Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic
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Abbreviations and acronyms

ADB  Asian Development Bank
AMS  Association of Medical Specialists
ASPAK *Aplikasi Sarana, Prasarana, dan Alat Kesehatan* (Application Infrastructure and Medical Devices)
ASU  air separation units
BEFON  Biomedical Engineering Foundation Nepal
BIG  Bangkok Industrial Gas Company Limited
BiPAP  bilevel positive airway pressure
BMEs  biomedical engineers
CCNAN  Critical Care Nurses Association of Nepal
CFR  case-fatality rate
CHs  civil hospitals
CMC  crisis management committee
CMHO  Chief Medical and Health Officer
CMSD  Central Medical Stores Department
COVID-19  coronavirus disease 2019
CPAP  continuous positive airway pressure
CSR  corporate social responsibility
DDMA  Delhi Disaster Management Authority
DG  diesel generator
DGDA  Directorate General of Drug Administration
DGHS  Directorate General of Health Services
DHs  district hospitals
DIW  Department of Industrial Works
DM&EOs  district monitoring and evaluation officers
DPMs  district programme managers
DPIIT  Department of Promotion of Industry and Internal Trade
EID  (national) emerging infectious diseases
<table>
<thead>
<tr>
<th>Acronym</th>
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<tr>
<td>DPR Korea</td>
<td>Democratic People’s Republic of Korea</td>
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<tr>
<td>eLMIS</td>
<td>electronic logistics management information system</td>
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<td>ESFT</td>
<td>Essential Supplies Forecasting Tool</td>
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<td>FTI</td>
<td>Federation of Thai Industries</td>
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<td>GHSC-PSM</td>
<td>Global Health Supply Chain Programme</td>
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<td>GIS</td>
<td>geographic information system</td>
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<tr>
<td>GMC</td>
<td>government medical college</td>
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<tr>
<td>GTBH</td>
<td>Guru Teg Bahadur Hospital</td>
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<tr>
<td>HAEFA</td>
<td>health and education for all</td>
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<tr>
<td>HCWs</td>
<td>health-care workers</td>
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<td>HDUs</td>
<td>high dependency units</td>
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<tr>
<td>HFNC</td>
<td>high-flow nasal cannula</td>
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<td>HFNO</td>
<td>high-flow nasal oxygen</td>
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<td>HSD</td>
<td>health systems development</td>
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<td>HUL</td>
<td>Hindustan Unilever Limited</td>
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<td>ICCC</td>
<td>integrated command and control centre</td>
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<td>ICRC</td>
<td>International Red Cross and Red Crescent Societies</td>
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<td>ICU</td>
<td>intensive care unit</td>
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<td>IIT</td>
<td>Indian Institute of Technology</td>
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<tr>
<td>IoT</td>
<td>Internet of things</td>
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<td>IPC</td>
<td>infection prevention and control</td>
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<tr>
<td>IPICOL</td>
<td>Industrial Promotion and Investment Corporation of Odisha Limited</td>
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<td>JFPR</td>
<td>Japan Fund for Poverty Reduction</td>
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<tr>
<td>JICA</td>
<td>Japan International Cooperation Agency</td>
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<td>KMML</td>
<td>Kerala Minerals and Metals Limited</td>
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<tr>
<td>LMICs</td>
<td>low- and middle-income countries</td>
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<td>LMO</td>
<td>liquid medical oxygen</td>
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<td>LMS</td>
<td>learning management system</td>
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<td>LPM</td>
<td>litres per minute</td>
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<td>LRP</td>
<td>learning resource pack</td>
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<tr>
<td>MCGM</td>
<td>Municipal Corporation of Greater Mumbai</td>
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<td>MGPS</td>
<td>medical gas pipeline system</td>
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<tr>
<td>MoH</td>
<td>Ministry of Health</td>
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<th>Acronym</th>
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<tr>
<td>MoHFW</td>
<td>Ministry of Health and Family Welfare</td>
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<td>MoHP</td>
<td>Ministry of Health and Population</td>
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<td>MOs</td>
<td>medical officers</td>
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<td>MoSD</td>
<td>Ministry of Skill Development</td>
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<tr>
<td>MSMEs</td>
<td>micro, small and medium enterprises</td>
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<tr>
<td>MT</td>
<td>metric tonnes</td>
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<td>MTPD</td>
<td>metric tonnes per day</td>
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<td>NCHIS</td>
<td>National COVID-19 Health Information System</td>
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<td>NGOs</td>
<td>nongovernmental organizations</td>
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<td>NIV</td>
<td>non-invasive ventilation</td>
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<tr>
<td>NMA</td>
<td>Nepal Medical Association</td>
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<tr>
<td>NMRA</td>
<td>National Medicines Regulatory Authority</td>
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<td>NOs</td>
<td>nursing officers</td>
</tr>
<tr>
<td>NSCCM</td>
<td>Nepalese Society of Critical Care Medicine</td>
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<td>NSF</td>
<td>Nick Simons Foundation</td>
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<td>NTF</td>
<td>National Task Force</td>
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<tr>
<td>OC</td>
<td>oxygen concentrator</td>
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<tr>
<td>OCHA</td>
<td>(United Nations) Office for the Coordination of Humanitarian Affairs</td>
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<td>ODAS</td>
<td>oxygen demand aggregation system</td>
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<td>ODTs</td>
<td>oxygen digital tracking system</td>
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<td>OSDMA</td>
<td>Odisha State Disaster Management Authority</td>
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<td>OSMCL</td>
<td>Odisha State Medical Corporation Limited</td>
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<td>PCR</td>
<td>police control room</td>
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<td>PESO</td>
<td>Petroleum and Explosives Safety Organization</td>
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<td>PHCs</td>
<td>primary health centres</td>
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<td>PHLMCs</td>
<td>province health logistic management centres</td>
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<tr>
<td>PM CARES</td>
<td>Prime Minister's Citizen Assistance and Relief in Emergency Situations</td>
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<tr>
<td>PMO</td>
<td>Principal Medical Officer</td>
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<tr>
<td>PSA</td>
<td>pressure swing adsorption</td>
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<td>PSU</td>
<td>public sector undertaking</td>
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<tr>
<td>QR</td>
<td>quick response</td>
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<td>RDSDE</td>
<td>Regional Directorate of Skill Development and Entrepreneurship</td>
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<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>RTAF</td>
<td>Royal Thai Air Force</td>
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<td>SAMES</td>
<td>Serviço Autónomo de Medicamentos e Equipamentos de Saúde</td>
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<tr>
<td>SDHs</td>
<td>sub-district hospitals</td>
</tr>
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<td>(WHO) SEARO</td>
<td>(WHO) Regional Office for South-East Asia</td>
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<tr>
<td>SIGA</td>
<td>Siam Industrial Gases Association</td>
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<tr>
<td>SingCham</td>
<td>Singapore Chamber of Commerce</td>
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<tr>
<td>SLOMC</td>
<td>state-level oxygen management committee</td>
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<tr>
<td>SoE</td>
<td>state of emergency</td>
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<tr>
<td>SOPs</td>
<td>standard operating procedures</td>
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<td>SpO2</td>
<td>oxygen saturation in blood</td>
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<td>TOT</td>
<td>training of trainers</td>
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<td>TSU</td>
<td>technical support unit</td>
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<tr>
<td>UAE</td>
<td>United Arab Emirates</td>
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<tr>
<td>UNICEF</td>
<td>United Nations Children’s Fund</td>
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<tr>
<td>UNOPS</td>
<td>United Nations Office for Project Services</td>
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<tr>
<td>USA</td>
<td>United States of America</td>
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<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
</tr>
<tr>
<td>VIE</td>
<td>vacuum insulated evaporator</td>
</tr>
<tr>
<td>VSA</td>
<td>vacuum swing adsorption</td>
</tr>
<tr>
<td>WHE</td>
<td>WHO Health Emergencies Department</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<td>ZBEs</td>
<td>zonal biomedical engineers</td>
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Foreword

Despite being an essential medicine, medical oxygen is a complex product. It must be produced at specified purity levels by a medical device or industrial plant. It requires a robust system to safely reach patients, involving sources, distribution, regulation and conditioning, delivery and patient monitoring. Oxygen generation systems need regular power supplies and maintenance to function adequately.

COVID-19 infections caused a spike in medical oxygen demand in the WHO South-East Asia Region, far exceeding pre-pandemic supply capacity. To meet demand with adequate supply, Member States developed oxygen demand monitoring and prediction tools; determined new ways to address production, procurement, transport, storage and usage of medical oxygen; and adapted clinical management, infrastructure and human resources. They leveraged an array of collaborations, including with bilateral agencies, multilateral organizations, development agencies and private partners, typically utilizing whole-of-government approaches.

The lessons learnt in increasing supply of medical oxygen to meet patient demand in the Region are many and are detailed in the following pages. These lessons should benefit responses to future spikes in demand for medical oxygen and could also spur ideas for addressing such needs involving other health products.

Dr Poonam Khetrapal Singh
Regional Director
WHO South-East Asia
Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic
Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic

1

Background

Over the past two years, COVID-19 has caused an unprecedented global crisis, led to loss of millions of lives, distressed public health systems and disrupted economic and social activities. The pandemic has challenged local, regional, national and global capacities to prepare and respond. The World Health Organization (WHO) Regional Office for South-East Asia (WHO SEARO) that serves 11 Member States – Bangladesh, Bhutan, Democratic People’s Republic of Korea (DPR Korea), India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand and Timor-Leste – studied how Member States responded to the spike in demand for medical-grade oxygen caused by the COVID-19 pandemic.

As of 11 August 2022, this group of nations accounted for nearly 60 million of the 584 million confirmed cumulative cases globally. The demand for hospital beds, human resources, drugs, testing kits and life-saving oxygen had risen to unprecedented levels. As COVID-19 infections surged in 2021, medical oxygen emerged as the single most important intervention for treating moderate and severe cases of COVID-19.

Each country in the WHO South-East (SE) Asia Region responded uniquely to the unprecedented demand for medical oxygen and adopted strategies and approaches that were best suited to mitigate the crisis. Various kinds of regulatory easing were ensured to ramp up production, strengthen supplies and ensure seamless access of oxygen to patients needing oxygen therapy. Apart from ramping up the production capacity of existing plants, steps were taken to revive defunct plants and set up new oxygen-manufacturing units to meet the oxygen demand within the countries.

Moreover, huge amounts of oxygen were imported by many countries from their neighbours and even beyond to bridge the gap between demand and supply. Donations of pressure swing adsorption (PSA) plants, oxygen cylinders, ventilators and concentrators were also accepted during the surge. These demonstrated an inspiring experience of global cooperation and collaboration to mitigate the devastating effect of the pandemic. At the same time, some countries were better equipped and prepared to respond to the oxygen demand due to the lower case-load that needed oxygen and/or better management and leadership, among other reasons.

Health Systems Development (HSD) and WHO Health Emergencies (WHE) teams of WHO SEARO collaborated to collect and document the experiences of Member States regarding strengthening the medical oxygen ecosystem, lessons learnt and promising practices that can be considered for adaptation and replication. This work covered four major aspects of medical oxygen management:

- Oxygen production capacity included a review of the strategies adopted by various Member States to enhance medical oxygen production to bridge the gap between oxygen demand and supply, especially in the case of emergency. The changes in the
regulatory environment enabled oxygen production from multiple sources. This review included experiences, promising practices and lessons learnt in oxygen production.

- Procurement included a review of the strategies for acquiring oxygen generation and storage capacity, either from other countries through a private vendor or within the country through private sources or from global sources. The review looked at procurement beyond its traditional outlook, which involves a financial transaction in exchange for a product, into acquisition through donations. Information on the unique processes that the Member States adopted to acquire oxygen systems to bridge the gap between demand and supply was also considered during this exercise.

- Clinical management and rational use of oxygen investigated the experience, challenges and mitigation strategies adopted by the Member States in the Region, where they invested in bolstering the skills of medical and technical professionals in oxygen therapy. The documentation also explored the initiatives for reduction in oxygen wastage, practices to rationalize use of oxygen and oxygen audits, if conducted, and the outcomes of these initiatives.

- Collaborations in the Region involved relevant actors, investigating successes and shortfalls during the crisis at different levels (international, national, local). The exercise studied coordination of donors and reviewed the challenges associated with capacity-sharing in the Region.

This exercise, conducted over three months from February to April 2022, was based on documentary evidence and interviews with key informants. The investigation team interviewed over 50 stakeholders from the Member States and reviewed over 265 documents, which included reports published by governments and development partners, which were provided by WHO focal points and key informants, as well as media reports that were available online.

The findings, analysis and recommendations of this exercise are being made available in seven country fiches and four thematic dossiers. DPR Korea and Maldives were not included for developing country fiches as the information required about the oxygen response in the countries could not be accessed on time or, as was the case in Bhutan and Myanmar, enough stakeholders were not available for interviews.

**Limitations**

For several aspects of this study, the data is limited as there was little literature available in the public domain that provided information on oxygen response in various Member States. Many Member States have not yet undertaken documentation of their oxygen response, further highlighting the relevance of the present work.

The study team did not get access to the capacity-strengthening materials, such as trainers’ guide, training presentations and learners’ materials to assess the quality of content. Nor did the study team observe any training in oxygen in any Member State or get access to recordings of the trainings carried out to assess the training delivery. The study was also limited in its assessment of the outcome of the trainings conducted in the Member States in clinical management of oxygen as it did not interact with or review the feedback from the participants in the trainings.

Procurement-related information was especially difficult to access, as none of the government stakeholders discussed their procurement processes. There was insufficient information in secondary
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Insights shared by key informants were also limited as most of them were not involved in the procurement processes. There was no opportunity to interview informants, who were directly involved in the supply chain management or in the regulatory process.

In some cases, the input from key informants also offered a limited perspective, as many of them, even from the governments, were handling only one facet or piece of the oxygen response, like capacity-strengthening of medical cadre or procurement of oxygen systems. As a result, they did not have information on the other aspects of the oxygen response of the country.
Thematic dossiers

Oxygen production capacity

Introduction

Oxygen in the market is available for industrial and medicinal use. Industrial oxygen may contain impurities and harmful contaminants and should not be inhaled as medicinal oxygen. Medicinal oxygen, which is considered a life-saving essential medicine, is vital for the effective treatment of hospitalized COVID-19 patients. Apart from being vital to COVID-19 treatment, medical oxygen is also essential for management of pneumonia, surgery and trauma, and for oxygen therapy administered to vulnerable groups such as the elderly, pregnant women and neonates. The allowable purity level of oxygen for medical purposes is 82% to over 99%, depending on production source.¹

Sources of oxygen

An oxygen supply system consists of an oxygen source or a production unit combined with storage unit(s). The appropriate choice of oxygen sources depends on many factors, including the amount of oxygen needed at the treatment centre; the infrastructure available, cost, capacity and supply chain for local production of medicinal gases; the reliability of the electrical supply; and access to maintenance services and spare parts. The common oxygen sources include oxygen-generating plants, liquid oxygen in bulk storage tanks and oxygen concentrators. The most common oxygen storage device used in health-care settings is a gaseous cylinder.

- Liquid oxygen plants: Cryogenically produced liquid oxygen is always generated off-site (not at a health facility). For oxygen produced by the air-liquefaction process, the International Pharmacopoeia defines the requirements of medical-use oxygen. Currently, medical oxygen via air-liquefaction must contain not less than 99.5% v/v of oxygen.² Health facilities can be equipped with large bulk-liquid oxygen tanks that are refilled periodically by supplier-owned tankers. A liquid oxygen tank supplies oxygen to the patient’s bedside via a centrally piped system [also referred to as the medical gas pipeline system (MGPS)] throughout the health facility by self-vaporization and for which a power supply is not required.

Although an economical option at hospitals with high oxygen demand, the use of liquid oxygen relies on external supply chain mechanisms and needs a bit more caution with respect to transport and storage due to the risks associated with higher pressures and cryogenic temperatures. Extra care should be taken in more extreme environments. As there should be at least three sources of oxygen, namely primary, secondary and reserve, the best practice is to have cylinders as a backup supply to liquid oxygen.³
PSA oxygen generation plants: A PSA oxygen plant serves as a large, central source of oxygen generation, using PSA technology (similar to concentrators) that can be located on-site at health facilities. The WHO interim guidance technical specifications for PSA plants, published in June 2020, specifies that “pressure swing adsorption technology to produce medical oxygen 93%±3 from ambient air”. Oxygen from a PSA plant can either be piped directly to bedside terminal units within patient areas or, with a booster compressor, be used to refill cylinders for oxygen distribution (either on-site or to neighbouring health facilities) or for backup oxygen supply. Oxygen plants require a reliable source of power. The best practice is to have cylinders as a backup supply.

Oxygen concentrators: An oxygen concentrator is a self-contained, electrically powered medical device, designed to produce concentrated oxygen from ambient air. An oxygen concentrator uses PSA technology to draw in air from the environment, removing nitrogen to produce a continuous source of more than 90% concentrated oxygen. It should not be used if the oxygen concentration falls below 82%. Oxygen concentrators are portable and can be moved between clinical areas, but they are also often set up to be stationary fixtures in patient areas. Concentrators, designed for portable medical support, are available in models that can deliver maximum flow rates of generally up to 10 litres per minute (LPM). When used with a flow splitter, concentrators can provide a continuous supply of oxygen to multiple patients at the same time. On the other hand, when used with a Y-connector, two concentrators can be used to deliver flow rates higher than their individual capacity. Concentrators can provide a safe and cost-effective source of oxygen, but they do require a source of continuous and reliable power and regular preventive maintenance to ensure proper functioning. The best practice is to have cylinders as a backup supply.

COVID-19 and oxygen response

In the WHO South-East (SE) Asia Region, no two countries’ tryst with COVID-19 was alike. Although the first cases of COVID-19 were reported by nearly all the Member States in the first quarter of 2020, some countries such as Maldives, Thailand and Timor-Leste witnessed very mild spikes in case-loads in the first year of the pandemic, before experiencing the first major surge around the middle of 2021, when the Delta variant became the dominant strain of the novel coronavirus. Bhutan remained an outlier in terms of the number of infections and fatality for a variety of reasons, such as a small and thinly spread population, a strong public health-care infrastructure, an effective disease surveillance system, and, above all, the sizeable government expenditure on public health.

India, Myanmar and Nepal experienced three distinct waves of the COVID-19 pandemic, while Bangladesh, Maldives, Sri Lanka, and Thailand witnessed four or more waves of different intensities. As shared earlier, there were nearly 57 million cases of COVID-19 reported from the South-East Asia Region, with around 773 000 COVID-19-related deaths by 23 March 2022, putting the case fatality rate (CFR) at 1.36%, which is marginally higher than the global average CFR of 1.29%. While Indonesia (2.58%), Myanmar (3.19%) and Sri Lanka (2.49%) had very high case fatality rates, Bhutan (0.04%) and Maldives (0.17%) reported the lowest CFRs from the Region.

Amid the relentless surge in COVID-19 due to the variant of the virus, many nations, with the exception of Bhutan, Maldives, and Thailand, witnessed overburdened hospitals, which had run short of medical oxygen, and loss of lives due to insufficient supplemental oxygen. Although
Thailand witnessed a surge in hospital admissions due to COVID-19 infections, they had sufficient oxygen to meet the demand.

At the peak of the Delta variant-led spike in COVID-19 cases, many countries in the Region, except Bhutan and Thailand that had adequate oxygen to meet the surge in COVID-19 cases, had reported a gap between demand and supply. For example, in July 2021, government sources indicated that the pre-pandemic daily demand for oxygen in Bangladesh was about 50 to 70 metric tonnes (MT), which reportedly increased 2.5–3 times during the second wave of the coronavirus outbreak. An independent assessment in July 2021 estimated that the country’s daily demand of medical oxygen had peaked to around 600 MT during the second wave.

Likewise, reports citing government data also showed that Indonesia’s daily need for oxygen had risen from 1928 MT per day (MTPD) to 2262 MTPD in July 2021. Another oxygen report prepared by WHO around July 2021 indicated that the daily demand of oxygen at the hospitals was about 2350 MT with nearly full occupancy of about 90,000 hospital beds in the country. One of Nepal’s key experts in medical oxygen stated that the daily demand in the country was estimated to be around 70 MT before the COVID-19 pandemic, which rose manifold to around 170–180 MTPD during the peak of the pandemic. Countries such as Maldives and Myanmar have not officially reported a gap in demand and supply; however, unverified media reports showed widespread oxygen shortage.

Our study observed that nearly every country in the Region had conducted an “oxygen readiness” assessment either in 2020 or in early 2021 with every report, except for Thailand, observing that the health systems required better preparation and strengthening of oxygen infrastructure for delivering oxygen therapy. For example, a study by the United Nations Children’s Fund (UNICEF) in Bangladesh in April 2020 had observed that 70% of the health facilities in the country lacked adequate oxygen infrastructure.

Another study conducted by Indonesia’s Ministry of Health (MoH), in collaboration with WHO, in September 2020, observed that nearly 60% of the hospitals had inadequate supply of oxygen to meet higher demand. With the surge in infections and the health facilities running out of medical oxygen, some countries, such as India, Nepal and Myanmar, among others, reported hoarding of oxygen devices, such as cylinders and concentrators, by “privateers” and speculative increase in prices of oxygen cylinders and concentrators being sold in the private market.

The study observed that across all the Member States, the governments took early measures and many significant interventions to prevent and control the spread of COVID-19 infection, which included the formation of high-level coordination groups and putting in place emergency response plans. All governments actively monitored changes in the COVID-19 infection rates in their countries and, in response, released directives and guidelines from time to time. However, oxygen response in each country was unique.

**Oxygen sources in the South-East Asia Region**

The study looked at sources of medical oxygen for a Member State as a whole and sources of medical oxygen at health-care facilities in a Member State. Countries such as India, Indonesia and Thailand, which had large and established petroleum and steel industries, produced oxygen through cryogenic methods and had liquid medical oxygen (LMO) as the primary source of medicinal oxygen. For example, Thailand produced around 1260 MTPD of oxygen, of which around 400–600 MTPD
were for medical use. Likewise, LMO was the primary source of oxygen in Indonesia. As Indonesia is a group of islands, moving LMO from the point of production to its point of use presents a logistic challenge. To overcome it, Indonesia had installed LMO storage tanks in 92% of its hospitals. While India produced 7200 MTPD of oxygen, nearly 85% of it was for industrial use, with around 1000 MTPD of oxygen kept for medicinal use.

Relatively less industrialized countries, which did not have large metal and petrochemical industries, such as Bhutan, Maldives, Nepal and Timor-Leste, had air separation units (ASUs) as primary sources of oxygen. ASUs in all the three countries were operating at suboptimal capacities before the pandemic due to low oxygen demand. For example, almost all the 26 ASUs in Nepal operated at around 25% capacity, due to which two ASUs became loss-making and were made defunct. Likewise, in Bhutan, three ASUs were operating between 25% and 65% of its capacity before the COVID-19 pandemic. Other countries, such as Bangladesh and Sri Lanka, relied on import of liquid oxygen from their neighbouring countries for their oxygen needs. For example, Bangladesh imported nearly 20% of its need for liquid oxygen from India. The study could not reliably collect information on sources of oxygen for Myanmar and DPR Korea.

Prior to the COVID-19 pandemic, hospitals in almost all countries in the SE Asia Region depended on oxygen cylinders as the primary source of medical oxygen. However, following the surge led by the Delta variant of the novel coronavirus, all countries diversified their oxygen sources by augmenting and expanding capacities of their existing sources of oxygen and by procuring other systems of oxygen production, such as cryogenic plants, ASUs, PSA oxygen plants and oxygen concentrators. They also enhanced oxygen storage and delivery capacities by increasing the number of oxygen cylinders and LMO storage tanks and establishing manifolds and medical gas pipeline systems at the hospitals.

As stated above, this section explores and provides insights into the COVID-19 situation in the Region, the oxygen demand-supply gap the countries experienced during the Delta variant-led COVID-19 wave and the overall oxygen response in various Member States, and the initiatives taken to enhance medical oxygen production to bridge the oxygen demand-supply gap, especially in the case of emergency. It also investigates the changes in the regulatory environment that enabled oxygen production from multiple sources and the logistics of moving oxygen supplies from the point of production to the storage points and health facilities.

Various approaches to enhancing oxygen production capacity

The Member States adopted various approaches to enhancing production of medical oxygen in their countries and its availability across health facilities.

- Enhancing production from existing plants: The study found several examples of the Member States mapping the current oxygen production capacities, identifying units that were performing below their expected capacity and enhancing oxygen production to reduce the demand-supply gap. For example, Bhutan increased the production of oxygen in its four functional oxygen-manufacturing units in Gelephu, Phuntsholing and Motanga from 30–65% capacity to full capacity.

Nepal, where 26 ASUs with a combined daily manufacturing capacity of about 170 MTPD were operating for about 4 to 6 hours/day on an average at only 25% of their total capacity, were encouraged to operate at full capacity, when oxygen demand started rising during the pandemic. This also led to a human resource crunch as the workers in
the oxygen plants got overworked and exhausted, and they were often infected with COVID-19.

Gas World Limited, a subsidiary of Industrial Gases Private Limited, in Sri Lanka, which is the only medical and industrial gas manufacturer other than Ceylon Oxygen, a unit of Linde AG, boosted its oxygen production capacity to 38 MTPD by commissioning an additional ASU in August 2021.8

Likewise, Thailand, which produced around 1260 MTPD of oxygen, ramped up oxygen production in the wake of surging COVID-19 cases during the third wave. The Department of Industrial Works (DIW), which was largely responsible for managing the oxygen supply during the COVID-19 crisis in the country, monitored the oxygen demand and worked synergistically with the Thai Gas Manufacturers Industry Club under the Federation of Thai Industries (FTI), the Siam Industrial Gases Association (SIGA) and other manufacturers to prevent demand-supply mismatch. Fifteen factories manufacturing oxygen in Ayutthaya, Saraburi, Chonburi, Rayong, Songkhla, Lamphun and Chiang Mai provinces assured cumulative production capacity of about 1860 MTPD.

### Reviving defunct oxygen-manufacturing plants: Kerala Minerals and Metals Limited in India and Bangkok Industrial Gas Company Limited in Thailand

The Kerala 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 Kerala Minerals and Metals Limited (KMML), which manufactures titanium dioxide, with a new 70 MTPD 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. The plant produced 7 MT of “waste” oxygen per day as a by-product of producing 63 MT of industrial oxygen (in gaseous form) and 70 MT of nitrogen per day. This wasted oxygen was then liquified to use for medical purposes.9

Bangkok Industrial Gas Company Limited (BIG), Thailand’s largest oxygen producer with a production capacity of 1000 MTPD, also restarted an additional ASU plant to help Thailand ramp up oxygen production during the crisis. It even helped the country to export oxygen to other countries such as India.10

**Conversion of industrial oxygen capacity to medical oxygen:** The study also observed countries, which were producing industrial-grade oxygen, working with the industries, allowed industries to produce medical grade oxygen subject to regulatory compliance. For example, in July 2021, as the demand for oxygen escalated, the Bangladesh government sent notices to various oxygen-manufacturing companies, asking them to suspend production of industrial oxygen, enhance production of medical-grade oxygen and provide it only to hospitals and clinics.11

The medical and industrial oxygen manufacturers in Bangladesh also came forward and rose to the occasion by voluntarily supplying medical oxygen to hospitals and clinics. For example, in Bangladesh, four oxygen-manufacturing units had donated 12 000 cylinders to 35 private and government hospitals in Bangladesh during March and April 2021.12
In India too, many states, such as Kerala, Odisha, and Maharashtra, among others, with guidance from the Petroleum and Explosives Safety Organization (PESO), Government of India, had allowed the industrial oxygen manufacturers in their states to produce medical grade oxygen and industrial oxygen cylinders and non-toxic and non-flammable gas cylinders (nitrogen, helium and argon) to medical oxygen cylinders (through a certified process of purging). Moreover, with help from PESO, some of the liquid argon and nitrogen tankers were also converted to liquid oxygen tankers to strengthen the liquid oxygen supply chain. As a result, in a state such as Maharashtra, which produced 1300 MTPD of oxygen, 80% of the oxygen was converted to medical oxygen and supplied to hospitals.

- **Commissioning new cryogenic plants/ASU plants:** In addition to increasing production by enhancing production from existing sources and converting industrial-grade oxygen to medical-grade oxygen, Member States also took initiatives to establish new oxygen production units as a long-term strategic measure to boost oxygen availability in the countries. For example, the Royal Government of Bhutan commissioned a new LMO plant in Motanga, which was established by SD Cryogenic Gases Private Limited. Bhutan supplied 40 MT of liquid medical oxygen to India in 2021, when India was experiencing a medical oxygen crisis. Likewise, a new factory was established in Rayong in Thailand in August 2021, which pushed the country’s total oxygen production capacity to 2200 MTPD.

As Nepal faced dire consequences when the Indian government banned oxygen export during the second wave to meet its own in-country needs, the Nepalese government announced the decision to establish the country’s first LMO manufacturing unit. However, data on its location and manufacturing capacity is not available.

**Incentivizing the private sector to establish oxygen production units**

To secure themselves against future demands of oxygen, many states in India offered incentives to private oxygen manufacturers to set up production units in their states. For example, the state of Delhi launched the Medical Oxygen Production Promotion Policy, 2021, which offered financial subsidies to private enterprises setting up oxygen production plants in the state.

The Maharashtra government announced ‘Mission Oxygen Swavalamban’ (self-reliance) that incentivized the micro, small and medium enterprises (MSMEs) for setting up new LMO tanks and ASUs. Under this mission, the state promoted investments by providing incentives and subsidies to the MSMEs with a special focus on remote rural/tribal districts.

Similarly, the Rajasthan government, in order to increase private sector participation in mitigating oxygen crisis, announced a special package with various incentives and facilities in April 2021 for setting up medical oxygen production plants. To get the advantage of the package, a private entity was expected to invest at least Rs 10 million (approximately US$ 130 000) and had to ensure that the plant was functional by the end of September 2021.

The Delhi state government in India commissioned two cryogenic bottling plants with a capacity of 12.5 MT, which would refill up to 1200 jumbo cylinders in a day, to further boost the buffer stock of 442 MT of liquid medical oxygen it had.
Conversion of industrial gas cylinders to oxygen gas cylinders: Other than increasing the production of oxygen, several Member States also took initiatives to increase oxygen storage capacity in the countries. One of the most common measures was to convert industrial gas cylinders to medical oxygen gas cylinders. For example, the Royal Government of Bhutan inventoried oxygen cylinders for industrial purposes as a back-up for additional oxygen supply. According to an expert working closely with the government on oxygen management, this was carried out so that during exigent situations, industrial oxygen cylinders can be converted to medical-grade oxygen cylinders and provided to hospitals. This was done through a certified process of purging.

The study also observed that the Department of Disaster Management, Kerala in India had issued an order informing all persons and entities holding industrial gas cylinders to hand them over to the district collectors, who were also the chairmen of the district disaster management authority in their respective districts, for conversion to medical oxygen cylinders. By this single initiative, Kerala mobilized an additional 7000 cylinders from industrial units and augmented its medical oxygen storage capacity, which led to an increase in the state’s ready storage capacity to 219 MT by April 2021 from 70 MT in March 2020.

Enhancing oxygen storage capacities: Another initiative that some Member States took to increase oxygen storage capacities involved increasing the buffer stock of oxygen storage devices. For example, COVID-19 treatment facilities in Maldives had a stock totalling 2402 jumbo oxygen cylinders, along with a reserve of 250 jumbo oxygen cylinders. The Sri Lanka government had placed order for 7000 jumbo cylinders to add to the 24 000 medical oxygen cylinders it already had in order to match the storage and distribution infrastructure with the availability of surplus oxygen. According to Sri Lanka’s Association of Medical Specialists (AMS), the country had 28 liquid oxygen tanks installed at hospitals with their storage capacities ranging between 3 kL and 20 kL (approx. 3.4 MT–23 MT). In India, Kerala provided licences and necessary support to 32 large hospitals in the state for storage of liquid oxygen, ensuring an additional storage capacity of 420 MT.

**Strategic oxygen reserves: Kerala, India**

Based on the distance between the production facility and supply units in the state, the state government also created three strategically located buffer storages as hubs – two in Kochi, situated in the central part of the state, and a third in the southern industrial part of the state. Put together, they added another 60 MT of medical oxygen storage capacity in the state. These initiatives led to a combined storage capacity of 1325 MT of liquid oxygen in the state, of which the Inox plant alone contributing 1000 MT had the single largest storage capacity in Kerala.

Procurement and commissioning of other oxygen production systems: Additionally, all Member States, without exception, expanded and diversified their sources of oxygen as part of the response efforts. Learning from their experience of not relying solely on a single source of oxygen, the governments diversified their oxygen sources to PSA oxygen plants and oxygen concentrators. They also acquired and placed oxygen storage units, such as oxygen cylinders and LMO tanks.
Rajasthan, India: Oxygen concentrators – easy to deploy and operate

As part of its strategy to maintain adequate oxygen supply to the health facilities, Rajasthan acquired and deployed over 50,000 oxygen concentrators (OCs) in the state. As LMO storage and PSA plants required time to procure, install, train and operate, apart from being centrally managed, oxygen concentrators were the best of the options to respond to the spike in oxygen demand. They could be procured locally by the state and was easy to deploy and operate. The Rajasthan government provided 6–7 units in each primary health centre and around 10 units in each community health centre across the state, apart from deploying them at higher-level facilities such as district hospitals, based on expressed need.

Rajasthan also established state-run oxygen concentrator banks across all districts in the state to support home-based care. The state government has placed over 500 units across the oxygen concentrator banks in Jaipur, the state capital, around 500 units in seven divisional headquarters and around 400 units in each of the 33 district headquarters. These oxygen concentrator banks are accessible through helpline number or via district drug warehouse. The beneficiary can take the oxygen concentrator on rentals, with a security deposit on a refundable basis.

While some of the acquisition was carried out via global and national procurement, a large part of the acquisition of oxygen systems was implemented through donations and contributions. The Asian Development Bank (ADB), WHO, UNICEF, the United States Mission, the United States Agency for International Development (USAID) and the United Nations Office for Project Services (UNOPS) were some of the most named contributors to strengthening oxygen systems via donations and procurement.

Before the COVID-19 pandemic, a large proportion of hospitals in the Region did not have captive oxygen production capacity. With COVID-19, nearly every country procured and installed PSA oxygen generation plants and oxygen concentrators at various hospitals in the country. Some countries, such as Maldives and Sri Lanka, procured a limited number of PSA plants while Nepal instructed all large hospitals with 100 beds or more to have PSA plants as one of the sources of oxygen.

The Government of India, through Prime Minister’s Citizen Assistance and Relief in Emergency Situations (PM CARES), and the state governments, through their funds, foreign aids, CSR initiatives and PSU support, have acquired and installed about 4000 PSA plants. However, as the installation and commissioning process of the PSA plants requires capital expenditure for procurement along with prerequisite infrastructure, such as medical gas pipeline network, adequate ventilated space and continuous power supply, including power backup, their uptake at smaller hospitals and specifically hospitals in rural areas have been challenging. Moreover, perception of their high operational and maintenance costs of PSA is not helping the cause.
### Regulatory actions to enhance oxygen manufacturing and preventing hoarding: Nepal

To monitor and enhance the oxygen manufacturing capacity of the country, Nepal took a few policy-level decisions with far-reaching impact. For instance, to ease the oxygen procurement process, the government provided tax relaxations on PSA plant imports and purchases. Moreover, to prevent hoarding and black-marketing, taking the government’s permission for procurement of medical oxygen was made mandatory. Therefore, all government, private or community hospitals had to produce a recommendation from the Ministry of Health and Population (MoHP) in order to refill cylinders. For better asset management, an e-logistics management system was also put in place to integrate information on commodities to track and identify procurement needs.

### Strengthening oxygen surface logistics: An India story

India, the seventh largest country in the world, covers around 2933 kilometres from east to west and 3214 kilometres from north to south. Moving oxygen within this huge landmass presents its unique challenges and solutions.

India, as per the national government data, built a fleet of over 2000 oxygen tankers with carrying capacity of about 30 000 MT of LMO by adding oxygen tankers to the fleet and by conversion of nitrogen and argon tankers to oxygen tankers. Yet, despite receiving allocation of LMO from the Government of India, many states, such as Rajasthan, was not able to fully lift the allocated oxygen from the oxygen manufacturing plants due to non-availability of a sufficient number of oxygen tankers. In addition to acquiring oxygen tankers, Rajasthan also received support from other states such as Haryana, Delhi, Uttar Pradesh and Chhattisgarh, which ensured the supply of oxygen to the state. This inter-state collaboration was observed in other parts of India as well.

Furthermore, to streamline and facilitate smooth distribution, many states in India subsidized transportation and introduced several rules, such as tankers to be run at full capacity with no idling time for any tanker. The running cost of oxygen tankers was also subsidized by the state.

To improve and optimize the oxygen supply chain, the state governments reconfigured the supply flow by creating a hub-and-spoke model, wherein the hospitals were mapped to their nearest suppliers. The model optimized the oxygen supply chain and decanting capacity of LMO.

To ensure obstruction-free passage and optimize delivery of oxygen to the destination facilities, many state governments deputed police escort for the oxygen tankers entering a state from the plants outside the state. Similarly, the medical oxygen tankers were escorted by police personnel of the state, where oxygen was being produced from the loading point up to the state boundary limits, to ensure unhindered movement. Moreover, LMO tankers were given the status of ambulances to facilitate their smooth movement.

At the start of the second wave, green corridors were set up for transportation of medical oxygen. All routes were mapped and those with bottleneck areas were outlined. Arrangements were also made to ensure real-time monitoring and tracking of all vehicles carrying medical oxygen by enabling them with GPS-tracking systems.
Lessons learnt

The strategies and approaches adopted by several Member States of the SE Asia Region to improve oxygen production capacities presents several lessons for building a resilient and responsive oxygen system in the Region. Although the lessons shared below are not exhaustive and there will surely be more of them, some of the lessons emerging from this study are:

- Oxygen requires a multipronged strategy: Oxygen is an essential, life-saving commodity. It has multiple sources of production; it has different devices of storage and means of transportation, depending on its state, and it lies in the shared domain of engineering and medicine, which makes the oxygen system complicated and challenging. Health systems must have diversified sources of oxygen. As COVID-19 showed, dependence on a single source of oxygen and lack of capacity at large hospitals to produce captive oxygen can acutely skew the demand-supply gap. The multipronged strategy for meeting the oxygen gap will work best if it includes widening the sources of oxygen production, strengthening existing oxygen sources and improving oxygen storage and management systems and supply chain innovations to unlock bottlenecks on oxygen logistics.

- Effective oxygen production requires data-backed and decentralized decision-making with multistakeholder engagement: Examples from various Member States showed that there are multiple stakeholders with regard to delivering medical oxygen to beneficiaries. Some of the promising practices that emerged from this study regarding coordination and leadership commitment are:
  - effective planning and forecasting of oxygen demand and landscaping oxygen production capabilities;
  - decentralized decision-making for regional and local players to customize oxygen response, based on their local priorities, such as in India and Thailand;
  - encouraging and incentivizing existing oxygen production units to optimize production and the carriers to optimize logistics during surge; and
  - private sector engagement in production of oxygen with the government coordinating its logistics to hospitals to enhance production efficiency on one side and supply chain management on the other.

- Investments in critical care are as important as primary care: During the pandemic, the surge in cases and demand for oxygen and the supply choke points in many Member States showed that investments in primary care alone are not adequate for saving lives. In addition to disease surveillance and vaccine management, there is a need for all countries to invest in critical care and adopt a more comprehensive approach to public health, especially in newly independent countries, to build a more holistic and resilient public health system.

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Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic

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Oxygen procurement

Introduction

The rapid spread of COVID-19 in 2021 and the sudden shortage of medical oxygen caught several nations off guard. Although countries such as Bangladesh, India, Indonesia, Nepal, Myanmar and Sri Lanka were more affected than others in terms of the demand-supply gap for medical oxygen, all Member States resorted to course corrections in their oxygen management strategy by revising their national pandemic preparedness plans and clinical guidelines that they had prepared in 2020. The study found that many Member States reconstituted their COVID-19 response committees and task forces and undertook oxygen landscape assessments so that they could respond strategically and more effectively to the unravelling situation.
In addition, several governments purchased vital oxygen and respiratory care equipment to provide immediate care to patients, who were in dire need of oxygen therapy. Despite a few Member States, such as Bhutan, India and Thailand, having in-house production capacities to meet the oxygen demand, nearly all Member countries procured oxygen, in cryogenic form, or oxygen production equipment, such as PSA oxygen plants or oxygen concentrators, or oxygen storage devices, such as oxygen cylinders and cryogenic tanks, to meet the local demands. These oxygen systems and their components were either procured through a tendering process or acquired through donations. This, in several Member States, was taken as a pre-emptive measure or as a necessity to meet the growing oxygen demand.

Furthermore, the study observed that governments of the Member States initiated procurement of oxygen systems through several mechanisms, such as centralized medical stores, open tenders and directly through ministries, or by establishing special funds or launching emergency policies. Additionally, the Member States revised their procurement frameworks and practices by easing regulations, custom duties, import taxes, etc., thereby facilitating the import of medical oxygen and equipment for its production, storage, and delivery.

Even as the Member States were trying to procure medical-grade oxygen and its production, storage, and delivery systems to strengthen the oxygen ecosystem, the study found that the global scale of the pandemic presented several challenges to their initiatives. The pandemic impacted the market availability of oxygen and oxygen equipment as the demand was global and suppliers were limited. To begin with, restrictions and delays along country borders due to lockdowns impacted the lag time between placement of order and delivery of equipment. The oxygen supply chains globally were stretched as coordination between governments, aid agencies and suppliers experienced disconnect. Delays in regulatory processes slowed down acquisition, among other causes.

Aside from these challenges, the high demand for oxygen in several Member States also resulted in a speculative increase in the price of retail oxygen equipment, such as cylinders and concentrators, as well as business malpractices, such as profiteering and hoarding of essential resources. The study also found that some oxygen equipment manufacturing companies experienced challenges to their operations, as not only their workforce was affected by COVID-19, but the supply of raw materials was also impacted.

The study also observed global cooperation and collaboration during the pandemic to strengthen oxygen capacities. As fatalities related to COVID-19 rose across countries, there was a global contribution of oxygen equipment and consumables in the form of donations. Aid poured in from a wide spectrum of sources, such as countries, multilateral and bilateral agencies, philanthropic organizations, corporations and individuals.

Finally, faster distribution and delivery of medical oxygen, equipment and consumables were as vital as procurement and acquisition. The study found that less than the desired number of cryogenic tankers posed a hurdle to transferring liquid medical oxygen from manufacturing facilities to hospitals. Nonetheless, the silver lining to all these challenges were the innovative approaches, such as repurposing of industrial gas tankers to oxygen tankers and such initiatives as the Oxygen Express, the Mumbai model, and the Oxygen Shuttle, among others, which ensured that medical oxygen reached patients in the shortest time possible.
While most Member States utilized their existing frameworks of procurement and distribution to ensure that medical oxygen reached patients, almost all of them used an array of digital tools and platforms to manage, procure, track and distribute oxygen supplies. Almost every country had developed a COVID-19 dashboard to keep its citizens informed about the number of active cases, fatalities and recoveries from the disease. Apart from this, some countries had developed dedicated platforms and mobile applications to list oxygen equipment, monitor their availability and track their distribution across the country.

This document is a thematic dossier on oxygen procurement and acquisition and the overall delivery of oxygen equipment and consumables in the South-East Asia Region. It provides insights into the strategies that were devised for acquiring oxygen generation and storage capacity, be it from other countries, through a private vendor, within the country through private sources or through oxygen procured from global sources. It looks beyond procurement into acquisition through donations and the overall distribution mechanisms, and it explores information on the unique processes that the Member States adopted to acquire oxygen systems to bridge the demand-supply gap. The document also highlights a few of the challenges that obstructed the supply chain and led to the demand-supply chasm.

COVID-19 and oxygen response

Since WHO designated COVID-19 as a pandemic in early 2020, there have been consistent efforts to ensure that the best approach and standard of care are instituted in the patient management process. When the demand for medical oxygen rose sharply in 2021, it became even more critical to evaluate the availability of various oxygen sources and ensure that oxygen was supplied and delivered to the patient on priority.

Each of the Member States responded differently to strengthening its oxygen ecosystem. Many launched initiatives and innovative approaches to rapidly and timely procure medical oxygen and make it available for generating and supplying oxygen to patients in critical need for it.

Constitution of committees, task forces and oxygen landscape studies

Most governments constituted national- and regional-level committees and task forces on the onset of COVID-19 in early 2020, with the primary goal of preparing a strategic response to the pandemic. These preparedness strategies included ramping up the existing health facilities by ensuring additional ICU/HDU beds, procuring adequate medicines and ventilators, and prepping the health-care workers with clinical management guidelines for patient care. The study found that a few countries, such as Bangladesh, Bhutan, Indonesia, and Thailand, conducted oxygen landscape mapping studies in 2020 to assess and forecast the likely demand and status of oxygen supplies in the countries in order to meet the demand, in case of an acute spurt in COVID-19 cases. However, based on the information it had, the study team observed that of all Member States, only Bhutan took pre-emptive measures and procured around 1000 D-type cylinders and 106 oxygen concentrators to prepare their hospitals.

The pandemic in 2021, led by the Delta variant of SARS-CoV-2, was the most devastating, when the unprecedent spike in COVID-19 cases caused sudden shortage of medical oxygen at various health facilities in most of the Member States, catching the governments off guard. Countries such as Bangladesh, India, Myanmar, Nepal and Sri Lanka were more affected than some other Member States in the Region, in terms of the demand-supply gap for medical oxygen. In response, several
Member States, learning from the previous years’ experience, revised their guidelines, reconstituted their COVID-19 response committees and task forces, and adapted their COVID-19 strategies to fit the unravelling situation. For instance, the Government of Sri Lanka revised the preparedness plan in April 2021, increasing the emphasis on patient care through accelerating equitable access to new COVID-19 tools, including vaccines, diagnostics and therapeutics.\(^1\)

Meanwhile, the Government of Thailand set up four committees – one for stockpiling oxygen devices, another for regularly carrying out needs assessment, the third for troubleshooting and the fourth committee for monitoring and evaluation. The four committees worked on oxygen demand and supply activities that were earlier managed by a centralized coordination centre. In India, each state responded uniquely. For example, the Delhi state government constituted a committee to examine the medical oxygen infrastructure at all state government-administered hospitals and recommended measures to augment the same expeditiously.\(^2\)

While the state of Odisha set up a dedicated Oxygen Task Force in April 2021 to manage the production, storage, distribution, transportation and overall management of oxygen, Rajasthan established a state-level oxygen management committee (SLOMC) in early May 2021 with the Secretary, Industries, as its chair.\(^3,4\) The committee had the state nodal officer for oxygen and assistant nodal officers from different departments as its members. The committee formed various subgroups, each assigned a role in oxygen management, such as coordination with the national government for allocation of oxygen from LMO-manufacturing plants, management and tracking of tankers for lifting of oxygen, management of LMO tanks, coordinating installation and commissioning of PSA plants in the state, formation of control rooms at state and district levels, among other things.

Apart from reconstituting committees and task forces, several Member States embarked on gathering data related to oxygen demand and consumption for the medical sector, including an effort to understand the industrial sector. Sometimes working alone and at other times, working with a technical partner, they collected and analysed the oxygen-related data to plan initiatives to curtail any potential future wave and mitigate its impact. Governments of several countries initiated these assessment exercises, viz. the Bangladesh government, in collaboration with UNICEF, conducted an oxygen landscaping exercise with an aim to facilitate development of a national medical oxygen plan for the country for the next 10 years.

As per the draft report, titled “Bangladesh national oxygen landscape report”, dated December 2021, the government started preparing for adequate oxygen supply to patients’ bedsides. Similarly, a report, titled “Oxygen for Indonesia Movement”, dated 23 July 2021, prepared by the Ministry of Health of Indonesia (also known as Kementerian Kesehatan Republik Indonesia), showed that the country’s annual production capacity stood at 866 MTPD against daily utilization of about 638.9 MT, of which 75% was used by industries and the remaining 25% was used for medical purposes.

**Two-pronged approach – procurement and acquisition and the overall distribution**

The unprecedented challenges that the Delta variant-led COVID-19 outbreak in 2021 brought to the Member States encouraged the governments in those countries to look beyond the traditional sources of medical oxygen – from production of liquid medical oxygen and its supply in gaseous form in oxygen cylinders to hospitals to other sources of oxygen production and supply, which would ensure improved availability of medical oxygen for patients.
The governments purchased vital oxygen and oxygen production and delivery equipment to immediately respond to the COVID-19 crisis. However, the study observed a lack of proper and reliable guidelines in emergencies, such as emergency procurement of health-care resources, such as medical devices (respiratory care devices, therapeutic devices, diagnostic equipment, laboratory equipment, reagents, etc.), in a comparatively short period, bypassing the protocols used as mandatory in a normal situation, which caused difficulties in ensuring appropriate discipline and good practices of system, such as procurement, supply chain and overall management.

The study found that not all Member States responded alike, as some countries had adequate resources, both in terms of in-house production capacity as well as financial resources to procure either liquid oxygen from other countries or oxygen production equipment to meet the local demands. But there were other countries, which relied on external assistance to arrange for the oxygen supplies required during the emergency.

More importantly, the study found that almost all Member States had either procured medical oxygen from other countries or acquired medical equipment through donations from entities, such as countries, multilateral and bilateral agencies, philanthropic organizations, corporates or individuals, either as a pre-emptive measure or as a necessity. Oxygen supply is typically achieved using oxygen cylinders (filled at an oxygen plant/ASU/PSA), oxygen concentrators (concentrating oxygen from air on-site), PSA/oxygen plants (piped directly or distributed via cylinders) or liquid oxygen (delivered from a specialized gas plant and stored on-site at very high pressure).

**Procurement**

- Procurement through centralized medical stores: In some countries, procurement of medical oxygen was carried out centrally by the respective government through mechanisms such as centralized medical stores, open tenders, directly through ministries, etc. or by establishing special funds or by launching emergency policies. For example, in Bhutan, the Medical Store and Distribution Division, Ministry of Health, in Phuentsholing functioned as a central medical store for meeting the requirements of all medical commodities and devices at public health facilities in the country. As infection rates soared, it procured and stored all the cylinders before distributing them to various hospitals in the country, as per the requirements of hospitals.

  Similarly, Timor-Leste procured all its medical equipment, drugs and consumables through a national medical store, known as Serviço Autónomo de Medicamentos e Equipamentos de Saúde (SAMES), which is a public institution within the Ministry of Health. In September 2021, the Ministry of Health procured 1500 empty cylinders through SAMES for distributions at hospitals, so that all hospitals in Timor-Leste could get at least 10 additional cylinders as reserve.

- Procurement through open tenders: The Government of Sri Lanka floated open tenders to place multiple orders for jumbo cylinders (also called D-type cylinders, which nominally contain 7000 litres of oxygen per cylinder). The study also observed that the Sri Lankan government had placed an order of 7000 jumbo cylinders to match the storage and distribution infrastructure with the availability of surplus oxygen, of which 400 were expected to be delivered by the end of May 2021. The study was unable to confirm the delivery of these oxygen cylinders.
Procurement through emergency funds: Countries, such as Bangladesh and India, established special emergency funds to procure and acquire oxygen supplies. India launched the Oxygen Production Policy 2021 and constituted the PM CARES fund. The Government of India, through PM CARES, and the state governments, through their funds, foreign aids, corporate social responsibility (CSR) initiatives and public sector undertaking (PSU) support, acquired and installed about 4000 PSA plants, over 300,000 oxygen concentrators and another 300,000 oxygen cylinders at various government medical college (GMC) hospitals, district hospitals (DHs), civil hospitals (CHs) and thousands of sub-district hospitals, such as community health centres (CHCs) and primary health centres (PHCs), in 734 districts across the country. These do not include the oxygen equipment established in private hospitals.

Similarly, Bangladesh bought 30 oxygen generators/PSA plants for hospitals through direct procurement system on an emergency basis, under the COVID-19 Response Emergency Assistance, a programme financed by the Asian Development Bank (ADB) in August 2021. Apart from these two countries, Her Royal Highness Princess Maha Chakri Sirindhorn of the Kingdom of Thailand granted special permission to acquire 540 high-flow oxygen concentrators, using the Chaipattana Fund for COVID-19. This was in addition to the oxygen that Thailand imported from the People’s Republic of China to meet the demand–supply gap in the country.

Contrarily, Maldives utilized its central budget to procure 4000 empty cylinders to support the additional requirements of the health facilities, although we found no information on the size and capacity of the cylinders. Likewise, Myanmar’s Ministry of Commerce imported 1294 MT of liquid oxygen, 114 MT of oxygen in cylinders, 40,491 empty oxygen cylinders, 69,146 household oxygen concentrators, 8 oxygen plants, 11 oxygen generators and 4 hospital-based oxygen-filling equipment (booster-compressor equipment).

In addition to these, in August 2021, Myanmar further imported 3389 oxygen concentrators, 95 MT of liquid oxygen, 2 MT of oxygen in cylinders, 5992 empty oxygen cylinders, one oxygen plant, 4 oxygen generators, 4459 household oxygen concentrators and other consumables. Moreover, 368 MT of liquid oxygen, 53 MT of oxygen in cylinders, 39,458 empty oxygen cylinders, 5 oxygen plants and 9 oxygen generators were further imported. We did not ascertain information on the type of oxygen plants and oxygen-filling machines.

Procurement through direct imports: The study found that countries, such as Nepal and Thailand, alleviated the oxygen demand-supply gap by importing oxygen from the People’s Republic of China during the pandemic. Thailand has long been self-sufficient in terms of its oxygen requirement and the need for oxygen was never a challenge for Thailand until the third wave. It has been traditionally importing oxygen cylinders from the People’s Republic of China as there are no domestic manufacturers.

The majority of the oxygen generators and oxygen concentrators were also imported from the People’s Republic of China, along with other necessary equipment, such as oxygen valves and pipes, of which the existing stock is now able to meet the national demand. Likewise, Nepal imported medical oxygen


from the People’s Republic of China and a few other neighbouring countries to enhance the oxygen storage and distribution capacity. In addition, India received 40 MT of oxygen per day from Bhutan. India also imported liquid medical oxygen from Singapore and oxygen cylinders from Thailand. Similarly, Bangladesh and Sri Lanka imported oxygen from India.

**Acquisition**

As mentioned earlier, as fatalities were rising across countries due to oxygen shortages, there was a global outpouring of donations in the form of oxygen equipment and consumables. Aid came from an array of sources, including countries, multilateral and bilateral agencies, philanthropic organizations, corporations and individuals.

- Acquisition through donations of oxygen equipment, etc. from other countries:
  - Among the Member States, India was one of the most severely impacted countries during the second wave of COVID-19 and it received generous humanitarian aid from almost all countries worldwide.

  Many countries from around the world came forward to support various Member States in the Region by providing financial and strategic support, medical equipment and devices. For instance, India supplied about 250 MT of liquid medical oxygen to Sri Lanka over a period of two months.10 In another initiative of support to Sri Lanka, Australia provided a total of 11.7 million Australian dollars for critical supplies and health system support to the Sri Lankan Ministry of Health.

  Likewise, Singapore donated 1500 oxygen concentrators to Indonesia. This was in addition to the arrangement between Indonesian and Singaporean governments for regular shipments of emergency oxygen supplies to Indonesia via an “Oxygen Shuttle” programme.11 In addition, Indonesia also received a donation of 1000 ventilators and 297 oxygen concentrators, each with a capacity of 5 litres per minute (LPM), from Australia. South Korea, along with the United Arab Emirates (UAE), also donated 200 oxygen concentrators and extended help to the people of Indonesia by sending 450 oxygen cylinders and 150 portable oxygen concentrators. Similarly, New Zealand sent 100 units of high-flow nasal cannula and Taiwan supported the country by sending 110 oxygen concentrators, each with a 5-LPM capacity. Furthermore, the People’s Republic of China supplied 120 ventilators and 400 oxygen concentrators, and India sent 300 units of oxygen concentrators and 100 MT of LMO.

  Maldives received assistance from the United States of America (the USA) and India in the form of oxygen concentrators and health-care teams respectively. Singapore sent 200 oxygen concentrators with a capacity of 10 LPM each to Myanmar to support the country’s fight against the COVID-19 pandemic. Additionally, in July 2021, the Government of Japan decided to provide up to 700 oxygen concentrators. Furthermore, Nepal received tranches of oxygen supplies from India, France, the USA and the People’s Republic of China, which helped mitigate the shortage of supplies.
Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic

Acquisition through donations of oxygen equipment by multilateral and bilateral agencies and other development partners: Apart from countries donating oxygen equipment, devices and consumables, international aid agencies, multilateral and bilateral agencies and philanthropic organizations also came forward to support these countries during the trying times. Some of these organizations, such as WHO, ADB, World Bank, UNICEF, UNOPS, USAID, Japan International Cooperation Agency (JICA), United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and International Red Cross and Red Crescent Societies (ICRC), among others, were already working in the Member States and could provide advisory support to the governments on preparedness and response strategies.

For example, WHO donated 2000 sets of oxygen concentrators, 24,000 sets of venturi masks, nearly 500,000 sets of venturi masks with oxygen nasal cannulae to Nepal. WHO donated medical equipment worth US$ 1.8 million to Sri Lanka. Besides, USAID donated state-of-the-art ventilators to Bhutan. Bhutan also received oxygen concentrators from numerous entities, such as Singapore Red Cross, Vision Spring and Give India. Furthermore, USAID provided US$ 2.5 million to strengthen the oxygen ecosystem in Sri Lanka. In addition, the Asian Development Bank and the World Bank provided financial aid to support the procurement of diagnostic equipment and materials for critical care facilities, including ICU beds, and other key medical equipment. In addition, the World Bank donated 120 high-flow nasal oxygen therapy units, 25 ICU ventilators, seven neonatal ventilators and 20 transport ventilators to Sri Lanka.

Additionally, UNOPS, under the World Bank-financed COVID-19 Emergency Response and Health Systems Preparedness Project, financed 1000 units of 10-LPM oxygen concentrators that were distributed to peripheral health facilities across Nepal in June 2021. Moreover, 2100 oxygen concentrators and seven oxygen-generating plants were procured through UNOPS. Furthermore, in September 2021, in coordination with the Ministry of Public Health of the Royal Thai Government, the UN country team in Thailand under UNOPS, and with Japan’s support, 868 oxygen concentrators of 10-LPM capacity each were delivered to Thailand. These concentrators were distributed among 79 hospitals and community health centres across all provinces of the country.

Furthermore, UNICEF provided around 600 oxygen concentrators to the Government of Nepal. The country also received 100 oxygen concentrators, along with medical supplies, from the Gradian Health Systems and the Nick Simons Foundation (NSF). Additionally, Australia delivered oxygen and related supplies to Sri Lanka through UNICEF, including 291 oxygen cylinders and 342 oxygen regulators. Likewise, UNICEF provided 550 oxygen concentrators to help treat patients with respiratory diseases in Thailand.

Acquisition through donations of oxygen equipment, etc. from corporate entities and individuals: Corporates and individuals went beyond their mandates to extend support to the affected countries by donating life-saving oxygen to those who needed it the most. For example, the Singapore Chamber of Commerce (SingCham) in Indonesia facilitated the shipment of six tanks of
liquid medical oxygen, oxygen concentrators and oxygen cylinders to Jakarta. Indo-Rama Synthetics Tbk and Indorama Ventures Indonesia donated 600 oxygen concentrators in July 2021. Apart from these, the Temasek Foundation and 15 other companies from Singapore and Indonesia donated more than 11 000 oxygen concentrators to Indonesia.

Similarly, the four medical and industrial oxygen manufacturers from Bangladesh donated 12 000 cylinders to 35 private and government hospitals, and they also pledged to refill the cylinders. In Sri Lanka, Unilever donated oxygen equipment such as oxygen concentrators. Furthermore, the study found reports that suggested religious leaders and industry leaders in Myanmar donated oxygen to the general public.

**Distribution**

During the pandemic, faster distribution and delivery of medical oxygen, equipment and consumables were as vital as procurement and acquisition.

- Distribution and delivery through existing frameworks: In most countries, the existing framework of procurement and distribution was utilized to ensure that medical oxygen reached the patients. For example, Bhutan and Timor-Leste utilized their centralized procurement and distribution network for oxygen delivery. Apart from this, a few countries have assigned the responsibility of delivering medical oxygen services to a particular department for better coordination. For example, in Sri Lanka, the Division of Biomedical Engineering Services within the Ministry of Health was responsible for installing and maintaining all medical equipment at most of the hospitals in the country.

For instance, Thailand had an extremely well-coordinated system. Several geographical nodal points were established that could produce medical-grade oxygen along with a strong transport network. An expert indicated that currently, there are 19–20 nodal points (having ASUs), where oxygen is generated and the whole distribution follows down from there towards the provinces and then to the districts, ensuring seamless distribution across the country.

- Digital platforms and tools for distribution, tracking and monitoring: The study observed that a plethora of digital tools and platforms were in use in various Members States during the pandemic to manage, procure and distribute oxygen supplies. For example, Indonesia was already using a centralized online procurement system, e-Katalog, to strengthen and streamline the tendering and procurement processes. Also, the central procurement agency of Timor-Leste, SAMES, was already using an electronic inventory system in which a mobile app (mSupply Mobile) had been installed on tablets at 24 health facilities in Dili District since 2016. Digital platforms and tools are enabling solutions that provide access to data related to suppliers and procurement details, drive complex analysis for better supplier strategies and enable tracking of oxygen equipment, thereby enabling more efficient operations.

Almost every country has developed a COVID-19 dashboard to keep its citizens informed about the number of active cases, fatalities and recoveries from the disease. Apart from this, some countries have developed dedicated platforms and mobile applications to list oxygen equipment, monitor their availability and track their distribution across the countries.
Facilitating oxygen procurement

The Member States implemented certain unique approaches to facilitate procurement of medical oxygen in the country and its availability across health facilities. These procurement processes were accentuated by regulatory eases and innovative models to further strengthen the supply chain ecosystem.

**Multimodal transport mix for ensuring sustainable oxygen supply and logistics**

Traditionally, medical oxygen has been exported either by road or by shipping vessels in most countries, depending on the geography and accessibility. For instance, prior to the COVID-19 pandemic, Bangladesh and Nepal imported oxygen from India by road. As countries were experiencing huge fatalities due to oxygen shortages, the governments started looking at mechanisms and interventions that could contribute to an improved oxygen supply system.

Among these innovative interventions, “Oxygen Express” from the Indian Railways is the most noteworthy. In India, despite adequate production of medical oxygen, shortages were experienced primarily due to unequal distribution of oxygen production units, which were primarily concentrated in the eastern part of India. The other reasons for the shortages included limited availability of LMO storage tanks and limited turnaround of refilled tanks reaching the facilities.

To mitigate the challenges of shortage of tankers and fast-track oxygen delivery to hospitals, the government introduced a series of long-haul/short-haul train services that carried medical oxygen in ISO cryogenic tankers to different parts of the country on 24 May 2021. The trains operated in two formats – firstly, freight trains carrying 16 MT of liquid oxygen in cryogenic ISO tanks were sent to the states and in the second method, LMO tankers, which were further loaded on to the trains, were transported to facilities prepared by the Indian Railways and the Indian Army for receiving these tankers.

A “green corridor” was being created for faster movement of these Oxygen Express trains. As per media reports, more than 35 000 MT of LMO were transported to 15 states and around 480 Oxygen Express trains were operationalized during the second wave of the pandemic in India. Furthermore, as the oxygen demand rose and fatalities increased in Bangladesh, the services of Oxygen Express were further extended to the neighbouring country between July and August 2021, with a total of about 1400 MT of LMO being supplied to Bangladesh from India through multiple trips.

In addition to roads and railways, ships loaded with medical oxygen were also sent to various countries. For example, two Indonesian ship owners offered free container slots to carry medical oxygen from Singapore. Another Indonesian company with business in logistics volunteered to arrange for the collection of the supplies in Singapore and have them delivered to the Indonesian authorities on their arrival in Jakarta. SingCham in Indonesia facilitated the shipment of six tanks of liquid medical oxygen, oxygen concentrators and oxygen cylinders to Jakarta. Apart from this, India supplied about 250 MT of liquid medical oxygen to Sri Lanka over a period of two months.

Given the urgency of medical oxygen in 2021, several oxygen equipment, such as oxygen concentrators, cylinders and liquid medical oxygen in cryogenic tanks, were airlifted from different countries to India. The Indian Air Force airlifted four cryogenic oxygen containers from Singapore’s Changi International Airport that reached India on 24 April 2021. Over 10 000 oxygen concentrators, manufactured by Philips, were airlifted from various countries. Other countries had also sent oxygen equipment through the air route.
Regulatory eases to overcome oxygen import challenges

The challenge of procuring oxygen during the 2021 surge was twofold – firstly, as most of the countries were struggling with oxygen shortage, the availability of oxygen was low. Secondly, pre-existing acts and regulations regarding use and import of oxygen were proving as barriers.

In a step towards easing the regulations, the Government of Bangladesh liberalized conditions to import medical oxygen to encourage intercountry collaboration to bridge the oxygen demand-supply gap. The governments of India and Bangladesh also agreed on a “green corridor” for seamless import of oxygen from India to Bangladesh. Likewise, the Government of Myanmar announced dropping all duties and licensing requirements for the import of oxygen concentrators for three months, starting in July 2021. Additionally, to ease the oxygen procurement process, the Nepal government provided tax relaxations on PSA plant imports and purchases.

In several countries, such as Bangladesh, India, Indonesia and Myanmar, the governments directed the industry to divert all industrial oxygen to health facilities by allowing them to produce medical grade oxygen subject to regulatory compliance. Oxygen generation and refilling units were also asked to stop selling and refilling oxygen cylinders in the private market and were instead directed to sell cylinders only to hospitals, clinics and quarantine centres, controlled by the Ministry of Health and Sports of Myanmar. The Delhi state government took over the oxygen supply chain by cancelling all previously existing contracts between private vendors and hospitals.

Furthermore, the Ministry of Commerce of Myanmar initiated diplomatic arrangements with Bangladesh, the People’s Republic of China, India and Thailand to import medicines and equipment through the border trade points. Moreover, the Ministry of Health, Indonesia expedited the license application process to manufacture and distribute medical devices in the country.

Digital platforms and tools for effective procurement and distribution

During the pandemic, a slew of digital platforms and tools were developed to manage and track resources and forecast demand and supply of oxygen. For instance, the e-Logistics Management System (e-LMS) of Nepal was also put in place to integrate information on commodities to track and identify procurement needs. Aplikasi Sarana, Prasarana, dan Alat Kesehatan (ASPAK) of Indonesia is a platform used for countrywide asset management of medical equipment, which includes tracking the availability of oxygen delivery devices and pulse oximeters.

For real-time monitoring of various oxygen devices, the Indian government developed the Oxygen Digital Tracking System (ODTS), Oxygen Demand Aggregation System (ODAS) and OxyCare – Management Information System (OCMIS). In addition to these, the state of Rajasthan used their existing Biomedical equipment Management & Maintenance software ‘e-Upkaran’, a web application developed by CDAC, where details of all oxygen concentrators could be found. The state of Kerala developed a COVID-19 Jagratha portal with geographic information system (GIS) mapping ability to map availability of liquid oxygen and gaseous oxygen production, distribution and retail/filling units, the number and type of oxygen cylinders and other logistics at both public and private health facilities with oxygen beds on a real-time basis.

In addition, the Delhi government started QR tagging of cylinders and installation of telemetry devices on LMO tanks for real-time monitoring and tracking. As per the experts working with
the Government of Delhi, the Union Ministry of Health and Family Welfare (MoHFW) has started installing internet of things (IoT) devices in all PM CARES-funded PSA plants in Delhi to monitor their utilization.

In this context, the Government of Bangladesh developed a central, real-time dashboard for officials to constantly monitor the state of oxygen availability at hospitals across the country. A total of 600 facilities reported their oxygen demand and supply through the dashboard during the COVID-19 crisis, which also included 50 private facilities. Similarly, the Indonesian government used the Essential Supplies Forecasting Tool (ESFT), developed by WHO, to calculate the demand and forecast requirement of oxygen, based on the number of active cases and bed occupancy. This dashboard facilitated coordination and helped in decision-making for optimum use of resources. Additionally, the government resorted to digital platforms and tools, such as ASPAK, for countrywide asset management of medical equipment, which included tracking the availability of oxygen delivery devices and pulse oximeters.

**Innovative models and approaches**

As the old saying goes, “Necessity is the mother of invention.” The oxygen shortage forced people to devise new strategies and innovations to tide over the crisis.

In India, Maharashtra’s “Mumbai oxygen model” is particularly noteworthy. In May 2020, the Municipal Corporation of Greater Mumbai (MCGM), along with a few other stakeholders, took initiatives to ensure an uninterrupted supply of medical oxygen across the city. Decentralized management and microplanning have been the key to the success of this model. The model has two aspects: centralized services and decentralized services.

The centralized services included the central dashboard providing a live status of bed availability across Mumbai hospitals; all oxygen-related purchases and infrastructure needs were taken care of by the Central Purchases Department, and standard operating procedures (SOPs) and COVID-19 treatment protocols were developed at the headquarters in discussion with the State COVID Task Force members and the deans of medical colleges. The decentralized system included a central war room with 24 peripheral control rooms providing essential services such as ambulances, doctors, telephone operators and other basic infrastructure. Additionally, Kerala came up with innovative models, buffer storage hubs of the state, for coordinated oxygen storage, supply and distribution across the states.

Similarly, Odisha involved the police department to ensure unhindered movement of medical oxygen from the loading point to the state boundary limits. Moreover, at the start of the second wave, green corridors were set up for the transportation of medical oxygen. All the routes were mapped and routes with bottleneck areas were outlined. Arrangements were also made to ensure real-time monitoring and tracking of all the vehicles carrying medical oxygen by enabling them with GPS tracking systems.

In addition, each health facility was mapped with the nearest refilling station. All empty cylinders at a health facility were collected on a daily basis and sent to the nearest refilling station, to which the facility was tagged, in a hired truck. Dedicated diesel generator (DG) power units were mobilized and installed to ensure that the oxygen-filling units in the districts continued operations without disruption in the event of a power outage.
In the case of the state of Delhi, the government cancelled all pre-existing contracts between hospitals and private vendors and took over the supply chain. Hospitals were then allocated vendors for sourcing oxygen by the state.

Oxygen concentrator banks made for another innovative approach for managing the demand for oxygen in home-care settings, thereby reducing the hospital admission load in the states of India. During the second wave, oxygen concentrator banks were created in the state of Delhi, with 200 oxygen concentrators available in each bank in each of the 11 revenue districts of Delhi. If patients in home isolation required oxygen, a team from the Delhi government ensured that the oxygen concentrators would reach their homes within two hours. A technician also accompanied the team that demonstrated the functioning of an oxygen concentrator to family members. Patients, who were not enrolled for home isolation, could call the helpline number, 1031, and avail of the service.

Similarly, Rajasthan also established state-run oxygen concentrator banks across all districts in the state to support home-based care. The state government has placed over 500 units across the oxygen concentrator banks in Jaipur, with around 500 units at seven divisional headquarters and around 400 units at each of the 33 district headquarters. These oxygen concentrator banks are accessible through their helpline number or via the district drug warehouse. A beneficiary can rent an oxygen concentrator by making a refundable security deposit.

**Shortfalls and challenges**

- The grey market and regulations: As the COVID-19 pandemic increased the global demand for oxygen, leaving patients literally “gasping for breath”, affected families scrambled for oxygen cylinders and concentrators to save lives. This demand led to profiteering and hoarding of essential resources.

In Myanmar, the prices of oxygen cylinders rose by 50%–90% per cylinder, depending on their oxygen capacity.24 Similarly, in India, several people were arrested for hoarding and black-marketing oxygen cylinders and concentrators. Reports from Nepal also had similar instances wherein families were found to be hoarding oxygen equipment. Furthermore, many cylinders were found to be missing in Nepal. According to an estimate, prior to the pandemic, there were about 140,000 cylinders while during the second wave, the country was left with only 90,000 cylinders.

Additionally, in Bangladesh, the retail price of oxygen cylinders also jumped manifold during the pandemic. Likewise, in Indonesia, the price of an oxygen cylinder had jumped by 180% to US$ 140 per cylinder from the usual US$ 50.25

To curtail hoarding and black-marketing of oxygen equipment, governments took series of stringent steps, such as anti-hoarding regulations and permission of the government for procurement and bringing the whole ambit of supply chain within its control.

- Poor operation and maintenance of oxygen equipment: During the pandemic, oxygen equipment such as PSA plants, oxygen cylinders, oxygen concentrators and devices such as BiPAP/CPAP and ventilators were procured and donated by various countries. However, the challenge of operating and maintaining such equipment as PSA plants and concentrators required a continuous source of electricity. Moreover, some equipment, such as oxygen concentrators, were from diverse brands with different functionalities, which in turn posed a challenge.
In order to ensure uninterrupted production, the state governments of Maharashtra and Odisha directed respective electricity departments to ensure a continuous supply of power for oxygen-manufacturing plants.

Similarly, the Government of Indonesia, in collaboration with WHO and the Japan International Cooperation Agency (JICA), conducted a two-day seminar 16–17 Feb 2022 on the operations and maintenance of oxygen concentrators by inviting key manufacturers to demonstrate their products.

**Shortage of ISO cryogenic tankers:** As the demand for oxygen far exceeded the supply due to the sudden spike in the number of infected patients, many countries faced a shortage of LMO. Even when governments were re-organizing the production and supply of liquid medical oxygen, there were problems of geography and logistics in ensuring timely access.

In India, cryogenically manufactured liquid oxygen was primarily produced in eastern India, with the demand coming primarily from northern and western states. There were insufficient cryogenic tankers to transport the liquid oxygen from the assigned manufacturing plants to hospitals.

Similarly, Bangladesh and Indonesia faced a similar shortage of cryogenic tankers for transporting liquid medical oxygen. While Nepal did not have any LMO-manufacturing plant, it had 26 ASUs, which met a large part of its oxygen requirement. Although Nepal reached out to India for LMO during the crisis, it could not receive supplies due to the export restrictions India had placed on the product at that time.

Responding to the emergency situation, the Government of India airlifted tankers from different states and also from other countries, and they ran Oxygen Express trains to transport liquid oxygen quickly. Corporates, such as Linde India, procured cryogenic ISO oxygen tankers, which could transport oxygen, using railways, not only for India, but also for Bangladesh.

**Lessons learnt**

As the Member States in the Region adopted different approaches to procuring oxygen equipment and strengthen their medical oxygen ecosystem, these have brought forth important insights and lessons for making the oxygen procurement processes more effective and efficient. Some of the key lessons emerging from this study are:

- Using data for decision-making enables a more strategic and effective oxygen response, including developing responsive procurement strategy, as the systematic assessments carried out at regular intervals in the Member States provided a landscape of oxygen capabilities, data for planning and forecasting oxygen demand, and drawing up an elastic oxygen supply chain.

- As each stakeholder brings a different capability, establishing a multistakeholder mechanism enables a robust oxygen ecosystem. As the study showed, in countries where stakeholders from the government to private-sector personnel, including oxygen production companies and private health-care representatives, were engaged, oxygen response was more sustainable. This ensured that all stakeholders’ capacities were leveraged for effective response.
In addition to setting up task forces for demand forecasting, procurement, distribution and delivery with a centralized coordination centre, it is also important to explore and establish regional cooperation, which can enable resource-sharing, facilitate the movement of oxygen across borders and help in closing the gap between oxygen demand and supply. As highlighted in the study, engagement with international aid agencies, bilateral and multilateral agencies, and corporate entities is essential, not only for financial and oxygen equipment support, but also for strategic advisories and the timely sharing of knowledge and resources, as they bring in global knowledge and help localize responses.

- Digital tools for demand analysis, procurement and monitoring make the process more efficient and improve procurement effectiveness, as demonstrated by the experience of some countries, such as Bangladesh, India, Indonesia and Thailand. These countries ensured real-time data-tracking of oxygen demand and production, supply chain-tracking and use of digital platforms through digital tools, such as ASPAK, e-Katalog, ESFT, e-LMS, GHSC-PSM, ODTS, ODAS and OCMIS. These tools played a vital role in optimum allocation and utilization of critical resources, such as oxygen. Similarly, several Member States deployed digital solutions, such as IoT, GPS, QR codes or RFIDs, for end-to-end tracking of portable oxygen devices, such as cylinders and concentrators, which contributed to reducing pilferages and also facilitated data-backed decision-making on procurement.

- Timely regulatory actions can ease availability of vital commodities and also reduce malpractices, such as hoarding and speculative price rise. As shown by several countries in the Region, reduction and sometimes temporarily eliminating regulatory structures, such as import duties and import-export documentation, as it happened between India and Bangladesh, accelerated oxygen delivery. Other actions, such as incentivizing the private sector to actively participate in the government-led initiatives for oxygen supply and management, further strengthened the procurement and distribution of medical oxygen.

Several countries also regulated the price of oxygen devices and movement of oxygen, with such actions as doorstep delivery, oxygen concentrator banks, etc., which prevented speculative inflation of essential commodities, prevented spurious products from becoming popular, made oxygen more accessible and helped reduce the risk to people’s lives. Countries such as India and Thailand also decentralized the decision-making process, including procurement and distribution, which enabled provinces to explore local solutions and made the service delivery more effective.

- Innovations emerge from crises. Several innovative approaches to making supply chain elastic have emerged from oxygen management during the pandemic. Initiatives, such as Oxygen Express, oxygen concentrator banks, oxygen shuttle programmes, among others, have demonstrated the mechanism that can strengthen the oxygen supply chain ecosystem and make it more agile.
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Clinical management

Introduction

Oxygen therapy has always been an essential component of clinical treatment and health-care systems. However, it has become all the more significant during the COVID-19 pandemic due to its crucial role in treating COVID-19 patients. Oxygen therapy or supplemental oxygen is the provision of medical oxygen as a health-care intervention, which is often required during surgery or for treatment of several respiratory diseases. The allowable purity level of oxygen for medical purposes is 82% to over 99%, depending on production source.¹

Oxygen therapy is recommended during hypoxemia, when the oxygen saturation in blood (SpO2) drops below 95%, which often is the case with severe COVID-19 patients.² Oxygen therapy is delivered using various oxygen delivery equipment, such as nasal cannula, oxygen mask, etc. It is delivered in low doses, ranging from 1–2 L/min. in children and starting at 5 L/min. in adults with nasal cannula, at moderate flow rates for use with venturi mask (6–10 L/min) or at higher flow rates (10–15 L/min.), using a mask with a reservoir bag.³ Oxygen can also be delivered at higher flow rates and in higher concentrations, using high-flow nasal cannula devices, non-invasive ventilation (NIV) and invasive ventilation devices.

Delivery of oxygen to patients is a critical care intervention and needs specialized training. Medical and paramedical staff in health care should have appropriate knowledge and skills to treat patients requiring oxygen therapy. Training should entail a wide range of issues regarding oxygen care ecosystem, such as sources of oxygen, maintenance and use of oxygen delivery equipment, assessing the need for oxygen therapy and monitoring patients on oxygen therapy, and preventing wastage. Additionally, health-care staff should be provided with SOPs and guidelines on various aspects of clinical management of patients on oxygen therapy as references.

Oxygen being a scarce resource, especially in times of crises such as COVID-19, hospitals should put in place measures for monitoring its use. Regular oxygen audits would not only help in monitoring its consumption pattern, but also in assessing its demand.
During the COVID-19 crisis, it was observed that countries in the SE Asia Region did take a lot of these measures as part of their clinical management strategies. Several countries in the Region conducted assessment studies to better understand their health systems and develop their strategies accordingly. The governments in the Member States not only carried out such assessments on their own, but also collaborated with international organizations, such as WHO, UNICEF and other development organizations, for conducting assessments of their health systems. These assessment studies helped countries understand their current and existing capacities to deal with the pandemic and hence, were in a better position to prepare themselves for the crisis.

Several countries tried to augment their health-care infrastructure and resources, using such measures as increasing their oxygen beds/bed capacities at hospitals for managing COVID-19 cases and increasing their pool of trained human resources for providing oxygen therapy and managing oxygen equipment. To take the load off from tertiary hospitals, some countries, such as Indonesia, made makeshift health-care facilities, such as “Oxygen Houses”, for treating mild to moderate COVID-19 patients. The study found that other countries, such as Bhutan, India and Thailand, promoted home isolation for such patients.

To build the capacities of both medical and paramedical health-care staff, oxygen therapy trainings were conducted by the countries, along with the development of learning packages, such as training modules, SOPs and guidelines on clinical management, leveraging national and global expertise, as carried out by India and Nepal.

Demand prediction exercises were also undertaken by countries to prevent sudden surge in oxygen demand thereby causing shortage. Countries such as Thailand had developed colour-coded patient stratification model, depending on case severity and associated oxygen demand. Furthermore, oxygen consumption had been monitored through oxygen audits by countries, such as India, which were carried out not only at the national level, but also at state and district levels. Also, measures to reduce wastage of oxygen were also implemented by countries, such as India, using “Oxygen Nurses” for optimum utilization of oxygen at patients’ bedsides.

Building oxygen infrastructure

The COVID-19 pandemic put huge stress on health-care infrastructure with many countries facing shortage of beds and oxygen therapy equipment for managing COVID-19 patients. Countries in the Region took several initiatives to improve the infrastructure capacities for better provision of oxygen therapy to patients.

Increasing oxygen beds at hospitals for COVID-19 management

Almost all Member States increased the number of beds, with access to oxygen infrastructure, for managing patients with COVID-19. The study found that the Member States had established dedicated hospitals for COVID-19 patients, in some cases, converting incorporating other health-care facilities into dedicated COVID-19 facilities. For example, Indonesia had demarcated around 130 referral hospitals across its 33 provinces for COVID-19 case management and also established a dedicated COVID-19 hospital in each of these provinces. They had also established makeshift hospitals and centres, called Oxygen Houses, during the second wave in 2021, to cater to the rising infection levels.
Similarly, Maldives had graded the COVID-19 emergency into four levels nationally and colour-coded each level, based on the transmission scenario. In addition to the 3000 beds for quarantine and another 2000 beds for isolation centres, Maldives had also set up six dedicated ICUs with ventilators in Greater Malé, dedicated COVID-19 clinics for migrant workers on Hulhumale Island and eight other COVID-19 facilities set up across the country.

Along similar lines, Sri Lanka also had four dedicated hospitals and a three-layered management approach to managing COVID-19 patients – Level I had intermediate care centres for asymptomatic patients, Level II had divisional hospitals for mild cases and Level III had tertiary care and specialized care with ICU and ventilator support. At the peak of the Delta wave, the Government of Thailand had set up at least 10,000 additional field hospital beds to manage the case-load. Similar examples were observed by the study team in other Member States as well.

**Increasing the health-care workforce**

Almost all countries in the Region faced a shortage of health-care staff with a spike in COVID-19 cases. The study observed that Member States adopted different approaches to supplementing this gap, from mobilizing volunteers to licensing paramedical staff.

- **Leveraging paramedical volunteers:** To augment human resources for health, Bhutan had taken support from volunteers, known as the De-Suung Plus – Guardians of Peace, during the second wave in 2021. These volunteers were trained and re-skilled to function as assistant nurses in managing asymptomatic and mild COVID-19 cases in the country.

- **Licensing professionals to meet the shortage:** Foreseeing a likely shortage of health workers in case of a surge in COVID-19 cases and hospitalization, countries, such as Maldives, mobilized nongovernment and private-sector health workforce, licensed retirees, medical trainees and volunteers, and fast-tracked onboarding of medical and nursing graduates by easing the licensing process and providing provisional licence to compensate for the shortage of doctors and nurses.

- Additionally, a team of specialized doctors were also sent from India to support the Maldives government for COVID-19 management.

**Establishing makeshift arrangements to reduce the burden on hospitals**

To take the burden off from tertiary hospitals or specialized care facilities, several countries in the Region took measures to establish temporary facilities to manage moderate cases of COVID-19 and promoted home isolation and home delivery of oxygen equipment. For example, the study was informed that Indonesia had set up “Oxygen Houses” to care for patients having mild and moderate symptoms requiring oxygen support. An “Oxygen House” is a special, semi-permanent health-care facility, equipped with oxygen supplies and treatment beds for COVID-19 patients with moderate symptoms.

In another initiative, the Indian state of Delhi had created oxygen concentrator banks during the second wave of COVID-19, with 200 oxygen concentrators in each bank of the 11 units, one in each revenue district. Rajasthan also deployed oxygen concentrators at all health facilities and set up oxygen concentrator banks in every district to build a network of small oxygen devices, which in case of an emergency could be activated to meet immediate needs.
The Delhi government also ensured the provision of oxygen concentrators at doorstep for patients in home isolation, who required oxygen. A technician accompanied the team of doctors to demonstrate the functioning of an oxygen concentrator to the family members. Similar initiatives with regard to doorstep delivery services for oxygen concentrators were noted in the Indian state of Odisha and Bangladesh.

**Strengthening capacities for oxygen management**

With the rise in COVID-19 cases, many countries suffered lack of trained medical and paramedical staff to tend to patients and efficiently deliver oxygen therapy as well as lack of biomedical engineers and technicians to maintain oxygen/respiratory care devices. An urgent need was also felt across the Region to build capacities of health-care professionals around clinical management of COVID-19 patients.

Furthermore, as the countries started strengthening their oxygen infrastructure, there was a strong need for not only employing trained technicians to manage, operate and maintain the oxygen equipment, but also equipping them with relevant knowledge products related to oxygen systems. Physical distancing and prevention of gatherings led the change in training approaches as many trainings were conducted virtually, either through live sessions or through a learning management system (LMS). These “new” capacity-building approaches had their own benefits and limitations.

**Clinical management guidelines and standardizing the operating procedures for oxygen management**

As COVID-19 was a new form of respiratory disease, most of the countries across the globe did not have a guideline to follow. Although international organizations, such as WHO and UNICEF, did issue guidelines on different aspects of oxygen management for COVID-19 patients, many countries took time to contextualize those for their local conditions. The study noted that several countries in the Region worked with WHO and UNICEF as well as other expert organizations to contextualize these international guidelines, covering various aspects of oxygen ecosystem, and disseminate them at national, provincial/state and regional levels.

Some countries, such as Bhutan, which started its preparation for the COVID-19 pandemic very early during the first wave, brought out two guidelines by May 2020 – the Bhutan National Pandemic Preparedness and Response Plan for COVID-19 and the Case Definitions for COVID-19 in May 2020, based on the WHO guidelines. The emergency committee of Bhutan also prepared a draft guideline for clinical management of severe acute respiratory infections in 2020. Although these guidelines had limited information on oxygen therapy and rational use of oxygen, the guidelines on early detection and case management of COVID-19 enabled reduction in the number of patients, who would require oxygen therapy. As a result, Bhutan has reported only a few cases that required oxygen management and just seven COVID-19-related deaths, among the lowest in the world.

Around the same time, in May 2020, the Directorate General of Health Services (DGHS) of Bangladesh, in collaboration with WHO and Bangladesh Society of Medicine, also circulated the National Guidelines on Clinical Management of Coronavirus Disease 2019 (COVID-19) to mitigate the spread of the pandemic in the country. The document defined types of cases, principles of supportive therapy, such as low- and high-flow oxygen therapy, use of devices such as high-flow nasal canula and CPAP.
Later, an updated version of the guideline, titled “Clinical management protocol for COVID-19”, was released in May 2021, which was followed in October 2021 by guidelines on the rational use of oxygen, titled “Handbook on oxygen sources, distribution and need estimation with rational use of oxygen in COVID-19 patient management”. DGHS developed these guidelines in collaboration with USAID, Save the Children and Bangladesh Society of Medicine. It also mentioned the process of using WHO COVID-19 Essential Supply Forecast Tool (ESFT) to estimate the total flow needs and anticipate the case-load, and it included various protocols for providing medical oxygen to COVID-19 patients.

Other Member States too followed similar initiatives. A set of guidelines, titled “Guidance on oxygen therapy for patients with COVID-19”, was disseminated by the Ministry of Health, Myanmar, in August 2021. This document provides detailed guidelines on the types of oxygen therapy and ways to administer oxygen to patients, and also mentions the processes for different devices, such as high-flow nasal oxygen (HFNO), CPAP or BiPAP, among others.

In September 2021, WHO published a document titled, “Case management guidelines for home-based care in Myanmar” for general practitioners and medical doctors; it was based on WHO Global Guidelines and adapted to the country’s context and needs. Similarly, the Ministry of Health, Sri Lanka, developed a clinical practice guideline on the clinical management of COVID-19 patients and the Ministry of Health, Timor-Leste, circulated the “Clinical guidelines for COVID-19 management” in April 2020, which was later updated in March 2021 and re-circulated to all health entities.

In another case, the Nepalese Society of Critical Care Medicine (NSCCM) and the Critical Care Nurses Association of Nepal (CCNAN) developed training modules to train health-care workers (HCWs) in how to identify sick patients, different clinical parameters to look for, different methods of oxygen supplementation, close monitoring regarding oxygen saturation targets, when to refer a patient to an ICU and how to manage patients going into shock. Specifically, the use of high-flow nasal cannula was restricted, and the use of non-invasive ventilation was promoted. These training materials and SOPs were disseminated across the country.

The study observed that in India, apart from the national-level guidelines on oxygen management and oxygen therapy, many states also developed locally applicable guidelines in response to the surge in infections and subsequent oxygen crisis. For example, the state of Maharashtra in India developed and disseminated a guidebook on medical oxygen management system, which laid down the foundation for improvement of management of medical oxygen and related devices at health facilities in the state. The guidebook, developed by the Department of Public Health, Government of Maharashtra, in July 2021 along with development partners, including USAID NISHTHA and PATH India, provides all the required technical details for effective, efficient and flawless oxygen management at health facilities.

The document is used in the state as a ready reference by health administrators, state- and district-level officers, procurement personnel, planning officers, programme managers, biomedical engineers and medical and paramedical staff handling oxygen devices for manufacturing-storage-transport-distribution purposes. PATH, with support of USAID RISE, had developed a learning resource pack (LRP) of five training modules, covering a wide range of oxygen management topics, from oxygen therapy to operation and maintenance of various oxygen equipment to rational use of oxygen. It delivered trainings with a mix of faculty members from leading academic institutions and industry experts.
Leveraging biomedical engineers managing vaccine cold chain for oxygen management

In July 2021, the state of Maharashtra leveraged the capacity of biomedical engineers, under the Health Equipment Maintenance and Repair Division, who were primarily working for strengthening the vaccine cold chain management, to address the issue of the lack of skilled human resource. Under this initiative, biomedical engineers were trained in oxygen management and the training was organized by the Public Health Department in collaboration with the Deputy Director Health Services (Transport Division), Pune, and PATH in the form of training of trainers (ToT) at the state level. The goal of this training was to disseminate appropriate knowledge to the facility-level teams and support them for oxygen system management. This approach was the first of its kind in the country.

There was also evidence of countries using e-learning platforms for strengthening capacities. For example, the study noted that USAID supported capacity enhancement for medical staff at public hospitals through an e-mentorship programme in Bangladesh, which had weekly online discussions, using case studies. Additionally, the study was also informed that non-medical workers had received training on a different platform in handling oxygen cylinders, but there was no evidence available to substantiate the claim. In June 2021, Health and Education for All (HAEFA) launched an online, self-learning clinical course that was developed to help physicians of Bangladesh acquire the most recent, evidence-based COVID-19 management skills in a convenient and interactive manner. This pre-recorded, web-based Advanced COVID-19 Clinical Management Certification Course is accessible on the DGHS, Bangladesh website, dghs.gov.bd.

Rationalizing use of oxygen

Oxygen audits

Oxygen was a scarce resource during the COVID-19 crisis. While it was claimed by experts in several Member States that their countries had put in place measures to ensure rational use of oxygen and prevent oxygen wastage, the study team did not get access to evidence, except from India, to substantiate claims of such initiatives.

The study found that the Supreme Court of India had set up a 12-member National Task Force (NTF) to facilitate public health response to COVID-19, including streamlining of oxygen distribution in the country, based on scientific and specialized domain knowledge, with flexibility accorded to the states to meet unforeseen demands due to emergencies.

The study also found that many states in India, such as Rajasthan and Kerala, had started monitoring consumption of oxygen at all hospitals. Each district had an audit committee, which comprised anaesthetists, administrative officers of the hospitals of a district, principals of government-run engineering and polytechnic colleges and industrial training institutes. It was assigned the task of monitoring daily oxygen consumption at hospitals. Both public and private hospitals provided daily updates on the number of patients in oxygen therapy, ICU beds and ICUs with ventilator beds on the state COVID-19 portal, along with details of the total consumption of oxygen.
Hospitals showing higher consumption of oxygen were selected for audit. The committee members visited the hospitals and observed the patients on oxygen beds, ICU beds and ICU beds with ventilators. Based on the guideline from the Government of India, they assessed whether oxygen was being administered judiciously through various oxygen delivery devices and if a patient’s oxygen saturation was being maintained. Based on the audit findings, the hospitals were asked to ensure that their systems were maintained properly, arresting any leakage, and that the health-care providers were oriented and trained in the optimal use of high-flow nasal cannulas in patients with acute hypoxemic respiratory failure.

**Measures for reducing oxygen wastage**

With the rapid surge in oxygen need due to COVID-19, the biggest hurdle that the countries faced was to match the demand with the supply. For example, Thailand’s Department of Disease Control and the International Health Policy Programme of the Ministry of Public Health stratified COVID-19 patients, using a model based on the severity level. Patients were divided as susceptible, exposed, infectious and recovered and were assigned a colour based on severity. The model was based on an assumption that each type of patient (green, yellow, red) required a different amount of oxygen.

For green patients, it was assumed that 20% of the cases would require oxygen at a maximum flow rate of 5 litres per minute. Patients in the red group would need, via ventilators, 50 litres of oxygen per minute. Yellow patients would require different amounts of oxygen as follows: 30% of the patients would require, via oxygen cannulae, 5 litres of oxygen per minute, 50% of the patients would require, via oxygen masks, 10 litres of oxygen per minute, and the remaining 20% would require, via high-flow cannulae, 20 litres of oxygen per minute. This helped in assessing and forecasting oxygen demand at the facilities.

Likewise, the state government of Kerala, India adopted an oxygen wastage reduction strategy to aid or avoid 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. Since September 2020, all COVID-19 patients in the state are triaged, depending on 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 centres, second-line treatment centres and COVID-19 hospitals.

**Oxygen nurses: A dedicated resource to reducing oxygen wastage**

As an innovative intervention, Nandurbar, a tribal district in Maharashtra, India, appointed “oxygen nurses” for optimum utilization of oxygen cylinders and prevention of oxygen wastage in June 2020. It dedicated one nurse to about 50 patients on oxygen. These oxygen nurses checked the oxygen usage by closing the valves or reducing the flow when the patient removed the mask while using the washroom, eating or talking over the phone and by reducing the oxygen flow when oxygen saturation levels improved. These nurses monitored the requirement of oxygen every 2–4 hours, round the clock, and had the discretion to increase or decrease the flow depending on patients’ needs. As a result, the district saved oxygen and became oxygen-surplus. It was then shared with the neighbouring districts. This initiative in Nandurbar was replicated in several districts across the state of Maharashtra in April 2021.
Leveraging technological tools to monitor oxygen demand and supply

Technology has truly helped in mitigating the impact of the COVID-19 crisis. Several technological tools were developed and utilized by the Member States for monitoring, tracking and taking corrective actions on different aspects of the COVID-19 response in each country, including clinical management of COVID-19. For example, Bangladesh had developed a central real-time dashboard, COVID-19 Dynamic Dashboard for Bangladesh, for officials to constantly monitor the state of oxygen availability at hospitals across the country. A total of 600 facilities, which also included 50 private facilities, regularly reported their oxygen demand and supply through the dashboard during the COVID-19 crisis.

Likewise, Indonesia also developed and deployed digital platforms and tools, such as ASPAK, for countrywide asset management of medical equipment, which included tracking availability of oxygen delivery devices and pulse oximeters. Nepal also used digital tools, such as e-LMS and GHSC-PSM, among others, to provide solutions for real-time and effective tracking of oxygen consumption and production, and its supply chain and logistics. These digital solutions for end-to-end tracking helped in data-backed decision-making.

The study also observed similar initiatives in India, Thailand and other Member States.

Lessons learnt

- Investing in health-care systems strengthening can help countries be prepared for better clinical management in times of crisis such as COVID-19. For instance, it was observed that with no high-dependency units (HDUs) and only five ICUs that were all concentrated in the national capital, Timor-Leste was underprepared for the COVID-19 pandemic. It could have been thoroughly overwhelmed if it had experienced the Delta variant-led wave of the pandemic as severely as some other parts of the world. On the other hand, Thailand’s response to the COVID-19 crisis is rooted in its four decades of investment in health infrastructure. Due to its strong basic infrastructure, acceleration of oxygen production and delivery was less challenging for the country and was managed well in time. Hence, it was felt that there is an urgent need for countries, especially young countries such as Timor-Leste, to invest in health-care infrastructure – both primary and critical care – and build a more holistic and resilient public health system to prepare themselves for all future crises.

- Effective surveillance, coordination and early case management of COVID-19 play a critical role in reducing the oxygen burden. Countries, such as Bhutan, put in place effective, event-based surveillance and assessments at national and district levels. Preliminary identification of vulnerable population, providing them with special attention and early intervention had helped the country reduce its demand for oxygen, thus reducing overall oxygen dependence. Similarly, Thailand has also developed a colour-coded model for stratifying patients, based on severity and oxygen need. Such a system of identifying and escalating cases, depending on oxygen need, had helped Thailand better assess and manage its oxygen demand.

- Establishing dedicated, temporary facilities with oxygen systems for moderate cases reduces burden on tertiary health-care facilities, which in turn could provide focused services to severe cases. It was observed that in many countries, several moderate and mild patients were hospitalized, occupying vital beds and putting hundreds of
severe patients of COVID-19, who required oxygen beds, at risk. This led to a diversion of highly qualified medical and paramedical resources and health commodities from patients with severe symptoms, risking the country with higher mortality. Managing mild to moderate cases at temporarily established, makeshift hospitals and Oxygen Houses, as carried out by Thailand, or promotion of home isolation for patients with mild symptoms, as implemented by many states in India, would help reduce the burden on tertiary hospitals in a country in times of crisis.

Strengthening human capacities through structured trainings in oxygen management, including oxygen therapy and management of oxygen devices, is essential as oxygen management is relatively “new” to many in the health systems. It was seen that in countries such as Bangladesh, India and Nepal, targeted training, with clear mandate for each cadre of health workers, contributed to capacity improvement across all levels, from community health workers to service providers at ICUs. With regard to effective leveraging of in-house capacities, countries, such as Maldives, built a rich and vibrant pool of health workers by mobilizing the nongovernment/private-sector health workforce, licensed retirees, medical trainees and volunteers, fast-tracked the medical/nursing graduates licensing process and provided provisional licences to compensate for the shortage of doctors and nurses for COVID-19 management. Also, capacity-strengthening is needed at multiple levels and over several rounds, especially in a less practised and niche area, such as oxygen therapy and oxygen management.

Collaboration with national and global organizations to leverage knowledge and technical expertise for capacity-strengthening of health-care staff is critical in the field of clinical management and patient care. Countries, such as Bangladesh, India, Myanmar and Nepal have collaborated with global organizations along with their in-country experts to not only develop the guidelines and SOPs for clinical care but also to conduct trainings for their medical and paramedical staff.

References


3. Ibid 1


Collaborations

Introduction

The World Health Organization has designated medical oxygen as an essential medicine and its value was felt the most during the COVID-19 pandemic. In 2021, there was an unprecedented demand for medical oxygen as patients infected with COVID-19 were experiencing shortness of breath. Although Member States prepared their health systems to respond to the pandemic in the best way possible, the rise in fatalities due to the high oxygen demand caught these countries off guard.

Warranting the overwhelmed health system and the loss of human lives, global communities stepped forward and demonstrated extraordinary collaboration to support the countries that were impacted the most. The support came from a wide spectrum of entities, including countries, multilateral and bilateral agencies, philanthropic groups, firms and individuals, among others. These humanitarian alliances demonstrated the spirit of solidarity and cooperation between nations, not only to address the current crisis, but also to work towards building a robust health system to protect future generations from any potential health emergency.

The current study clearly brings out five broad categories of collaborations that worked in tandem to respond to the devastating health emergency in the SE Asia Region countries. These include:

- **Collaborations with bilateral agencies**: Bilateral collaborations were either between governments of countries or with government departments. These collaborations were sought to procure medical oxygen and medical equipment, strengthen existing health infrastructure or develop new ones and share technical knowledge and capacity-building.

- **Collaborations with multilateral organizations**: These collaborations brought greater overall benefits to the Member States, rather than individual countries dealing with the disease on their own. Moreover, prior to COVID-19, multilateral organizations were already present in most of the countries as strategic and technical advisers for health system-strengthening. During the pandemic, they extended their involvement further by helping with additional funds and by supporting as procurement enablers and deployers of medical and other essential supplies.
Collaborations with development agencies: The overall role of development partners, philanthropic organizations and nongovernmental organizations in collective response to the pandemic, working alongside government agencies, is significant. These agencies procured medical oxygen and ensured that it was available to patients.

Whole-of-the-government approach: The study found that the rise in COVID-19 cases led governments to bring in various departments under the folds of committees or task forces to monitor, supervise, and respond to any change in the status of COVID-19 cases by bringing out guidelines for various stakeholders to enable effective response and by ramping up screening and surveillance at their key entry points to minimize the import of new infections and new variants of SARS-Cov-2. The whole-of-the-government approach improved coordination, reduced interdepartmental inefficiencies and enhanced response to the pandemic.

Collaborations with private partners: Apart from these, private collaborations were witnessed between many diverse entities, such as corporates, philanthropic organizations, suppliers and vendors, among others. As the experience of every Member State showed, the private sector was leading in oxygen production. Even in the case of equipment for captive oxygen production, such as PSA oxygen plants and oxygen concentrators, the private sector and corporates were the lead partners. Another area where private sector engagement contributed to a more effective response was logistics management.

This thematic dossier will help readers comprehend the various types of collaborative efforts that evolved during the health crisis as well as the partnerships forged for the long-term sustainability of the pre-existing or newly created oxygen ecosystems. The documents also illustrate collaborations that are effective and briefly discuss less productive partnerships. The dossier includes approaches that are notable and can be shared and replicated across the Region.

Oxygen collaborations

The Member States adopted various collaborative approaches for the availability of medical oxygen across the health facilities in the countries. The alliances demonstrated the spirit of solidarity and cooperation between nations, not only to address the current crisis, but also to work towards building more resilient health systems.

Collaboration for strategic oxygen response

The study found that several organizations extended strategic support to the Member States by collaborating on developing national preparedness plans and clinical guidelines for COVID-19 management for effective management of the pandemic.

Strategic oxygen response by the bilateral organizations: The study reveals that the bilateral collaboration on strategic oxygen preparedness and response has been limited. The study documented a few examples wherein bilateral collaborations between two countries could be observed. For example, in the case of Timor-Leste, the Government of Australia extended support by providing strategic advice for COVID-19 response and early recovery and by supplying essential medical equipment, consumables and medicines. Similarly, in Bangladesh, USAID collaborated with the Directorate General of Health Services, Save the Children and Bangladesh Society of Medicine to launch
Strategic oxygen response by the multilateral organizations: Several multilateral organizations extended strategic support to the Member States by collaborating on developing national preparedness plans and clinical guidelines for COVID-19 management for effective management of the pandemic. For example, the governments of Bhutan, Sri Lanka, and Timor-Leste received active support from the World Health Organization, along with agencies such as the World Bank and the Asian Development Bank, in preparing their national COVID-19 preparedness strategies.

Similarly, Indonesia collaborated with multilateral organizations such as WHO, World Bank, United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and International Red Cross and Red Crescent Societies to provide strategic and advisory support to prepare the country for effective pandemic control. Furthermore, WHO, UNICEF and International Federation of Red Cross and Red Crescent Societies (IFRC) came forward to support Timor-Leste’s national preparedness and its response to the COVID-19 pandemic.

The governments of many countries initiated these oxygen demand-and-supply assessments in their countries by collaborating with these multilateral organizations. For example, the Bangladesh government, in collaboration with UNICEF, conducted an oxygen-landscaping exercise with the aim of facilitating the development of a national medical oxygen plan for the country for the next 10 years. A similar study was also conducted in November 2020 by the World Health Organization for the Government of Sri Lanka to assess the preparedness of government hospitals in the country to handle and respond to the pandemic.

Additionally, since the early days of the global outbreak in Timor-Leste, support from international agencies to strengthen the national health sector’s preparedness and response to COVID-19 is being provided under the technical coordination and leadership of the World Health Organization. WHO, UNICEF and other development partners continued to support the Ministry of Health in monitoring the situation by conducting supportive supervision visits in villages and communities in Dili and other municipalities to help assess and ensure the continuity of essential health services.

Strategic oxygen response by whole-of-the-government: The study reveals that almost all governments in the Member States constituted committees and task forces for preparing and effectively responding to the pandemic. Various departments were part of these groups and they worked in a synchronized manner to address the health emergency. For example, the Government of Thailand set up four committees – one for stockpiling of oxygen devices, another to regularly carry out needs assessment, the third for troubleshooting and the fourth committee for monitoring and evaluation. The four committees worked on oxygen demand-and-supply activities that were earlier managed by a centralized coordination centre.

Likewise, in India, each state had a unique approach to setting up the committees, as per the requirements of the states. For example, the Delhi state government constituted a committee to examine the medical oxygen infrastructure at all state government-administered hospitals and recommend measures to augment the same expeditiously.
While the Indian state of Odisha set up in April 2021 a dedicated Oxygen Task Force to manage the production, storage, distribution, transportation and overall management of oxygen, the state of Rajasthan established a State Level Oxygen Management Committee (SLOMC) in early May 2021 with the Secretary of Industries as its chair. The committee had the state nodal officer for oxygen and assistant nodal officers from different departments as its members. The committee formed various subgroups, each assigned a role in oxygen management, such as coordination with the national government for allocation of oxygen from LMO-manufacturing plants, management and tracking of tankers for lifting oxygen, management of LMO tanks, coordinating installation and commissioning of PSA plants in the state and formation of control rooms at state and district levels, among others.

Strategic oxygen response by development organizations, private organizations and institutions: While the other stakeholders such as development partners or not-for-profit sector organizations, private companies and corporates, and academic and technical institutions that played an important role in strengthening the oxygen response in the Member States, mostly in infrastructure development, procurement and strengthening of oxygen therapy and ecosystem, there was limited evidence on their strategic role in national preparedness strategy and response plan.

Collaboration for strengthening oxygen infrastructure

Concerns related to access of medical oxygen existed in many regions of the world even prior to the COVID-19 crisis. The pandemic exacerbated it further by putting a burden on already fragile health systems. The study found several examples of Member States lacking oxygen generation plants, oxygen devices, such as oxygen concentrators as one of the easiest sources of providing oxygen to patients, and health infrastructure. This led to various oxygen infrastructure-strengthening collaborations. Furthermore, countries in the SE Asia Region supported one another, as their proximity aided in the rapid delivery of medical oxygen.

Bilateral cooperation for strengthening oxygen infrastructure: In this study, several examples show that countries such as the United States of America, Australia and Singapore, to name a few, came forward and supported the Member States with funds for COVID-19 preparedness, oxygen augmentation and technical support. For example, the US Ambassador to Sri Lanka and Maldives presented ICU equipment, which included 40 oxygen concentrators and associated equipment, to the Maldivian Ministry of Health and the Maldivian National Defence Force to support their continued COVID-19 response. The United States of America also provided tranches of oxygen supplies to Nepal. According to the data with the Department of Health Services, between 14 April 2021 and 4 July 2021, the country received 4126 oxygen concentrators and 6945 oxygen cylinders, among others, from a number of foreign governments and domestic and international agencies. In April 2021, the US embassy in Timor-Leste donated 20 CPAP machines to the Integrated Crisis Management Office, Government of Timor-Leste, to support the country in its fight against COVID-19. Besides, USAID donated state-of-the-art ventilators to Bhutan, which also received oxygen concentrators from numerous entities such as the Singapore Red Cross, Vision Spring and Give India. Furthermore, USAID provided US$ 2.5 million to strengthen the oxygen ecosystem in Sri Lanka.
The study also observed collaborative initiatives and support coming from many countries in the Asia and Oceania Region. The People’s Republic of China was another key bilateral support in the Region during the pandemic. Apart from providing Nepal with oxygen supplies at the peak of infection in 2021, it also supplied oxygen devices, such as cylinders, to Thailand. Furthermore, the People’s Republic of China supplied 120 ventilators and 400 oxygen concentrators to Indonesia. The Indian state of Rajasthan also reported receiving oxygen concentrators from the People’s Republic of China.

Similarly, Australia supported countries, such as Bangladesh, Indonesia, Nepal, Sri Lanka and Timor-Leste, not only with funds for the purchase of essential medical supplies, but also with oxygen and related equipment.7 In another example, Singapore donated oxygen and oxygen equipment to Indonesia and Myanmar to support the fight against the COVID-19 pandemic. Other countries from the Asia and Oceania Region, which were active in extending bilateral assistance for strengthening oxygen infrastructure in the Region, were South Korea, the United Arab Emirates, New Zealand and Japan.

Moreover, Member States extended support to each other to save millions of precious lives. For instance, Bhutan supplied about 40 MTPD of oxygen to India by expediting the construction of a manufacturing unit.8 India, like China, contributed to strengthening oxygen infrastructure in its neighbourhood. For example, although India temporarily froze all exports for a brief period, later it provided Nepal with oxygen supplies to mitigate oxygen shortages. India also sent a team of health-care specialists to support Maldives. Similarly, Thailand had also been supporting other countries during the COVID-19 pandemic. In May 2021, the Royal Thai Air Force (RTAF) transported 15 concentrators to India donated by the Thai government to the Indian Red Cross, along with 15 concentrators donated by the Hindu Samaj of Bangkok. In addition, 100 oxygen cylinders had been separately offered by the Indian Association of Thailand to India to help mitigate the mounting oxygen crisis in the country.9

Assistance by multilateral agencies: Multilateral organizations, such as WHO, ADB, World Bank, UNICEF, UNOPS, OCHA and ICRC, among others, came forward to support these Member States during these trying times. For example, WHO donated 2000 sets of oxygen concentrators, 24 000 sets of venturi masks, and nearly 500 000 sets of venturi masks with oxygen nasal cannulas to Nepal. Sri Lanka received medical equipment worth US$ 1.8 million from WHO.10

Additionally, UNOPS, under the World Bank-financed COVID-19 Emergency Response and Health Systems Preparedness Project, financed 982 units of 10-LPM oxygen concentrators that were distributed to peripheral health facilities across Nepal in June 2021.11 Moreover, 2100 oxygen concentrators and seven oxygen-generating plants were procured through UNOPS. Furthermore, in September 2021, in coordination with the Ministry of Public Health of the Royal Thai Government, the UN country team in Thailand under UNOPS and with Japan’s support, 868 oxygen concentrators of 10-LPM capacity each were delivered to Thailand. These concentrators were distributed among 79 hospitals and community health centres across all provinces of the country.12

Furthermore, UNICEF provided around 600 oxygen concentrators to the Government of Nepal. The country also received 100 oxygen concentrators along with medical supplies from the Gradian Health Systems and the Nick Simons Foundation (NSF).13 Additionally, Australia delivered oxygen and related supplies to Sri Lanka through UNICEF, including
291 oxygen cylinders and 342 oxygen regulators. Likewise, UNICEF provided 550 oxygen concentrators to help treat patients with respiratory diseases in Thailand.

The Asian Development Bank and the World Bank provided financial aid to support the procurement of diagnostic equipment and materials for critical care facilities, including intensive care unit beds, and other key medical equipment. For example, the World Bank donated 120 high-low nasal oxygen therapy units, 25 ICU ventilators, seven neonatal ventilators and 20 transport ventilators to Sri Lanka.14

Collaboration with development agencies: The development agencies, philanthropic organizations and nongovernmental organizations also ramped up aid efforts through exemplary work, such as providing free oxygen equipment and services to patients in need in the Member States. For example, the Temasek Foundation and 15 other companies from Singapore and Indonesia donated more than 11,000 oxygen concentrators to Indonesia.15 Furthermore, the study found reports that suggested religious leaders and industry leaders in Myanmar donating oxygen to the general public.

Also, the Indian Institute of Technology (IIT), Delhi handed over 105 oxygen cylinders to the Government of the National Capital Territory of Delhi (which roughly corresponds to the boundaries of the state of Delhi) that would augment medical oxygen capacity in some of the COVID-19 hospitals by 4765 LPM of oxygen. The Delhi government in partnership with Ola Foundation and Give India had set up oxygen concentrator banks to cater to home-based patients requiring medical oxygen. Similarly, the Democracy People Foundation gave 800 oxygen concentrators with 10-LPM capacity each to hospitals and nongovernmental organizations in Delhi under its initiative, Mission Oxygen.16 Apart from countries and government agencies, multilateral and bilateral organizations, such as USAID through its NISHTHA Project, Jhpiego and implementation agency PATH, provided support for installation of oxygen-generating plants and augmenting liquid medical oxygen in the state. PATH had also set up technical support units in 14 states to support the respective governments in oxygen infrastructure-strengthening.

Collaborations with private and corporate entities and individuals: The study observed that corporates and individuals also stepped up efforts to support the affected countries by donating life-saving oxygen to those who needed it the most. For example, SingCham in Indonesia facilitated shipment of six tanks of liquid medical oxygen, oxygen concentrators and oxygen cylinders to Jakarta.17 Indo-Rama Synthetics Tbk and Indorama Ventures Indonesia donated 600 oxygen concentrators in July 2021. Similarly, the four medical and industrial oxygen manufacturers in Bangladesh donated 12,000 cylinders to 35 private and government hospitals and they also pledged to refill the cylinders.18

In Sri Lanka, Unilever donated oxygen equipment, such as oxygen concentrators. In India, several corporate entities came forward to support the Government of the NCT of Delhi with medical supplies. For instance, HCL supported the Delhi government with 12,000 oxygen cylinders, each with a capacity of 40 LPM, and 21 PSA plants, which generate 8800 LPM of oxygen, catering to around 1500 patients at a time.19 Similarly, the Uttam Group installed 22 PSA oxygen generation plants at Delhi hospitals.20

Furthermore, a Member of the Rajya Sabha, the Upper House of Indian Parliament, in collaboration with Turn Your Concern Into Action Foundation, launched auto-ambulances to ensure that mild, symptomatic patients with oxygen saturation levels
between 85% and 90% could reach nearby hospitals on time. The services were “free of cost” and were equipped with oxygen cylinders and sanitizers. Likewise, Her Royal Highness Princess Maha Chakri Sirindhorn of Thailand came forward to help the country by giving five high-flow oxygen concentrators to Ananda Mahidol Hospital in the Lopburi province during the third wave. Her Royal Highness also granted permission to acquire 540 high-flow oxygen concentrators, using the Chaipattana Fund against COVID-19 (and other epidemics).

Whole-of-the-government collaboration: The whole of the government working together to strengthen the oxygen infrastructure has been the standout feature of the pandemic response. For example, in many countries, either the Ministry of Industries or the Ministry of Commerce was responsible for procuring oxygen and oxygen devices, whereas the Ministry of Transport or its equivalent was managing oxygen logistics. Other ministries, apart from the Ministry of Health, were engaged in deploying oxygen solutions at health facilities. These interdepartmental collaborations were observed in several Member States, such as India, Indonesia, Nepal and Sri Lanka.

The study found not only collaboration between different ministries of the national government, but also collaborations between national and provincial government bodies. In Indonesia, MoH and the Ministry of Industry collaborated with the regional governments to transport oxygen to remote areas and islands. In India too, where, on one hand, the Central government, through PM CARES Fund, provided the states with oxygen equipment, the state governments too partnered with Central government agencies, such as the Indian Council of Medical Research and nationalized industries, to procure and install oxygen systems at state government-administered public health facilities.

**Collaboration for strengthening the oxygen supply chain**

The study found that the global scale of the pandemic presented several challenges as the market availability of oxygen and oxygen equipment was limited. The oxygen supply chains globally were stretched as coordination between governments, aid agencies and suppliers experienced disconnect where delays in regulatory processes caused slowdown in acquisition, among other causes. To alleviate these challenges, multidimensional collaboration was observed to facilitate supply of oxygen to hospitals and patients.

Bilateral collaboration for oxygen supply chain: Several examples were observed in the study wherein Member States initiated innovative approaches to overcome the oxygen supply challenges, such as creating Oxygen Express and green corridors for seamless movement of oxygen carriers and engaging national security agencies to expedite the supply of oxygen. India was one of the countries that used the above-mentioned approaches to supply oxygen to Bangladesh.

Furthermore, Thailand and Singapore supplied medical oxygen to India and the Indian Airforce was entrusted with airlifting these cryogenic tanks from these countries. Apart from these, the Singapore government arranged for regular shipments of emergency oxygen supplies to Indonesia via an "Oxygen Shuttle" programme. Additionally, in May 2021, the Royal Thai Air Force transported 15 concentrators to India as part of a donation from the Thai government to the Indian Red Cross.
In addition, the aid agencies also shared technical knowledge to strengthen the oxygen supply chain. For example, USAID’s Global Health Supply Chain Programme (GHSC-PSM) developed an electronic logistics management information system (eLMIS) dashboard. This platform facilitated timely decision-making for COVID-19-related emergencies.

- **Multilateral collaboration for oxygen supply chain**: The WHO Essential Supplies Forecasting Tool was used widely by Member States to calculate the oxygen demand and bed availability, based on the active case-loads.

- **Whole-of-the-government collaboration for oxygen supply chain**: Government departments efficiently coordinated with each other to ensure a seamless oxygen supply for COVID-19 patients. For example, in Indonesia, the Ministry of Industry had pledged to use 90% of industrial oxygen for medical purposes. In Sri Lanka, the Sri Lankan Navy made arrangements to import medical-grade oxygen from India and the Division of Biomedical Engineering Services within the Ministry of Health managed, installed and maintained all medical equipment in most of the hospitals in the country. Similarly, Thailand had an extremely well-coordinated system. Several geographical nodal points were established that were capable of producing medical-grade oxygen along with a strong transport network. An expert indicated that currently, there are 19–20 nodal points (having ASUs), where oxygen is generated and the whole distribution follows down from there towards the provinces and then to the districts, ensuring seamless distribution across the country.

  Additionally, the Indian state of Kerala came up with innovative models – buffer storage hubs – for coordinated oxygen storage, supply and distribution across the states. Apart from this, the Maharashtra government devised a system for judicious distribution of oxygen, which is popularly known as the “Mumbai oxygen model”. The key to the success of this model included decentralized management and microplanning. Some of the stakeholders involved in this model were the Municipal Corporation of Greater Mumbai, the Central Purchases Department, the State COVID Task Force, and the Food and Drug Administration Office.

- **Private sector collaboration for oxygen supply chain**: The private sector extended its support in ironing out the supply chain network during the pandemic. For instance, in Thailand, the government closely monitored the oxygen demand and worked synergistically with the Thai Gas Manufacturers Industry Club under the Federation of Thai Industries (FTI), the Siam Industrial Gases Association and other manufacturers to prevent demand-supply mismatch. Besides, Linde Bangladesh imported ISO cryogenic tanks for supplying liquid medical oxygen to the country. Furthermore, two Indonesian shipowners offered free container slots. Another Indonesian company with business in logistics volunteered to arrange for the collection of the supplies in Singapore and have them delivered to the Indonesian authorities on their arrival in Jakarta.

**Collaboration for capacity-building, training and knowledge-sharing**

Prior knowledge of the novel coronavirus and its clinical management was limited. The onset of the disease was sudden and the spread was rapid, with no proven therapeutic solution for the pandemic. There were no standardized clinical management guidelines, standard operating procedures or training modules that could prepare and keep the health-care providers updated to handle patients
effectively. Hence, capacity-building, training and knowledge-sharing among health-care providers, technicians and associated professionals were even more crucial. However, these trainings had limitations as they were mostly conducted virtually due to COVID-19 restrictions.

- Capacity-strengthening initiatives with bilateral organizations: The study observed that various bilateral aid agencies, such as USAID and JICA, among others, assisted the Member States in strengthening capacities on handling oxygen equipment, rational use of oxygen, triaging and related preventive measures. For example, USAID supported the Bangladesh government in developing and launching an e-mentorship programme, which had weekly online discussions, using case studies for capacity enhancement of medical staff at public hospitals. In Bhutan, USAID assisted the Ministry of Health to address the shortage of medical personnel from high-risk districts in critical care management, ICU management and ventilator management.

In India, USAID, through its projects NISHTHA and RISE, assisted over 20 states in the country to strengthen the capacity of medical as well as engineering teams on oxygen management. In another instance, JICA, in collaboration with WHO in Indonesia, assisted the Ministry of Health to conduct a two-day seminar on the operations and maintenance of oxygen concentrators.

- Capacity development with multilateral organizations: The World Health Organization was at the forefront of capacitating and training health-care workers in oxygen therapy or the use of oxygen equipment during the pandemic. For example, WHO in Bangladesh, supported the government in training non-medical workers in how to handle oxygen cylinders. It also conducted a comprehensive training in infection prevention and control (IPC) for physicians and nurses at medical colleges and district hospitals across the eight divisions. While WHO conducted online trainings in critical care and use of ventilators in Maldives, it carried out training in clinical management of COVID-19 in multiple batches for health-care workers in Myanmar. These trainings were facilitated by the WHO Health Systems Strengthening (HSS) team, in partnership with other UN agencies, such as the United Nations Population Fund (UNFPA), global and local technical organizations and not-for-profit organizations.

- Capacity-strengthening with development partners and nongovernmental organizations: The study noted several occasions wherein development partners and other local nongovernmental, technical and academic organizations stepped up efforts to assist Member States in training the health workforce. For example, the Biomedical Engineering Foundation of Nepal (BEFON), a not-for-profit organization, collaborated with the Government of Nepal to orient and train health workers in effective use of oxygen and operations and maintenance of oxygen equipment, covering subjects from basic circuit set-up to preventive maintenance to tips on prolonging the lifespan of the machines as well as avoiding wastage of oxygen.

As stated earlier, the study also observed collaborations with associations of medical and paramedical professionals, such as the Nepalese Society of Critical Care Medicine and the Critical Care Nurses Association of Nepal to develop training modules on COVID-19 management, including oxygen supplementation, for HCWs. Save the Children and Bangladesh Society of Medicine in collaboration with USAID assisted the Directorate General of Health Services, Bangladesh to develop guidelines on the rational use of oxygen titled, “Handbook on oxygen sources, distribution and need estimation with rational use of oxygen in COVID-19 patient management”.

Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic
Likewise, in India, PATH, a US-based international not-for-profit organization, was designated as the technical support unit for oxygen management in 14 states of India, where it was involved in developing training modules and conducting a series of virtual, classroom-based and hands-on capacity-strengthening initiatives for the public health workforce, including oxygen therapy, operation and maintenance of oxygen equipment and rational use of oxygen.

Apart from the not-for-profit entities, the private sector also played a valuable role in strengthening capacities in some Member States. For example, Linde Sri Lanka has a dedicated team of trainers, which periodically trains hospital staff, both medical and non-medical, in oxygen therapy, handling equipment and their overall maintenance. However, the role of the private sector in capacity-strengthening was limited and scattered.

Capacity-strengthening in the whole-of-the-government approach: The study found one instance from India, which had documented its initiatives to involve non-health departments in strengthening capacities of its workforce with regard to oxygen management. In India, the Directorate General of Training under the Ministry of Skill Development and Entrepreneurship, Government of India, has collaborated with the Indian Institute of Technology, Kanpur, and the Naval Dockyards, Vishakhapatnam, to develop certified courses on operations and maintenance of respiratory equipment and PSA oxygen plants, and build a pool of trained technicians certified to handle oxygen equipment.

Lessons learnt:

- A global pandemic will cause a breakdown in supply chain at the global level. For instance, the study observed that India had banned the export of medical oxygen at the peak of its Delta variant-led spike during the COVID-19 pandemic, when it struggled to meet the oxygen demand in the country. As a result, some Member States, such as Nepal, which were dependent on India for medical oxygen requirements, were left behind. Likewise, when Sri Lanka sought to procure oxygen equipment, the breakdown in oxygen supply chain caused significant delays in the acquisition of those vital equipment. The two cases illustrate that collaborations might become strained during a global pandemic and that is a requirement to revisit and expand collaborative arrangements to mitigate risks.

- Bilateral partnerships are more effective in procurement of medical oxygen and in securing financial aid. The study shows that the bilateral partnerships, whether between two governments or between two government agencies, were most productive when procuring medical oxygen, as countries such as India, Thailand and others provided oxygen in cryogenic form to other countries in the Region.

In addition, many European Union countries, the People’s Republic of China, the United States of America and Australia also provided medical oxygen to several Member States. Another area where bilateral cooperation was more effective involved delivery grant-in-aid to low- and middle-income countries (LMICs) to help them procure oxygen equipment and also invest in strengthening oxygen response.

- Multilateral agencies and development organizations are more effective partners for assisting procurement of oxygen equipment, facilitating pooled support and extending
technical assistance. Although there was evidence of multilateral agencies, such as the World Bank and the Asian Development Bank, providing grant-in-aid to Member States, most multilateral agencies, such as WHO, UNICEF and UNOPS, played the role of procurement enablers, helping Member States with technical specifications of oxygen equipment, identifying vendors and supporting deployment of oxygen devices.

In addition, multilateral organizations and several not-for-profit entities and professional bodies were engaged in providing technical assistance and capacity-strengthening for oxygen management by assisting the Member States in developing technical guidelines and learning packages and delivering training in knowledge and skill-building on oxygen. They were also involved in providing technical assistance for undertaking oxygen assessment and oxygen demand forecasting in almost all Member States.

Whole-of-the-government approach is more effective in a pandemic response than in a single ministry-led response. All Member States established task forces and coordination committees with representation of all government departments. The pandemic was not seen only as a health emergency, but also as a health emergency with wide ramifications, one which would require a collective response from the government. The whole-of-the-government approach improved coordination, reduced interdepartmental squabbles and enhanced response to the pandemic. In most Member States, the task forces were led by officials for ministries other than health, which in turn improved ownership of every department.

Private sector entities are better partners for oxygen production and logistics management. As the experience of every Member State showed, the private sector was leading the oxygen production. Even in case of equipment for captive oxygen production, such as PSA oxygen plants and oxygen concentrators, the private sector and corporates were the lead partners.

Another area where the private sector engagement contributed to a more effective response was logistics management. For example, Linde India procured ISO cylinders for transporting cryogenic oxygen across the country and from India to Bangladesh over railways, now popularly called the Oxygen Express. Likewise, Indonesia used services of shippers to transport oxygen from the point of production to the point of use across the islands. Even, for inland logistics, the oxygen tankers were managed and operated by private sector entities in many Member States.

Military infrastructure can be leveraged for mass equipment transport, but this is only applicable in case of bilateral partnerships. The military across the world has the capability to operate in difficult terrains, in some of the most demanding circumstances and with limited resources. They have large and fast-moving ships, helicopters and some of the largest transport aircraft in the world.

Many countries, such as the United Kingdom, the People’s Republic of China, South Korea, India and Australia, used military transport to deliver medical oxygen and oxygen equipment to some of the Member States in the Region. However, the study found that this mode was used only when the collaboration was bilateral in nature and that too between two governments.
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Country fiches

Bangladesh

From the beginning of the pandemic till 20th March 2022, Bangladesh has reported 1 950 609 infections, (i.e., 1.17% of total population), with 29 117 coronavirus-related deaths and a case fatality rate (CFR) of 1.49%. This makes Bangladesh the 42nd most-affected country in terms of total infections (absolute value), the 32nd most-impacted country based on COVID-19 related deaths (absolute value).

Fig. 1: Curved line graph of daily new cases of COVID-19 in Bangladesh, February 2020 to February 2022

On 18th March 2020, Bangladesh reported its first coronavirus death and since then, it has witnessed four waves of COVID-19 infection. The first wave, which was the mildest but the longest of all, lasted from early April 2020 to January 2021 with almost 4000 daily new cases being reported during the peak. The second wave began in March 2021, immediately after the first wave ended, and lasted until May 2021, with approximately 7600 daily new cases reported at its peak—and positivity rates exceeding 23 per cent. Once again in early June 2021, Bangladesh saw the surge in cases immediately after the previous wave subsided, which marked the beginning of the third and the most devastating wave of the pandemic in the country. The third wave lasted until September 2021 during which about 16 000 daily new cases and about 250 daily deaths were reported during the peak. During this time, the hospitals struggled under the strain, with many
promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic. After some respite between September and December 2021, the infections in country rose rapidly from January until February 2022 which marked the fourth wave with the reporting of peak daily new cases like the third wave, but the peak daily deaths were only about a fifth of the third wave.

Bangladesh’s oxygen response

During the pandemic, the Ministry of Health and Family Welfare (MOHFW), Government of People’s Republic of Bangladesh led the country’s response to COVID-19. As part of its COVID-19 preparedness, the government set up an International Health Regulations Emergency Committee for COVID-19 under the chairmanship of Minister, MOHFW. In March 2020, Bangladesh released ‘National Preparedness and Response Plan for COVID-19, Bangladesh’ to facilitate planning, identify response levels and conduct risk assessments.4

Amid the COVID-19 pandemic in Bangladesh, the MOHFW has been taking several initiatives to strengthen the health care system. In August 2020, the government released a report on Joint National Health Facility Preparedness and Readiness Assessment for COVID-19 Response that included an assessment study conducted by Directorate General of Health Services (DGHS), MOHFW, in collaboration with the development partners. The assessment survey was conducted for 120 health facilities between May and June 2020. The finding of the study showed that 84 facilities (70%) did not have any on-site oxygen plant or liquified medical oxygen system. The survey results also showed that all the facilities had functional oxygen cylinders (of any size) while only 25 facilities (20.8%) had functional oxygen concentrators of 5 or 10 LPM capacity. Furthermore, consumables such as High Flow Nasal Cannula with accessories were available in only 24 facilities (20%).

In a separate study conducted earlier by United Nations International Children’s Emergency Fund (UNICEF) in April 2020, it was observed that 70 per cent of the health facilities in Bangladesh lacked adequate oxygen infrastructure, indicating that the health system was underprepared to meet the surge in oxygen demand.5

As the country was reeling under the devastating second and third waves of infection in 2021, it became imperative that all data related to oxygen demand and consumption for the medical sector, including an understanding of the industrial sector, is collected, and analyzed to curtail any potential future waves. To undertake such an assessment, the Bangladesh government, in collaboration with UNICEF conducted an oxygen landscaping exercise with an aim to facilitate development of a national medical oxygen plan for the country for the next ten years. As per the draft report titled, ‘Bangladesh National Oxygen Landscape Report’ dated December 2021, the global dearth of knowledge about COVID-19 response also played a pivotal role in the initial dilemma to prepare the health sector for an effective response. MOHFW initially prepared by procuring and installing ventilators followed by high flow nasal cannulas. Subsequently after the second wave, the country started preparing for adequate oxygen supply to the patient’s bedside. Moreover, medical oxygen providers were advised to boost oxygen production and supply capacity and the suppliers were also urged to set up refilling stations close to public hospitals in every district. Also, medical oxygen which was imported through road pre-COVID-19, was imported through railways. Furthermore, MOHFW moved towards strengthening self-capacity of oxygen distribution by enhancing oxygen pipeline network in hospitals, by installing vacuum insulated evaporator (VIE) tanks (also called LMO tanks) filled with LMO, and by procuring and distributing concentrators and cylinders. Besides this, on-site Pressure Swing Absorption (PSA) oxygen generators in key facilities were installed to enhance on-site oxygen manufacturing capacity and to reduce reliance on cylinder
refilling. Additionally, the government is looking at procuring vacuum swing adsorption (VSA) oxygen generation systems for similar reasons to PSA plants but with higher efficiency.

Bangladesh also had a central real-time dashboard, ‘COVID-19 Dynamic Dashboard for Bangladesh’, for officials to constantly monitor the state of oxygen availability in hospitals across the country.6 A total of 600 facilities reported their oxygen demand and supply through the dashboard during the COVID-19 crisis which also included 50 private facilities.

Oxygen sources, production and procurement

In July 2021, Government sources indicated that Bangladesh’s pre-pandemic daily demand for oxygen was about 50 to 70 metric tons (MT), which reportedly increased by 2.5–3 times during the second wave of coronavirus outbreak.7 An independent assessment in July 2021 estimated that the country’s medical oxygen daily demand had peaked to around 600 MT during the second wave.

In Bangladesh, the Central Medical Stores Department (CMSD) is the main procuring center of DGHS. According to a media report published in April 2021, CMSD had 2058 oxygen concentrators and 7220 oxygen cylinders in its stocks.8

Liquid medical oxygen (LMO) was the primary source of medical oxygen in Bangladesh, which was used to meet almost all of the oxygen demand. Bangladesh depended on one-fifth of its LMO supplies from India, with the remaining produced by five entities that manufactured and supplied LMO under the license from the Directorate General of Drug Administration (DGDA), Bangladesh.

As per the draft report titled, “Bangladesh National Oxygen Landscape Report” dated December 2021, among these five entities, GPH Ispat and Linde Bangladesh are the two major players. GPH Ispat’s Green factory at Kumira, Sitakundu of Chattogram is the largest plant in Bangladesh which has the capacity to produce a maximum of 300 MT of liquid oxygen per day.9 As per media reports, GPH Ispat donated 1000 oxygen cylinders to solve the oxygen crisis of government hospitals in Chattogram in April 2020 and pledged to refill the empty cylinders.10 Another entity, Linde Bangladesh maintains the sole medical only oxygen manufacturing plant in Bangladesh. It manages 2 plants, one at Chittagong and the other at Rupganj, Narayanganj. The Chittagong plant can produce 20 MT per day (MTPD) of liquid oxygen and the Narayanganj plant can produce 70 MTPD of liquid oxygen with the total capacity from two units amounting to 90 MTPD (MTPD). During the COVID-19 emergency, with support from the government of Bangladesh, Linde India also transported oxygen in 19 trains (each carrying 200 MT in a total of 10 tanks) of liquid oxygen from Jamshedpur, India via Benapole. Additionally, Bangladesh has a pool of companies that are the key providers of manifold system in the public and private sector – such as Spectra Oxygen Limited, Safeguard, Anifco HealthCare, Tradevision, HM Traders and Widespread Solutions. Furthermore, there are multiple companies that provide oxygen plants and generators in the country such as - Linde Bangladesh, Spectra Oxygen Limited, Widespread Solutions, and Anifco HealthCare Limited.

Additionally, as part of the response efforts, WHO had also facilitated the procurement and distribution of 200 oxygen concentrators, 400 pulse oximeters, 100 venturi masks, and 100 nasal cannulas across 17 district hospitals and provided 65 patient monitors to 10 tertiary level health facilities in March 2021.

In July 2021, as the demand for oxygen escalated, the government sent notices to various oxygen manufacturing companies asking them to suspend production of industrial oxygen and...
enhance production of medical grade oxygen and provide it only to hospitals and clinics.\textsuperscript{11} The government further liberalized conditions to import medical oxygen to encourage inter-country collaboration to ease the oxygen demand-supply gap. Besides, a country expert divulged that the medical and industrial oxygen manufacturers came forward in a big way by voluntarily supplying medical oxygen to hospitals and clinics. This was also supported by media reports that confirmed that four oxygen manufacturing units have donated 12,000 cylinders to 35 private and government hospitals in Bangladesh during March and April 2021.\textsuperscript{12} Linde Bangladesh initiated a rental scheme to meet the emergency, however no further information is available in the secondary literature.

In addition, the government procured 30 PSA oxygen plants for hospitals through direct procurement system on an emergency basis, under the COVID Response Emergency Assistance, a program financed by the Asian Development Bank in August 2021.

\textbf{Clinical management and rational use of oxygen}

In May 2020, the Directorate General of Health Services (DGHS) under the Ministry of Health and Family Welfare circulated the National Guidelines on Clinical Management of Coronavirus Disease 2019 (COVID-19) in collaboration with the World Health Organization and Bangladesh Society of Medicine. This guideline was part of the Bangladesh’s strategy to mitigate the spread of the pandemic. It defined types of cases, principles of supportive therapy such as low and high flow oxygen therapy, use of devices such as high flow nasal canula, CPAP etc. Additionally, an updated version of the guideline titled, ‘Clinical Management Protocol for COVID-19’ was released in May 2021. Apart from the definitions and processes mentioned in the earlier version, this document had information on disease epidemiology, patho-physiology, and differentiation of case management in adults and children.

In addition to the case management guidelines, a document was launched on 28th October 2021 on the rational use of oxygen titled, “Handbook on Oxygen Sources, Distribution and Need Estimation with rational use of oxygen in COVID 19 patient management”. It was developed by DGHS in collaboration with the United States Assistance for International Development (USAID), Save the Children and Bangladesh Society of Medicine. The document defined the types of oxygen sources and devices used to provide oxygen therapy. It also mentioned the process of using WHO’s COVID-19 Essential Supply Forecast Tool (ESFT) to estimate total flow needs and anticipate the case load, and also included various protocols for providing medical oxygen to COVID-19 patients.

Besides the guidelines, in October 2020, USAID supported the capacity enhancement for medical staff in public hospitals through an e-mentorship program, which had weekly online discussions using case studies.\textsuperscript{13} Additionally, non-medical workers also received training on a different platform on handling oxygen cylinders. There was no information available on oxygen specific training programs in Bangladesh for medical and non-medical professionals. However, WHO was supporting the Government of Bangladesh with comprehensive trainings on infection prevention and control (IPC).\textsuperscript{14} Two batches of four days each, from 8th to 11th March and from 13th to 16th March 2021, were conducted that trained 65 physicians and nurses from medical colleges and district hospitals under eight divisions. Additionally, in June 2021, the Health and Education for All (HAEFA) launched an online, self-learning clinical course that was developed to help the physicians of Bangladesh acquire the most recent, evidence-based COVID–19 management skills in a convenient and interactive manner.\textsuperscript{15} This pre-recorded, web-based advanced COVID-19 clinical management certification course is accessible on the DGHS Bangladesh website (dghs.gov.)
As per HAEFA website, till date 836 heath workers have completed the certified course of which only 426 candidates have passed the MCQ test and received a certificate.

During the pandemic, all the trainings were virtual, due to the rising cases in the country. Some of the stakeholders reflecting on the gap between training and practice that they had observed during their hospital visits shared that the technicians managing oxygen did not reflect the knowledge enhancement, like they did not know how to monitor consumption, when to report, how to identify any leakage and what to do if there is a leak, among other gap areas. Some key stakeholders also observed that the care givers and members of patients’ family regulated the oxygen flow without medical advice, resulting in oxygen wastage and risk to the patient, which requires better monitoring, regulation, and patient education.

Apart from the government initiatives, the people of Bangladesh came up with innovative ideas and practices that can be replicated in other countries. For example, Shongjog – was a platform that was helping the patients by delivering medical oxygen at their doorsteps. A low-cost CPAP ventilator device, Oxyjet, was also innovated for hypoxemic COVID-19 patients and it does not require electricity to operate. Additionally, basic consumables like face-shields were 3D printed to curtail the spread of infection.

Collaborations

Many multilateral organizations, like United Nations and its arms, and countries through their development assistance arms, like USAID, or directly, like India, came forward to help Bangladesh respond to the surge in demand for oxygen. For example, the US Government through USAID provided a grant of US$96 million to support Bangladesh’s response to COVID-19. Organizations like Asian Development Bank (ADB), World Health Organization (WHO) and the Global Fund contributed to procurement of oxygen equipment and small oxygen devices, and their deployment in health facilities. In addition to medical devices, WHO, UNICEF and USAID contributed to development of guidelines, conducted oxygen assessments and trained health care workers on oxygen management.

Bangladesh and India collaborated and adopted many innovative measures to improve availability of oxygen in the country. Intercountry cooperation, such as supply of medical oxygen from India to Bangladesh through Oxygen Express, naval ships, Green Corridor - easing regulatory rules on exports and imports, and medicine supply from Bangladesh to India, are some of the practices that could be replicated as strategies for regional cooperation. For example, Linde India procured ISO oxygen tankers which could transport oxygen using railways. India provided LMO to Bangladesh through Oxygen Express, in two of the 14 ISO Oxygen Tankers. India and Bangladesh also eased restrictions on movement of medical goods, especially oxygen products, across the border resulting in quicker transfer of oxygen.

Promising practices

- Regular situational assessments for effective decision-making: Bangladesh conducted several rounds of assessments to understand the country’s readiness to respond to COVID-19. From a study in April 2020 with April 2020, which assessed health facilities readiness, to the Joint National Health Facility Preparedness and Readiness Assessment for COVID-19 response in August 2020 to Bangladesh National Oxygen Landscape Report in December 2021, these regular assessments provided valuable information and insights to the state government for informed and strategic decision making.
Use of digital tools for oxygen monitoring and capacity strengthening: Use of digital applications for real-time monitoring of oxygen availability in hospitals through COVID-19 Dynamic Dashboard for Bangladesh, to WHO’s COVID-19 Essential Supply Forecast Tool (ESFT) to estimate total flow needs and anticipate the case load, to online, self-learning clinical courses, like, the Health and Education for All (HAEFA), Bangladesh illustrated the use of digital tools at times when human interfaces were limited.

Doorstep delivery of oxygen devices: While Linde Bangladesh initiated a rental scheme for individuals to rent oxygen cylinders to meet the emergency needs, other initiatives like Shongjog was an e-platform that was helping the patients by delivering medical oxygen at their doorsteps. These initiatives improved access to oxygen for mild and moderate cases, thereby reducing load on hospitals.

Multi-modal oxygen transport: At the peak of oxygen demand, when oxygen transport by road was limiting large scale availability, Bangladesh imported medical oxygen from India through railways, now popularly called Oxygen Express, naval ships and operated a Green Corridor, where the governments on both sides, Bangladesh and India eased regulatory process for movement of medical supplies, including oxygen.

Lessons learned

There is a need for sourcing medical oxygen from various sources: The health systems must have diversified sources of oxygen. Dependence on a single source of oxygen and lack of capacity in large hospitals to produce oxygen further complicated the demand-supply gap in Bangladesh.

Virtual trainings should be completed with other approaches for capacity strengthening: Virtual trainings have limitations in effective transfer of knowledge and skills. Virtual trainings must be augmented with hands-on training sessions, learning videos for regular reference and wherever possible, classroom trainings and demonstrations.

Regularly updating and circulating guidelines on clinical management of COVID-19 and Standard Operating Procedures (SOPs), etc. on procurement, installation, operation, and maintenance of oxygen devices, etc. are important to enhance health systems capacity for oxygen management.

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Indonesia

Indonesia, the fourth most populous country in the world, reported its first case of COVID-19 on 2nd March 2020.\(^1\) According to the Johns Hopkins University’s COVID-19 dashboard, the pandemic had hit Indonesia most in the Southeast Asian region, with incidence rate of 223 per 100,000 citizens and the case fatality ratio exceeding 3 per cent.\(^2\) At the peak of second wave, i.e., on 15th July 2021, the number of new cases were 56,757. By March 2022, Indonesia has about 5,974,646 confirmed cases with 154,062 fatalities, becoming the 20th most affected country by all cases of COVID-19 and 9th most affected country by the numbers of COVID-19 related deaths.

Fig. 2: Curved line graph of daily new cases of COVID-19 in Indonesia\(^3\)

Indonesia’s oxygen response

Considering the spread of COVID-19 in the country in early 2020, Indonesia’s Ministry of Health, through an official decree (01.07/Menkes/169, dated 10th March 2020) demarcated 132 referral hospitals across 33 provinces for COVID-19 case management. By this action, a dedicated COVID-19 hospital was also established in each of the provinces. Following this, another Presidential decree (Keputusan Presiden) No.7/2020 was released in April 2020, to constitute the COVID-19 Acceleration Task Force, headed by Badan Nasional Penanggulangan Bencana (BNPB, or National Agency of...
Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic

Disaster Management) as National Commander. BNBP declared 91-day emergency status on the pandemic starting from 29th February until 29th May 2020, and individual task forces were established in each of the 25 provinces. The aim of the task force was to increase national resilience in the health sector, accelerate the handling of COVID-19 pandemic through synergies between ministries/agencies and local governments, improve preparedness and capabilities in preventing, detecting, and responding to COVID-19 infections, among others.

Amid the relentless surge in COVID-19 due to highly infectious Delta variant of the virus, the national media reported accounts of overburdened hospitals running short of medical oxygen. As per the Oxygen Survey Report 2020–2021 conducted by Indonesia’s Ministry of Health, in collaboration with the World Health Organization (WHO), in September 2020, only 57.1% (n=109) hospitals out of 191 had inadequate supply of oxygen to meet the higher demand.

In early July 2021, 63 patients were reported to have lost their lives due to insufficient supplemental oxygen at the Central General Hospital in Yogyakarta. The report was denied by the hospital later. Furthermore, the Head of Bali’s Health Agency reported to the news agencies that the patients in Bali required around 113.3 Metric Tonne (MT) of oxygen, while the hospitals only had 40.5 MT. Reports citing government data also showed that Indonesia’s daily oxygen need had risen from 1928 MT to 2262 MT per day (MTPD) in July 2021. Another oxygen situation update presentation, report prepared by WHO around July 2021 indicated that the daily demand of oxygen in the hospitals was about 3860 MT with nearly full occupancy of the 90 000-odd hospital beds in the country. Furthermore, media reports mentioned that the warning from the Red Cross and the Red Crescent Societies on the pandemic turning catastrophic in the country prompted a steep rise in retail prices of oxygen equipment. The price for an oxygen cylinder had jumped by 180% to US$140 per cylinder from the usual US$50. The report doesn’t mention the size or type of the cylinder.

Apart from the shortages in oxygen stocks, there were logistical and transport challenges related to the movement of oxygen from one point to another, such as, distances between manufacturing/refilling units and the hospitals, lack of cryogenic tankers for LMO distribution, among others.

In an effort to bridge the huge demand supply gap, the government of Indonesia redeployed about 90% of the industrial oxygen to the hospitals. Besides these efforts, one of our country experts disclosed that the Indonesian government used the Essential Supplies Forecasting Tool (ESFT) developed by the World Health Organization to calculate the demand and forecast requirement of oxygen based on number of active cases and bed occupancy. This dashboard facilitated coordination and helped in decision-making for optimum use of resources.

**Oxygen sources, production and procurement**

Prior to COVID-19, the main source of medical oxygen in Indonesian hospitals was Liquid Medical Oxygen (LMO) with on-site storage tanks. The Oxygen Survey Report- 2020–2021 confirmed that before September 2020, almost 92% (n=213) hospitals out of 231 hospitals relied on LMO and had on-site storage (LMO) tanks. Additionally, the report also stated that only 14% (n=33) hospitals had on-site oxygen generators (PSA plant) as a source of oxygen. However, the report does not throw light on the total storage capacity of LMO tanks and manufacturing capacity of PSA plants.
As per another country report titled, “Oxygen for Indonesia Movement”, dated 23rd July 2021, prepared by Ministry of Health Republic of Indonesia (also known as Kementerian Kesehatan Repuplik Indonesia) showed that Indonesia’s annual production capacity stood at 866 MT per day against daily utilization of about 638.9 MT, of which 75% is used by industries and the remaining 25% was used for medical purposes. Currently, there are five oxygen manufacturing units in Indonesia – Samator Group, Linde Indonesia, Air Liquide Indonesia, Air Products Indonesia and Iwatani Industrial. Moreover, oxygen production in the country is regulated by the Ministry of Industry.

The government estimated that there was still a shortfall of around 1300 MTPD of oxygen, after increasing production capacity and repurposing industrial and imported oxygen. The government decided to procure oxygen concentrators to fill the oxygen demand-supply gap.

During the COVID-19 surge of July 2021, apart from diverting industrial oxygen for medical use, the Indonesian government received oxygen equipment, such as oxygen concentrators, cylinders, liquid medical oxygen (LMO), ventilators etc., from various countries. Moreover, 36 PSA plants were procured and installed at various hospitals in the country. As per the specifications for oxygen cylinder, liquid oxygen tanks and ISO tanks given by Health Facility Directorate, the Center for Health Crisis in the Ministry of Health, Indonesia, also procured storage devices for creating medical oxygen buffer for distribution in case of additional demand. The empty cylinders and oxygen tanks were stored in central warehouse and distributed as per the demand.

To strengthen and streamline the tendering and procurement processes, Indonesia also developed a centralized online procurement system, e-Katalog, to effectively manage and improve the procurement of oxygen delivery devices including pulse oximeters. Moreover, the Ministry of Health expedited the license application process to manufacture and distribute medical devices in the country. A representative from the Ministry of Health clarified that the procurement was completely managed by Indonesian government, and that no big private sectors or philanthropic organization were engaged for procuring oxygen equipment.

As Indonesia is a group of islands, moving LMO from the point of production to its use presents a logistical challenge. To overcome it, Indonesia had installed LMO storage tanks in 92 per cent of its hospitals. The two ministries of Health and Industry collaborated with regional governments and private logistics sector for transporting oxygen to remote areas and islands and respond to their oxygen needs.

Clinical management and rational use of oxygen

To combat the surge in COVID-19, the government of Indonesia developed and released its first COVID-19 Health Operational Plan in April 2020. The objective of the document was to operationalize the disaster management response with a component of clinical management of COVID-19 patients. This document has been disseminated across various provinces in Indonesia. and its updated version was released in February 2021. However, oxygen therapy was not covered in this document.  

Besides the 132 referral hospitals in the 33 provinces dedicated to COVID-19 management, the Ministry of Health also established makeshift hospitals and centers during the second wave of 2021, to cater to the rising infection levels. The police hospitals, military hospitals, and hospitals operated by state-owned enterprise were also converted to dedicated COVID-19 hospitals to meet the rising demand of hospital beds. As per a country expert, “Oxygen houses” were also setup to care for patients having mild and moderate symptoms requiring oxygen support.
Additionally, the government resorted to digital platforms and tools, such as Aplikasi Sarana, Prasarana & Alat Kesehatan, or Application Infrastructure and Medical Devices (ASPAK), for countrywide asset management of medical equipment, which included tracking availability of oxygen delivery devices and pulse oximeters.\textsuperscript{11}

Although very limited information is available from secondary sources on initiatives for capacity building and training of healthcare workers, the Oxygen Survey Report-2020–2021 stated that until September 2020, the average number of staff members trained in oxygen therapy in hospitals in Java was around 160 and staff outside Java from 105 of the 231 participant hospitals. Moreover, the report also divulged that the number of staff trained on ventilators, intubations, and high flow nasal canula (HFNOs) were much lower as compared to other types of trainings, highlighting the urgent need for capacity building.

As Indonesia was receiving Oxygen concentrators (OCs) of various models from different countries, operating them became challenging. The Ministry of Health (MoH), in collaboration with the World Health Organization (WHO) and the Japan International Cooperation Agency (JICA), conducted a two-day seminar on the operations and maintenance of Oxygen Concentrators (OCs). The objective of the seminar was to demonstrate the operations and maintenance of these OCs. This seminar invited speakers from key manufactures to demonstrate their product to healthcare workers, technicians, among others. About 1000 participants attended the online demonstration session, as per country expert.

Collaborations

As Indonesia was among the worst hit countries during 2021 by coronavirus, multisectoral collaboration with government departments, countries, multi-lateral and bilateral agencies, and corporates was the need of the hour to save millions of lives.

Indonesian government departments coordinated with the Ministry of Health to ensure seamless oxygen supply for COVID-19 patients. For e.g., the Ministry of Industries committed to deploy 90% of the industrial oxygen for medical use. Similarly, the Ministry of Education and Culture in collaboration with the Ministry of Health, the Indonesian Medical Students Executive Board Association and WHO held a webinar training on “Basic literacy training on COVID-19 for health volunteers”.

Many countries came forward to support Indonesia during these trying times by supplying oxygen equipment and other consumables. The Ministry of Health received support and aid for strengthening oxygen systems from countries like Swiss, South Korea, China, Turkey, India, Singapore, Canada, Malaysia, New Zealand and Australia, among others. According to a report, prepared by WHO, Singapore donated 1500 oxygen concentrators to Indonesia. Besides this, Singapore government arranged for regular shipments of emergency oxygen supplies to Indonesia via an “Oxygen Shuttle” program on 19th July 2021.\textsuperscript{12} Four ISO tanks containing 80 MT of liquid oxygen arrived in Jakarta and the next consignment was scheduled a week later in July 2021. In addition to this, Australia donated 1000 ventilators, and 297 oxygen concentrators of 5 LPM capacity each. South Korea also donated 200 oxygen concentrators along with the United Arab Emirates (UAE) helping the people of Indonesia by sending 450 oxygen cylinders and 150 portable oxygen concentrators. Similarly, New Zealand sent 100 units of High Flow Nasal Cannula and Taiwan supported by sending 110 oxygen concentrators of 5 LPM capacity each. Moreover, China supplied 120 ventilators and 400 oxygen concentrators and India sent 300 units of oxygen concentrators.
and 100 MT Liquid Medical Oxygen (LMO). Indonesia also received a Global Fund grant through COVID-19 Response Mechanism for procurement of 30 ICU ventilators, 400 oxygen concentrator, 300 High Flow Nasal Cannula (HFNC), 330 patient monitors, two mobile oxygen generator for remote setting area, two diesel generator sets and 2000 oxygen cylinders.

Furthermore, international multilateral and bilateral aid organizations such as the World Health Organization (WHO), World Bank, Japan International Cooperation Agency (JICA), United Nations Office for the Coordination of Humanitarian Affairs (OCHA), and International Red Cross and Red Crescent Societies (ICRC) collaborated with the government to provide strategic, advisory, and financial assistance to prepare the country for effective pandemic control. Digital platforms and tools were developed in collaboration with development agencies to manage resources, forecast demand and supply of oxygen and track resources.

Finally, many companies extended their support to the government in its efforts to save lives. For example, PT. Indo-Rama Synthetics Tbk and PT. Indorama Ventures Indonesia donated 600 oxygen concentrators in July 2021. Similarly, the Singapore Chamber of Commerce (SingCham), Indonesia facilitated the shipment of six tanks of liquid medical oxygen (LMO), oxygen concentrators and oxygen cylinders to Jakarta. Additionally, the Temasek Foundation and 15 other companies from Singapore and Indonesia donated more than 11,000 oxygen concentrators to Indonesia. Apart from these, two Indonesian shipowners offered free container slots. Another Indonesian company with business in logistics volunteered to arrange for the collection of the supplies in Singapore and have them delivered to the Indonesian authorities on their arrival in Jakarta.

**Promising practices**

- **Use of digital platforms:** Digital interventions such as Aplikasi Sarana, Prasarana Alat Kesehatan, or Application Infrastructure and Medical Devices (ASPAK), e-Katalog, and ESFT played a key role in Indonesia’s response to COVID-19. It helped the government in resource assessment, allocation, forecasting and effective decision-making.

- **Establishing makeshift facilities with oxygenated beds for managing mild to moderate cases:** Indonesia had set up ‘oxygen houses’, buildings that have been designated for those who suffer from breathing difficulties due to the toxic smoke of the annual haze season and fires and are in desperate need of clean air. These oxygen houses, equipped with oxygen cylinders, masks and cannulas, were upgraded with oxygen concentrators and provided care for patients having mild and moderate symptoms requiring oxygen support. In some cases, the facilities were semi-permanent structure constructed near an oxygen manufacturer, had around 500-beds each, which have direct access to oxygen supplied from gas manufacturer.

- **Dedicated oxygen supply line:** Oxygen Shuttle, a program that was on top of assistance the Singapore government sent, including oxygen cylinders, oxygen concentrators, ventilators, as well as other medical supplies and equipment, is an example of creating dedicated oxygen supply arrangements between two countries, which can be leveraged at times of emergency. Initiatives like these can contribute to making the oxygen supply chain more elastic and proactive.
Lessons learned

- Inter-departmental co-ordination and collaboration, along with commitment from leadership helped in bridging the oxygen demand-supply gap along with ensuring oxygen production in full capacity during COVID-19 surge.
- Managing mild to moderate cases at temporarily established makeshift hospitals and oxygen houses reduced the burden on tertiary hospitals in the country.
- Strengthening the health system through building adequate health facilities with enough resources and capacity building and training of healthcare workers can better prepare a country for potential health crisis in future.

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Other resources
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Nepal

As of 23rd March 2022, Nepal has reported around 978,231 cases of COVID-19, including 963,592 recoveries and 11,951 deaths. The mortality rate for COVID-19 has been at 1.22% for Nepal. Nepal experienced three waves of COVID-19 infections. The first wave of cases was seen between July 2020 and February 2021 with a peak around October 2020. The second wave occurred between March 2021 and October 2021 with peak around May 2021. The third wave emerged in early 2022 surpassing the highest number of daily infections previously reported by Nepal. It peaked in February 2022 and has been on the decline since then.  

Fig. 3: Daily new cases of COVID-19 in Nepal

Nepal’s oxygen response

To address the rise in COVID-19 cases in the country and the burgeoning oxygen demand, the Nepalese government undertook significant interventions including the formation of a high-level Coordination Committee for the prevention and control of COVID-19, which later became the COVID-19 Crisis Management Centre. The committee was set up on 1st March 2020 and was led by the Deputy Prime Minister and the Minister for Defence. The committee undertook a series of significant interventions to reduce the COVID-19 burden in the country. In addition, the Ministry of Health and Population (MoHP), Government of Nepal, formulated a (HSERP) in May 2020 with the objective to prepare and strengthen the health system response and to minimize the adverse impact of COVID-19 pandemic. The plan comprised of multiple public health and social measures, including hospital-based interventions and overall COVID-19 management guidelines. To further support and strengthen its efforts in effective management of COVID-19, the government launched a mobile phone app called ‘Hamro Swasthya’ along with a web portal COVID19.mohp.
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gov.np to track, trace and control the spread of COVID-19 infections. Additionally, for potent asset management and demand estimation, an e-Logistics Management System was set up to integrate information on oxygen and COVID-19 related commodities, to track and identify procurement needs and prevent hoarding.

In terms of medical oxygen demand for Nepal, no reliable data was available to include in this report. However, one of the country’s key experts in medical oxygen stated that the daily demand was estimated to be around 70 MT per day (MTPD) before the COVID-19 pandemic, which rose multi-fold to around 170–180 MT/day during peak of the pandemic. This led to massive shortage of oxygen in the country.

To meet the rising demand of medical Oxygen in the country, medical oxygen cylinders were imported from China and a few other neighboring countries to enhance the Oxygen storage and distribution capacity. As shared by one of the key respondents, Nepal’s demand for oxygen cylinders shot up to 50 000 per day during the peak of the second wave in May 2021. However, during the same time, the country’s combined oxygen manufacturing and cylinder refilling capacity was only about 19 000 cylinders a day, which led to serious supply chain issues.

Therefore, during the pressing times in the second wave, due to shortage of medical oxygen and uncertainty over oxygen supplies, many hospitals in Kathmandu and other large cities in Nepal could not admit patients in spite of having enough beds and human resources to manage the surging cases. During the second wave, when the oxygen demand was at its peak in India, it had to restrict export of oxygen to meet its own in-country demand. This export ban by India further worsened the oxygen crisis in Nepal.

Oxygen sources, production and procurement

Pre-COVID-19 pandemic, Air Separation Units (ASUs) were the only manufacturing source of gaseous oxygen in Nepal. Currently, there are about 26 ASUs in the country with a combined daily manufacturing capacity of about 17 000 cylinders (~170 MTPD) which are managed entirely by the private sector. Due to low oxygen demand before onset of the pandemic, the ASUs operated only at 25% of their total capacity (operational for about 4–6 hours/day) which also led to defuncting of 2 ASUs. However, with rising oxygen demand during the pandemic, the ASUs operated at 100% capacity. This has also led to human resource crunch as the workers in the oxygen plants got over worked, exhausted, and affected with COVID-19 themselves.

Although LMO is an imperative source of medical oxygen for healthcare facilities, it had no in-house LMO manufacturing capacity of its own. As Nepal faced dire consequences due to Indian ban on oxygen export during the second wave, the Nepalese government has approved setting up of the country’s first LMO manufacturing unit, which would take a few months. However, the data on its location and daily manufacturing capacity is not yet available.

In addition to the oxygen manufactured at industrial sites such as LMO units and ASUs which come with supply chain challenges, Pressure Swing Adsorption (PSA) plants and oxygen concentrators are two other sources of medical oxygen. Both these sources of oxygen operate on PSA technology and come with no or very limited supply chain challenges as oxygen is manufactured on hospital site. To further strengthen oxygen production in the country, all large hospitals with 100 beds or more, have been instructed to have PSA plants as one of the sources of oxygen. However, as the PSA plants installation and commissioning process requires capital expenditure for procurement along with prerequisite infrastructure such as medical gas pipeline network, adequate ventilated space,
continuous power supply including power backup, their uptake in smaller hospitals and specifically hospitals in rural areas have been challenging. As the capacity of the newly installed PSA plants is many times higher than the capacity needed to meet normal demand, hospitals are concerned about the sustainability and continued operability of the PSA plant. Moreover, perception of their high operational and maintenance costs of PSA is also posing further challenges.

In addition to PSA plants, oxygen concentrators are an important manufacturing source of medical oxygen available with hospitals. Therefore, to bridge the supply-demand gap of medical oxygen in Nepal and mitigate the severe lack of oxygen in the second wave of COVID-19, many countries donated supplies including oxygen concentrators to Nepal. Nepal received over 1800 units were donated by WHO and another 600 came from UNICEF. While a portion was distributed to district-level health offices, many concentrators are presently being stored in “oxygen concentrator banks”, that have been established in each of the Province Health Logistics Management Centers (PHLMCs). Moreover, according to the data available with the Department of Health Services, the country received over 8000 oxygen concentrators during the second wave. However, there is no data available on the total concentrators available in the country.

In addition to the manufacturing sources such as PSA plants and concentrators, gaseous medical oxygen cylinders are an important storage and transport source available to hospitals. Like in many countries, oxygen supply was primarily managed by private agencies in Nepal. Moreover, it was reported that only a few of the hospitals in the country own any oxygen cylinder, which are held by the private agencies. During the pandemic, as the oxygen demand rose, it led to speculative price hike for oxygen cylinders. As a result, hospitals in some districts were unable to afford the security deposits against the cylinders they wanted to obtain from the private vendors. Furthermore, during the pandemic, many cylinders were also lost. As per the estimate around 50 000 cylinders went missing, from the pre-pandemic count of about 140 000 cylinders.

Finally, to monitor and enhance the country’s oxygen manufacturing capacity, some policy level decisions were taken. For instance, to ease the oxygen procurement process, government provided tax relaxations on PSA plant imports and purchases. Moreover, to prevent hoarding and black-marketing, it was made mandatory to take government’s permission for procurement of medical oxygen. Therefore, all the government, private or community hospitals had to produce a recommendation from the Ministry of Health and Population in order to refill cylinders. As mentioned earlier, an e-Logistics Management System was also put in place to integrate information on commodities and track/identify procurement needs.

Clinical management and rational use of oxygen

During the first wave, there was a lack of preparedness in terms of patient care and training of hospital staff regarding oxygen therapy and management. There were no clinical guidelines that existed on oxygen therapy and rational use of medical oxygen. Moreover, the use of high flow nasal cannula (HFNC) was highly prevalent in the country which led to wastage of oxygen. In addition, it was observed that large scale hospital admissions occurred at the start of COVID-19 pandemic with oxygen being administered to anyone who was feeling shortness of breath. However, the rapid surge of COVID-19 cases in Nepal raised a demand for clinical trainings to enhance the skills of healthcare workers to better care for critically ill patients. Thus, the Ministry of Health and Population (MoHP), National Health Training Center (NHTC), Nepal Medical Association (NMA), and the World Health Organization (WHO), Country Office for Nepal came together and organized the Critical Care Training for Health Care Workers: COVID-19 Program. The training was attended by
more than 11,000 medical professionals comprising doctors, nurses, specialists, and paramedics from all corners of Nepal. This virtual training program was conducted in five batches around the rational use of available resources by providing essential knowledge and skills in critical care while also equipping participants to better deal with oxygen therapy, clinical management of COVID-19, infection prevention and control, use of mechanical ventilators, and end of life care.

For further skill enhancement, the Nepalese Society of Critical Care Medicine (NSCCM) and Critical Care Nurses Association of Nepal (CCNAN) created the training modules to train Healthcare Workers (HCWs) on how to identify sick patients, clinical parameters to look for, different methods of oxygen supplementation, close monitoring of oxygen saturation targets, referring the patient to ICU, and managing patients going into shock. Specifically, the use of High Flow nasal cannula (HFNC) was restricted, and the use of non-invasive ventilation (NIV) was promoted. These training materials and SOPs were disseminated across the country. Finally, to better manage the pandemic and capture the medical oxygen demand, an estimation of oxygen need was carried out regularly across hospitals and wards. The number of hospital beds and ICU beds were also enhanced to tackle the rise in cases, even at the district level.

Collaborations

The Government of Nepal collaborated with a wide spectrum of stakeholders, like WHO, UNDP, UNICEF, FHI 360, National Innovation Center Nepal, Biomedical Engineers Foundation of Nepal (BEFON), Centre for Democratic Engineers Nepal (CDEN) among others, to support in need analysis, procurement, maintenance and overall management of oxygen producing, storing, distribution and delivery devices including trainings to clinical and medical staff for proper use & handling of oxygen devices.

To strengthen the pandemic response, the Government of Nepal collaborated with the UN and several other countries and agencies to get the needed support during the COVID-19 crisis. The country received a flood of oxygen supplies from India, France, US and China which helped mitigate the shortage of supply. It was observed that 100% of Nepal’s liquid oxygen needs were met by India which supplied liquid oxygen to the country through Indian LMO tankers. According to the data with the Department of Health Services, between 14th April 2021 and 4th July 2021, the country received 6945 oxygen cylinders from a number of foreign governments and domestic and international agencies.

UNICEF provided around 600 oxygen concentrators to the Government of Nepal. These were distributed to each of the provinces in Nepal to have equal access to oxygen. Gradian Health Systems and the Nick Simons Foundation (NSF) also provided 100 oxygen concentrators along with medical supplies. Additionally, UNOPS, under the World Bank financed COVID-19 Emergency Response and Health Systems Preparedness Project, financed 1000 units of 10 LPM oxygen concentrators, which were distributed to peripheral health facilities across the country in June 2021. DAK Foundation provided 55 oxygen analyzers to test and assure proper functionality of oxygen concentrators for its appropriate flow with adequate concentration in July 2021.

To strengthen oxygen supply-chain, GHSC-PSM (The USAID Global Health Supply Chain Program) developed an electronic logistics management information system (eLMIS) dashboard for COVID-19 commodities to facilitate timely decision-making by senior-level decision-makers in Nepal. Once the commodities started to arrive, GHSC-PSM tracked shipment arrivals, the supply and demand across all provinces and the movement of commodities as they moved through the supply chain.
UNICEF Nepal has contracted the Biomedical Engineering Foundation of Nepal (BEFON) for repair and maintenance of respiratory care devices in Nepal including extra fund of around NPR 10 000 000 for spare parts management for these equipment to ensure availability of these critical equipment. Through this engagement, BEFON also oriented and trained health workers on effective use of oxygen and operations and maintenance of oxygen equipment.

National Health Training Centre (NHTC) Nepal collaborated with WHO CO Nepal to form a committee of biomedical engineers to conduct Training of Trainers (ToT) to Biomedical Engineers to strengthen maintenance and management of respiratory care devices as well as user trainings for oxygen/respiratory care devices to medical officers and nurses at few hospitals.

**Promising practices**

- Developing partnerships for knowledge sharing and capacity building of human resources: Partnerships with technical agencies and industry associations, Biomedical Engineering Foundation of Nepal (BEFON), Nepal Medical Association (NMA), World Health Organization (WHO), Nepalese Society of Critical Care Medicine (NSCCM), Critical Care Nurses Association of Nepal (CCNAN) etc. has really helped the country to expedite and strengthen capacity building initiatives and has also proved to be a significant step in making the oxygen systems more sustainable.
- Ramping up in-country capabilities to not only mitigate current crisis but also prepare for any future ones: Development of in-country oxygen production capacity by having at least one LMO production plant to reduce dependence on other countries and become self-sufficient to face all future crisis.
- Implementing measures for rational use of oxygen to prevent wastage: It was found that lot of oxygen was getting wasted due to irrational use while delivering it to patients. Thus, restricting the use of High Flow Nasal Cannula or any such high flow oxygen delivery equipment helped in optimizing use of oxygen and preventing wastage. Also, capacity building of medical and paramedical staff was done on rational use of oxygen and monitoring of oxygen usage.
- Leveraging technology to improve tracking of supply and consumption: Use of digital tools, like E-LMS and GHSC-PSM to provide solutions for real time and effective tracking of oxygen consumption and production, its supply chain and logistics. Digital solutions can be deployed for end-to-end tracking and data-based decision making.

**Lessons learned**

- Putting in place a robust monitoring mechanism can go a long way in managing scarce resources especially in time of crisis. Establishing an effective tracking system for portable oxygen devices, like cylinders and concentrators, would contribute to reducing pilferages. Use of technologies like GPS, QR codes or RFIDs with cylinders and oxygen concentrators can be possible solutions.
- Regulating illegitimate activities through strict administrative measures can prevent worsening of crisis situation. It has been observed that pandemics or emergencies also lead to profiteering and hoarding of essential resources. Effective price control mechanisms and anti-hoarding regulations, along with actions to prevent spurious products becoming extremely important to mitigate risks to lives.
Engaging with partners across different domains and fields helps in leveraging their capabilities and deal with the crisis better through synergistic efforts. Collaborations with professional bodies, national and global technical institutions and development partners provide a more sustainable and efficient oxygen response, as they help leverage each other’s capacities and reach.

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Other resources

Sri Lanka

Sri Lanka witnessed the first confirmed case of COVID-19 pandemic on 27th January 2020. Since the onset of the pandemic, a total of 654,336 infections (i.e., 3.03% of the total population) have been recorded, with 16,361 coronavirus-related deaths and a case fatality ratio of 2.50.

Fig. 4: Curved line graph of daily new cases of COVID-19 in Sri Lanka.

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Sri Lanka experienced three waves of the pandemic. The first wave started in October 2020 and peaked in February 2021. By April 2021, the number of active infections declined as the government took preventive measures like active surveillance, early detection, isolation and case management, and contact tracing, in addition to imposing various social restrictions to control the infection levels. The second wave began in the month of May 2021 and lasted till the end of October 2021. During this wave, Sri Lanka experienced a double-bell curve, with two peaks: the first peak happening by the end of May or early June 2021, before a brief dip and then a rapid surge in daily new infections to an all-time high of over 6500 cases in August 2021. It was during this wave that a spike in fatalities was observed with the infectious Delta variant of the novel coronavirus. By the end of August 2021, Sri Lanka was ranked fourth in the world in reporting the highest number of daily deaths. The daily infections plateaued to an average of around 1000 cases per day till the end of 2021, when the arrival of the Omicron variant resulted in the third but less fatal wave. The third wave, caused largely by the Omicron variant of the SARS-Cov-2 virus, began ebbing by the start of March 2022.

**Sri Lanka’s oxygen response**

Given the urgency of the situation, the Government of Sri Lanka announced in early May 2020 a COVID-19 management strategy, led by the Ministry of Health. In April 2020, a guideline on the strategic preparedness and response plan was developed in collaboration with the development partners including the World Health Organization (WHO), the World Bank, and the Asian Development Bank (ADB). The overall goal of this plan was to stop further transmission of COVID-19 and to mitigate its impact. The strategic objective was to contain the pandemic by limiting human to human transmission, identifying, isolating, and caring for patients early, communicating critical risks and event information to all communities and countering misinformation; and minimizing impacts through multi-sectoral partnerships. These guidelines were revised in April 2021 with additional objectives such as protecting the vulnerable through vaccination, reduce mortality and morbidity from all causes by ensuring that patients with COVID-19 are diagnosed early and given quality care and through accelerating equitable access to new COVID-19 tools including vaccines, diagnostics and therapeutics. A national call center (1390) was also established under the supervision of the Additional Secretary of Medical Services to respond to queries related to COVID-19 from the general public.

Between May and November 2021, the healthcare system in Sri Lanka was overburdened as the second wave of COVID-19 primarily driven by the Delta variant of SARS-CoV-2 hit the country. Amidst the surge in COVID-19 fatalities, a huge demand for medical oxygen was noticed. Media reports suggested that there was no less than 30% increase in the demand for oxygen to handle the rapid rise in new active patients. It was also reported that by 18th August 2021, the daily demand of medical oxygen in Sri Lanka had shot up to 44 MT.

To avoid creating the situation of panic among the general public, the government regularly assured the people of Sri Lanka that the country had an adequate supply of oxygen to meet its needs. Moreover, the public was informed of the enhanced capacity which could be tapped into by ramping up the production in the existing oxygen manufacturing units to meet the rising demand. The government also placed multiple orders for empty jumbo cylinders (also called D-type cylinders) to iron out oxygen storage and distribution issues, while there was an adequate availability of oxygen.
Furthermore, many international aid agencies in Sri Lanka as well as the corporate entities in Sri Lanka came forward to support the government by providing financial and strategic advisory support, and by donating oxygen equipment such as oxygen concentrators, oxygen cylinders, oxygen regulators, ventilators, etc.

**Oxygen sources, production and procurement**

A study was conducted in November 2020 by the WHO for the Government of Sri Lanka, to assess the preparedness of government hospitals in the country to handle and respond to the pandemic. The study showed that all 129 hospitals in the country had oxygen cylinders as the primary source of medical oxygen supply for the patients. Bullnose large (D type) and small (B type) were the most common cylinder types used within hospitals. In addition, the availability of 17 oxygen generating/Pressure Swing Absorption (PSA) plants, 40 liquid oxygen tanks (LMO), and 23 oxygen concentrators was reported in the island-wide hospitals. The study further reported that wall oxygen was available only among 42% (n=54) of the hospitals. About 75% (n=97) of the hospitals had ambulances with adequate oxygen delivery infrastructure to transfer patients from one hospital to another with minimal complications. However, the study did not provide any information on the overall oxygen manufacturing and storage capacity of the oxygen sources in Sri Lanka.

In a separate media report in May 2021, the Health Minister stated that Sri Lanka’s hospital system had 24,000 medical oxygen cylinders. The same report also stated that to match the storage and distribution network with the availability of surplus oxygen, the government had placed an order of 7000 empty jumbo cylinders, of which 400 were expected to be received by the end of May 2021. The report also acknowledged the presence of piped oxygen from a liquefied gas (LMO) tank in several hospitals. Furthermore, as per a country expert in oxygen ecosystem, the Sri Lankan government had collaborated with the World Bank and UNOPS to set up 10 and 3 PSA plants, respectively.

Around the same time in May 2021, Sri Lanka’s Association of Medical Specialists (AMS) had observed that the country had 28 liquid oxygen (LMO) tanks installed in hospitals with their storage capacities ranging between 3 kL - 20 kL (approx. 3.4 – 23 MT). AMS stated that out of the 28 LMO tanks, only two had capacities of 20 kL. Due to the limited availability of LMO tanks, the hospitals had to largely depend on jumbo (D-type) cylinders to meet their demand.

Apart from the on-site oxygen manufacturing capacity in the form of PSA plants and concentrators, Sri Lanka also has two medical and industrial gas manufacturing units, i.e., Ceylon Oxygen, a unit of Linde AG, and Gas World Ltd, a subsidiary of Industrial Gases Pvt Ltd., which supplied oxygen to various health care facilities in the country. Together, they produce around 75 MT of oxygen per day, of which a portion is allocated for industrial use. In August 2021, Gas World Ltd. boosted its oxygen production capacity to 38 MT per day by commissioning an additional air separation unit (ASU).

Pre-empting the need for oxygen equipment like cylinders, oxygen generating plants etc., the government floated tenders with stringent price control. However, the global surge in demand for oxygen equipment, which prioritized supply to meet the need in European and other wealthier countries, had resulted in breakdown of global supply chain for oxygen. As a result of this demand-supply chasm, the price control norms were openly flouted, as noted by the country expert.
As the COVID-19 infections raged in mid-2021, the island nation had to resort to importing oxygen from neighboring countries to augment its supplies. The Sri Lankan cabinet approved import of 480 kL (approx. 550 MT) LMO into the country. Besides this, the government decided to import additional 100 MT of oxygen from India, which reached Sri Lanka in August 2021. Another consignment of 150 MT of oxygen from India reached Colombo in September 2021.

As it happened with many countries, Sri Lanka also collaborated with various agencies to strengthen its health system and respond effectively to the pandemic. The country collaborated with the WHO, the World Bank, and the ADB to develop the guidelines for COVID-19 preparedness and response strategy in early 2020, which were revised in 2021. These development partners, along with others such as United States Agency for International Development (USAID), United Nations International Children’s Emergency Fund (UNICEF), and United Nations Office of Project Services (UNOPS), helped the government augment its medical oxygen by donating oxygen plants, cylinders, concentrators, etc.

**Clinical management and rational use of oxygen**

Sri Lanka had four dedicated hospitals and a three-layered management approach to manage the COVID-19 patients. Level I had intermediate care centers for the asymptomatic patients, level II had divisional hospitals for mild cases, and level III had tertiary care and specialized care with intensive care units (ICU) and ventilator support. Treatment facilities were developed according to the needs of patients at different levels.

Sharing evidence from the study on 129 hospitals mentioned earlier, an oxygen systems expert in Sri Lanka observed that most of the hospitals had at least one dedicated staff responsible for management, installation, and maintenance of medical equipment. Some hospitals specifically reported the availability of a bio-medical engineer to operate and maintain oxygen therapy related equipment. Moreover, the clinical trainings and capacity building of medical officers (MOs) and nursing officers (NOs) were mostly focused around overall COVID-19 management, such as sample collection, testing, and management of patients in Intensive care units (ICU) and high dependency units (HDU).

However, no information was found on the trainings pertaining specifically to oxygen ecosystem management. Additionally, from the discussions held with the country expert, it was discovered that the staff attending the ICUs and HDUs patients were well versed on the use of oxygen equipment and consumables but needed capacity enhancement specifically on the rational use of oxygen. While it was shared by many stakeholders in Sri Lanka that multiple online trainings were conducted to further capacitate the healthcare workforce, no information was available on the curriculum and dates when they were conducted.

Finally, the Ministry of Health, Sri Lanka, developed a clinical practice guideline on the clinical management of COVID–19 patients. This guideline has been reviewed and revised based on evolving evidence as the disease situation progresses. This guideline has been immensely useful in the early detection and management of suspected and confirmed cases of COVID-19. This document also includes a comprehensive clinical case definition and timely initiation of infection prevention control (IPC) measures.
Collaborations

To further support Sri Lanka’s efforts in COVID-19 management, international agencies such as the World Bank donated 120 high-low nasal oxygen therapy units, 25 ICU ventilators, seven neonatal ventilators, and 20 transport ventilators. Moreover, 2100 oxygen concentrators and seven oxygen-generating plants were procured through the UNOPS. Additionally, Australia delivered oxygen and related supplies through UNICEF, including 291 oxygen cylinders and 342 oxygen regulators. Furthermore, USAID funded $2.5 million to strengthen the oxygen ecosystem in Sri Lanka.

Multi-country collaborations were also witnessed as India supplied about 250 MT of liquid medical oxygen to Sri Lanka over a period of two months. Moreover, Australia provided a funding of $11.7 million for critical supplies and health system support to the Ministry of Health. Additionally, philanthropic organizations, such as World Vision Lanka, donated four high-flow nasal oxygen therapy machines to the Division of Biomedical Engineering Services of the Ministry of Health.

Government departments worked in tandem to support and strengthen the health system. The Sri Lankan Air Force developed a Heated Humidified Oxygen Therapy Unit that could deliver temperature-controlled oxygen with full humidity at high flow rates to patients with respiratory complications. On the other hand, the Sri Lankan Navy made arrangements to import medical-grade oxygen from India. To support the effective management of the equipment, the Division of Biomedical Engineering Services within the Ministry of Health managed, installed and maintained all the medical equipment in most of the hospitals in the country. Also, corporates such as Unilever Ltd., Sri Lanka also donated 32 oxygen concentrators to the Ministry of Health.

Promising practices

Network of ambulance services fitted with adequate oxygen came as a boon during the pandemic: An assessment study on the preparedness of hospitals in Sri Lanka showed that about 75% (n=97) of the hospitals had ambulances with adequate oxygen delivery infrastructure to transfer patients from one hospital to another with minimal complications. As the incidences of COVID-19 increased, the requirement for a prehospital ambulance service became even higher. Sri Lanka’s SuwaSeriya ambulance service, with the telephone number 1990, has been used exclusively to transport COVID-19 patients from their homes to a designated nearest hospital or health facility, while continuing to provide emergency care for non-COVID-19 emergencies. Since May 2021, around 30% of all emergency calls to the SuwaSeriya ambulance system have been related to COVID-19 crises, and the system has been upgraded. The ambulance service was launched by a grant of $7.56 million provided by India in 2016. At present, 297 SuwaSeriya ambulances are operational throughout the country and are managed entirely at the expense of the Government through the SuwaSeriya Foundation established under the 1990 SuwaSeriya Foundation Act No. 18 of 2018. Furthermore, the Japan Fund for Poverty Reduction (JFPR) grant supplemented the government’s efforts to increase the efficiency of the ambulance system by transporting the COVID-19 patients to the nearby health centers, safely and timely.

Centralized technical health service with dedicated staff in each hospital: In some of the government hospitals in Sri Lanka, there were dedicated biomedical engineers to operate and maintain oxygen therapy related equipment. This arrangement had helped the hospitals in technology assessment, equipment planning, procurement,
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Encouraging local innovations, like Heated Humidified Oxygen Therapy Unit: Apart from many other innovations in the oxygen space, the Heated Humidified Oxygen Therapy Unit was noteworthy in Sri Lanka. It is a device that can deliver temperature-controlled oxygen with full humidity at high capacity to patients with respiratory complications. This innovation was done to address the imminent shortage of ventilators in the country in the face of the global pandemic. The device is a concept of Vidya Jyothi Dr Bandula Vijay and was innovated with the contribution of Professor Ranil De Silva, Dr Thilanka Ratnapala and a team of medical experts. The manufacturing of the device was undertaken by the Maintenance Unit of the Sri Lankan Air Force Engineering Corps. A prototype was manufactured and put through rigorous testing to check its limitations, safety features and performance standards. The same was presented to the National Medicines Regulatory Authority (NMRA) of Sri Lanka and successfully completed its evaluation with compliance to IEC 60601 Electrical Safety. The prototype unit has now been installed at the General Sir John Kotelawala Defence University Hospital in Werahera. Two more units have been manufactured and are currently being utilized at Sri Lankan Air Force Hospitals in Colombo and Katunayake. on both sides, Bangladesh and India eased regulatory process for movement of medical supplies, including oxygen.

Lessons learned

- Preemptive readiness, surveillance, and foresight helped the country better prepare for managing the pandemic. Adopting a multi-pronged strategy for meeting the oxygen gap, which included widening the sources of oxygen production, strengthening existing oxygen sources and collaboration with neighboring countries, worked well in addressing the oxygen crisis in the country.

- Digital platforms and tools are very effective in monitoring and tracking disease and supply chain related data, especially during a pandemic of such stature. Notwithstanding the fact that Sri Lanka has the National COVID-19 Health Information System (NCHIS) as one of the key digital health innovations supporting COVID-19 information management in Sri Lanka, digital systems on procumbent and delivery would be useful to effectively manage the resources.

- The COVID-19 pandemic has brought the need for regional health cooperation to the spotlight and also validated the benefits of continued regional cooperation. So far, this collaboration and cooperation have been highly beneficial to the curb the crisis in the region through mobilizing resources, knowledge sharing and identifying urgent investment needs. Beyond the pandemic, cooperation will be needed in developing a regional strategy for health and other key areas such as promoting digital platforms for the oxygen ecosystem and disaster resilience.
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Thailand

Thailand detected its first COVID-19 case in early January 2020, making it the first case to appear outside China. Till 16th March 2022, there have been 3,250,642 confirmed cases in the country including 3,004,752 recoveries. With about 23,921 deaths, the mortality rate for COVID-19 has been at 0.7% for Thailand, which puts it among the countries with low case fatality rates in the world. From the start of the pandemic, Thailand has experienced five waves of COVID-19 infections. The country witnessed the first surge of infections in March 2020 which lasted up to May 2020. For one year between December 2020 and December 2021, Thailand experienced three more waves, with each wave more severe than the previous one. Its fourth wave flooded the country with patients infected with Delta variant of COVID-19 with a peak in August 2021. It gradually saw a decline till December 2021, only to rise up yet again.

![Fig. 5: Daily new cases of COVID-19 in Thailand](image)

Data suggests that from early 2022, the country saw its latest fifth wave of infections. At the time of writing this report in March 2022, 70 coronavirus-related deaths were reported by the Center for COVID-19 Situation Administration (CCSA), raising the pandemic’s death toll in Thailand to 23,848 out of which 2,150 fatalities were since the start of this year alone.

**Thailand’s oxygen response**

To address the COVID-19 crisis, the Thai Government implemented many policy level initiatives. Following the detection of its first COVID-19 case in early January 2020, the Department of Disease Control of the Ministry of Public Health activated its emergency operations which included meticulous
monitoring of the situation, developing an incident plan and preparing the workforce and health facilities to respond to the challenges of the potential outbreak. The government also introduced number of public health measures to control the spread of virus in the country. Thailand declared COVID-19 a dangerous communicable disease under its Disease Control Act, B.E. 2558 in late February 2020 to intensify active surveillance and control of the disease (Government Gazette, 2020), two weeks prior to WHO declaring COVID-19 a pandemic.

With the gradual rise in infections, the government further escalated the response from the ministerial level to the national level through the National Emerging Infectious Diseases (EID) Committee and set up a Center for COVID-19 Situation Administration (CCSA) led by the Prime Minister. The CCSA began to serve as a single command center employing a whole-of-government approach in managing the COVID-19 response in a comprehensive manner.

In addition to CCSA, government implemented various other administrative measures such as development of Integrated Plan for Multilateral Cooperation for Safety and Mitigation of COVID-19 to ensure quick response to the crisis. Regular interim assessments of the country’s COVID-19 response were done, and midcourse corrections were undertaken, as needed.

Furthermore, the government had also set up four committees (Stockpiling, needs assessment, Trouble shooting, and Monitoring/evaluation) working on oxygen demand and supply issues in the country which were managed by a centralized coordination center.

**Oxygen sources, production and procurement**

Thailand has long been self-sufficient in terms of its oxygen requirement. An expert observed that the fulfilling the need for oxygen was never a challenge for Thailand up until the third wave when the demand exceeded the supply for a short period. Thailand has industrial capacity to produce oxygen of a quality that is high enough to be used for medical purpose as well. Hence, there was never a serious oxygen shortage in the country.

According to Director General of the Department of Industrial Works (DIW), as on 27th July 2021, Thailand produced 1260 MT of oxygen per day, out of which 400–600 MT was utilized for medical purpose and about 600 MT for industrial use. The DIW was largely responsible for managing the oxygen supply during the COVID-19 crisis in the country. DIW coordinated with the industrial gas manufacturers under the Federation of Thai Industries, gas-filling factories as well as the gas container suppliers to meet the rising oxygen demand during the COVID-19 crisis.

The government closely monitored the oxygen demand and worked synergistically with the Thai Gas Manufacturers Industry Club under the Federation of Thai Industries (FTI), the Siam Industrial Gases Association (SIGA) and other manufacturers to prevent demand-supply mismatch. In the wake of surging COVID-19 cases during the third wave, Thailand government ramped up the oxygen production in the country. 15 factories manufacturing oxygen in Ayutthaya, Saraburi, Chonburi, Rayong, Songkhla, Lamphun and Chiang Mai provinces assured cumulative production capacity of about 1860 MTPD. Further, in August 2021, a new factory was established in Rayong, pushing the country’s total production capacity to 2200 MTPD.

Thailand has been importing oxygen cylinders from China as there are no domestic manufacturers. During the third wave, majority of the oxygen generators and oxygen concentrators were also imported from China along with other necessary equipment such as oxygen valves and pipes, of which existing stock is now able to meet the national demand.
Private organizations such as Bangkok Industrial Gas Company Limited (BIG) also came forward to support oxygen production during the crisis. BIG, Thailand’s largest oxygen producer with a production capacity of 1000 MT per day, also restarted an additional ASU plant to help Thailand ramp up oxygen production. It even helped the country to export oxygen to other countries such as India.6

The Royal Highness Princess Maha Chakri Sirindhorn of Thailand came forward to help the country by bestowing five high-flow oxygen concentrators to Ananda Mahidol Hospital in Lopburi province during the third wave. Her Royal Highness also granted permission to acquire 540 high-flow oxygen concentrators, using the Chaipattana Fund against COVID-19 (and other epidemics).7

In terms of procurement and logistics, Thailand has an extremely well-coordinated system. Several geographical nodal points were established that were capable of producing medical grade oxygen along with a strong transport network. An expert indicated that currently there are 19–20 nodal points (having ASUs) where oxygen is generated and the whole distribution follows down from there towards the provinces and then to the districts, ensuring seamless distribution across the country. In terms of procurement and logistics, Thailand has an extremely well-coordinated system. Several geographical nodal points were established that were capable of producing medical grade oxygen along with a strong transport network. An expert indicated that currently there are 19–20 nodal points (having ASUs) where oxygen is generated and the whole distribution follows down from there towards the provinces and then to the districts, ensuring seamless distribution across the country.

Clinical management and rational use of oxygen

Thailand has invested heavily in its healthcare infrastructure and workforce in the last four decades. In addition to urban hospitals, building up district hospitals and health centers has resulted in nationwide expansion of rural health services and access to health services at the community level. Also, all Thai people have access to essential healthcare services under the national Universal Health Coverage scheme for the past two decades. This has really helped Thailand in efficiently tackling the COVID-19 crisis.

The Department of Disease Control and the International Health Policy Program of the Ministry of Public Health stratified the COVID-19 patients using a model based on severity level. Patients are divided as susceptible, exposed, infectious and recovered and are assigned a color based on severity. The model was based on an assumption that each type of patient (green, yellow, red) required a different amount of oxygen.

For the green patients, it was assumed that 20% of the cases would require oxygen at a maximum flowrate of 5 liters per minute. The patients in the red group would need, via a ventilator, 50 liters of oxygen per minute. Yellow patients would require different amounts of oxygen as follows: 30% of the patients would require, via an oxygen cannula, 5 liters of oxygen per minute, 50% of the patients would require, via an oxygen mask, 10 liters of oxygen per minute, and the remaining 20% would require, via a high-flow cannula, 20 liters of oxygen per minute. This helped in assessing and forecasting oxygen demand in the facilities.

To prepare for the pandemic, apart from assessing oxygen demand, government also invested in providing extra beds at existing facilities as well as allocating additional facilities for quarantine.
To strengthen clinical management response, several clinical guidelines and standard operating procedures for healthcare workers were developed including hospital preparedness guidelines, clinical practice and treatment guidelines, guidelines on using personal protective equipment, and guidelines on the establishment of field hospitals in case of a widespread pandemic.

At the peak of Delta wave, Thai government had to set up at least 10 000 more field hospital beds to manage the case load. However, the country never faced any shortage of trained personnel while managing the COVID-19 crisis. To add on to the clinical management, government also mobilized a large pool of volunteers to support referral of patients which required oxygen.

**Collaborations**

Thailand has collaborated with many national and international organizations to tackle the COVID-19 crisis. Bangkok Industrial Gas Company Limited or BIG – Thailand’s Innovative Industrial Gas Solutions – and PTT Global Chemical Public Company Limited or GC – the leading global chemical company sent 360 MT of liquified medical oxygen to five hospitals for treatment of COVID-19 patients and critical patients during the third wave of the pandemic.9

In September 2021, to support Thailand’s COVID-19 response, UNICEF provided 550 oxygen concentrators to help treat patients with respiratory diseases.10 Additionally, in September 2021, in coordination with the Ministry of Public Health of the Royal Thai Government, the UN Country Team in Thailand under UNOPS and with Japan’s support, delivered 868 oxygen concentrators of 10-litre capacity to Thailand. These concentrators were distributed among 79 hospitals and community health centers across all provinces of the country.11

Despite undergoing the crisis, Thailand has also been supporting other countries during the COVID-19 pandemic. In May 2021, Royal Thai Air Force (RTAF) transported 15 concentrators to India as part of donation from Thai Government to Indian Red Cross, along with 15 concentrators donated by the Hindu Samaj of Bangkok. In addition, 100 oxygen cylinders had separately been offered by the Indian Association of Thailand to India to help mitigate the mounting oxygen crisis in the country.12

**Promising practices**

- Early acknowledgement of crisis, robust planning and preparedness: Thailand’s acknowledgement of COVID-19 crisis by declaring it a dangerous communicable disease under its Disease Control Act and employing a whole-of-government approach in managing the COVID-19 response in a comprehensive manner, has worked out well in mitigating the crisis.
- Prediction of oxygen demand: Thailand’s color coding of COVID-19 cases that triaged the patients (green, yellow, red) to identify those who need oxygen therapy worked well even during the peak of Delta wave. This system of predicting oxygen need, identifying, and escalating cases, depending on symptoms and severity, with SOPs for actions at each stage is worth considering for institutionalization.
- Conducting assessment exercises for response planning: Carrying out regular interim assessments of the country’s COVID-19 response along with midcourse corrections helped in effective management of the crisis and reducing the fatalities.
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- Administrative measures with strong centralized coordination mechanism: Setting up of committees (stockpiling, needs assessment, trouble shooting, and monitoring/evaluation) managed by a centralized coordination center to work on various oxygen demand and supply issues is a promising administrative intervention.

- Robust supply chain process: A well-coordinated procurement and logistics system with geographical nodal points producing medical oxygen being established along with a strong transport network.

- Effective leveraging of in-house capacities: Thailand has built a rich and vibrant pool of trained health workers, meeting the WHO benchmarks who are licensed to deliver healthcare services. As the cases of COVID-19 were centered around urban agglomeration, Thailand was also able to mobilize resources and move trained medical officers, nurses, and technicians from less affected regions to more affected pockets for COVID-19 management.

Lessons learned

- Long term investment in strengthening of health systems and processes can help in absorbing shocks like COVID-19 pandemic in a much effective manner. Thailand’s response to COVID-19 crisis lies in its four decades of investment in health infrastructure and achieving universal health coverage. Due to the country’s strong basic infrastructure, acceleration of oxygen production and delivery was less challenging for the country and was managed well in time.

- Health sector reforms, including strengthening Emergency Medical Services, enhancing referral system, and effortless mobilization of voluntary workforce along with public health services, is an important step in pandemic preparedness.

- Having mechanisms in place for early detection of crisis and proactive planning for impending crisis allow more response time to mitigate the impact. Thailand declared COVID-19 a dangerous communicable disease under its Disease Control Act at the start of the crisis. Early acknowledgement of a problem gave more time to respond, and prepare well for a more calibrated response, resulting in lesser damage.

- Being open to collaboration and learning help in leveraging strengths of partners which is much needed at the time of crisis like COVID-19. Private sector engagement in production of oxygen with government coordinating its logistics to hospitals, enhanced production efficiency on one side and supply chain management on the other, had been critical for an effective pandemic response.

- Decentralizing and delegating responsibilities help in better coordination of services specially in times of crisis. Thailand’s decentralized health systems gave more power to the regional and local players to customize the health system response bases on their local priorities.

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Timor-Leste

The global COVID-19 pandemic has affected every country in the world, and Timor-Leste was no exception. The first case in Timor-Leste was confirmed on 21st March 2020.

In the early days of COVID-19, the proactive containment strategies led to only about 100 people being infected in the country until February 2021. The country has so far witnessed three waves of infection. In March 2020, the number of confirmed cases surged rapidly from just over 100 to almost 1000 by mid-April 2020, threatening the country’s fragile health system. The first wave lasted until July 2020 with a peak around May 2020. The second wave and the third wave had their peaks around August 2021 and February 2022, respectively. Among the three waves, with the peak daily new cases of 532, the second wave was the most severe. By March 2022, 20,789 infections have been reported in the country along with 129 coronavirus-related deaths, resulting in overall case fatality rate of 0.6%.
Timor-Leste’s oxygen response

As an early response measure, the Government of Timor-Leste declared a State of Emergency (SoE) on 28th March 2020, following the first confirmed case of COVID-19 pandemic in the country. The declaration was initially meant to last until 26th April 2020 but was subsequently extended until 27th May 2020. Soon after, the government established a Crisis Management Committee (CMC) that was responsible for coordinating all COVID-19 responses and all other COVID-19 related matters. The CMC was set up and operated from the Centro Convencoes de Dili (CCD) in Dili. Earlier in February 2020, the Prime Minister’s Office announced the decision to establish an Inter-ministerial Coordination Committee to prevent and control COVID-19 in Timor-Leste. This committee included the Ministry of Health (MoH), Ministry of Finance, Ministry of Foreign Affairs and Cooperation, Ministry of State Administration, Ministry of Transport and Communication, Ministry of Defense and Interior, Ministry of Education, Youth and Sports, Ministry of Agriculture and Fisheries, the Secretariat of Social Communication, the Chief of Armed Forces, the Commander General of Policia Nacional Timor-Leste and the Integrated Centre for Crisis Management. Around the same time, the MoH also established a helpline number – 119, for people to access or inquire about any COVID-19 related information.3

Since the early days of the global outbreak, support from international agencies to strengthen the national health sector preparedness and response to COVID-19 is being provided under the technical coordination and leadership of the World Health Organization (WHO). United Nations Children’s Fund (UNICEF), WHO and other development partners continue to support the MoH in monitoring the situation by conducting supportive supervision visits in villages and communities in Dili and other municipalities to help assess and ensure continuity of essential health services.4 Australia has been Timor-Leste’s primary partner in its immediate COVID-19 response and early recovery.

Oxygen sources, production and procurement

Timor-Leste procures all its medical equipment, drugs and consumables through a national medical store known as ServicoAutonomo de Medicamentose Equipamentos de Saude (SAMES), which is a public institution within the MoH. SAMES uses an electronic inventory system in which a mobile app (mSupply Mobile) has been installed on tablets in 24 health facilities in Dili District since 2016. As per a country expert, SAMES floats tenders for the supply of oxygen each year. This estimation is based on two parameters, - average monthly consumption the year prior and the current demand. Following the estimation, SAMES engages with single or multiple suppliers for all its procurements.

Timor-Leste currently has only two suppliers of medical oxygen to the hospitals through SAMES, i.e., Daikyo Industrial Gas Sdn. Bhd. and Oxigenio Carlo Dame Ida, as reported by a country expert. Daikyo is a liquid medical oxygen (LMO) based refiller and supplies oxygen by refilling the cylinders, whereas Oxigenio Carlo Dame Ida has two oxygen plants and the oxygen is supplied to health facilities through cylinders. However, it is not clear if the oxygen plants are Air Separation Units (ASUs) or Pressure Swing Absorption (PSA) plants. Moreover, as per a country expert working closely on oxygen system, there are 88 oxygen concentrators available in the country, of which six are non-functional as they got damaged in the recent floods. There is just one PSA plant in the country and no further information was provided by the expert.

At the time when the second wave of COVID-19 was raging through the country, the then Director of SAMES Provisioning, revealed that, around 800 registered oxygen cylinders were in use at different care centers in Timor-Leste. In June 2021, SAMES supplied 60 oxygen cylinders
to two isolation centers in Vera Cruz and Lahane; however, due to higher demand, another 100 cylinders were supplied to these centers in August 2021. Moreover, in September 2021, the MoH procured 1500 empty cylinders through SAMES for distribution in the hospitals, so that all hospitals in Timor-Leste could get 10 additional cylinders as reserve.

Furthermore, the Department of Foreign Affairs and Trade, Australia, dispatched 84 oxygen cylinders in September 2021 to SAMES for the treatment of patients with COVID-19 at the isolation center in Vera Cruz. Additional 100 cylinders were sent to Timor-Leste the following week. Other than these sources, UNICEF, with support from the Government of Portugal, procured and supplied 15 oxygen concentrators to Timor-Leste in August 2021, which were distributed to the isolation centers and national and regional hospitals.

Clinical management and rational use of oxygen

To effectively manage the pandemic, the MoH, Timor-Leste circulated the Clinical Guidelines for COVID-19 Management in April 2020, which was later updated in March 2021 and recirculated to all health entities. The updated version included the experiences gathered and lessons learnt from the previous year’s pandemic and had guidelines for health care workers to protect themselves. Moreover, the updated version had an additional section on palliative care. However, there were no specific guidelines on oxygen therapy in both the versions.

A country expert also reported that there was a lack of critical care infrastructure within the country with just five intensive care units (ICU), which were all in the national hospital at Dili. Additionally, the country had two isolation centers for care of mild patients and a 55-bed critical care center for moderate to severe patients. However, there are no high dependency units (HDUs) or critical care units (CCUs) outside of the capital. Finally, capacity building of healthcare staff is highly critical to survive, adapt, and thrive in a fast-changing situation such as the COVID-19 pandemic. However, there is no information available on any government initiative to capacitate and train healthcare workers in oxygen therapy or the use of oxygen equipment.

Collaborations

As mentioned earlier, international aid agencies, such as the WHO, UNICEF and International Federation of Red Cross and Red Crescent Societies (IFRC) came forward to support Timor-Leste’s national preparedness and its response to the COVID-19 pandemic.

In April 2021, the United States embassy in Timor-Leste donated 20 continuous positive airway pressure (CPAP) machines to the Government of Timor-Leste Integrated Crisis Management Office to support Timor-Leste in the fight against COVID-19.

Furthermore, the Government of Australia had extended support to Timor-Leste by providing strategic advice for COVID-19 response and early recovery and through supplying essential medical equipment, consumables, and medicines.

Lessons learned

- Timor-Leste has a fragile health system and has limited capacity for managing critical cases, few functional isolation facilities and difficulties procuring timely medical supplies. Timor-Leste’s health system has now incorporated a proper emergency response mechanism and is doing all that it can to detect cases and prevent them from spreading.
Strengthening the public health system with appropriate human resource and equipment could go a long way in responding to potential pandemics in the future.

- Long term collaborations with other countries and aid agencies have helped leverage global technical capacities to respond to the crisis better. The WHO has been supporting Timor-Leste to strengthen its health system by providing technical support in health care. Global aid agencies such as the European Union (EU), the Grand Duchy of Luxembourg, Irish Aid, the Government of Japan, the French Ministry for Europe and Foreign Affairs, the UK Department for International Development and Belgium have been financially supporting these health-related activities in the country.

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India

COVID situation and oxygen preparedness

Since January 2020, the world has been in confrontation with the COVID-19 pandemic, which has been hitting the humanity in waves. Till March 2022, India has witnessed three waves of COVID-19 pandemic, which has infected over 43 million people in the country and claimed over 516,000 lives. The Delta variant caused a devastating second wave of COVID-19 from March to June 2021 across India, as the country saw the daily demand for medical oxygen rising sharply, with a catastrophic effect.

As the demand for oxygen far exceeded the supply due to the sudden spike in the number of infected patients, India faced shortage of liquid medical oxygen (LMO). The sudden and sharp spike in demand for medical oxygen put the market mechanisms in disarray in India as the government and private hospitals that depended on LMO for its oxygen needs through the market were completely overwhelmed. Even when the central government was reorganizing the production and supply of liquid medical oxygen, there arose problems of geography and logistics in ensuring timely access. Cryogenically produced liquid oxygen was mostly generated in the eastern states of India, while the demand for it was coming largely from northern and western states. The state governments, which were asked to pick the liquid oxygen from the assigned facilities, needed more tankers in service. However, India only had around 1200 cryogenic oxygen tankers at that time, which was insufficient for servicing the requirements.

The Government of India and many Indian states stepped up their efforts to rapidly overcome the demand-supply gap. It constituted an Inter-ministerial Empowered Group to streamline oxygen production and supply across the country. It launched the Oxygen Production Policy 2021. The Government of India, through the PM CARES Fund, and the state governments through their funds, foreign aids, CSR initiatives, private sector and PSU support acquired and installed about 4000 PSA plants, over 300,000 oxygen concentrators and another 300,000 oxygen cylinders in 734 district hospitals and thousands of sub-district hospitals, like Community Health Centers (CHCs), Health and Wellness Centers (HWCs) and Primary Health Centers (PHCs) across the country. This does not include the oxygen equipment established in private hospitals. As per the central government, India has over 2000 oxygen tankers with carrying capacity of about 30,000 MT of LMO by adding oxygen tankers to the fleet and by conversion of nitrogen and argon tankers to oxygen tankers.

Besides strengthening oxygen infrastructure, the government introduced several initiatives to ensure sustainable and rational use of oxygen, for example, setting up COVID-19 helpline numbers, establishing guidelines on flow rates, capping prices of liquid oxygen, gaseous oxygen, and concentrators. In other measures, the government established a National Consortium of Oxygen to enable supply of critical raw materials, setting up of small oxygen plants, PSA plants, concentrators, and ventilators, among other devices in the country. The government introduced several digital interphases, like Oxygen Digital Tracking System (ODTS), Oxygen Demand Aggregation System (ODAS) and OxyCare – Management Information System (OCMIS) for real-time monitoring of various oxygen devices.

While the Government of India was initiating many measures in partnership with state governments and other stakeholders to address the shortage of medical oxygen in the country, many state governments were taking initiatives to not only address the immediate demand for oxygen but also build a sustainable oxygen ecosystem to avoid a future shock. Some states, like...
Kerala and Odisha, had planned and were prepared with a surplus of oxygen. While other states, like Uttar Pradesh and Rajasthan, repurposed their nitrogen and argon tankers for the transportation of medical oxygen. Several large corporations engaged in petroleum refining, and steel production units were advised to convert industrial grade oxygen from their plants to medical grade oxygen and supply them to hospitals across the country. The Government of India airlifted tankers from other countries and ran Oxygen Express trains to transport liquid oxygen in quick time. Some states, like Delhi, imported cryogenic tankers and oxygen plants to augment their oxygen supplies. Other states such as Madhya Pradesh and Maharashtra offered incentives to private companies to set up cryogenic oxygen plants and manufacture cryogenic containers.

This section captures experience of five Indian states - Kerala, Maharashtra, Odisha, Delhi, and Rajasthan. Each state was affected by COVID-19 differently, had its unique oxygen ecosystem and had a distinctive response to oxygen management. Kerala has been recognized as a state that prepared well in advance and had a surplus of oxygen when the second wave of the pandemic hit the state. Maharashtra accounted for the highest number of COVID-19 cases and COVID-19 related deaths in the country, i.e., over 18% of all COVID-19 cases and nearly 28% of all COVID-19 deaths in India. Delhi, which is the seat of not only a state government but also the central government and an urban agglomeration, accounted for nearly five per cent of all COVID-19 cases and deaths in the country and experienced some of the most pressing challenges of a federal structure when responding to a crisis. Odisha, located in eastern India, has oxygen manufacturing units which were utilized to meet the spike in oxygen demand during the second wave. Rajasthan, a state in western India, did not experience as severe an impact of the second wave as states like Maharashtra, Delhi, and Kerala, but its oxygen infrastructure was challenged.

**Delhi**

The state of Delhi reported its first case of the COVID-19 on 2nd March 2020. From the beginning of the pandemic till 21st March 2022, 1,863,899 cases have been reported, (i.e., 0.11% of total population), with 26,147 coronavirus-related deaths and a case fatality rate (CFR) of 1.40%. This makes Delhi the 8th most-affected state in India in terms of total infections (absolute value), 12th the most-impacted state in India.

**Fig. 7: COVID-19 cases reported in Delhi**
Broadly, the state has experienced three waves of the pandemic so far. The first wave that started in March 2020 ended in July with peak cases at about 4000 per day. There have been two intermittent spikes between August 2020 and the end of 2020. The devastating second wave started in April 2021, and at its peak, the number of active cases was 28,000 cases per day. The state experienced its third wave in early 2022.

During the initial stages of the pandemic, around March 2020, the government set up the first committee to contain the infection spread by implementing measures such as closing public places and institutions and quarantining passengers, among others. Soon after, in June 2020, as the infection rates surged, the government formed a second committee to strengthen the healthcare infrastructure and assess the overall preparedness of hospitals with COVID-19 cases. In July 2020, there were reports of a COVID-19 war room being set up by the government to cover all aspects such as testing, bed strength, medical equipment, ambulance infrastructure, and containment zones.

**Delhi’s oxygen response**

At the peak of the second wave of COVID-19 between April and May 2021, Delhi became one of the worst-affected states in the country. As shortness of breath emerged as a major concern among COVID-19 patients, there was an inordinate spurt in demand for oxygen. The crisis led many hospitals to sound an alarm, and the state government placed an emergency request to the central government to increase the medical oxygen quota to narrow the growing gap between the demand and supply of medical oxygen in the state.

As the demand-supply gap further deepened, procuring medical oxygen became challenging. The state didn’t have its own oxygen manufacturing unit, and manufacturing units that were allocated for procuring medical oxygen were spread across seven states. Since the state didn’t have enough ISO cryogenic tanks to bring the medical oxygen to the health facilities, the situation became even more grim. As per reports, the state could maneuver only 17 tankers of approximately 20 metric tonnes (MT) each from refilling units operating within its territory. Besides supply chain challenges, there were also reports of oxygen supplies being stopped from reaching Delhi by adjoining states. In addition to this, as there were desperate calls from families of patients for hospital beds, oxygen, oxygen equipment and devices, malpractices, such as hoarding, black marketing, false price inflation, etc., flourished, leading to a further shortage of medical oxygen for those who were in dire need. Additionally, a separate argument states that there have been delays in placing orders for ISO cryogenic tanks and that a more pre-emptive approach in installing a Pressure Swing Adsorption (PSA) plant would have reduced the demand-supply gap.

To mitigate the above challenges, the state government formed a twenty-four member “Oxygen Audit Committee” to ensure continuous monitoring of the oxygen stocks and consumption in April 2021. Moreover, the Crime Branch launched an investigation against people hoarding and black-marketing oxygen equipment and essential medicines in Delhi. Additionally, by the end of April 2021, the Delhi Disaster Management Authority (DDMA) had directed the Delhi Police to provide a green corridor for vehicles carrying oxygen for supplies in hospitals. The DDMA also appointed two senior IAS officers to ensure smooth oxygen supply to all hospitals in the national capital.

In May 2021, as the infection rates plummeted, the government formed two committees. The first one is a thirteen-member committee to prepare an action plan for the next wave of COVID-19 after assessing the status and projected requirements of the health infrastructure such
as hospitals, oxygen plants, and drug supplies in the city. And the second one is an eight-member expert committee to devise a strategy for mitigation and management of the next wave, especially the preparation required for the specialized needs of children in the city. Both the committees were chaired by the Additional Chief Secretary (Power) and the Nodal Officer (COVID-19). Additionally, the government issued a list of 79 oxygen refilling centers for individuals in home isolation across the city. A web portal was launched on 6th May 2021 to streamline distribution of the life-saving gas to coronavirus patients in home isolation, non-COVID-19 hospitals, and nursing homes. In May 2021, the state inaugurated Integrated Command and Control Centre (ICCC). This center will provide information related to hospitals, oxygen, vaccination and other aspects of COVID management in the state and it will be collected, collated and analyzed on real time basis to help the government to take an informed decision.

Various countries, multi and bi-lateral agencies, philanthropic organizations, corporate entities, and individuals came forward to support the government in augmenting the oxygen supplies for COVID-19 patients, besides the aforementioned initiatives.

**Oxygen sources, production and procurement**

While Delhi’s medical oxygen requirements were primarily met by liquid medical oxygen (LMO) prior to the second wave of COVID-19, the oxygen crisis in the NCT propelled the state government to widen the sources of oxygen and improve oxygen storage capacity.

In the early days of the oxygen crisis in April 2021, the government of the NCT of Delhi was in negotiations with the central government to enhance the allocation of LMO to meet their estimated demand of 700 MT per day, which a day later was revised to 976 MT per day. The central government, which was already catering to requests from several other states, responded by increasing the supply to Delhi from 378 MT per day to 590 MT per day, in a staggered manner between 21st April 2021 and 1st May 2021.

Additionally, the Government of India had allocated and commissioned 26 PSA plants through Prime Minister’s Citizen Assistance and Relief in Emergency Situations (PM CARES) Fund in Delhi. Other than PM CARES, the Delhi State Government also acquired 51 PSA plants through CSR funding and another 20 PSA plants were provided by the Ministry of Petroleum and Gas, Foreign Aid and the Railway Board, taking the total number to 97 with a total oxygen production capacity of 116.06 MT per day. The state government reported in February 2022 that a total of 97 PSA plants had been commissioned so far. As most PSA plants were being installed in government hospitals, private hospitals did not show much interest in having an on-site oxygen generation plant on their hospital premises. Thus, the state government launched the Medical Oxygen Production Promotion Policy in 2021 to offer financial subsidies for setting up oxygen production plants in private hospitals.

In addition, the Medical Oxygen Production Promotion Policy also covered liquid oxygen (LOX) manufacturing facilities of a minimum of 50 metric tonnes (MT) capacity up to a total of 100 MT; non-captive oxygen generation plants of a minimum of 10 MT and a maximum of 50 MT capacity up to a total of 200 MT; captive oxygen generation plants of a minimum of 500 liters per-minute (LPM) (approx. 1 MT/day) capacity at hospitals and nursing homes up to a total capacity of 200 MT; acquisition of cryogenic tankers of a minimum capacity of 10 MT to exclusively ferry liquid medical oxygen (LMO) up to a total capacity of 500 MT; and the setup of liquid medical oxygen
storage tanks of a minimum 10 MT capacity up to a total capacity of 1000 MT. Along with the capital subsidy, the policy also provided power subsidies to the LOX generation plants and non-captive oxygen generation plants at INR 4 per unit consumed in the manufacturing process for the first five years.

According to government data released in December 2021, the national capital had a buffer stock of 442 MT of liquid medical oxygen. Furthermore, the state has commissioned two cryogenic bottling plants with a capacity of 12.5 MT each, which will be able to refill up to 1200 jumbo cylinders in a day.

In January 2022, the Delhi government assured that it now has an installed storage capacity of 996 MT of LMO, compared to about 730 MT in May 2021, when the second wave hit the state. The government also created a buffer reserve of 8 LMO tanks with a combined capacity of 442 MT. Additionally, cylinders with a total oxygen storage capacity of about 233 MT are with different hospitals, nursing homes, and COVID Care Centers across the state. Furthermore, the administration has 6000 “D-type” cylinders and an additional 9115 cylinders are with the Delhi Transport Corporation (DTC) as reserve supplies.

To ensure efficiency in oxygen procurement and logistics, quick response (QR) tagging of cylinders is being done, and telemetry devices have been installed in LMO tanks. Also, dashboards for PSA deployment, cylinder movement, and oxygen consumption were developed for real-time monitoring and tracking. As per the experts working with the Delhi state government, Ministry of Health & Family Welfare (MoHFW) has started installing Internet of Things (IoT) devices in all PM CARES plants in Delhi, which will be helpful in regularly sharing data to enable real-time tracking, reporting and decision making. At the time of writing this report, IoT had been installed in 10 PM CARES funded PSA oxygen plants.

Historically, cylinder refilling has been based on private contracts agreed upon between hospitals and vendors. However, during the second wave, the unexpected oxygen demand spike led to the government taking over the oxygen supply chain by cancelling all the previously existing contracts. Hospitals were then allocated vendors for sourcing oxygen by the state. Consumption of oxygen from LMO tanks and cylinders was being closely monitored by the state administration via its dashboard, which gives detailed information. Moreover, there are close to 7900 oxygen concentrators available in various Delhi hospitals.

Clinical management and rational use of oxygen

In early June 2020, The Delhi government issues a guideline for the clinical management of the COVID-19 patients in the state-run and private hospitals. In the first wave, oxygen provision at home was not recommended for patients under home isolation. Many facilities, including the LNJP Hospital, Rajiv Gandhi Super Specialty Hospital (RGSSH) and Guru Teg Bahadur Hospital (GTBH) were converted into dedicated COVID-19 hospitals, and private facilities were also told to reserve beds, to treat swelling number of patients.

The surge in infections specially during the second wave led to huge shortage of hospitals beds, ICU beds, and other oxygen equipment in the state. To address the rising cases, government worked towards increasing beds in hospital facilities with oxygen delivery equipment. State government informed that the bed capacity in hospitals had been increased to 25 106 during the second wave of COVID-19 in May 2021. As of December 2021, the government has arranged
for 30,000 oxygen beds including 10,000 ICU beds. Additionally, 6,800 ICU beds will be ready by February 2022, bringing the total number of ICU beds to around 17,000.

During the second wave, oxygen concentrator banks were created, with 200 oxygen concentrators available in each bank in every one of the 11 revenue districts of Delhi. In case patients under home isolation required oxygen, the Delhi government’s team ensured the oxygen concentrators would reach their homes within two hours. A technician also accompanied the team who demonstrated the functioning of oxygen concentrator to the family members. Patients who were not enrolled under home isolation could call 1031 and avail the facility.

To strengthen the oxygen delivery services, regular trainings of hospitals’ medical and paramedical staff were conducted on various aspects of oxygen therapy and management including biomedical equipment trainings. PATH played a key role in conducting these training exercises in the state.

While the Directorate General of Training under the Ministry of Skill Development and Entrepreneurship, Government of India, in collaboration with the Indian Institute of Technology, Kanpur and the Naval Dockyards, Visakhapatnam, has developed certified courses on operations and maintenance of respiratory equipment and PSA oxygen plant, many states, including Delhi, acknowledged that there was not enough time to build capacities for a whole new cadre of technicians to operate and manage the respiratory care equipment. The Delhi government, with assistance of PATH, has undertaken a series of virtual, classroom based and hands-on practical capacity strengthening initiatives for its public health systems, which include oxygen therapy, operation, maintenance and management of oxygen equipment and rational use of oxygen. The training modules have been developed with financial assistance of USAID, and the trainings are delivered with a mix of faculty from leading academic institutions and industry experts in the country.

**Collaborations**

As Delhi experienced unprecedented infection rates, multitude of collaborations between state and entities such as countries, bilateral and multilateral agencies, philanthropic organizations, corporates, and individuals was observed.

The Government of the NCT of Delhi collaborated with France to procure 21 PSA plants, and Thailand provided 8 oxygen tankers. The government received support from agencies such as the Indian Railways, which supplied a total of 2,434 MT of oxygen through the oxygen express, between 24th April and 5th May 2021. Similarly, the Indian Air Force supported by airlifting oxygen tankers from other countries and states.

Additionally, the India Army and Delhi Police supported immensely in bringing oxygen into Delhi and distributing it among hospitals. Officers of the Delhi government were stationed at the plant along with a team from the Delhi police to get the tankers filled in time and escorted back. A roster for every tanker was prepared to maximize the effectiveness of the trips. The supply coming by train needed to be decanted quickly and sent back for the next round. Imported from different countries, containers often have different nozzles, thus requiring entirely new sets of equipment to open them. Tankers arriving at Delhi Cantonment station could not be decanted there due to space constraints; therefore, a quick arrangement was made with the help of the Indian Army to use its ground for decanting. Once these tankers entered Delhi, Delhi Transport Corporation (DTC) bus drivers boarded the tankers as backup and police control room (PCR) of the Delhi police cleared the road for movement within the city.
Apart from the above-mentioned agencies, Indian Institute of Technology (IIT), Delhi provided strategic recommendations to the Government of NCT of Delhi for the improvement of oxygen infrastructure and supply chain management in Delhi in May 2021. Apart from that, IIT Delhi handed over 105 oxygen cylinders to the Government of the NCT of Delhi that will augment medical oxygen capacity in some of the COVID-care hospitals by 4765 LPM of oxygen.

Besides countries and government agencies, multilateral and bilateral organization such as USAID through its NISHTHA Project, Jhpiego and implementation agency, PATH provided support in installation of Oxygen generating plant (PSA) and augmenting liquid medical oxygen in the state.

Several corporate entities came forward to support the government with medical supplies. For instance, HCL supported the Delhi Government with 12,000 oxygen cylinders each with a capacity of 40 LPM and 21 PSA plants which generate 8800 LPM of oxygen, catering to around 1500 patients at a time.24 Similarly, Uttam Group installed 22 PSA oxygen generation plants in Delhi hospitals.25 The Delhi government in partnership with Ola Foundation and Give India had set up oxygen concentrator bank to cater to the home based patients requiring medical oxygen.26 Similarly, the Democracy People Foundation gave out 800 oxygen concentrators with 10 LPM capacity to hospitals and non-governmental organizations (NGOs) in Delhi under its initiative Mission Oxygen.27 Furthermore, a Rajya Sabha MP, in collaboration with TYCIA Foundation, launched auto-ambulances with an objective to ensure that mild symptomatic patients with oxygen levels between 85 to 90 can reach nearby hospitals in time. The services were ‘free-of-cost’ and were equipped with an oxygen cylinder and sanitizers.28

**Promising practices**

- Innovative approaches are effective in resource planning and management in health emergencies: Setting up of oxygen concentrator banks in every district of Delhi helped in managing the demand for oxygen in home care settings; thereby, reducing the hospital admission load in the state. Educating people on how to use the oxygen delivery equipment helped in optimizing oxygen use, preventing wastage of oxygen.

- Centralized supervision with dedicated resource can reduce inefficiencies in a health system: The state government ensured that every government hospital had one appointed doctor who functioned as Oxygen Nodal officer. In bigger government hospitals, an officer from the government administrative services was appointed for regular monitoring and coordination of oxygen demand forecast and supply.

**Lessons learned**

- Strengthening the oxygen ecosystem with a futuristic strategy: The healthcare system must have a variety of oxygen sources as it is a vital life-saving resource. Provisions for producing captive oxygen within health facilities can reduce the demand-supply gap and dependence on a single source of oxygen. A futuristic strategy for expanding oxygen production sources and strengthening the supply chain network can better prepare the state for any potential health emergency.

- Establishing a multi-stakeholder mechanism enables a robust oxygen ecosystem: The state had formed multi-member task forces to bring together different capabilities into one platform to respond to the pandemic. Cooperation from other departments, such as the Indian Air Force, Railways, and Police Department, eased the procurement
processes. Collaborations from other countries, development partners, and corporate entities were also essential, not only for financial and oxygen equipment support, but also for strategic advisories and the timely sharing of knowledge and resources, as they bring in global knowledge and help localize responses.

Using data for decision-making enables a more strategic and effective oxygen response, including developing a responsive procurement strategy, as the systematic assessments done at regular intervals in Member States provide a landscape of oxygen capabilities, data for planning and forecasting of oxygen demand, and the elastic oxygen supply chain.

References


Kerala

The 1st case of COVID-19 pandemic in the country was detected in Thrissur district of Kerala on 30th January 2020. Since then, Kerala has been one of worst hit COVID-19 states in the country, with 6,527,150 confirmed cases by 21st March 2022. With 67,339 deaths, Kerala’s mortality rate for COVID-19 stands at 1.03%. So far, the state has witnessed three surges of COVID-19 cases. The 1st wave started in March 2020 and lasted till June 2020 where despite the enormous number of cases the state managed to keep the mortality rate at a very low rate. The 1st wave was followed by some intermittent spikes in infections from August 2020 through October 2020 which gradually went down by January 2021. However, the state again saw an increase in cases with the onset of a more severe 2nd wave in April 2021. The 2nd wave, which continued till September 2021, was followed by a 3rd wave in early January 2022. Experts were of the view that this latest 3rd wave saw its peak in February 2022 as the cases are on a decline since.

Fig. 8: Kerala’s COVID-19 reported cases

Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic
Kerala’s oxygen response

Kerala has been one of the leading states in management of COVID-19 crisis in India. Despite accounting for the second largest number of COVID-19 cases in the country, it has managed to keep mortality rate among the lowest in the country. Even during the 2nd wave, when there was huge demand-supply mismatch for medical oxygen in several parts of the country, Kerala reported a surplus of medical oxygen stock. It transported medical oxygen on tankers to Goa, Karnataka, and Tamil Nadu, to meet the demands of the hospitals there, which were filling up with COVID-19 patients.

Yet, this was not always the case. Till 2019, i.e., the year before COVID-19 struck Kerala, the state was dependent heavily on Tamil Nadu and Karnataka for the regular supply of LMO. Earlier, in March 2020, the oxygen demand in Kerala was around 20–30 MT per day, both public and private institutions included. This consumption increased to 180 MT around the last week of May 2020, during the first wave of COVID-19. With the onset of COVID-19, the state leveraged its strong public health systems and civil administration infrastructure to provide all the necessary support to the COVID-19 management, including patient homecare, by ramping up the oxygen supply. Their efforts to reduce burdens on hospitals were successful and were also recognized by the World Health Organization (WHO) in July 2020 as a promising practice.

Early into the pandemic, the state government set up 24x7 oxygen war rooms at state level as well as in all the districts with a single nodal point for oxygen monitoring. The state war room had representatives from nine departments and agencies – Industries, Health & Family Welfare, Revenue, Disaster Management, Police, Transport, Petroleum & Explosive Safety Organization (PESO), Finance, and Information Technology (IT), with a 24x7 helpline and a clearly defined roles and responsibilities for improved coordination. The state created IT enabled platforms to map and track oxygen demand for both government and private health institutions.

Just before the onset of 2nd wave, the Government of Kerala and PESO took an initiative to increase medical oxygen production and ramp up medical oxygen storage in the state. Kerala produces its medical oxygen through various central and state Public Sector Undertakings (PSUs), i.e., industries owned and operated by the national or the state government. The major producers of oxygen – industrial and medical - in the state are Inox with 149 MT per day capacity, Kerala Minerals and Metals Ltd. (KMML) with 6 MT per day capacity, Cochin Shipyard with 5.45 MT per day capacity and Bharat Petroleum Corporation with 0.322 MT per day. In addition, Kerala has 11 air separation units (ASU) that produce around 44 MT of oxygen per day.

Oxygen sources, production and procurement

Kerala was able to predict the demand for medical oxygen and initiate actions incredibly 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 oxygen cylinders to medical oxygen cylinders. By April 2020, within four months of the first case of COVID-19 in the state, PESO had informed the oxygen manufacturers in the state to convert excess industrial oxygen to medical oxygen and industrial oxygen cylinders and non-toxic and non-flammable gas cylinders (nitrogen, helium, and argon) to medical oxygen cylinders.

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. 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 MT 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. The plant produced seven MT of 'waste' oxygen per day as a by-product of producing 63 MT of industrial oxygen (in gaseous form) and 70 MT of nitrogen per day. This wasted oxygen was then liquefied to use for medical purposes.4

Not relying only on LMO, the Department of Promotion of Industry and Internal Trade (DPPIT), under the Ministry of Commerce and Industries, Government of India, and the Central Medical Service Society, under the MoHFW, jointly floated tenders in October 2020 for PSA oxygen generation plants for the government hospitals to enable the public sector with oxygen generation capacity. Five of these PSA oxygen plants were set up in Kerala, at the medical college and hospitals in Thiruvananthapuram, Pariyaram, Kottayam, Thrissur, and Ernakulam. Through this initiative, the state added two additional suppliers of medical-grade oxygen—Praxair India Private Limited and KMML.

Around the same time, the Kerala State Disaster Management Authority also issued an order informing all persons and entities holding industrial gas cylinders to hand them over to the District Collectors, who were also the chairmen of the District Disaster Management Authorities, for conversion to medical oxygen cylinders. In March 2020, Kerala had 7000 type D cylinders with a cumulative storage capacity of around 70 MT. With a few auxiliary storage capacities, Kerala had a ready storage capacity of 99.39 MT of medical oxygen. By this single directive, Kerala mobilized an additional 7000 cylinders from industrial units and augmented its medical oxygen storage capacity, which led to an increase in the state’s ready storage capacity to 219 MT by April 2021.5 Out of this, 35 MT per day was used for COVID-19 care units and another 45 MT per day by non-COVID care units during the 2nd wave. The Government of Kerala also provided licenses and necessary support for strengthening infrastructure at 32 large hospitals in the state for storage of liquid oxygen, adding further storage capacity of 420 MT. The state also identified the Bharat Petroleum Corporation Limited’s Kochi 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 as hubs – two at Kochi, which is situated in the central part of the 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. These initiatives led to a combined storage capacity of 1325 MT of liquid oxygen in the state, of which Inox plant alone contributing 1000 MT, had the single largest storage capacity in Kerala.

Furthermore, to streamline and facilitate smooth distribution, transportation was subsidized, and several rules were introduced such as tankers to be run at full capacity with no idling time for any tanker. The running cost of oxygen tankers was also subsidized by the state. To improve and optimize oxygen supply chain, the state reconfigured the supply flow by creating a hub-and-spoke model, as mentioned above, that mapped the hospitals to its nearest suppliers. Hub and Spoke model optimized the oxygen supply chain and decanting capacity of LMO. Furthermore, to streamline and facilitate smooth distribution, transportation was subsidized, and several rules were introduced such as tankers to be run at full capacity with no idling time for any tanker. The running cost of oxygen tankers was also subsidized by the state. To improve and optimize oxygen supply chain,
the state reconfigured the supply flow by creating a hub-and-spoke model, as mentioned above, that mapped the hospitals to its nearest suppliers. Hub and Spoke model optimized the oxygen supply chain and decanting capacity of LMO.

**Clinical management and rational use of oxygen**

The state government adopted an oxygen wastage reduction strategy to aid or avoid 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. 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, and referred to one of the three categories of hospitals—first-line treatment centers, the second-line treatment centers and COVID-19 hospitals. To face the second wave, the state significantly increased the number of ICU beds, oxygenated beds, and ventilators across hospitals.

Further, 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 to properly arrest any leakage and the health care providers were oriented and trained on the optimal use of high-flow nasal cannulas in patients with acute hypoxemic respiratory failure.

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, oxygen cylinders and other equipment in both public and private health facilities with oxygen beds. The state government collects data real-time analyzing daily oxygen usage and weekly usage history and fed the evaluating to allocate requirement, assess wastage and reconfigure stock situation.

Leveraging the human resources capacities, Kerala dealt with oxygen needs for COVID-19 patients through its network of health workers at the grassroot level such as with accredited social health activists (ASHAs) and panchayat-level workers. It also minimized the oxygen wastage at the facility by developing clear protocols on the rational use of oxygen for the hospital staff.

**Collaborations**

Kerala collaborated with many inter-state private sector entities to fulfil its oxygen demand during COVID-19 pandemic. PESO was the key coordination department for medical oxygen supply and was responsible for monitoring and ensuring the supply of medical oxygen to all states and Union Territories. PESO, Kerala along with the state’s Department of Health & Family Welfare, has been monitoring the oxygen needs of the state since March 2020. They have been ramping up the medical oxygen supply in the state accordingly. The state government collaborated with Inox Air Products Private Limited, located in Kanjikode, to supply medical oxygen to all the big hospitals in the state, including medical college hospitals.

Additionally, the state partnered with KMML, a Kollam based public sector undertaking which manufactures Titanium Dioxide, to turn wasted oxygen to liquid medical oxygen to add on to the oxygen supply in the state.
Furthermore, Prana Air for Care, a crowdfunding campaign, was launched by Government Medical College Hospital, Thrissur, in September 2020, and the hospital was able to crowdsource pipeline connections for 600 beds, costing INR 12 000 per bed through this initiative. Furthermore, Prana Air for Care, a crowdfunding campaign, was launched by Government Medical College Hospital, Thrissur, in September 2020, and the hospital was able to crowdsource pipeline connections for 600 beds, costing INR 12 000 per bed through this initiative.9

Promising practices

- Leveraging all sources of oxygen and repurposing them for medical oxygen: The Government of Kerala, like the Government of India, put in place several key regulations to guide the production, storage and distribution of medical oxygen. Measures like the use of industrial oxygen producing units for 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.
- Establishing state and district oxygen war rooms for active monitoring of the ground situation: In anticipation of a worsening COVID-19 situation in the country, the Government of Kerala set up an ‘oxygen war room’ and ‘oxygen storage center’ in Thiruvananthapuram to cater to the demands of hospitals across the state. The centralized control room ensured that patients did not have to run around or contact different hospitals themselves to find beds. The teams at the control room could allocate beds based on patients’ need as ascertained by medical officers.
- ‘Oxygen nurses’ to monitor and control oxygen wastage: Deploying existing human resources to regularly monitor oxygen consumption could reduce oxygen wastage, like the use of “Oxygen Nurses” to ensure rational use of oxygen in hospitals was also undertaken by the Government of Kerala.
- Incentives/benefits provided to private sector for active participation in oxygen supply and management: Economic incentives were provided such as subsidized transportation charges for private sector and government funded transportation means. Regulatory incentives were also provided for speeding up installation of new oxygen production units by fast-tracking legal clearances which helped in rapidly increasing oxygen production.

Lessons learned

- Active monitoring of essential commodities, demand forecasting and planning for emergencies enables more effective response: Anticipating the oxygen crisis and developing an emergency plan at the start of the pandemic, had helped Kerala in managing its oxygen demand and reducing fatalities due to shortage of oxygen supply. Capturing and updating day-to-day oxygen-related data, from production to delivery to patients in the hospitals and use of digital tools, also helped in a data-driven supply of oxygen, which is essential for successfully overcoming shortages in oxygen supply. Regulation of oxygen ecosystem, like 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.
Widening the sources of oxygen production provides more elasticity to oxygen management: It is important to build multiple sources of oxygen supply, such as LMO, PSA plants, concentrators, and cylinders, along with 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.

Creating buffer capacities for oxygen is important, even in normal times: 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 using the hub and spoke model could help in further streamlining storage and demand-based supply of oxygen.

Controlling oxygen wastage is as important as increasing oxygen production: 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 done by Kerala, where they oriented and trained their healthcare human resources in oxygen therapy and rational use of oxygen.

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Maharashtra

The first case of the COVID-19 pandemic in Maharashtra was confirmed on 11th March 2020. The state as of 22nd March 2022, accounts for 7 872 512 cases including 7 723 468 recoveries. With 143 767 deaths, the fatality rate for COVID-19 in Maharashtra is 1.83% which is higher than the national average which is currently at 1.2%. The state has witnessed three waves of COVID-19 so
far. The first wave started in March 2020 and lasted till November 2020, followed by the second wave which was most severe of all and occurred between March 2021 and August 2021. Like many other states in India, Maharashtra experienced the most recent last wave from January 2022 through February 2022.

**Fig. 9: COVID-19 daily new cases in Maharashtra**

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**Maharashtra’s oxygen response**

Maharashtra has certainly been one of the worst affected states accounting for the largest share of all COVID-19 infections in the country. As the state grappled with rising COVID-19 cases, especially during the second wave, patients were struggling to find hospital beds and oxygen support. At the peak of second wave state’s daily demand touched 1800 MT which was much more than its daily production capacity of 1300 MT liquid medical oxygen; thus, leading to a demand-supply gap.

In terms of distribution of cases across the state, more than half of the COVID-19 cases in Maharashtra were being reported from four major cities, namely Mumbai, Thane, Pune and Nagpur. With a very high population density, Maharashtra’s Mumbai city which is also the state capital and often referred to as the financial capital of India, faced a higher positivity rate as compared to other parts of India. Moreover, the city faced severe shortage of beds and oxygen during the second wave as bed occupancy rates surged and took its toll on the city’s health infrastructure. However, the officials managed to control the situation in only a few days and Mumbai soon became self-sufficient in terms of meeting and sustaining its medical oxygen demand. Overall, the city had better manage its fight against the pandemic when compared to other metropolitan cities in India. This was acknowledged by the Prime Minister’s Office, the Supreme Court, the Bombay High Court (HC), as well as NITI Aayog.

During the pandemic, the Municipal Corporation of Greater Mumbai (MGCM) had taken many initiatives to ensure an uninterrupted supply of medical oxygen across the city. Soon after the first wave hit Maharashtra, in May 2020, a system was devised for judicious distribution of the vital gas, which is the popularly known as the ‘Mumbai oxygen model’. The model sought to provide an uninterrupted supply of medical oxygen to COVID-19 care facilities by adopting multipronged strategies of decentralizing the response, efficient resource management, leveraging of technology.
for rapid information dissemination, and real-time monitoring. Some of the stakeholders involved in this model were Municipal Corporation of Greater Mumbai (MGCM), Central Purchases Department, State COVID-19 Task Force, and Food and Drug Administration Office. In the Mumbai oxygen model, certain aspects are centralized (monitoring and management of hospital beds for COVID-19 care) with some services decentralized (COVID-19 war rooms). The centralized services include the following:

- The central dashboard, which provides a live status of bed availability across Mumbai hospitals. The SOP and policy formulations are also managed centrally.
- Central Purchases Department takes care of the large infrastructure needs and oxygen storage structures in different hospitals of MGCM.
- The SOPs and COVID-19 treatment protocols have been developed at the headquarters in discussion with the State COVID-19 Task Force members and the deans of medical colleges.

The Municipal Corporation of Greater Mumbai (MCGM) decentralized its central war room structure and created 24 peripheral control rooms in all the 24 wards for localized COVID-19 response. Each of these control rooms are equipped with ambulances, doctors, telephone operators and other basic infrastructure. With each ward responsible for about 700,000 people, this arrangement effectively distributes the massive logistical burden of the all-Mumbai central command center.

By deploying the model, Mumbai was able to ensure an uninterrupted supply of oxygen. Despite the disruptions in supplies, the total available stock of oxygen in the health facilities matched the actual consumption by the patients. The city’s death rate due to COVID-19 was at 0.6 percent, among the lowest in the world.

**Oxygen sources, production and procurement**

During the second wave, Maharashtra had a total daily capacity to produce 1300 MT oxygen, of which 40 per cent was diverted for industrial use while 60 per cent was utilized for medical purposes. However, in view of the shortage, the Maharashtra government had asked suppliers to ensure that the maximum supplies were directed towards hospitals. The state has two major suppliers - Inox Air Products and Linde India, with a combined daily manufacturing capacity of 800 MT. During the crisis, corporates with in-house oxygen manufacturing facilities, such as JSW Steel’s Mangaon facility in Pune, came forward to provide oxygen for hospitals. To continue uninterrupted production, the government also directed the Electricity Department to ensure continuous power supply for oxygen manufacturing plants.

Additionally, to bridge the demand supply mismatch during the second wave crisis, the government floated a global tender in April 2021 for 40,000 oxygen concentrators, 132 PSA (pressure swing adsorption) oxygen plants, 25,000 MT of liquid medical oxygen and 27 oxygen ISO tanks for storing oxygen as buffer stock for emergency use. A three-member committee was set up for the procurement of these quoted items, however no company had shown interest in supplying. Additionally, the railways formulated guidelines to allow transportation of liquid medical oxygen in cryogenic tankers through special “Oxygen Express” trains via roll on roll off (Ro-Ro) service, after Maharashtra and Madhya Pradesh made a request to meet the shortage of the gas used for COVID-19 patients in the state. A Ro-Ro service carrying three tankers loaded with Liquid Medical Oxygen (LMO) left Hapa in Gujarat and reached Kalamboli in Maharashtra on 26th April 2021.
Further, in anticipation of the third wave and the potential oxygen requirement, in May 2021, the State devised Mission Oxygen Swavalamban for increasing oxygen production in the state. The mission intended to incentivize the MSMEs for setting up of new LMO tanks and ASUs. Under this mission, state promoted investments by providing incentives and subsidies to the MSMEs with special focus on remote rural/tribal districts. The state set a target of augmenting oxygen production — needed in hospitals to treat severe cases — to 3000 metric tonnes (MT) a day. In the first phase of the mission, the target was to augment production by 2300MT within six months and the remaining 700 MT within two years. However, as of December 2021, production has increased only by 350 MT — that’s a shortfall of nearly 2000 MT of the required target.

Data from public health departments suggests that, as of November 2021, 268 PSA plants have been installed and 156 LMOs are used in ICUs and thigh oxygen dependency units. The installed LMO tanks can collectively store up to 2307.8MT of medical oxygen now while PSA plants can generate another 265MT.8

**Clinical management and rational use of oxygen**

Suffering from surge of infections and subsequent oxygen crisis, Maharashtra gave special attention to clinical management of oxygen, on using it rationally and efficiently. In this regard, the State undertook capacity building activities for the clinical teams on rational and efficient use of oxygen as well as for the bio medical engineers and oxygen system handlers on oxygen systems operations and maintenance. The state along with technical assistance from PATH prepared and disseminated a comprehensive Guidebook on medical oxygen management system which laid down the foundation for medical oxygen systems management and related devices in health facilities in the state. The guidebook, developed by the Department of Public Health, Government of Maharashtra with support from PATH (supported by USAID NISHTHA), in July 2021 provides guidance to make informed decisions about oxygen management system for optimal utilization of oxygen devices according to the requirement and the resources available in health facilities across Maharashtra. It also provides all the required technical details for effective, efficient, and flawless oxygen management at health facilities. The document serves as a ready reference book for administrators, state and district level officers, procurement personnel, planning officers, program managers, biomedical engineers, and medical and paramedical staff handling oxygen devices for the manufacturing-storage-transport-distribution purposes. Additionally, the guidebook also provides tools for proper functioning, maintenance, and safety of the oxygen equipment and oxygen audit.

Additionally, Maharashtra developed several state level guidelines and SOPs for operations and management of oxygen storage and delivery equipment such as LMOs, PSAs, concentrators, oxygen cylinders, etc. Communication material such as posters and leaflets related to dos and don’ts of oxygen handling and delivery were also developed for hospital administration and clinical staff and have been placed at various hospitals across the state.

Further, to identify leakages and irrational use of oxygen, the state also encouraged internal oxygen audits. The audit teams — comprising district collectors and principals of government-run engineering and polytechnic colleges and industrial training institutes — were set up in all districts. In May 2021, after reporting of a few safety related accidents, the audits identified that in majority of these medical units, there are leakages in oxygen ducts or in the valves of cylinders. It was also reported that oxygen audits and judicious use of oxygen helped large dedicated COVID-19 hospitals (DCH) in Pune and Pimpri Chinchwad, Maharashtra to save over 30 MT of life-saving gas per day.9
Additionally, as part of third-wave preparedness, the state planned to install various oxygen systems—Liquid medical oxygen (LMO) tanks, pressure swing adsorption (PSA) plants and oxygen concentrators—across various government health facilities. Moreover, the government focused on improving the availability of oxygen supply systems such as medical gas pipeline systems (MGPS), manifold systems and oxygen cylinders at the public health facilities. To run these newly installed oxygen systems, it is crucial to have trained and skilled staff, which however was a challenge for the health system. To overcome this challenge, Maharashtra, formed a training strategy in May 2021, to train existing Bio Medical Engineers as master trainers, which mainly included a mix of in person class-room trainings and practical demonstrations of the oxygen systems. The trainings were conducted from 28th June to 6th July 2021. While PATH supported the state on oxygen systems operations and maintenance training, JHPIEGO supported on clinical component of rational use of oxygen. The goal of this training was to disseminate appropriate knowledge to the facility level teams and support them for oxygen system management. This approach was the first of its kind in the country. Considering the need for more trainers at district level, the state also trained 37 Cold Chain Technicians, posted at district level as master trainers for oxygen systems management. This training was conducted in 2 batches of 18 and 19 participants each and was supported financially by PATH.

As per the MoHFW guidelines, state conducted capacity building programs on rational use of oxygen and also on the technical trainings of operations and maintenance of PSA plants. For the rational use of oxygen, state nominated and trained around 72 stewards as master trainers from all the districts across the state. These stewards were trained virtually in December 2021. The trained stewards further conducted trainings of clinical teams in all the facilities across the state. For operations and maintenance of PSA plants, MoHFW in coordination with Ministry of Skill Development (MoSD) and Regional Directorate of Skill Development and Entrepreneurship (RDSDE) conducted multiple rounds of 10-hour trainings of the facility staff on operations and maintenance of PSA plants. In Maharashtra 4 rounds of trainings were conducted from 15th November 2021 to 15th January 2022 to train about 900+ hospital staff.

It was seen that the unprecedented demand for Liquid Medical Oxygen (LMO) was aggravated by shortage of adequately skilled LMO drivers trained in handling and transportation of Liquid Medical Oxygen. To combat this challenge, Logistics Skill Council, working collaboratively with National Skill Development Corporation (NSDC), under the guidance of Ministry of Skill Development and Entrepreneurship; and Ministry of Commerce, Logistics Division, has launched training of drivers for handling of hazardous chemicals and liquid oxygen. Involving multiple stakeholders such as LMO Manufacturers, LMO Transporters, Indian Chemical Council, the training program aims to create a pool of 2800 drivers to transport LMO in oxygen tankers, which is the most important commodity for medical management of COVID-19 across hospitals.

Furthermore, Maharashtra Government medical colleges and hospitals (GMCHs) had dedicated ‘Oxygen Nurses’ for clinical management and efficient use of oxygen. These nurses checked the oxygen usage regularly and took relevant steps such as turning off the flowmeters when the patients are not using oxygen and reducing the oxygen flow when oxygen saturation levels improved, to prevent oxygen wastage. This is an ongoing practice now that the nurses continue to do when there are COVID-19 patients.
Collaborations

The state of Maharashtra partnered with the private sector to reinforce its fight against the COVID-19 pandemic. Hindustan Unilever Limited (HUL) provided RT-PCR testing kits and other supplies including pulse oximeters, PPE kits, masks, oxygen concentrators and 29 ventilators to government hospitals in Maharashtra. To augment the quarantine infrastructure as required by the government, HUL tied up with Apollo Hospitals, State Bank of India, Oyo, Lemon Tree and others to create isolation facilities equipped with medical supervision to help reduce the burden on hospitals while providing acute care for patients in need. Another private sector partner, Honeywell, along with its NGO partners, and in consultation with the state government, established a COVID-19 critical care center equipped with beds, oxygen, PPE kits and other basic medical infrastructure. 10

In terms of respiratory care, the central and state government ensured adequate planning, procurement and management of PSA plants, ventilators, concentrators, and other respiratory care equipment along with capacity building of healthcare workers to ensure rational use of medical oxygen. 68 PSA plants were procured through PM CARES fund, 19 through PSUs and 270 through the state government. PATH, an international not-for-profit organization with a decade of experience in respiratory care management, was identified to establish and function as the Technical Support Unit for Oxygen to the state.

In addition, in an accelerated effort to expand access to oxygen care, partners came forward to support the growing demand of Oxygen. USAID provided 300 oxygen concentrators while UNICEF provided capacity building support across the state. Similarly, 112 PSA plants were procured through CSR funding from companies such as Google.org, NSE Foundation, Reliance Foundation, Tata Trusts etc. Groups like Mahagenco, Mumbai Metropolitan Region Development Authority, Maharashtra State Road Development Corporation, Maharashtra State Electricity Distribution Company Limited, MLA funds, MP Funds, Mayor Funds, ZP CESS etc. were among others who supported the state amidst the oxygen crisis and contributed around 55 PSA plants.

Promising practices

- Monitoring of oxygen consumption by dedicated taskforce to ensure rational use of oxygen and reduce wastage: The Government medical colleges and hospitals (GMCHs) in Maharashtra had dedicated ‘Oxygen Nurses’ with one nurse for about 50 patients. These Oxygen nurses checked the oxygen usage by turning off the flowmeters or reducing the flow when patients removed the mask while using the washroom, eating, or talking on the phone and also by reducing the oxygen flow when oxygen saturation levels improved. These nurses monitored the requirement of oxygen every 2–4 hours, round the clock and had the discretion to increase or decrease the flow depending on the patients’ needs.

- Deploying innovative strategies to ensure effective management of Oxygen like the Mumbai Oxygen Model: While COVID-19 response has been decentralized to district levels across many states, the Mumbai Oxygen Model demonstrates the added value of decentralizing COVID-19 war rooms to sub city or ward levels for large and populous cities like Mumbai; centralized management of oxygen beds, even for private hospitals, and actively regulating its allotments based on identified need and availability ensures better care for those who need hospitalization the most; establishment of buffer reserves for medical oxygen and mapping the depots to the nearest facilities is a good measure to enable an uninterrupted supply of oxygen to health facilities during peak surges;
vital to track the oxygen demand and supply sources in real time to better manage the medical oxygen distribution; and deploying qualified resources, such as engineers, to track oxygen consumption and demand would contribute to preventing oxygen wastage, enable more effective deployment of the oxygen resources, and enhance judicious use of medical oxygen.

- Leveraging the existing technical HR to operate and maintain Oxygen Infrastructure: There are very few trained persons in the public health system, especially at district and sub-district level facilities, who understand the complexity of integration and maintenance of the newly deployed oxygen systems and know how to manage them. To address this gap, the state government decided to strengthen capacities of the biomedical engineers (BMEs) working with the Health Equipment Maintenance and Repair (HEMR) division of the state’s health department. The BMEs and other technicians of the HEMR Division in the state have been involved in managing, operating and maintaining the Vaccine Cold Chain management systems. Engaging BMEs who manage vaccine cold chains to manage oxygen systems is an approach that had never been attempted before in the country – this was the first such initiative of its kind.

- A district level approach, to decentralize the oxygen management: Maharashtra has also demonstrated the sub-city level approach that is health system driven and optimally utilizes the available resources. For example, Nandurbar, a tribal district in Maharashtra that anticipated its demand well in advance and made arrangements accordingly that included adequate ambulances, ventilators, beds, oxygen plants, vaccines, medicines, trained medical staff among others. They also appointed oxygen nurses for optimum utilization of oxygen cylinders and prevention of oxygen wastage in June 2020. The success of this intervention resulted in multiple districts being oxygen surplus, which could then be shared with the neighboring districts. The success story of Nandurbar led to the implementation of this practice across the state of Maharashtra in April 2021.

**Lessons learned**

- Decentralized decision-making enables improve emergency response: It is a crucial step towards strengthening, especially large, densely populated cities in the fight against COVID-19. This approach divides the workload on the centralized team through formulation of multiple teams which consist of various stakeholders, thereby efficiently handling the increasing cases. The “Mumbai model” has showcased that optimum utilization of resources through inventory management, decentralization of responsibilities and response, and a robust real-time monitoring system can help overcome disasters.

- Regular monitoring and tracking the demand and supply is essential to ensure seamless supplies: It is vital to track the oxygen demand and supply sources in real-time to better manage the medical oxygen distribution. For example, in Mumbai, the war rooms tracked oxygen tankers and staff was stationed at oxygen cylinder refilling stations. A proper system was put in place to monitor and manage oxygen supply and usage. This would also ensure buffer reserves for medical oxygen to contribute to an uninterrupted supply of oxygen to health facilities during peak surges.

- Capacity strengthening of staff is critical to ensure rational use of oxygen: Judicious use of medical oxygen and prevention of wastage through leakages is critical to sustain the oxygen reserves. This can be ensured by training the workforce on various
Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic

aspects of oxygen management, like oxygen therapy, operation and maintenance of oxygen equipment, and oxygen supply chain management. The Maharashtra experience shows that a mix of virtual training, classroom training, live demonstrations and on-site mentoring is ideal for sustainable capacity enhancement.

References

Odisha

Odisha confirmed its first case of COVID-19 pandemic in mid-March 2020. Until 22nd March 2022, Odisha has reported 1,287,225 COVID-19 cases including 1,277,497 recoveries. With 9,116 deaths in the state, COVID-19 case fatality rate (CFR) stands at 0.7%. The state has so far witnessed three different waves of the pandemic. The state witnessed its first wave between July and November 2020 which peaked around late September 2020 with over 34,000 active cases being reported in a day (~4,000 new cases a day). With a few months of interval, the second wave which started in April 2021 and ebbed in August 2021, was three times more severe than the first one with about 100,000 active cases being reported in a day (~11,600 new cases a day) around mid-May 2021. The state experienced a third wave of COVID-19 from January 2022 to February 2022 which was not as severe as the second wave both in terms of oxygen requirement and mortality rate.

Fig. 10: Daily new cases of COVID-19 in Odisha, India

Odisha’s oxygen response

Odisha is one of the few states in India that had a surplus of oxygen owing to the presence of multiple industrial oxygen plants. Moreover, during the peak of the second wave, the state reported a demand of 70 MT/day against the production capacity of 350 MT/day. In addition, in the wake of an elevated oxygen demand due to rising COVID-19 cases in May 2021, Odisha government enforced Essential Services Maintenance Act (ESMA) on the production, distribution and transportation of liquid oxygen for six months. Furthermore, to tackle the COVID-19 crisis, in April 2021 the Government of Odisha set up a dedicated Oxygen Task Force to manage the production, storage, filling, transportation, and overall management of Oxygen. This task force was chaired by Principal Advisor to the Chief Minister and had nine members which included the Principal Secretary of Industries Department, Additional Chief Secretary Health, Secretary of Works Department, MD Odisha State Medical Corporation Limited (OSMCL) and Director of Industries.

One of the first key decisions taken by the task force in its first meeting was to convert industrial oxygen produced by the large steel plants into medical oxygen. Odisha has about 70
large steel manufacturing plants at vital locations that use industrial oxygen. Of the many steel manufacturers present in the state, a few steel majors like Tata and Jindal, rose to the challenge by curtailing their production to provide as much as 5 to 10 percent of their industrial oxygen requirement for medical use.\(^6\)

In the month of July 2021, the state also constituted a State Technical support unit (State oxygen TSU) for ensuring fast tracking of PSA plants and LMO installation along with ensuring rational use of oxygen at facility level by taking up capacity building related to oxygen management. This TSU has been established by PATH with support from USAID NISHTHA. Furthermore, in April 2021, the state government reported that procurement had been initiated for setting up LMO storage tanks at 15 locations, including at Veer Surendra Sai Institute of Medical Sciences and Research, Burla. The government had also begun obtaining 8000 D type cylinders and 10 000 B type cylinders.

**Oxygen sources, production and procurement**

Prior to COVID-19 pandemic, liquid oxygen plants were the major manufacturing source and cylinders were the main mode of delivery in the state. At the start of second wave, Odisha’s oxygen consumption was found to be around 26 MT in a day against the LMO production capacity of 375 MT/day (demand calculated at the start of second wave). Moreover, the state’s storage capacity through oxygen cylinders was about 130 MT.\(^7\)

As part of its health system strengthening effort for smooth delivery of medical oxygen to patients, since October 2020, the state has planned to ramp up its medical oxygen availability by setting up of PSA oxygen generation plants and LMO storage units at health facility level. A total of 82 new PSA plants were set up majorly in District Headquarter Hospitals (DHHs) and Sub District Hospitals (SDHs) across its 30 districts, with central and state funding as well as through CSR initiatives and 3 PSA plants are in process of installation. Also total 44 LMO tanks are being planned to be installed at health facility level using State funding.

To boost the storage capacity and strengthen oxygen supply chain, in the month of April 2021, the Odisha State Medical Corporation (OSMCL) floated tenders for procurement of 18 000 more cylinders to ensure regular and reliable supply of medical oxygen at the COVID-19 care Centers located in rural areas. The state government also urged the national government to supply 10 000 jumbo (D type) cylinders, 20 000 B-type cylinders, five cryogenic oxygen tanks of 10 000 liter capacity each, 30 000 flow meters and 25 000 adult and 5000 pediatric masks. And procured 5000 oxygen concentrators, after this procurement the state was equipped with total 10 214 Oxygen concentrators including 5 LPM and 10LPM both.

To ensure smooth and safe logistics of oxygen cylinders, the Police Department was given the responsibility of logistics and transportation of medical oxygen. Additional Director General (Law and Order) was appointed as the Nodal Officer to supervise the logistics of medical oxygen. Medical oxygen tankers were escorted by the Odisha Police to ensure unhindered movement from the loading point up to state boundary limits. The Police Department was also directed to coordinate with their railway counterparts. Moreover, at the start of second wave green corridors were set up for transportation of medical oxygen. All the routes were mapped and routes with bottleneck areas were outlined. Arrangements were also made to ensure real time monitoring and tracking of all the vehicles carrying medical oxygen by enabling them with GPS tracking systems.
In addition, each health facility was mapped with the nearest refilling station. All the empty cylinders in a health facility were collected on daily basis and sent to the nearest refilling station to which the facility was tagged in a hired truck. The drug inspector of the district was appointed in-charge of ensuring that the cylinders are refilled and sent to facilities in time. To ensure that the oxygen filling units in the districts continue operations without disruption in anticipation of power outage, dedicated diesel generator (DG) power units were mobilized and installed. Furthermore, dedicated Executive Engineer and electricians were assigned to the units to always ensure seamless operations of the DG power units.

In the month of May for monitoring and surveillance of oxygen delivery, a central control room was established at the Industries Department to coordinate with the district-level teams and generate reports, observe trends, and create projections using online oxygen dashboard. This dedicated oxygen dashboard was created to get real-time updates on the oxygen consumption, refilling, and movement scenario across the entire State. The dashboard was linked to active case load; thus, enabling the distribution of oxygen cylinders amongst districts on data driven, need-based assessment. Another control room was established at Odisha State Disaster Management Authority (OSDMA) to receive and respond to emergency calls from the districts on their oxygen requirements which were being met by diverting oxygen cylinders.

In Odisha, one of the key unforeseen challenges during the mid of second wave pandemic was the arrival of cyclone “Yaas”, especially in the highly affected districts of Balasore, Bhadrak and Mayurbhanj. To counter the impact of the cyclone, additional oxygen cylinders were diverted to COVID Health Centers in these highly affected districts.

Clinical management and rational use of oxygen

Although the state had surplus oxygen production to tackle the oxygen demand during the COVID-19 pandemic, it took every step possible to ensure efficient delivery of oxygen to the patient. At the start of second wave, the state government enhanced the bed capacity to 20,347 which included COVID-19 Care Centers beds with oxygen support. During the second wave, doorstep delivery services for Oxygen Concentrators was also started by the state. Oxygen concentrators were booked online through dashboard and delivered at the doorstep of the patient. State Govt. issued the SOP on rational use of Oxygen during April 2021. In addition to this USAID NISHTHA partner PATH team provided virtual and onsite trainings to facility staffs such as PSA plant operators, gas technician on operation and maintenance on PSA plants, and training also provided to doctors, staff nurses and other paramedic staff on rational use of medical oxygen. At state level a two-day virtual training was conduct for all Hospital managers across the on basics of oxygen sources and rational use of medical oxygen in the month of December 2021, State has arranged an orientation on Oxygen demand aggregated system (ODAS) portal for all senior district officials including CDM&PHOs with support from USAID NISHTHA partner PATH team. International and National guidelines were revised and contextualized as per the state’s requirement. State has issued 42 Guidelines on COVID-19 management along with lock down measures as required during May 2020- Jan 2022. A total of 20 COVID training capsules including one on medical oxygen therapy have been uploaded in State website (https://health.odisha.gov.in/tcbm.html) in addition to various training materials on COVID management. Apart from these State govt. has also issued four guidelines related to Oxygen management with guidance notes for district and health facilities.
Collaborations

Odisha took the corporate partnership route as an integral part of its response to the calamitous oxygen crisis. An effective and at-scale Public-Private-Partnership (PPP) model for disaster management was developed by the state during the second wave. It got support from many large steel industries like Arcelor Mittal to enhance its oxygen storage, transportation and distribution capacity. In August 2021, ArcelorMittal provided the state with 10,000 cylinders that were shipped from China via air transport. The shipment was jointly organized by Arcelor Mittal and the Industrial Promotion and Investment Corporation of Odisha Limited (IPICOL).

Furthermore, as part of the interstate collaboration, Odisha sent medical oxygen to oxygen deficient states grappling with COVID-19 induced oxygen crisis. By June 2021, Odisha managed to send around 28,000 MT of liquid oxygen to 17 states in the country.

Promising practices

- An effective and at-scale Public-Private-Partnership (PPP) model for COVID-19 and Oxygen management: The state of Odisha has vast experience of managing natural disasters and when the delta variant ravaged the country with patients desperately seeking medical oxygen, the government embarked on a PPP model to tide over the crisis. A task force for oxygen management was set up by the government that included the major steel industry representatives. The steel industry produces a huge amount of captive industrial oxygen in the state. As the demand for liquid medical oxygen (LMO) increased, these industries converted up to 10 per cent of their industrial oxygen into LMO and supplied it to the states who need it the most. The state government created green corridors and provided police escorts to ensure that there was zero interruption in the movement of oxygen in the state. Some other steel companies, in collaboration with the Industrial Promotion and Investment Corporation of Odisha Limited (IPICOL), came on board and airlifted 10,000 cylinders from China. A dedicated oxygen dashboard was created to get real-time updates on the oxygen consumption, refiling, and movement scenarios across the entire state. Apart from the private players, many public sector majors like Odisha Hydro Power, Odisha Mining Corporation, Indian Oil, and Mahanadi Coal Field, have also extended a helping hand, bearing the cost of hospitals as part of their CSR initiative.

- Building a network of oxygen devices and services to ensure their availability during emergency: Odisha has been able to successfully supply oxygen devices to the patients through various initiatives such as doorstep oxygen concentrators, rental services for oxygen cylinders and dedicated helpline for assistance with refilling oxygen cylinders at government approved rates. All these services were provided either through a dashboard or a dedicated helpline.

Lessons learned

- Early detection, proactive planning and management of the crisis allow more response time to mitigate the impact: Early detection, proactive planning and management of the crisis allow more response time to mitigate the impact. The state government declared the pandemic a health emergency well in advance. This acknowledgement of the communicable disease helped the state with early detection and surveillance and gave more time to respond, leading to a lesser loss of human lives.
Efficient interdepartmental coordination and government stewardship enabled undisturbed oxygen supply: The oxygen taskforce set up by the government ensures that all the departments and partners involved in the supply chain of medical oxygen are working in tandem. The coordination between these entities was strengthened further by the creation of a web application that tracked the demand for, and movement of, oxygen tankers, as well as provided assistance in refilling empty cylinders. The state also deployed the police department to create a green corridor for the seamless movement of medical oxygen from production sites to the health facilities.

In-person capacity building and trainings on oxygen equipment are more effective than virtual trainings: A hands-on demonstration of using or practicing oxygen equipment is more effective as supervision and interaction with the trainer are required. It’s extremely difficult for trainers to replicate the same level of interaction and relationship in a virtual environment. Virtual training must be augmented with hands-on training sessions, learning videos for regular reference, and, wherever possible, classroom training and demonstrations.

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Rajasthan

COVID-19 made its appearance in Rajasthan on 2nd March 2020, when the state reported the first case. Since then and until 21st March 2022, Rajasthan has recorded 1 282 657 cases of COVID-19 and 9551 COVID-19 related deaths. As a result, the case fatality rate (CFR) of Rajasthan is 0.75%, one of the lowest in the country. Like the rest of Indian states, Rajasthan has witnessed three surges of COVID-19. The first wave was long, lasting nine months. It began in March 2020 and peaked at the end of November 2020, before subsiding in mid-January 2021. The second wave, which began in early March 2021 and rapidly surged to its peak in early May 2021, with over 18 200 daily new infections, was the most devastating one. Led by Delta variant of the novel
coronavirus (SARS-CoV-2), the second wave in Rajasthan, lasted for three months till end of June 2021. After a lull of six months, the COVID-19 cases witnessed another surge in Rajasthan by the end of December 2021. The third wave was shorter and milder, with lower peak and lower fatalities than the second wave.

Fig. 11: COVID-19 daily new cases in Maharashtra

Rajasthan’s oxygen response

During the first wave of COVID-19, when the peak caseload in Rajasthan was around 28 000 active cases, the peak daily consumption of oxygen through D-type oxygen cylinders was 170 MT per day (MTPD) in the state, which the state could manage with existing resources. However, during the second wave, when the peak active caseload was over 200 000 active cases, the demand for oxygen in Rajasthan had touched 625 MTPD against a supply of 366 MTPD. The highest daily consumption of oxygen recorded during the second wave in Rajasthan was 404 MT on 16th May 2021.

The oxygen shortage was reported all-around. Rajasthan was under-prepared to meet the sudden rise of oxygen demand, as it had less allocation of oxygen from the Government of India. Even when oxygen was available, although short of the projected demand, the state did not have adequate oxygen tankers to transport the liquid medical oxygen from the distantly located liquid oxygen manufacturers to the health facilities. In many cases, the hospital did not have sufficient storage devices to stock oxygen. There were many reported incidents of oxygen suppliers not honoring the agreement to supply oxygen to hospitals and diverting the oxygen to individuals and households at premium pricing through grey market.

In response to the growing demand for oxygen in the state, Rajasthan established a State Level Oxygen Management Committee (SLOMC) in April 2021 with the Secretary, Industries, as its chair. The committee had the State Nodal Officer for Oxygen and Assistant Nodal Officers from different departments as its members. The committee formed various subgroups, each assigned a role in oxygen management, like coordination with the national government for allocation of oxygen from plants, management and tracking of tankers for lifting of oxygen, management of Liquid Medical Oxygen (LMO) tanks, coordinating installation and commissioning of PSA plants in the state, formation of Control room at state and district levels, among others.
While, on one hand, the state worked on resetting the disrupted oxygen supply chain, on the other hand, the state rapidly expanded its oxygen supported beds. From around 7,500 oxygen supported beds in 376 hospitals in the state in March 2020, the state government increased oxygen beds to nearly 14,400 by late April 2021. As of March 2022, the state has over 20,260 oxygen beds across 758 hospitals in the state. Likewise, the number of ICU beds were increased to over 4,470 by end of April 2021 and to over 5,200 by March 2022 in the state.3,4

Oxygen sources, production and procurement

Rajasthan depended primarily on LMO as the source of medical oxygen before the COVID-19 pandemic. While some tertiary hospitals across the state have LMO storage tanks, many of the hospitals depend on oxygen cylinders, which are supplied by private agencies (also referred to as LMO-based refillers) that purchase the LMO, convert it to gaseous oxygen and fill the cylinders at the refilling stations. Rajasthan, as on August 2020, had 30 Air Separation Units (ASUs), comprising of LMO units, LMO based refillers and Air Separation Units (ASUs) of different capacities in the state. The individual capacity and the cumulative oxygen production capacity of these plants was around 180 MT. Rajasthan government, in order to increase private sector participation in mitigating oxygen crisis, announced a special package with various incentives and facilities in April 2021 for the setting up of medical oxygen production plants. To get the advantage of the package, a private entity was expected to invest at least Rs 10 million and had to ensure that the plant was functional by the end of September 2021.

After the Government of India centralized the oxygen logistics management from large liquid medical oxygen manufacturers, Rajasthan was provided an increased allocation of LMO by the Government of India from Liquid Medical Oxygen Plants like INOX from Bhiwadi, Alwar, Jamnagar etc. starting with 65 MT on 14th April 2021, to rapidly increasing it to 395 MT by 17th May 2021, from five plants, of which four were outside Rajasthan. When the responsibility of lifting the allocated oxygen from the plants was assigned to the state, the SLOMC formed a sub-group to coordinate and maintain record of LMO received at state level. Even at the peak allocation levels, Rajasthan received only four percent of the total 9,540 MT of medical oxygen the Government of India was allocating to states and Union Territories.

When the supply was initiated from 18th April 2021, the state had only seven oxygen tankers, with a carrying capacity of 57.8 MT. The State’s Transport Department acquired all the oxygen tankers available in the state and converted the nitrogen tankers to oxygen tankers through purging and support from PESO to make arrangements for lifting the allocated LMO. This action also led to a momentary conflict when one of the oxygen suppliers, INOX, alleged that some of its oxygen tankers were seized by Rajasthan authorities and took the matter to court. After mediation by the central government authorities and the court, the Rajasthan government assured of not obstructing the supply of medical oxygen going out of the state. During the peak period, the state acquired 57 tankers with a total capacity of transporting 786 MT of LMO.

The state had 56 oxygen storage tanks, including LMO storage tanks in government and private hospitals, Liquid Argon storage tanks (converted for LMO storage), liquid oxygen storage at ASUs, with a total capacity of 1080 kL (~1232 MT) and 26,856 D-type cylinder filling capacity (~260 MT) per day.
Learning from its experience of not relying solely on a single source of oxygen, the state government diversified its oxygen sources to Pressure Swing Adsorption (PSA) oxygen plants and oxygen concentrators. Before the COVID-19 pandemic, none of the public sector hospitals had PSA plants. Rajasthan acquired 21 PSA plants through Public Sector Undertakings (PSUs), three (3) through foreign aid, 161 PSA plants through state funds and CSR initiatives, in addition to 51 plants through PM CARES, taking the total number of PSA plants in the government hospitals to 236. The cumulative capacity of the plants is not available in public domain. The state is planning to increase the total PSA plants from 236 to 450 in the near future, which will have a cumulative capacity to support 36 000 oxygen cylinders (~350 MT) per day.

As part of its strategy to maintain adequate oxygen supply to the health facilities, Rajasthan acquired and deployed over 50 000 oxygen concentrators (OCs) in the state. As LMO storage and PSA plants required time to procure, install, train and operate, besides them being centrally managed, oxygen concentrators were the best of the options to respond to the spike in oxygen demand. They could be procured locally by the state and were easy to deploy and operate. The Rajasthan government provided 6–7 units in each Primary Health Center and around 10 units in each Community Health Center across the state, besides deploying them at higher level facilities like District Hospitals etc. based on expressed need. Rajasthan also established state run Oxygen Concentrator Banks across all the districts in the state to support home based care. The state government has placed over 500 units across the oxygen concentrator banks in Jaipur, around 500 units at seven divisional headquarters and around 400 units at each of the 33-district headquarters. These oxygen concentrator banks are accessible through helpline number or via District Drug Warehouse. The beneficiary can take the oxygen concentrator on rentals, with a security deposit on refundable basis.

Rajasthan government has also deployed E-Upkaran, a web application of the Medical, Health and Family Welfare Department of the state that helps manage and maintain equipment and instruments on one platform. It has details of all the OCs available in the state and facilitates repair and maintenance of oxygen concentrators state-wide. Rajasthan government has also deployed E-Upkaran, a web application of the Medical, Health and Family Welfare Department of the state that helps manage and maintain equipment and instruments on one platform. It has details of all the OCs available in the state and facilitates repair and maintenance of oxygen concentrators state-wide.

Clinical management and rational use of oxygen

As the number of hospitalizations increased during the second wave, the consumption of oxygen also increased in proportion to the active cases. With it, the state started monitoring the consumption of oxygen in all hospitals based on the number of patients admitted. Each district was encouraged to form an audit committee, which comprised of anesthetists and administrative officers of the hospitals of the district. This committee was assigned the task of monitoring daily oxygen consumption in the hospitals. All the hospitals across the state were advised to daily provide patient wise details on oxygen therapy, ICU beds and ICU with ventilator beds in the state’s COVID-19 portal, along with details of total consumption of oxygen. The hospitals showing higher consumption of oxygen were selected for audit. The members visited the hospitals and observed the patients on Oxygen beds, ICU beds and ICU beds with ventilators and, based on the guideline from the Government of India, assessed whether oxygen was being administered judiciously through various oxygen
delivery devices and if the patients’ oxygen saturation levels were being maintained. The health facilities which were not using oxygen judiciously were instructed to do so as per the guidelines. Apart from this, regular monitoring of oxygen consumption of all Medical Colleges of the state was done based on oxygen consumption and availability at 9.00 am every day. Their oxygen supply and consumption were also monitored regularly at 8-hour intervals and any issues that occurred were reported to the higher authorities. There is no evidence in public domain on which facilities were audited since the state and district oxygen audit committees were established.

An excellent example of rational use of oxygen is the 430-bedded Mahatma Gandhi District Hospital in Bhilwara. While their oxygen generating plant produces oxygen for 100 cylinders every day, they have also continued supply of cylinders from private vendors to ensure adequate stock of oxygen for the patients. Besides producing and storing oxygen, the hospital has put spotlight on saving oxygen. They have appointed a dedicated team of three doctors and three technicians who monitor the oxygen points of the centralized lines and the cylinders all through the day, every day to ensure no leakage and wastage. Based on the past oxygen consumption pattern, the hospital has benchmarked maximum and minimum oxygen consumption for every patient, to decide the desired oxygen flow. Serious patients are prioritized over patients whose oxygen saturation levels are around 93–94%.

The oxygen audits resulted in recommendations to the state government to strengthen the oxygen delivery services and conduct regular trainings of hospitals’ medical and paramedical staff. The State Institute of Health and Family Welfare (SIHFW) developed training content on oxygen management and trained various cadres of health workers in 2020 and 2021. Between October 2020 and December 2021, SIHFW organized several rounds of trainings and trainings of trainers (TOTs) on Oxygen Therapy and Operating Oxygen Concentrator for medical officers and nursing staff. The technical sessions in these trainings were taken by expert faculties from Sawai Man Singh Medical College, Rajasthan University of Health Sciences, nodal officers of Department of Medical and Health Services, representatives of Development Partners, like WHO and UNICEF and faculty of SIHFW. As part of the initiative, SIHFW used Virtual Conference for maximum participation. Multiple participants from across Rajasthan have been trained to become the Master Trainers. SIHFW has uploaded the training related presentations and videos on its website for use in further trainings at the district and block levels to ensure that all medical, paramedical and field staff receive the trainings.

To enhance knowledge and skills of oxygen service providers, the National Health Mission (NHM) Rajasthan, with support of PATH, USAID’s NISHTHA project partner, had put plans to train its district level health officials on oxygen management systems and digital solutions. The trainings, which were held in the months of October 2021 and November 2021 across the seven zonal headquarters of the state, were conducted in person by subject matter experts, in a classroom setting. The participants in these trainings, which covered all 33 districts of the state, were the Chief Medical and Health Officer (CMHOs), the Additional CMHOs (Health), the Principal Medical Officer’s (PMOs), the Medical Superintendents, the District Program Managers (DPMs), the District Monitoring and Evaluation Officers (DM&EOs) and Zonal Biomedical Engineers (ZBEs) among others who are handling oxygen systems at their districts and health facilities, or are involved in implementation and decision making on oxygen management for their respective districts and facilities.
Collaborations

Many multilateral organizations, like the World Health Organization (WHO) and United Nations Children’s Fund (UNICEF), and bilateral organizations, like the USAID, through its implementing partners came forward to help Rajasthan respond to the surge in demand for oxygen. PATH, an international not-for-profit organization with a decade of experience in respiratory care management, was identified to establish and function as the Technical Support Unit for Oxygen to the state.

Rajasthan government received oxygen equipment from many countries, like it acquired oxygen concentrators from Russia, China, and United Arab Emirates (UAE), besides getting oxygen concentrators allocated from the Government of India. Rajasthan also received aid from the United Kingdom, in form of PSA Oxygen Plants. Corporates, like the Torrent Group, Larsen and Toubro among others in Rajasthan, have committed to set up 73 oxygen plants at government hospitals through donations and CSR funds.

UNICEF, WHO and USAID, in addition to donating medical devices, contributed to development of guidelines, conducted oxygen assessments and trained health care workers on oxygen management.

Besides multilateral organizations, bilateral donors and corporates, Rajasthan also received support from other states like Haryana, Delhi, Uttar Pradesh, and Chhattisgarh, which ensured the supply of oxygen in the state. At times, the state government deputed police department to escort the oxygen tankers entering the state from the plants outside the state to ensure that the tankers get a free passage in the state.

Promising practices

- **Rational use of oxygen to avoid leakage and wastage:** The Bhilwara model known for its ruthless containment during the first wave has proved to be an example in maintaining oxygen supply for its patients. Pre-empting and good planning are the reasons they have been able to ensure rational use of oxygen. Besides reducing oxygen wastage at the patient’s end, the hospital officials have also appointed a dedicated team of 3 doctors and 3 technicians to regularly monitor oxygen leakage and wastage at all points, from source (plant/storage tanks/manifold) to the supply (MGPS) to bedside.

  Similarly, Bikaner’s Oxygen Mitra model is another successful model that was praised by the Prime Minister wherein the administration has put in place a combination of best practices, spanning from correct identification of oxygen requirement in patients, monitoring the use of oxygen based on actual need, plugging leakages and irregularities in supply and forecasting the demand. Overall, 200 Oxygen Mitras were deputed to monitor oxygen usage in wards of COVID care facilities, resulting in saving of over 200 oxygen cylinders out of 18 000 cylinders used daily. This practice had reduced the usage of oxygen helping save 6000 cylinders in a month.

- **Building a network of oxygen devices to ensure their availability during emergency:** Rajasthan has been able to successfully acquire oxygen concentrators, deploy them at all health facilities and set up oxygen concentrator banks in every district. This has helped build a network of small oxygen devices, which in case of an emergency can be activated to meet the immediate need. This will also give time for an administration to look for longer term solutions.
Lessons learned

- Strengthening health infrastructure: It is critical to prepare ourselves and the health systems for pandemics like these and ensure availability of oxygen to meet the demand. We could do that by setting up more oxygen beds and ICU beds with as well as without ventilators, while securing oxygen supplies to help in improving oxygen response.

- Effective mapping and management of oxygen logistics: Oxygen logistics is a critical element in ensuring availability of oxygen at all facilities. Even when there is oxygen, in LMO form, allocated to a state, it requires a ready fleet of oxygen tankers to pick the allocated stock from the plants and transport to the destination. To achieve this, it is important that a detailed landscaping and mapping of all oxygen manufacturers and tankers in the state is done, along with placement of a dedicated team of professionals and officials to monitor the demand and movement of LMO.

- Diversification of oxygen sources: In a federal structure, dependence on a single source, like LMO, could constrain the oxygen response even if the state has adequate sources of oxygen production. Like, in case of Rajasthan, in spite of having adequate LMO units and LMO based refillers, they experienced shortage of LMO, as the central government took control of all liquid oxygen production and redistributed it to all states. For such situations, having captive oxygen generation capacity through PSA plants and oxygen concentrators, and adequate storage through manifold rooms and storage tanks, will play a significant role in ensuring oxygen availability.

- Capacity building to train healthcare workers on the rational use of oxygen: Capacity strengthening is needed at multiple levels and over several rounds, especially in a lesser practiced and niche area, like oxygen therapy and oxygen management. Collaboration with global as well as national organizations, brings in global knowledge and technical expertise for capacity strengthening.

References


Other resources

Recommendations

Recommendations for scaling-up and replication

Using a logical framework to capture the strategies and interventions for medical oxygen management, the review noted several promising practices which, enriched by the lessons learnt and identified, can be recommended for scaling-up and replication. While these highlight many parallels in the measures implemented by Member States in response to the surge in demand for oxygen, it is clear that there is no one solution to building a sustainable oxygen ecosystem. Several characteristics stand out from the good practices identified, which can be summarized as features that can enable highly effective oxygen responses, composed of the following elements:

1. a comprehensive response, which addresses demand, supply and service delivery as being intertwined with public health priorities;
2. capacity, functions and resources within and beyond the health system to meet the oxygen needs and maintain pandemic-related and non-related critical care; and
3. resilience to catastrophic events, while continually learning, monitoring and adjusting in the light of emerging evidence or the evolving epidemiological situation.

Deriving from these key features, eight recommendations are proposed against which Member States can review their own practices to further improve their health systems for the current pandemic and as preparedness for potential future crisis.

Recommendation 1: Develop and institutionalize an oxygen management plan

The humanity has witnessed respiratory epidemics, such as severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), in the 21st century, which required oxygen intervention. Furthermore, oxygen is also essential for management of several ailments, such as pneumonia, chronic obstructive pulmonary disease, heart failure, asthma and trauma, post-partum haemorrhage (PPH), among others, which are some of the key public health challenges in many LMICs.

While all Member States have developed COVID-19 preparedness and response plans, it is important that countries prepare long-term oxygen response plans for future health emergency situations. The oxygen management plan should be integrated into the larger national and provincial health programmes in a country, such as respiratory care programmes, neonate care programmes, initiatives for trauma and other critical care services, among others. Learning from the experience across Member States in the Region, such as Sri Lanka and Thailand, it is recommended that the oxygen management plan has:
A multistakeholder task force: A task force be comprised representatives of relevant government departments, such as health, industry and transport, among others, and subject experts, identified from research organizations and leading national and global institutions, and representatives of the private sector, such as gas manufacturers’ associations, equipment manufacturers and suppliers, etc.

Clearly defined terms of reference (ToR): The task force may be provided with clear ToR for it and its subgroups, defining the roles and responsibilities of its constituent members, i.e. demand-tracking, oxygen production, procurement of oxygen systems, installation and commissioning, operation and maintenance of oxygen systems, logistics and audit, among others. For better performance, the ToR may also highlight the tasks that the task force will perform during normal times and when activated during an emergency.

Decentralized and widened procurement mechanism during emergency: There should be clear guidelines for decentralized procurement and options of widening the procurement mechanism, including regulatory easing for improving production, procurement and logistics, especially during emergency to improve supply chain efficiencies. A coordination mechanism between the Central government and the provincial administration for decentralized planning has shown to make the process more efficient.

An untied health emergency fund: This can be made available for oxygen response, to national as well as provincial administrative structures.

Standard operating procedures for a multilayered response: Examples include categorization of health facilities, depending on infrastructure and resources for oxygen management.

Other components that Member States may further consider for inclusion in the oxygen management plan, some of which have been detailed as separate recommendations, are:

- oxygen monitoring mechanism, a mechanism for monitoring of consumption of oxygen, including real-time monitoring, using digital technology, such as telemetry and IoT, and regular and periodic oxygen audits shall improve the oxygen ecosystem in the country,
- an elastic oxygen supply chain, where Member States may consider expanding the sources of oxygen in improving in-country sources, encouraging private sector engagement not only for oxygen production and refilling, but also for manufacturing oxygen therapy-related equipment, and expanding oxygen storage facilities, including strategic oxygen reserves;
- a capacity-strengthening plan, which may include initiatives to build, deploy and sustain a pool of trained resources for equipment maintenance and of health-care providers with regard to rational and hygienic use of oxygen, minimizing wastage and adhering to safety norms; and
- an annual biomedical maintenance plan, which would include respiratory care equipment, regular mock drills and regular testing of oxygen for purity and quality.
Recommendation 2: Establish an integrated digital ecosystem for a comprehensive oxygen response

As the study highlighted, several Member States, such as Bangladesh, India and Indonesia, among others, used digital platforms to monitor, track and strategically enhance oxygen production, procurement and transportation to points of use. Some Member States used digital tools for monitoring oxygen supply and consumption, while others used them for capacity-strengthening. While many of these initiatives were isolated, the use of digital platforms enabled real-time monitoring of the changing ecosystem, provided data for decision-making, improved productivity by reducing human errors and enhanced the flexibility of oxygen response as it automated various functions and delivered quick solutions and results, which would not have been as readily available with the traditional approaches.

It is recommended that Member States develop and deploy a unified oxygen management platform, which has modules for oxygen demand-tracking, oxygen production-tracking, monitoring oxygen consumption at points of use, procurement management, logistics management, asset management and tracking, operation and maintenance management and skilling and e-learning, among others. The task force constituted for oxygen response, as suggested in the recommendation above, may be allowed to manage this unified platform as the nodal coordination centre, with different levels of administrative rights to the provincial task force and others involved in oxygen management. The digital tool can also help with dynamic decision-making and as a resource allocation tool, based on information flowing into the system.

Recommendation 3: Establish clear actions for an immediate as well as a more systemic oxygen response

It is recommended that the oxygen management plan clearly defines the oxygen response. As observed during the study, there are two sets of responses from several Member States to the inflated oxygen demand – actions to immediately bridge the gap between oxygen consumption and oxygen availability, and actions to build long-term resilience. Repurposing industrial-grade oxygen to medical-grade oxygen and repurposing nitrogen and argon tankers and gas cylinders, in addition to using faster means of mass oxygen transport, such as flights and railways, can be considered for immediate oxygen response.

To build oxygen resilience not just for COVID-19, but also for other health-care needs that require oxygen, the Member States should continue actions to reduce dependence on a single source of oxygen and diversify. Towards this objective, installation of PSA oxygen plants at large health-care facilities and deployment of oxygen concentrators at smaller medical facilities may be considered for building captive sources of oxygen production, closer to the point of use. Furthermore, the Member States may also consider expanding oxygen storage capacity and building strategic or buffer reserves, such as what the Indian state of Kerala created, or establishing oxygen concentrator banks, as seen in the Indian states of Rajasthan and Delhi.

Along with these initiatives, those Member States, which do not have adequate capacity to produce medical oxygen to meet the elevated oxygen demand, would benefit well if they develop collaborations with oxygen-surplus countries in the Region and globally in order to develop an elastic medical oxygen supply chain. More on this has been discussed in other recommendations.
Recommendation 4: Guidelines for emergency movement of essential commodities, such as oxygen

While the Member States have diversified the sources of oxygen, as we have highlighted above, there is also a need for strengthening oxygen logistics and reducing the lag time to deliver oxygen. Our review highlights five areas requiring urgent action for Member States to rapidly move oxygen from cryogenic plants and ASUs to points of use, during an oxygen emergency:

- **Establishing green corridors:** It is recommended that Member States develop a detailed oxygen logistics plan with demarcated, cleared-out special routes for oxygen tankers or vehicles carrying ISO tankers to escape traffic congestion and reach the destination in the shortest time possible. These green corridors may not only be for movement of oxygen carriers within the country but also between countries.

- **Police escorts and/or ambulance status to oxygen-carrying vehicles:** Wherever establishing a green corridor is not possible, Member States could consider providing police escorts to vehicles carrying medical oxygen from the point of production to the border up to where the Member State or its federal unit has jurisdiction and from the border to the point of use, as was carried out in the states of Odisha and Rajasthan in India. One may also consider giving oxygen-carrying vehicles the status of an ambulance during emergencies, for their smooth and quick movement.

- **Deregulating movement of goods:** It is important that Member States have a provision in the oxygen emergency response plan for reducing or temporarily suspending regulations that hamper movement of essential health commodities, such as oxygen, including custom duties and import-export documentation. For instance, Bangladesh reduced regulatory documentation for movement of oxygen and other health essentials across its borders, during the peak of its oxygen crisis. These deregulations would reduce the stoppage time of vehicles carrying life-saving commodities and enable improved access to medical oxygen.

- **Additional fleet of oxygen carriers:** As the study showed, several countries in the Region experienced a challenge to finding the fleet of oxygen tankers and other oxygen carriers. While repurposing other gas tankers to oxygen tankers and transferring cryogenic ISO tanks on railways can be adopted for immediate response to an acute spurt in oxygen demand, long-term solutions will require building a strategic reserve fleet of oxygen carriers, which can be pressed into service in case of an emergency.

- **Real-time monitoring of oxygen logistics:** As highlighted above, the study reiterates the recommendation to have a digital dashboard, where all oxygen carriers are mapped and tracked with GPS and GIS, which, in times of emergency, shall allow the Member States to rapidly realign the oxygen distribution.

Recommendation 5: Active monitoring of demand and supply of essential commodities, such as oxygen

As was observed during the study, the Member States that regularly and actively monitored oxygen demand, consumption and supply were able to respond more effectively to the evolving epidemiological situation. A couple of similarities among these Member States were that (a) they had an oxygen demand forecasting mechanism, either fully automated or manually updated, with
a digital dashboard, as seen in India and Thailand, among others, and (b) they had conducted regular oxygen readiness assessments, such as what Bangladesh implemented.

It is recommended that, as part of the oxygen emergency response plan, Member States consider regular oxygen assessment, which investigates the status of oxygen consumption, oxygen production and oxygen storage in the country, and undertakes periodic oxygen demand forecasting. In addition, the Member States are recommended to conduct periodic oxygen audits at national, provincial and facility levels to identify points of oxygen wastage and, based on the audit findings, undertake actions to address the causes of wastage. These exercises may be better utilized if their results are added to the integrated digital ecosystem for oxygen management.

**Recommendation 6: Invest in strengthening critical care – oxygen infrastructure and human resources for oxygen management**

In most Member States, critical care is neglected. Member States, such as Thailand, which took action to strengthen disease surveillance and critical care by learning from their tryst with severe acute respiratory syndrome coronavirus (SARS-CoV) and MERS-CoV, did not experience any oxygen crisis. Evidence shows that their health systems were better prepared with oxygenated beds and ICUs and piped oxygen to cushion the spike in COVID-19 cases. It is recommended that Member States, in order to build long-term resilience of their health systems, increase the number of oxygen beds and ICU beds, with piped oxygen, at all medical colleges, tertiary-care facilities and hospitals with neonatal ICUs. In addition to strengthening oxygen production and storage infrastructure, such as PSA oxygen plants, oxygen concentrators and cylinders, it is important that Member States also invest in smaller oxygen devices essential for effective oxygen delivery, such as ventilators, CPAP and BiPAP machines, masks and cannula, among others.

While almost all Member States established makeshift facilities and designated them for COVID-19 care, in most cases, these facilities were established after the COVID-19 cases had peaked. Following the example of “Oxygen Houses” in Indonesia, Member States may consider making provision and preparation for makeshift facilities with key oxygen infrastructure and resources. This is likely to not only reduce the burden of caring for mild and moderate cases from tertiary hospitals, but also help in more efficient delivery of oxygen to patients.

During the pandemic, several new oxygen systems were deployed in all Member States, which required a pool of biomedical engineers and trained technicians to manage the equipment. It is recommended that Member States should consider expanding the range of occupations utilized for oxygen management and strengthening their capacities.

Another important investment in strengthening critical care is building an elastic health workforce. As this pandemic showed, while there may not be a need for an expanded health workforce in normal times, during a health emergency, when health workers work round-the-clock and feel exhausted, putting at risk their mental health, there is a need for a reserve health workforce. Some Member States temporarily reinstated retired health professionals, others trained and upskilled volunteer health workers and licensed them as support nurses, among other such initiatives. To meet the temporary but essential requirement of more health workers, the Member States should create, populate, maintain and regularly update a registry of health workers, health volunteers and people trained in paramedical skills, for providing support to mainstream health-care workers. This “reserve” health workforce can be called to service in cases of health emergency to meet the demand of additional health-care workers.
Recommendation 7: Regularly strengthen capacity for oxygen management

Capacity-strengthening for oxygen management has emerged as one of the key gap areas in this study. While some Member States had undertaken several initiatives to strengthen the capacity of the medical teams regarding oxygen therapy, there was limited evidence of capacity-strengthening initiatives for operation and maintenance of oxygen systems.

It is recommended that Member States, which have developed SOPs for oxygen therapy, operation, management and maintenance of various oxygen equipment, among other oxygen-related areas, such as procurement, should regularly update them, based on new knowledge and as per globally accepted best practices. These SOPs may also be shared with other Member States, which may not have developed the SOPs, so that they may review and adapt them as per their local conditions. Widely disseminating the SOPs related to medical oxygen will ensure that they are effectively practised.

It is also recommended that Member States plan for regular training of different cadres of health workforce in oxygen therapy, operation and maintenance of oxygen equipment and/or oxygen programme management, depending on their terms of reference and roles in oxygen management. While these trainings may be conducted virtually, through live virtual sessions or through LMS, it is important that they are complemented by in-person trainings, live demonstrations and mentoring on site, for more effective transfer of knowledge and skills.

Recommendation 8: Build multistakeholder collaborations for a more comprehensive oxygen response

Many Member States activated comprehensive responses through collaborations at various levels, including through whole-of-government approaches and creation of multi-ministry task forces, in addition to bilateral cooperation and partnerships with multilateral organizations and private sector to ensure that evidence is translated into policy, and practices that enhance their approaches to strengthen health systems in oxygen response.

It is recommended that every Member State undertakes a landscape assessment – global and local – of oxygen sources (countries with surplus oxygen and companies with oxygen-manufacturing capacities), oxygen equipment manufacturers and spare parts manufacturers, logistics partners, technical agencies, thinktanks and knowledge partners that can contribute strategic technical input, among others. This assessment may be used to elicit more effective response from strategic partners. As the study found, heavy oxygen equipment procurement was mostly supported by bilateral partners, while technical and capacity-building support required partnerships with multilateral agencies and technical experts, and in-country oxygen production was carried out in partnership with the private sector in most Member States. Member States may consider developing oxygen credit lines with countries that have surplus oxygen that can be activated in case of emergency.

Recommendation 9: Sustainability Plan

The study noted huge investments for building oxygen capacity in hospitals to respond to the pandemic. However, this investment needs to be sustained so that such investments can be utilized for health systems strengthening and future pandemic response. It is recommended that Member
States have strong operations and maintenance plans for such equipment, which could be through an outsourced agency or by developing in-house capacity. The latter option is preferred.

In some cases, booster compressors for filling cylinders can be installed at certain PSA plants, with a hub & spoke model for supplying oxygen cylinders to nearby smaller facilities. Because PSA plants are energy intensive, the addition of green energy like solar power generation plants may be explored to reduce electricity costs. This will not only make the health facility self-sufficient in terms of generating oxygen but also in powering the oxygen production equipment. Evidence on cost-effectiveness of this solution is yet to be established.

In conclusion, the findings of this study and the emerging recommendations may not be new and there have been prior incremental moves to strengthen the oxygen ecosystem and make them more sustainable. The oxygen response to COVID-19 requires dynamic systemic transformation. The oxygen crisis in 2021 brought attention to the importance of medical oxygen as a life-saving commodity as never before. It also had demonstrated the interdependencies of a range of health, social and economic structures. The oxygen crisis during the COVID-19 pandemic is a call for transformation and investment in building a more elastic and resilient oxygen ecosystem. The pandemic provides a renewed prospect for solidarity, both within and between countries, for a more coordinated oxygen response. It also reaffirms that a collaborative, people-centric and whole-of-the government approach to medical oxygen is needed for a health system that is able to respond to future crises.
Promising practices and lessons learnt in the South-East Asia Region in accessing medical oxygen during the COVID-19 pandemic