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*COVID-19 information note 18*

# Solar-powered oxygen delivery in Somalia: the vital need beyond COVID-19

## Health services in Somalia before COVID-19: the serious consequences of underinvestment and fragility

Somalia has suffered from decades of conflict, war, political instability and climatic shocks such as recurrent droughts and floods. The result of this long-term hardship has been underinvestment in health and social services and hence weakened and fragmented health systems. The universal health coverage index for Somalia was 27 out of 100 in 2019 which is one of the lowest in the world – the global average is 60.3.[1] The emergence of the coronavirus disease 2019 (COVID-19) pandemic and the resultant disruption of essential health services in this fragile setting have created an environment where many determinants of poor health outcomes among Somali people have been exacerbated. Even before COVID-19, maternal and infant deaths in Somalia were among the highest in the world. Furthermore, decades of war, insecurity and protracted crises had led to the migration of skilled health workers from the country. Today, for every 1000 people in Somalia, fewer than one doctor/nurse/midwife is available.[2] With so few health workers, the current health system struggles to deliver both basic and comprehensive life-saving health interventions.

## COVID-19 and the need for oxygen in Somalia: the search for innovative solutions

During May–June of 2020, when the first wave of the COVID-19 pandemic hit Somalia, the fragility of the health system was clearly exposed: it struggled to manage patients presenting with severe symptoms of COVID-19. People were needlessly dying because of the lack of available medical oxygen. Using the WHO's case management inventory tool for biomedical equipment for COVID-19,[3] the WHO Somalia country office assessed the availability of oxygen in the country and planned for a surge in demand for oxygen as COVID-19 cases spiked.

***A survey conducted by WHO in 2020 showed that only 26% of health facilities surveyed had at least one oxygen source, while only 4% had oxygen concentrators and 22% had access to oxygen cylinders.***

This situation led the WHO country office to develop a data-driven strategy for scaling up oxygen availability in Somalia using a phased approach. The first part of this strategy was to equip all 1200 primary health care centres in the country with oxygen concentrators and distribute pulse oximeters to over 3000 community health workers. However, in this impoverished setting, only one in four health facilities had access to the power grid or an uninterrupted supply of electricity, which is needed for commonly used oxygen delivery systems.[4] Therefore, the WHO country office decided to set up solar-powered oxygen concentrators in remote health centres in the country. Accordingly, in 2021, the WHO country office, with support from Grand Challenges Canada, delivered and installed solar-powered medical oxygen equipment in the paediatric

[1] The Global Health Observatory. UHC service coverage index (SDG 3.8.1). World Health Organization; 2021 (https://www.who.int/data/gho/data/indicators/indicator-details/GHO/uhc-index-of-service-coverage).

[2] Abdi A, Ahmed AY, Abdulmunim M, Karanja MJ, Solomon A, Muhammad F, et al. Preliminary findings of COVID-19 infection in health workers in Somalia: a reason for concern. Int J Infect Dis. 2021;104:734–6.

[3] Biomedical equipment for COVID-19 case management – inventory tool: interim guidance. World Health Organization; 2020 (https://www.who.int/publications/i/item/WHO-2019-nCov-biomedical-equipment-inventory-2020.1).

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ward of Hanano hospital in Galmudug, which is one of the most insecure and inaccessible areas of Somalia. This innovative and cost-effective solution provided access to oxygen in a setting where access to electricity and the power grid was not consistent or guaranteed.

## Solar-powered oxygen delivery system: its value over other oxygen delivery systems

Methods commonly used to deliver oxygen in hospital in resource-limited settings include compressed oxygen cylinders and oxygen concentrators. The cylinders require a reliable supply chain linking the oxygen production plant to the hospital. However, these chains may be adversely affected by poor road conditions (especially during the rainy season), costs of transportation and weak stock management, making this an inefficient delivery method. Furthermore, fuel for transportation of oxygen cylinders to health centres that are far from an oxygen plant has an environmental cost. Although ordinary concentrators are a good replacement for cylinders, they too need a power grid or standby generators to function, but these too require fuel and can break down, making them expensive to operate and maintain in resource-poor settings. In contrast, because the system exclusively uses freely available solar energy and air, i.e. "green energy". Another advantage of solar-powered oxygen concentrator system is that this system is designed to run continuously (including at night and on cloudy days) and can turn ambient air into medical oxygen using solar energy alone with battery banks without any hydroelectric power input. This system is thus a continuous off-the-grid operation providing uninterrupted service.

***The solar-powered oxygen concentrator system uses solar power to produce medical oxygen and does not need a power grid or generator for its operation. Therefore, a solar-powered oxygen delivery system has several advantages, for example: low operating costs; consistency and reliability even during power grid outages; ease of use for hospital staff; reduced oxygen waste; and reduced carbon footprint – essentially a zero carbon footprint***

The solar-powered oxygen system installed at Galmudug state in Somalia consists of photovoltaic cells which are installed on the roof of the hospital. These cells collect solar energy from the sun which is stored as electricity in a battery bank. This electricity is used to power three ordinary oxygen concentrators for the production of medical oxygen. The feasibility, safety and efficiency of solar-powered oxygen concentrator system have been demonstrated through a proof-of-concept study and a randomized controlled trial, showing non-inferiority compared with cylinder oxygen in terms of length of hospital stay, duration of oxygen therapy and recovery time.[5]

## Solar-powered oxygen delivery system in Somalia: the data on its value

Between March and October 2021, after this solar-powered medical oxygen system was installed, 171 care seekers of all age groups (range: 1 day to 89 years) received medical oxygen (Table 1). These patients presented with very low

**Table 1: Characteristics and outcomes of 171 patients treated with solar-powered oxygen at Hanano General Hospital, 6 March–31 October 2021**

| Characteristic of patients | No. (%) |
|---|---|
| *Age group*[a] | |
| < 1 week | 70 (40.9) |
| 1 week to < 1 year | 13 (7.6) |
| 1–4 years | 26 (15.2) |
| 5–19 years | 10 (5.8) |
| 20–49 years | 15 (8.8) |
| 50–69 years | 29 (17) |
| ≥ 70 years | 8 (4.7) |
| *Sex* | |
| Female | 80 (46.8) |
| Male | 91 (53.2) |
| *Diagnosis on admission* | |
| COVID-19 | 25 (14.6) |
| Birth asphyxia | 70 (40.9) |
| Pneumonia | 43 (25.1) |
| Other acute respiratory diseases | 7 (4.1) |
| Heart disease | 3 (1.8) |
| Trauma | 14 (8.2) |
| Other | 9 (5.3) |
| *Duration of oxygen therapy in days*[b] | |
| 1 | 85 (49.7) |
| 2 | 36 (21.1) |
| 3 | 23 (13.5) |
| 4 | 17 (9.9) |
| 5 | 3 (1.8) |
| 6 | 2 (1.2) |
| 7 | 2 (1.2) |
| 9 | 1 (0.6) |
| 10 | 1 (0.6) |
| 21 | 1 (0.6) |
| *Outcome* | |
| Death | 3 (1.8) |
| Discharge without disability | 163 (95.3) |
| Transfer to another facility | 5 (2.9) |
| *SpO2 %*[c] | **Median (IQR)** |
| At initiation of oxygen | 60 (19) |
| On discharge | 99 (32) |

COVID-19: coronavirus disease 2019; SpO2: peripheral oxygen saturation; IQR: interquartile range.
[a] Median age (range) = 1 year ( 1 day to 89 years)
[b] Median duration (range) = 2 days (1 day to 21 days)
[c] $P < 0.001$ (comparing to SpO2 at initiation of oxygen and at discharge from hospital).

[4] Humphreys G. Harnessing Africa's untapped solar energy potential for health. Bull World Health Organ. 2014;92(2):82–3.
[5] Turnbull H, Conroy A, Opoka RO, Namasopo S, Kain KC, Hawkes M. Solar-powered oxygen delivery: proof of concept. Int J Tuberc Lung Dis. 2016;20(5):696–703.

oxygen saturation levels (less than 60%) and were either birth asphyxiated or had severe breathing difficulties as a result of various life-threatening and emergency medical conditions. Most (95%) of these patients were discharged without any disability after receiving the solar-powered medical oxygen and correcting their low oxygen saturation level. Furthermore, 84% needed only 3 days to correct their oxygen saturation level while 50% of patients were discharged without disability within 24 hours of admission meaning that their mean oxygen saturation level improved within 24 hours. Children younger than 5 years comprised 64% of those who received oxygen from this solar-powered system; their mean oxygen saturation level improved from less than 35% to over 99% within 1 to 2 days. Although, this solar-powered medical oxygen system was initially set up to support management of COVID-19 patients, children with neonatal asphyxia, pneumonia and other acute respiratory diseases made up the majority of the patients (70%) who received medical oxygen from this system. Patients with COVID-19 symptoms comprised of 15% care seekers. The knowledge and experience accumulated so far from this innovation in a fragile context show that solar-powered oxygen systems are efficient and cost-effective. For more than 95% of care seekers, their oxygen saturation level improved from a mean of 63% on admission to 98% at discharge.

## Effectiveness of solar-powered oxygen delivery system in other low-resourced settings: the evidence so far

As with Somalia, other countries with similar settings have seen the value and effectiveness of the use of a solar-powered oxygen concentrator system. Table 2 gives an overview of evidence seen so far.

**Table 2: Level of care and evidence supporting the use and value of a solar-powered oxygen concentrator system**

| Level of care | Evidence supporting the use of solar-powered oxygen concentrator systems | Country |
|---|---|---|
| Hospitals | Implementation of the system was associated with a 50% decrease in 30-day mortality in children with hypoxaemia from respiratory illness.<br>Installation of these systems was associated with a reduced frequency of interruptions to oxygen therapy from fuel shortages or need to share systems between many patients, suggesting an improvement in the quality of care being delivered. | Democratic Republic of the Congo [6] |
| Primary health care centre and hospital | The solar-powered oxygen delivery system provided good quality oxygen reliably in health facilities with poor power availability and user satisfaction was rated high.<br>Field testing also showed that this system produced a median oxygen concentration of 89.8% (range 88.0–99.7%) – higher than the specified minimum of ≥ 82% – and oxygen was available from the solar-powered system for all patients who needed oxygen. | Gambia and Fiji [7] |
| Health centres and district hospitals in remote areas | A solar-powered oxygen programme, supported by quality improvement was associated with a 40% reduction in overall paediatric mortality, an over 50% reduction in mortality from pneumonia, and a reduction in referrals from health centres and district hospitals across nine rural provinces.<br>In the postintervention period, an estimated 348 lives were saved, at a cost of US$ 6435 per life saved and over 1500 referrals were avoided.<br>Solar-powered oxygen systems supported by continuous quality improvement can be achieved at large scale in rural and remote hospitals and health care facilities, and was associated with reduced child deaths and reduced referrals. | Papua New Guinea [8] |
| Health centres and district hospitals | The use of solar-powered oxygen was cost-effective relative to no oxygen and grid-powered concentrators. It was also cost-saving compared with concentrators powered by fuel generators.<br>The costs of solar-powered oxygen were US$ 26 per patient treated and US$ 542 per life saved. In secondary analyses, solar-powered oxygen was more cost-effective than grid-powered concentrators (incremental cost-effectiveness ratio US$ 140 per DALY saved) and resulted in cost savings relative to concentrators powered by fuel generators (cost saving of US$ 7120). | Uganda and other African countries [9] |
| Health facilities in rural areas | Improved oxygen systems, which include a reliable source of oxygen therapy using concentrators, and pulse oximetry for detection of hypoxaemia can reduce mortality from pneumonia by up to 35% | Papua New Guinea [8] |

[6] Conradi N, Claude KM, Lee BE, Saleh A, Mandhane P, Hawkes M. Utility of solar-powered oxygen delivery in a resource-constrained setting. Pulmonology. 20211;S2531-0437(21)00224–5.

[7] Howie SR, Ebruke BE, Gil M, Bradley B, Nyassi E, Edmonds T, et al. The development and implementation of an oxygen treatment solution for health facilities in low and middle-income countries. J Glob Health. 2020;10(2):020425.

[8] Duke T, Hwaihwanje I, Kaupa M, Karubi J, Panauwe D, Sa'avu M, et al. Solar powered oxygen systems in remote health centers in Papua New Guinea: a large scale implementation effectiveness trial. J Glob Health. 2017;7(1):010411–010411

[9] Mian Q, Huang Y, Conroy A, Opoka R, Namasopo S, Hawkes M. Solar-powered oxygen delivery to treat childhood pneumonia in low-resource settings: a randomised controlled non-inferiority trial and cost-effectiveness study. Lancet Glob Health. 2019;7:S10.

**Table 2: Level of care and evidence supporting the use and value of a solar-powered oxygen concentrator system**

| Level of care | Evidence supporting the use of solar-powered oxygen concentrator systems | Country |
|---|---|---|
| Rural hospital (district level) | The median length of stay for patients receiving solar-powered oxygen was 4.1 days which was 0.41 days less than patients receiving cylinder oxygen (95% CI –1.2 to 0.43 days less). This met the prespecified criterion for non-inferiority of within 1 day. Mortality was similar between the solar-powered and cylinder groups, 17% and 12%, respectively ($P = 0.62$).<br>Solar oxygen had a cost per DALY saved of US$ 27, which was substantially lower than the reported cost for oxygen cylinders (US$ 50 per DALY saved) and other interventions for pneumonia such as pneumococcal and *Haemophilus influenzae* type b vaccines.<br>Maintenance costs of solar oxygen are projected at US$ 90 per month (including battery replacements) over the life of the system. Health care workers reported that solar oxygen systems are easier to use than oxygen cylinders. | Uganda [10] |
| Regional hospital | Solar energy can be used to concentrate oxygen from ambient air and oxygenate critically ill children with hypoxaemia in a resource-limited setting.<br>Immediate improvement in peripheral blood oxygen saturation was documented (median change 12% (range 5–15%; $P < 0.0001$). The case fatality rate of the children with hypoxaemia was 6/28 (21%). The median recovery times to sit, eat, wean off oxygen and hospital discharge were 7.5 hours, 9.8 hours, 44 hours and 4 days, respectively. | Uganda [5] |

DALY: disability-adjusted life year.

## Solar powered oxygen delivery system in Somalia: support to scale up and gather evidence

This innovative system of solar-powered oxygen delivery was set up by the WHO country office of Somalia with financial support from Grand Challenges Canada and the University of Alberta. Several departments within the three levels of WHO – including the Innovation Team at the WHO headquarters, the WHO Regional Office for the Eastern Mediterranean and the WHO Somalia country office – have collaborated to support this innovative pilot projects. In addition, various United Nations agencies and implementing partners have provided support to turn this idea into a reality. WHO is working with the multipartner Global Action Plan for Healthy Lives and Well-being for All (SDG3 GAP) to match demand and supply of life-saving oxygen in Somalia. The implementation of this innovative solution is also coupled with research supported by the UNICEF/UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) to gather evidence on the feasibility, use and cost–effectiveness of the system in a complex context such as Somalia, and its effect on survival.

## A benefit of the COVID-19 response in Somalia: the opportunity to increase access to medical oxygen

Pneumonia is the leading cause of death in children younger than 5 years and accounts for more than 800 000 deaths a year globally, which is more than the combined child mortality from HIV/AIDS, tuberculosis and malaria.[11] Pneumonia is the leading cause of death in children younger than 5 years in Somalia also. About 21% of child deaths occurring in Somalia are attributed to pneumonia. It is estimated that pneumonia killed 15 165 children younger than 5 years in Somalia in 2018 – about two children every hour. The global target is to reduce pneumonia-related deaths in children under 5 years to 3 per 1000 live births; the current figure in Somalia is 24 pneumonia deaths per 1000 live births, which is very far from the global target.

[5] Turnbull H, Conroy A, Opoka RO, Namasopo S, Kain KC, Hawkes M. Solar-powered oxygen delivery: proof of concept. Int J Tuberc Lung Dis. 2016;20(5):696–703.

[10] Mian Q, Huang Y, Conroy A, Opoka R, Namasopo S, Hawkes M. Solar-powered oxygen delivery to treat childhood pneumonia in low-resource settings: a randomised controlled non-inferiority trial and cost-effectiveness study. Lancet Glob Health. 2019;7:S10.

[11] United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). Levels & trends in child mortality: report 2018. Estimates developed by the United Nations Inter-agency Group for Child Mortality Estimation. New York: United Nations Children's Fund; 2018 (https://www.unicef.org/media/47626/file/UN-IGME-Child-Mortality-Report-2018.pdf).

Oxygen is a smart investment for Somalia. The WHO country office intends to scale up this solar-powered oxygen system as well as pressure swing adsorption plants to overcome gaps in access to medical oxygen in the country. Replicating the system can save many more lives, and this will help the country move closer to attaining WHO's Triple Billion targets, and the health-related Sustainable Development Goals. Global evidence shows that up to 35% of childhood deaths from pneumonia are preventable with the use of simple medical oxygen.[12] Thus the WHO country office in Somalia hopes that by building strategic partnerships with innovators, funders, SDG3 GAP agencies and the private sector, demand for medical oxygen and innovation will increase. This will accelerate the impact of this new initiative in reducing deaths from childhood pneumonia. As of December 2021, the WHO country office also delivered and installed two containerized pressure swing adsorption oxygen plants in two central locations as part of its drive to scale up oxygen availability in Somalia. Each of these plants can deliver bedside oxygen to 25 intensive care patients through a pipeline and can refill 100 40-L oxygen cylinders a day. Capitalizing on the COVID-19 response, the WHO country office intends to increase access to medical oxygen in Somalia to reverse the large health inequities that exist in one of the most disadvantaged countries in the world.

## Further reading

WHO in Somalia. Solar-powered medical oxygen systems saving lives in Somalia: using innovation to accelerate impact in a fragile setting. WHO Regional Office for the Eastern Mediterranean; 2021 (http://www.emro.who.int/somalia/news/solar-powered-medical-oxygen-systems-saving-lives-in-somalia-using-innovation-to-accelerate-impact-in-a-fragile-setting.html).

Counting every breath: a data-driven strategy to improve access to medical oxygen for COVID-19 patients in Somalia. Information note 4. WHO Somalia; 2020 (http://www.emro.who.int/images/stories/somalia/documents/covid-19-information-note-4.pdf?ua=1).

Every breath counts: utilizing the COVID-19 response to increase access to oxygen. Information note 9. WHO Somalia; 2021 (http://www.emro.who.int/images/stories/somalia/documents/covid-19-information-note-9.pdf?ua=1).

Solar-powered oxygen saving the lives of Somali children. VOA; 2022 (https://www.voanews.com/a/solar-powered-oxygen-saving-the-lives-of-somali-children/6412993.html).

WHO Eastern Mediterranean Region. Solar-powered oxygen innovation in Somalia. YouTube; 2021 (https://www.youtube.com/watch?v=2E4vujBzoTY).

[12] Duke T, Wandi F, Jonathan M, Matai S, Kaupa M, Saavu M, et al. Improved oxygen systems for childhood pneumonia: a multihospital effectiveness study in Papua New Guinea. Lancet. 2008;372(9646):1328–33.



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