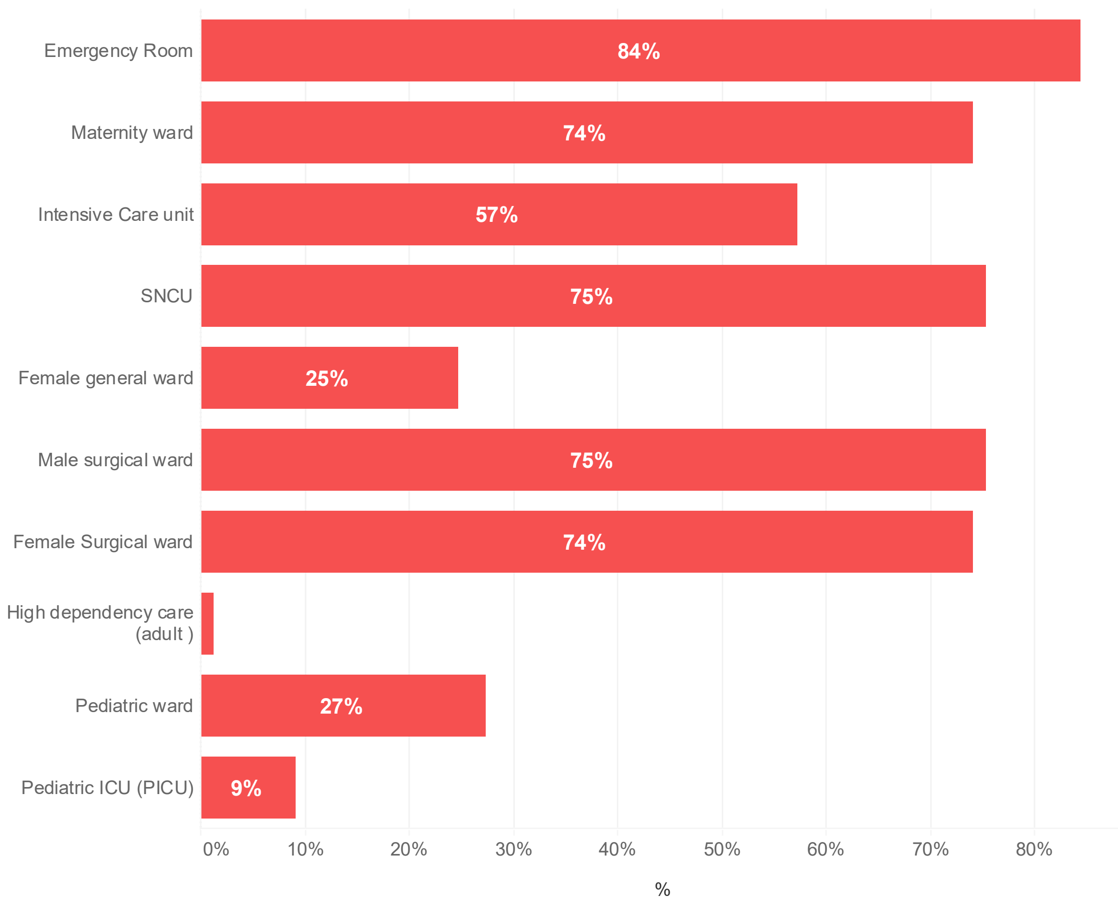
Table 12. Number of facilities surveyed with piping, by bulk oxygen source.

Source type	# of facilities	% of reporting facilities
Oxygen only	5	28%

Source type	# of facilities	% of reporting facilities
Oxygen and air	2	11%
Oxygen, air, and vacuum	13	72%
Total	**18**	**100%**

Among facilities with piping infrastructure, critical wards with high oxygen demand (e.g., ICUs, emergency rooms, high-dependency care units, and special newborn care units / newborn ICUs) are fully piped. Maternity wards also reported being 100% piped. However, access to piped oxygen may be limited by the number of available bedside wall units. **Figure 4** shows the percentage of wards with bedside wall units.

Figure 4. Percentage of wards with bedside wall units.



Abbreviation: SNCU, special newborn care unit.

Emergency vehicles

Emergency vehicles equipped with an oxygen source are important for transportation of patients to facilities, as well as between facilities, for more specialized care. **Table 14** summarizes the availability of emergency vehicles equipped with an oxygen source, such as a concentrator, in surveyed facilities.

Table 13. Facilities surveyed with emergency vehicles that are or are not equipped with oxygen.

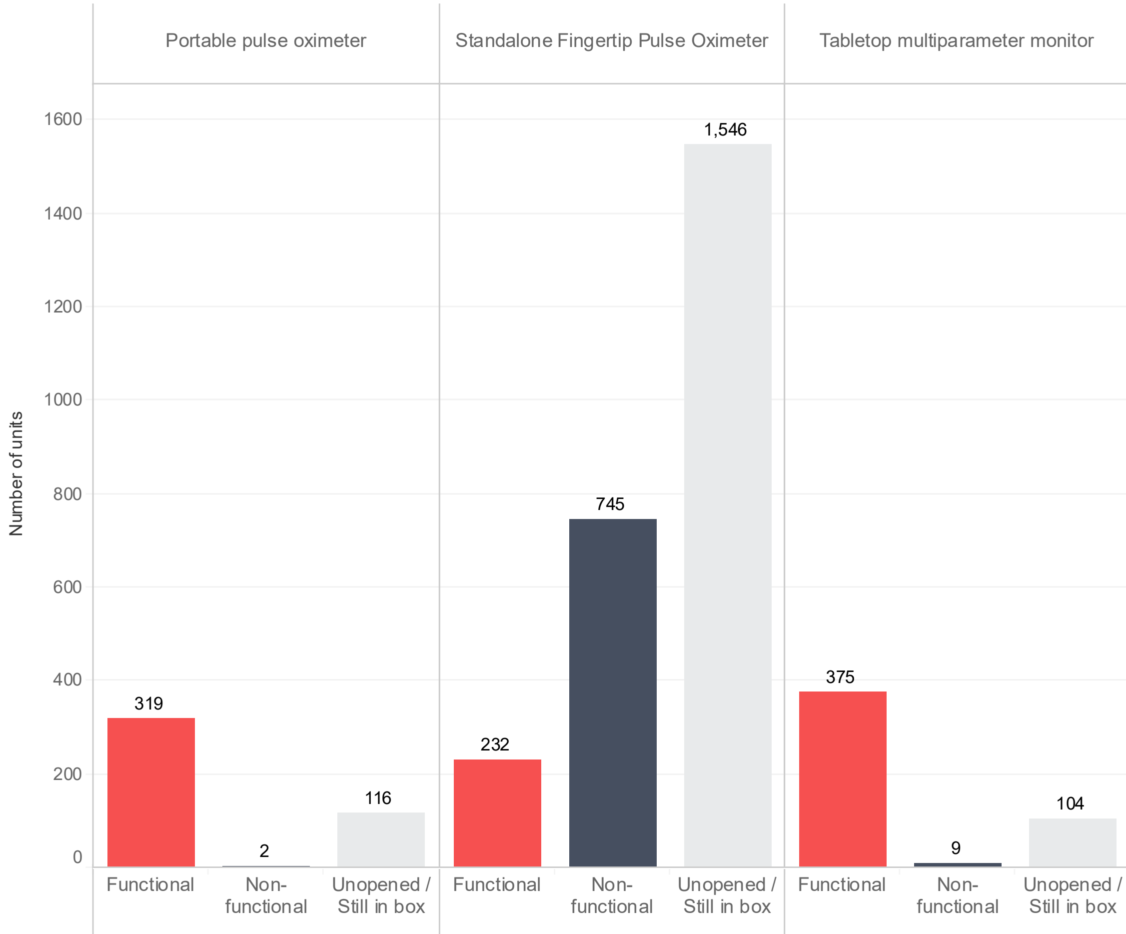
	# of facilities	% of facilities
Equipped with oxygen	11	32%
Not equipped with oxygen	23	68%
Grand total	**34**	**100%**

Hypoxemia screening

Pulse oximeters

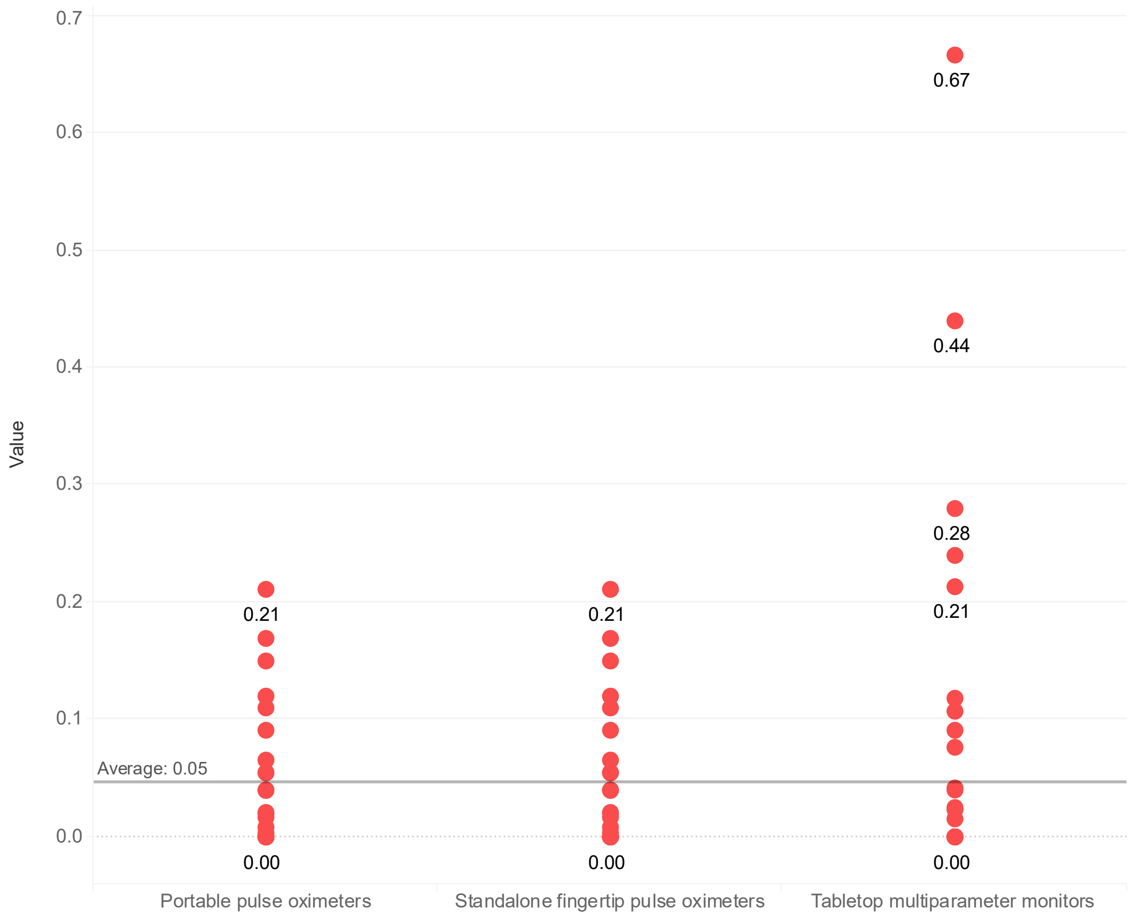
Pulse oximeters are essential for timely diagnosis of hypoxemia (low blood oxygen levels) and are important for safe oxygen therapy across various applications, including COVID-19 treatment, surgery, pneumonia treatment in both children and adults, and neonatal care.[8] Survey respondents reported using three types of devices for patient monitoring and pulse oximetry: portable pulse oximeters, tabletop multiparameter monitors, and standalone fingertip pulse oximeters (**Figure 5**). For all equipment, a functional device is one that powers on and is not visibly damaged. This definition does not reflect the device's calibration status or quality.

Figure 5. Availability and functionality of pulse oximeters and patient monitors in surveyed facilities.



Ideally, oxygen therapy is administered with pulse oximetry; therefore, it is useful to compare pulse oximeter quantities to bed counts and to counts of other respiratory care equipment. For all types of pulse oximeters, there is an average of one device to every 60 beds in a facility. This is highly variable across facilities, with Women Hospital Osmanabad reporting the most devices at a ratio of 0.67 (1 pulse oximeter to every 1.5 beds) and 2 facilities reporting no pulse oximeters (**Figure 6**).

Figure 6. Ratio of pulse oximeters and patient monitors to beds in surveyed facilities.

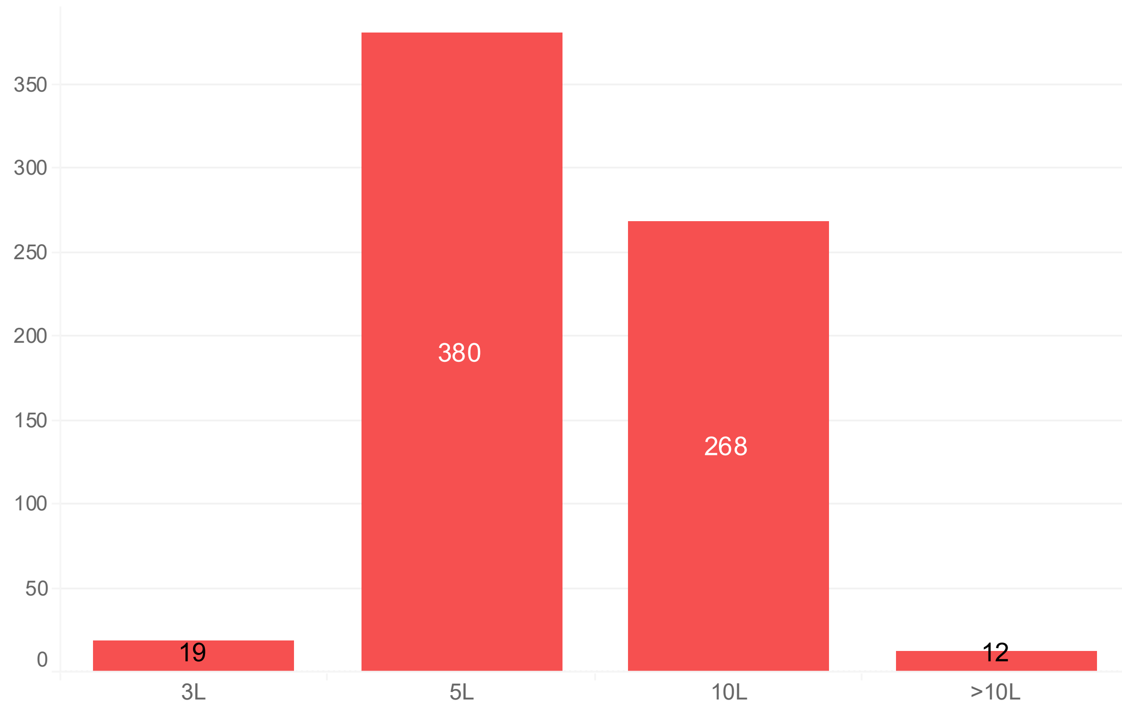


Hypoxemia treatment

Concentrators

Oxygen concentrators produce medical oxygen from atmospheric air. They provide a continuous source of oxygen, assuming regular maintenance and the availability of necessary consumables and delivery devices (such as masks and tubing).[9] The World Health Organization recommends high flow rates (above 10 liters per minute) for severe and critical COVID-19 patients.[9] Oxygen provided at lower flow rates is critical for treatment of respiratory distress and other illnesses. **Figure 7** shows the distribution of concentrators by flow rate across the surveyed facilities. Again, in this context, a functional device is one that powers on and shows no visible signs of damage. However, this does not reflect the quality of oxygen it produces.

Figure 7. Number of functional concentrators in surveyed facilities, by flow rate capacity.



Of the 34 facilities surveyed, 22 (65%) have oxygen concentrators. **Table 15** presents the availability of oxygen concentrators in critical wards across facilities. All facilities with oxygen concentrators also had an additional bulk oxygen source (PSA, LOX tanks, or cylinder manifold).

Table 14. Availability of oxygen concentrators in critical wards.

Ward/unity type	# of facilities with concentrators	Total # of facilities with ward/unit
Emergency	16	17
Surgical (female)	12	12
High-dependency care (adult)	2	2
Intensive care	9	9
Surgical (male)	12	12
Maternity/labor	13	13
Pediatric intensive care	1	1
Special newborn care / newborn intensive care	14	15
Grand total	**79**	**81**

Cylinders

Oxygen cylinders are metal canisters that must be refilled regularly and delivered to health facilities by an oxygen supplier. They require minimal maintenance and no electricity, making them suitable in settings with poor infrastructure. However, like other oxygen delivery and production devices, they depend on the availability of consumables such as refills, masks, tubing, and cylinder assembly units to facilitate oxygen delivery.

Reported weekly cylinder procurement costs vary by facility, ranging from US$310 at District Hospital Amravati to $31 at Women Hospital Gadchiroli. More detailed pricing data are needed to better understand cylinder procurement costs.

The distribution of available cylinders by district is shown in **Table 16**. On average, cylinders are filled and transported 117 kilometers from the filling plant to a health facility.

Table 15. Number of available oxygen cylinders per each surveyed district.

District	# of cylinders
Ahmadnagar	509
Akola	115
Amravati	280
Aurangabad	500
Beed	150
Bhandara	2,166
Buldhana	350
Dhule	964
Gadchiroli	160
Gondia	200
Hingoli	360
Latur	110
Nagpur	937
Nanded	738
Nandurbar	1,112
Nashik	495
Osmanabad	506
Parbhani	324
Pune	497
Raigad	665
Ratnagiri	1,046
Satara	591
Sindhudurg	565
Thane	226

District	# of cylinders
Wardha	729
Washim	610
Grand total	**14,905**

High-flow oxygen delivery devices

Ventilators

Ventilators pump air with supplemental oxygen into a patient's airways during severe respiratory distress, when they are unable to breathe on their own.[10] Ventilators require patients to be intubated. These devices are often key components of ICU beds. Facilities were assessed for two types of ventilators: transportable/portable and stationary intensive care. Ventilators are limited across medical facilities in Maharashtra. Only 15 of the 34 surveyed facilities (44%) reported possessing ventilators. **Figure 9** shows the number of ventilators reported by type and functionality.

Figure 8. Number of ventilators by type and functionality.

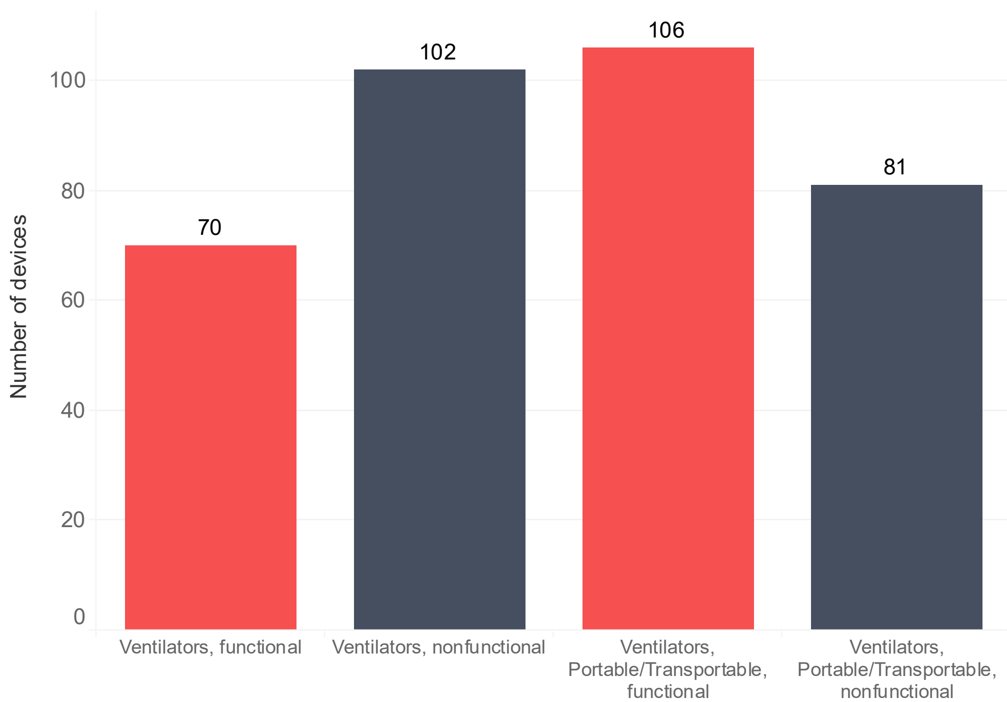


Table 17 shows the distribution of ventilators by district.

Table 16. Distribution of ventilators by district and functionality.

District	Stationary, functional	Stationary, nonfunctional	Portable / transportable, functional	Portable / transportable, nonfunctional
Ahmadnagar	0	0	0	0
Akola	0	0	0	0
Amravati	13	13	15	13
Aurangabad	0	0	0	0
Beed	0	0	0	0
Bhandara	0	0	0	0
Buldhana	0	0	0	0
Dhule	0	0	0	0
Gadchiroli	0	0	0	0
Gondia	0	0	0	0
Hingoli	0	0	0	0
Latur	20	0	6	0
Nagpur	0	0	0	0
Nanded	0	0	0	0
Nandurbar	0	0	20	0
Nashik	1	0	7	1
Osmanabad	2	4	3	2
Parbhani	0	0	0	0
Pune	0	0	5	0
Raigad	2	0	9	0
Ratnagiri	0	0	0	0
Satara	0	0	11	0
Sindhudurg	0	0	7	0
Thane	0	0	16	1
Wardha	32	85	7	64
Washim	0	0	0	0
Yavatmal	0	0	0	0

Continuous positive airway pressure (CPAP) / bilevel positive airway pressure (BiPAP)

CPAP and BiPAP are two modes of noninvasive ventilation. In CPAP, a constant flow of pressurized room air is delivered through tubing via a face mask.

Figure 10 quantifies reported CPAP and BiPAP machines by functionality.

Figure 9. Number of available bilevel and continuous positive airway pressure machines, by functionality.

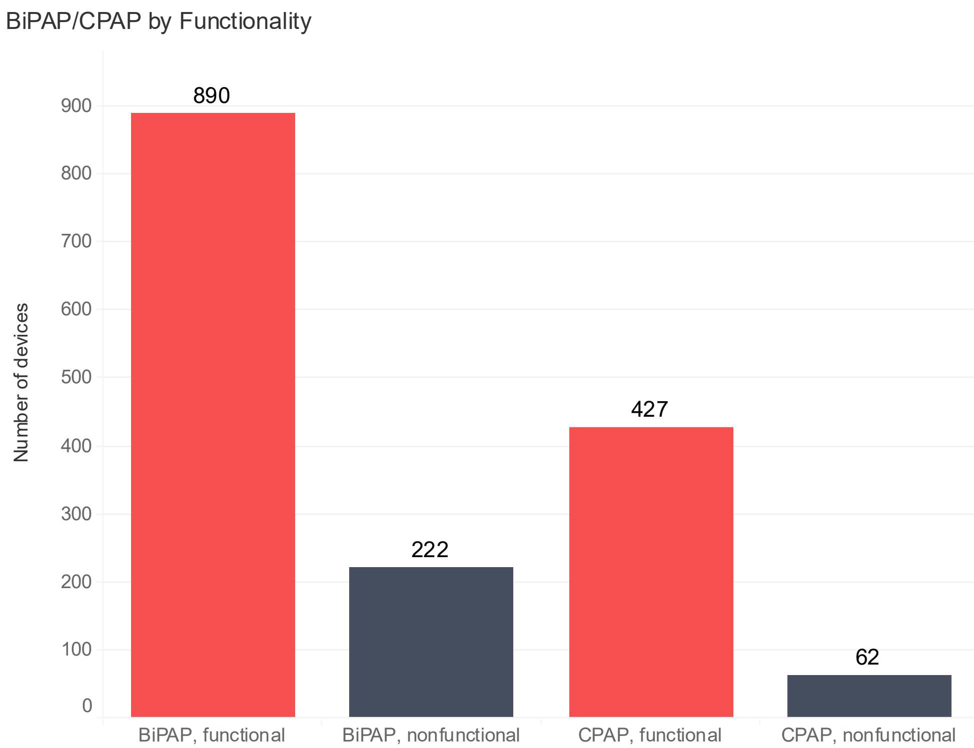


Table 18 shows the distribution of machines across districts.

Table 17. Distribution of bilevel and continuous positive airway pressure machines by district and functionality.

District	BiPAP, functional	BiPAP, nonfunctional	CPAP, functional	CPAP, nonfunctional
Ahmadnagar	0	0	0	0
Akola	8	0	14	0
Amravati	0	0	0	0
Aurangabad	0	0	0	0
Beed	0	0	0	0
Bhandara	0	0	0	0
Buldhana	0	0	0	0
Dhule	0	0	0	0
Gadchiroli	0	0	0	0
Gondia	0	0	0	0
Hingoli	0	0	0	0
Latur	58	0	55	0
Nagpur	0	0	0	0
Nanded	0	0	0	0
Nandurbar	4	0	6	0

District	BiPAP, functional	BiPAP, nonfunctional	CPAP, functional	CPAP, nonfunctional
Nashik	10	0	50	0
Osmanabad	4	0	6	0
Parbhani	0	0	0	0
Pune	39	1	53	0
Raigad	0	0	39	0
Ratnagiri	0	0	12	0
Satara	66	0	80	0
Sindhudurg	4	3	27	0
Thane	0	0	85	5
Wardha	697	218	0	57
Washim	0	0	0	0
Yavatmal	0	0	0	0

High-flow nasal cannulas

A high-flow nasal cannula is an oxygen delivery system capable of supplying humidified and heated oxygen at a flow rate of up to 60 liters per minute, a much higher rate than traditional low-flow nasal cannulas. **Figure 11** shows the availability of high-flow nasal cannulas by functionality.

Figure 10. Availability of high-flow nasal cannulas, by functionality.

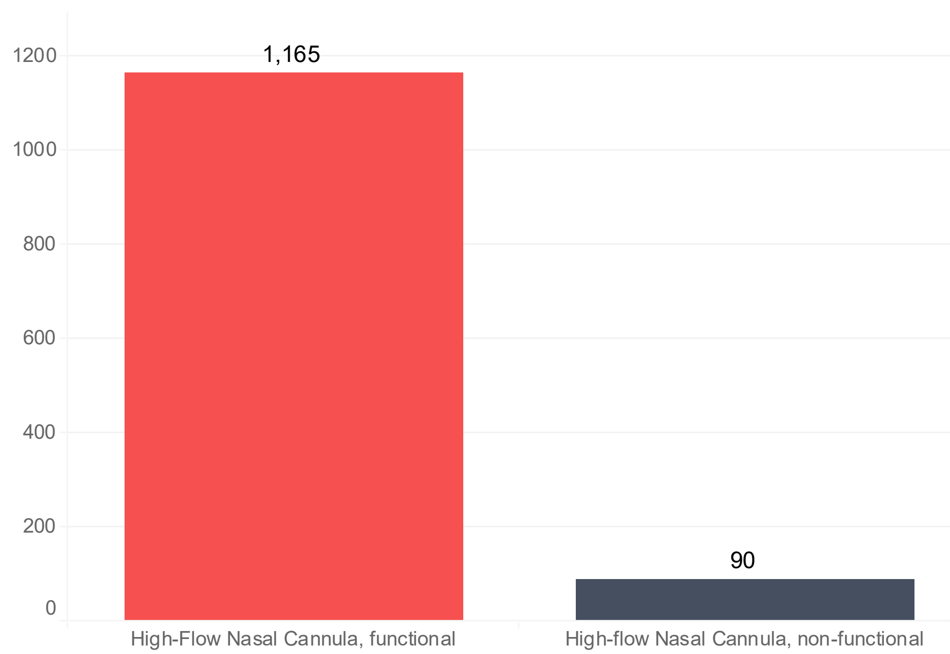


Table 19 shows the distribution of high-flow cannulas across districts.

Table 18. Distribution of high-flow nasal cannulas, by district and functionality.

	High-flow nasal cannula, functional	High-flow nasal cannula, nonfunctional
Ahmadnagar	0	0
Akola	23	0
Amravati	0	0
Aurangabad	0	0
Beed	0	0
Bhandara	0	0
Buldhana	0	0
Dhule	0	0
Gadchiroli	0	0
Gondia	0	0
Hingoli	0	0
Latur	12	0
Nagpur	0	0
Nanded	0	0
Nandurbar	7	0
Nashik	24	0
Osmanabad	100	0
Parbhani	0	0
Pune	112	32
Raigad	44	0
Ratnagiri	0	0
Satara	60	0
Sindhudurg	53	0
Thane	85	0

Wardha	645	58
Washim	0	0
Yavatmal	0	0

Consumables

Oxygen consumables are devices or delivery interfaces that facilitate the administration of oxygen therapy to patients. These are typically single-use, though some are reusable with shorter lifespans than medical devices and require different management practices.

Unlike capital assets, the availability of consumables can fluctuate significantly over time. As a result, consumable quantities reported here may be lower or higher than average at a given facility, depending on the timing of recent inventory orders.

Table 20 shows variation in consumable stock across surveyed facilities, including the average number of units and standard deviation for each item.

Table 19. Variation in consumable stock across surveyed facilities.

	Facilities with > 0 units	Total units	Average units	Standard deviation
CO2 detector	2	620	1	8
Catheters	16	3,352	16	52
EndoTube™ (Merlyn Medical)	10	2,604	3	10
Nasal cannula	18	8,352	28	104
Nasopharyngeal cannula – reusable	0	0	0	0
Non-rebreather mask	12	1,547	5	19
Oropharyngeal cannula – reusable	0	0	0	0
Oropharyngeal cannula – single use	0	0	0	0
Oxygen mask	18	10,799	29	50
Resuscitation balloon	0	0	0	0
Suction device, electric	0	0	0	0

	Facilities with > 0 units	Total units	Average units	Standard deviation
Suction device, manual	0	0	0	0
Venturi mask	11	2,214	15	39

Total quantities of each consumable varied significantly. Nasal cannulas had the highest standard deviation, suggesting that a few facilities had a large stock while others had very little. Comparing the availability of oxygen consumables with delivery equipment is important for evaluating how effectively medical equipment is being used in facilities. For instance, if a facility has a very large number of oxygen concentrators but very few masks for oxygen delivery, its treatment capacity may be constrained. Additional data on consumable counts are provided in **Appendix B**.

Conclusion

The data collected through this biomedical equipment assessment yield new insights into the respiratory care capacity of health facilities in Maharashtra. This report provides an overview of the availability of oxygen delivery equipment, oxygen production equipment, and consumables critical for providing respiratory care. In particular, the data suggest gaps in hypoxemia screening equipment, such as pulse oximeters. Significant progress has been made in oxygen production capacity, which has increased by over 50% from 2018 to 2022, but there are critical shortages of important small delivery devices, such as oxygen masks, at many facilities.

Understanding the availability of respiratory care equipment is the first step toward accurately estimating the gap in equipment supply and assessing facility capabilities and limitations in treating hypoxemic patients. An overall unequal distribution of equipment was observed across the surveyed facilities in Maharashtra. Equitable allocation of new equipment will be more complex than simply purchasing equipment to fill the gap and dividing it among facilities.

Key recommendations for next steps:

- Use the gap analysis alongside oxygen needs estimations to develop costed operational plans to increase the availability of respiratory care equipment.
- Develop specific requests and advocacy directed at the Ministry of Health and Family Welfare, donors, and partners to address potential budget shortfalls.
- Establish long-term data management systems for tracking respiratory care equipment inventories and oxygen-related clinical indicators for routine monitoring and evaluation of the medical oxygen ecosystem.

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Appendix A Project team

Data collection

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- Danielle Connor, Senior Monitoring and Evaluation Officer
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- Satish Tajne, State Lead

Appendix B. Additional tables on respiratory care equipment by district

Table 20. Distribution of flowmeters by district.

District	Flowmeters (2L/min)	Flowmeters (5L/min)	Flowmeters (10L/min)	Flowmeters (15L/min)	Flowmeters (>15L/min)
Ahmadnagar	0	0	0	0	0
Akola	0	0	0	100	0
Amravati	0	25	31	6	0
Aurangabad	0	0	0	0	0
Beed	0	0	0	0	0
Bhandara	0	0	0	0	0
Buldhana	1	0	0	4	80
Dhule	0	0	0	100	0
Gadchiroli	0	0	0	85	0
Gondia	0	0	0	0	0
Hingoli	0	0	0	0	0
Latur	0	2	9	40	0
Nagpur	0	0	0	0	0
Nanded	0	0	0	0	0
Nandurbar	0	0	0	98	0
Nashik	25	25	15	0	0
Osmanabad	0	1	2	86	28
Parbhani	0	0	0	0	0
Pune	86	40	0	0	0
Raigad	56	14	0	0	0
Ratnagiri	0	0	0	0	0
Satara	35	25	15	0	0

District	Flowmeters (2L/min)	Flowmeters (5L/min)	Flowmeters (10L/min)	Flowmeters (15L/min)	Flowmeters (>15L/min)
Sindhudurg	10	40	7	0	0
Thane	102	98	0	0	0
Wardha	0	0	0	0	0
Washim	0	135	145	0	0
Yavatmal	6	43	1	0	0

Table 21. Distribution of flow splitters by district and flow splitter type.

District	2 outlets, 1L/min	2 outlets, 2L/min	3 outlets, 1L/min	3 outlets, 2L/min	4 outlets, 1L/min	4 outlets, 2L/min	5 outlets, 1L/min	5 outlets, 2L/min	Other, 1L/min	Other, 2L/min
Ahmadnagar	0	0	0	0	0	0	0	0	0	0
Akola	0	0	0	0	0	0	0	0	0	0
Amravati	0	0	0	0	0	0	0	0	0	0
Aurangabad	0	0	0	0	0	0	0	0	0	0
Beed	0	0	0	0	0	0	0	0	0	0
Bhandara	0	0	0	0	0	0	0	0	0	0
Buldhana	1	1	1	1	1	1	1	0	0	0
Dhule	0	0	0	0	0	0	0	0	0	0
Gadchiroli	0	0	0	0	0	0	0	0	0	0
Gondia	0	0	0	0	0	0	0	0	0	0
Hingoli	0	0	0	0	0	0	0	0	0	0
Latur	0	0	0	0	0	0	0	0	0	0
Nagpur	0	0	0	0	0	0	0	0	0	0

District	2 outlets, 1L/min	2 outlets, 2L/min	3 outlets, 1L/min	3 outlets, 2L/min	4 outlets, 1L/min	4 outlets, 2L/min	5 outlets, 1L/min	5 outlets, 2L/min	Other, 1L/min	Other, 2L/min
Nanded	0	0	0	0	0	0	0	0	0	0
Nandurbar	0	0	0	0	0	0	0	0	0	0
Nashik	0	0	0	0	0	0	0	0	0	0
Osmanabad	0	0	0	0	0	0	0	0	0	0
Parbhani	0	0	0	0	0	0	0	0	0	0
Pune	5	0	25	0	0	0	0	0	0	0
Raigad	0	0	5	0	2	2	0	0	0	0
Ratnagiri	0	0	0	0	0	0	0	0	0	0
Satara	5	0	0	5	0	0	0	0	0	0
Sindhudurg	0	9	0	9	0	0	0	0	0	0
Thane	40	6	10	0	0	0	0	0	0	0
Wardha	0	0	0	0	0	0	0	0	0	0
Washim	0	0	0	0	0	0	0	0	0	0
Yavatmal	1	0	0	3	1	3	0	2	0	0

Table 22. Distribution of cylinder assembly units by district.

District	# of units
Ahmadnagar	0
Akola	62
Amravati	0

District	# of units
Aurangabad	0
Beed	0
Bhandara	0
Buldhana	0
Dhule	65
Gadchiroli	10
Gondia	0
Hingoli	0
Latur	10
Nagpur	0
Nanded	0
Nandurbar	73
Nashik	18
Osmanabad	4
Parbhani	0
Pune	3
Raigad	0
Ratnagiri	4
Satara	19
Sindhudurg	17

District	# of units
Thane	42
Wardha	0
Washim	0
Yavatmal	20

Table 23. Distribution of oxygen concentrators by district.

District	Oxygen concentrators (3L)	Oxygen concentrators (5L)	Oxygen concentrators (8L)	Oxygen concentrators (10L)	Oxygen concentrators (>10L)
Ahmadnagar	0	0	0	0	0
Akola	0	21	0	12	0
Amravati	0	11	0	31	0
Aurangabad	0	0	0	0	0
Beed	0	0	0	0	0
Bhandara	0	0	0	0	0
Buldhana	10	5	5	0	0
Dhule	0	8	0	19	0
Gadchiroli	0	37	0	0	0
Gondia	0	0	0	0	0
Hingoli	0	0	0	0	0
Latur	0	15	0	0	0
Nagpur	8	2	0	0	0

District	Oxygen concentrators (3L)	Oxygen concentrators (5L)	Oxygen concentrators (8L)	Oxygen concentrators (10L)	Oxygen concentrators (>10L)
Nanded	0	5	0	16	0
Nandurbar	0	30	0	24	0
Nashik	0	5	0	16	0
Osmanabad	0	19	0	15	10
Parbhani	0	0	0	0	0
Pune	0	36	0	0	0
Raigad	0	26	0	2	0
Ratnagiri	0	51	0	39	0
Satara	0	20	0	28	0
Sindhudurg	0	33	0	0	0
Thane	0	51	0	39	0
Wardha	0	0	0	57	0
Washim	0	58	5	22	2
Yavatmal	1	3	0	1	0

Table 24. Distribution of pulse oximeters by district.

District	Portable pulse oximeter	Standalone fingertip pulse oximeter	Tabletop multiparameter monitor
Ahmadnagar	0	0	0
Akola	0	15	44
Amravati	0	80	0

District	Portable pulse oximeter	Standalone fingertip pulse oximeter	Tabletop multiparameter monitor
Aurangabad	0	0	0
Beed	0	0	0
Bhandara	0	0	0
Buldhana	0	0	0
Dhule	0	11	28
Gadchiroli	0	26	0
Gondia	0	0	0
Hingoli	0	0	0
Latur	0	12	4
Nagpur	0	0	0
Nanded	0	0	0
Nandurbar	0	11	48
Nashik	0	2	25
Osmanabad	0	1	50
Parbhani	0	0	0
Pune	0	12	64
Raigad	0	6	22
Ratnagiri	0	0	5
Satara	0	2	22
Sindhudurg	0	12	26

District	Portable pulse oximeter	Standalone fingertip pulse oximeter	Tabletop multiparameter monitor
Thane	0	41	37
Wardha	0	0	0
Washim	0	0	0
Yavatmal	0	1	0

Table 25. Distribution of delivery interface devices by district.

District	CO2 detector	Catheters	EndoTube*	Nasal cannula	Non-rebreather mask	Oxygen mask	Resuscitation balloon	Venturi mask	Suction device, electric	Suction device, manual	Oropharyngeal cannula, reusable	Oropharyngeal cannula, single use	Nasopharyngeal cannula, reusable
Ahmadnagar	0	0	0	0	0	0	0	0	0	0	0	0	0
Akola	0	160	255	300	0	45	0	0	0	0	0	0	0
Amravati	0	65	15	65	0	1,890	0	200	0	0	0	0	0
Aurangabad	0	0	0	0	0	0	0	0	0	0	0	0	0
Beed	0	0	0	0	0	0	0	0	0	0	0	0	0
Bhandara	0	0	0	0	0	0	0	0	0	0	0	0	0
Buldhana	0	0	0	0	0	0	0	0	0	0	0	0	0
Dhule	0	30	35	100	0	36	0	0	0	0	0	0	0
Gadchiroli	0	1	0	13	0	122	0	0	0	0	0	0	0
Gondia	0	0	0	0	0	0	0	0	0	0	0	0	0
Hingoli	0	0	0	0	0	0	0	0	0	0	0	0	0
Latur	17	34	99	171	0	76	0	13	0	0	0	0	0
Nagpur	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanded	0	0	0	0	0	0	0	0	0	0	0	0	0
Nandurbar	0	111	150	710	0	108	0	1	0	0	0	0	0
Nashik	0	35	0	65	65	210	0	35	0	0	0	0	0
Osmanabad	0	0	526	1,300	5	50	0	10	0	0	0	0	0
Parbhani	0	0	0	0	0	0	0	0	0	0	0	0	0
Pune	0	130	9	295	75	180	0	35	0	0	0	0	0
Raigad	0	42	0	75	19	65	0	22	0	0	0	0	0
Ratnagiri	0	0	0	0	0	20	0	0	0	0	0	0	0

Satara	0	45	0	100	37	220	0	45	0	0	0	0	0
Sindhudurg	0	45	0	90	25	150	0	37	0	0	0	0	0
Thane	0	159	0	194	77	105	0	40	0	0	0	0	0
Wardha	386	22	258	578	36	664	0	66	0	0	0	0	0
Washim	601	386	623	647	72	1,658	0	646	0	0	0	0	0
Yavatmal	0	63	63	12	2	62	0	0	0	0	0	0	0

* EndoTube is a trademark of Merlyn Medical.