



**HFES**  
Systems That Work for **Humans**

# HFES + INTERNATIONAL SYMPOSIUM

on Human Factors and  
Ergonomics in Health Care

2023

**Human Factors for Health Equity**  
A Case Study in Inclusive Medtech Design with  
Organizations in Low- and Middle-Income Countries (LMICs)



# Agenda

- Introduction
- The opportunity: using human factors principles to **design medtech for more people**
- Case study
- Lessons for practitioners
- Q&A



LIGHTING & ETCO2 MONITORING FOR SAFE SURGERY



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AINA DIAGNOSTICS FOR CHRONIC DISEASE



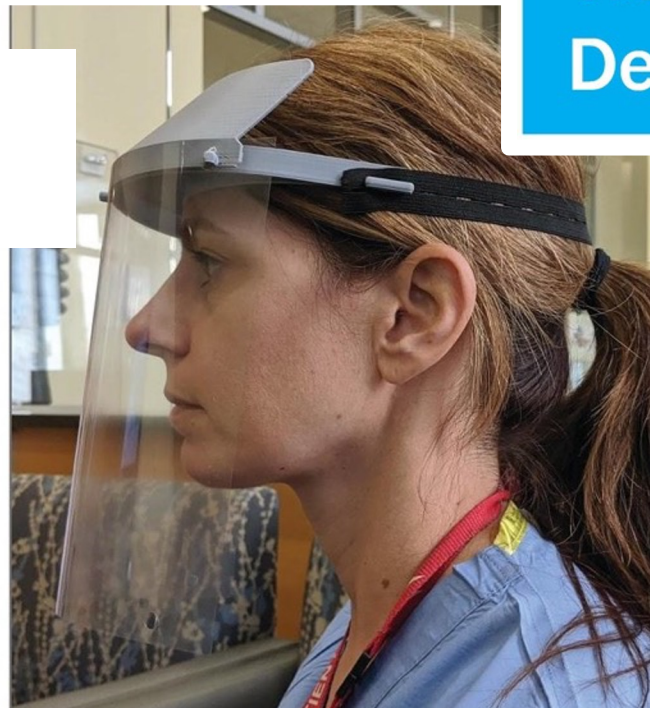
Photo © Jana Care 2019



COVID-19 OPEN-SOURCE FACE SHIELD



Photo CC BY-SA 4.0 Design that Matters



AIR2O2 OXYGEN THERAPY FOR PNEUMONIA

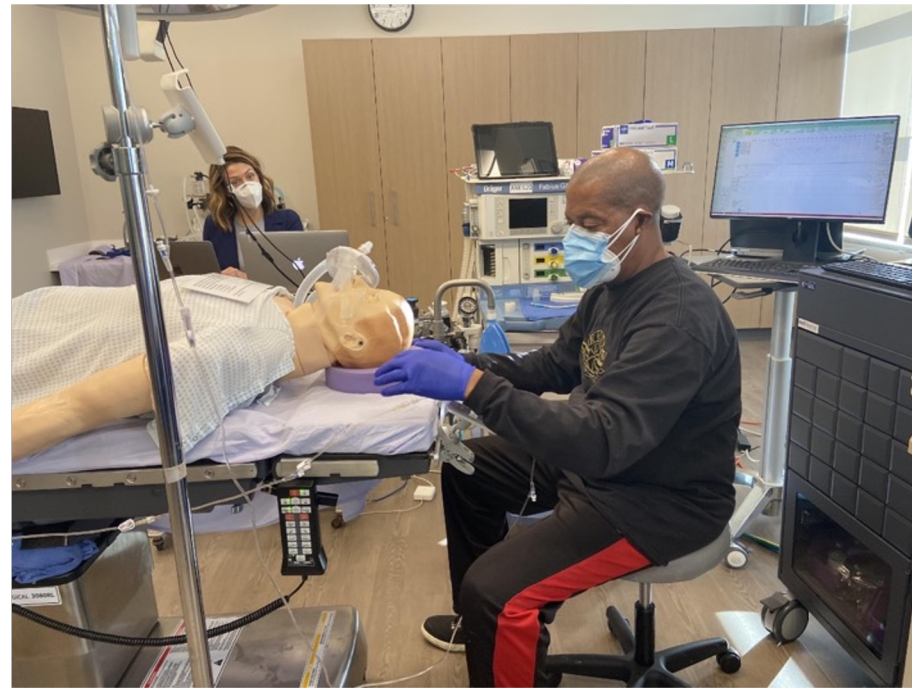


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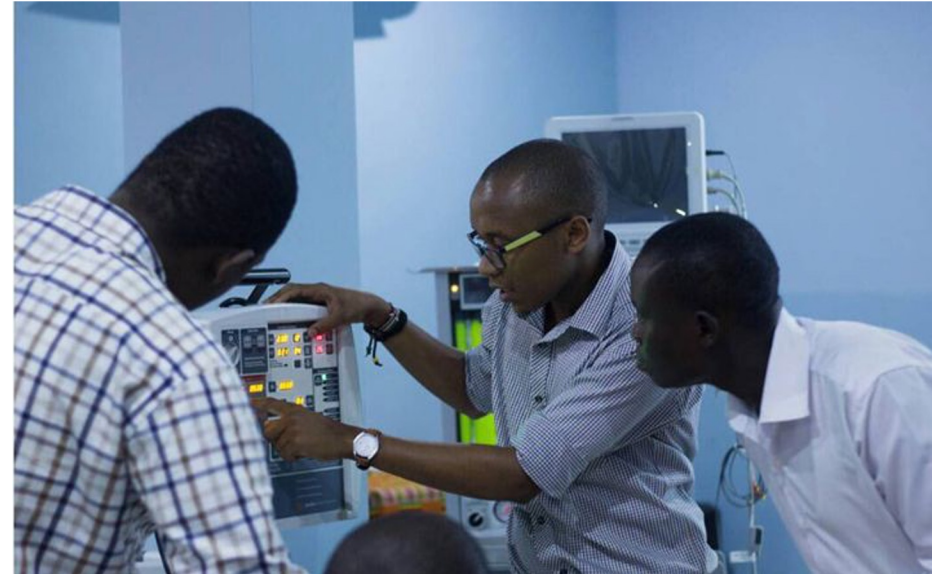
[www.loring-hf.com](http://www.loring-hf.com)



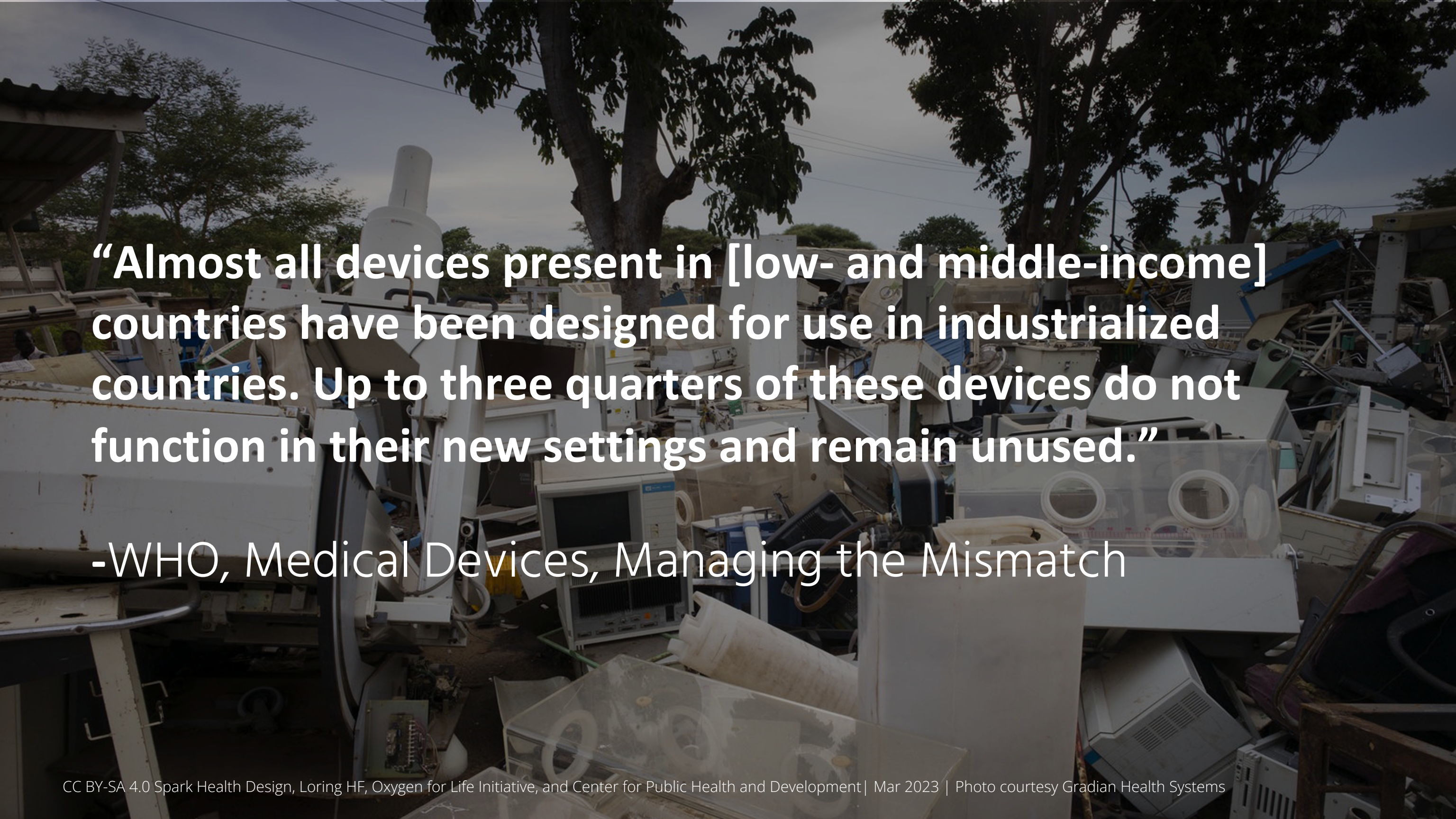
oxygen4life.org



cphdev.org







**“Almost all devices present in [low- and middle-income] countries have been designed for use in industrialized countries. Up to three quarters of these devices do not function in their new settings and remain unused.”**

**-WHO, Medical Devices, Managing the Mismatch**

A large pile of discarded medical equipment, including monitors, incubators, and other devices, outdoors. The equipment is mostly white and grey, with some blue accents. It is piled up in a way that suggests it has been abandoned or is waiting to be disposed of. The background shows some trees and a cloudy sky.

Most medical devices  
are not designed  
for most people.

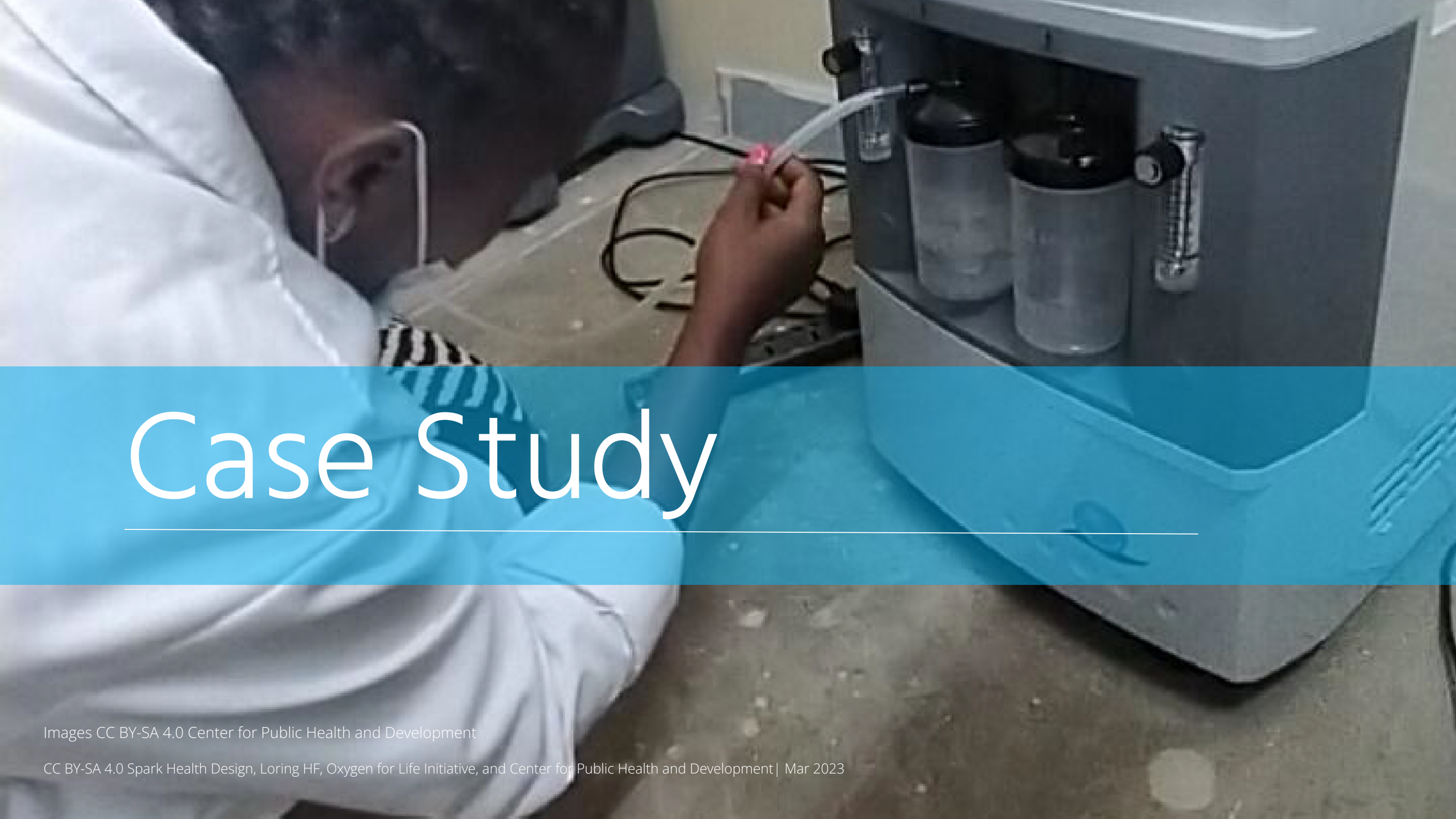




Intended uses

Intended users

Intended contexts



# Case Study

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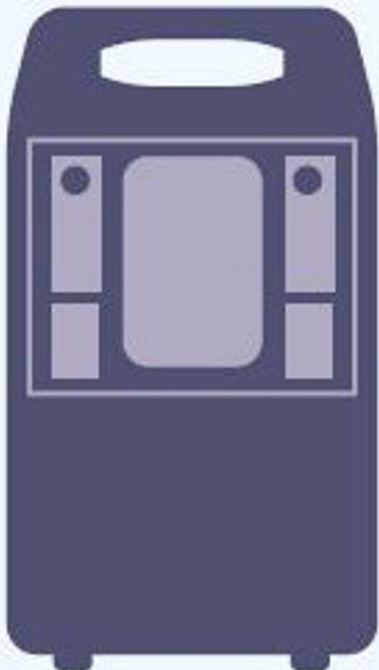


Image Source: bipap.co.in



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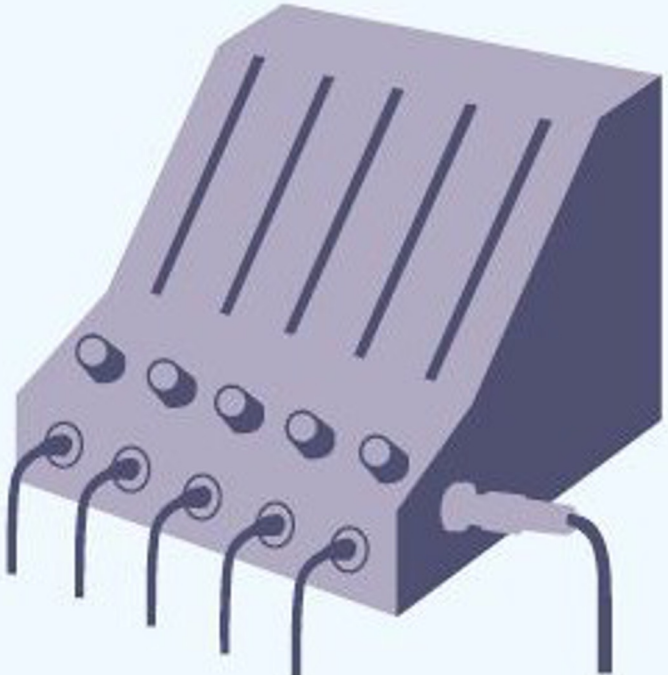
Evaluation focus



Concentrators



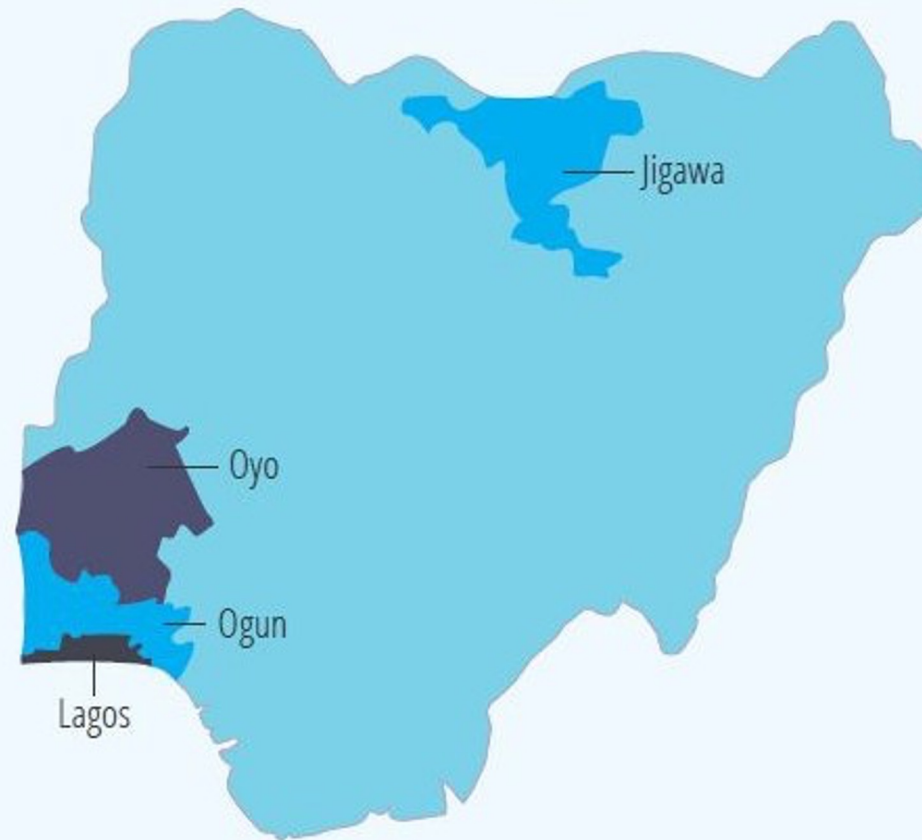
Humidifier bottles



Flow splitters

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## Facilities and Participants in Nigeria



2 Primary Care  
7 Secondary Hospitals  
2 Tertiary Hospitals

15 Nurses  
11 Biomed

## Facilities and Participants in Kenya



2 Level 4 Health Centres  
1 Level 5 Hospital

11 Nurses  
6 Biomed

# Use-Related Risk Analysis (URRA)

## Drive DeVilbiss 10L Concentrator

High Level Task	Task#	User Type	Sub Task#	Task Description	Potential Use Error	Hazardous Situation	Potential Harm	Risk level	Harm Severity	Critical Task
Remove from box	1	BME(T)s	1.1	Open box and remove device	Use a sharp object to open the box	Damage to device	Delay of therapy: Major	High	5	Y
					Drop the device	Damage to device	Delay of therapy: Major	High	5	
Position	2	BME(T)s, Nurses, Attendants	2.1	Position near power outlet	Position device too far from outlet	Cannot plug device into socket	Delay of therapy: Minor	Medium/Low	2	Y
						Power cord poses tripping hazard in order to reach the outlet; a person trips over the power cord	Physical Trauma: Major	High	5	
		BME(T)s, Nurses, Attendants	2.2	Position near patient	Position device too far from patient requiring a tube longer than 30m with flows up to 5 LPM	Flow rate at patient lower than concentrator setting	SpO2 too low: Major	High	5	Y
				Position device too far from patient requiring a tube longer than 6m with flows up 5-10LPM	Flow rate at patient lower than concentrator setting	SpO2 too low: Major	High	5	Y	



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## What participants say

- Background and past use of oxygen concentrators
- Preferred product features card sort

## Opportunities

## What participants do

- Simulated use of provided oxygen concentrators
- Observations of actual use and contextual inquiry

# Intended Use Context | Home vs. HCF



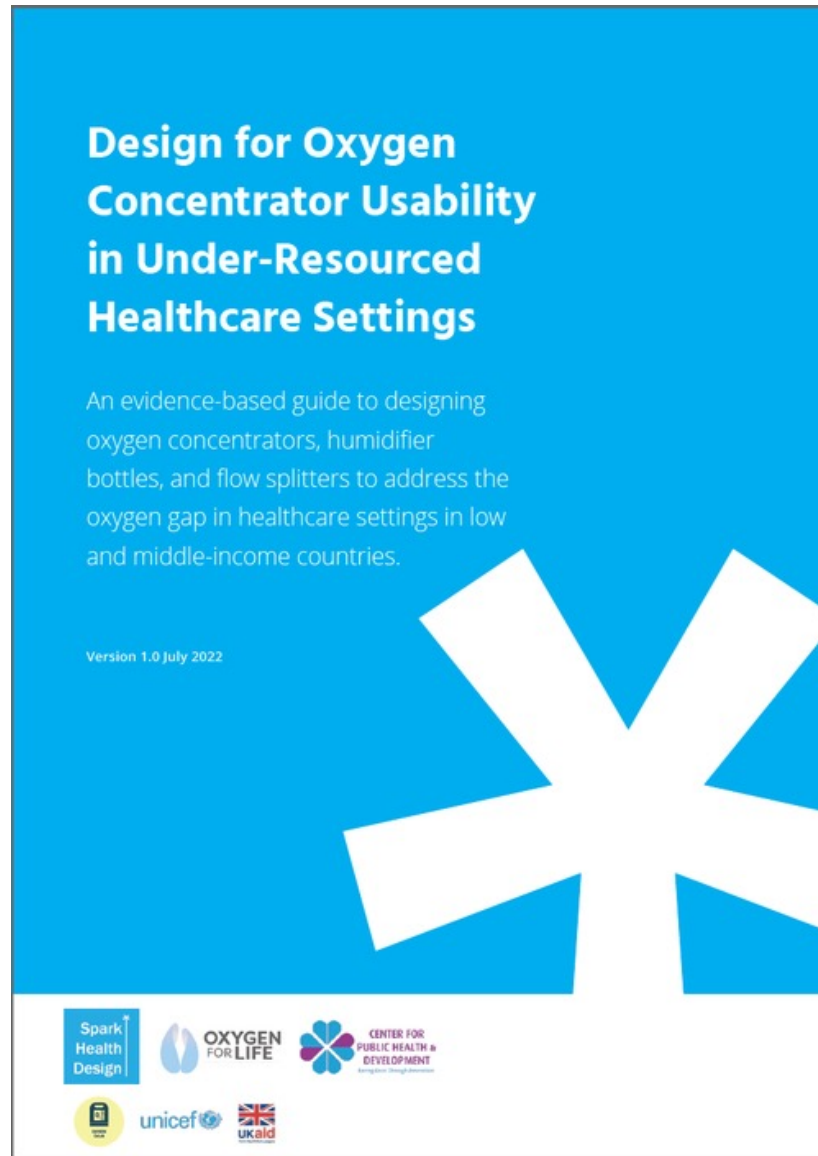
- Space
- Noise
- Flooring
- Temp & humidity
- Particulates
- Infection risk





# 12 Opportunities, 100s of Ideas

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## Opportunities — Concentrator

- C-01 Intuitive Dual Flow Control
- C-02 Display and Labeling for Nurses
- C-03 Improve Concentrator Durability
- C-04 Compatible with Power in LMICs
- C-05 Nurse-Maintained in a Dusty Environment
- C-06 Prompt the Biomedics to Change System Filters
- C-07 Malfunction-Specific Information for Repair
- C-08 Repair or Replace Parts with Basic Tools

## Opportunities — Flow Splitter

- F-01 Convey Flow In = Flow Out

## Opportunities — Humidifier Bottle

- H-01 Hard-to-Use-Wrong Humidifier Bottle
- H-02 Redesign the Semi-Disposable to be Reusable
- H-03 Prompt to Change Water and Disinfect

# C-02 | Display & Labeling for Nurses



*“This (leftmost light) is the oxygen alarm light, I’m not familiar with other ones.”*

Nurse 007, Secondary Hospital, Ibadan, Oyo State, Nigeria, Canta V8-WN-NS



*“I don’t know the meaning of the indicator light.”*

Nurse ML\_003\_N, Level 5 Hospital, Nairobi, Kenya, AirSep NewLife Intensity 10

# C-02 | Display & Labeling for Nurses

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## **Opportunity**

Redesign the concentrator display and labelling to build nurse confidence in use and basic troubleshooting.

# C-08 | Repair or Replace Parts with Basic Tools

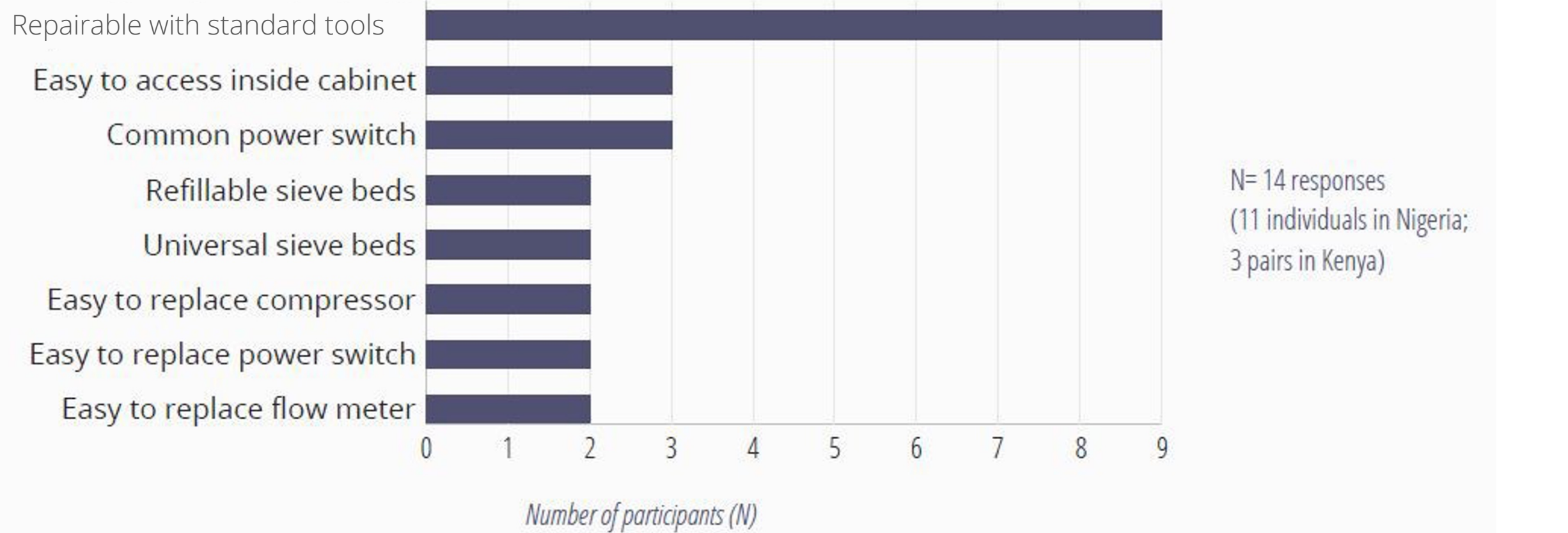
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*“We have so many types of concentrators, different makes. We find that whenever we look for spare parts, they’re not compatible with certain equipment. When the manufacturer makes a certain equipment or oxygen concentrator, **ensure that the spare parts are readily available in the market for easier maintenance.**”*

Biomed MT\_005\_B, Level 4 Health Centre, Nairobi, Kenya

# C-08 | Repair or Replace Parts with Basic Tools

Figure 53b: Top five features related to parts repair and replacement as reported by BME(T)s.



N= 14 responses  
(11 individuals in Nigeria;  
3 pairs in Kenya)

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# C-08 | Repair or Replace Parts with Basic Tools

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## Opportunity

Make it easy for technicians with minimal biomedical-specific training and basic tools to identify, source, access, and replace concentrator parts.

# H-02 | Redesign the Semi-Disposable to be Reusable

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*“The part that breaks most frequently is the humidifier bottle. It usually breaks during handling at the top where it is attached to the concentrator. When the humidifier bottles needed to be replaced, we couldn’t purchase other bottles locally, so the concentrators were not in use.”*

Biomed KY\_001\_B, Level 4 Health Centre, Nairobi, Kenya

# H-02 | Redesign the Semi-Disposable to be Reusable

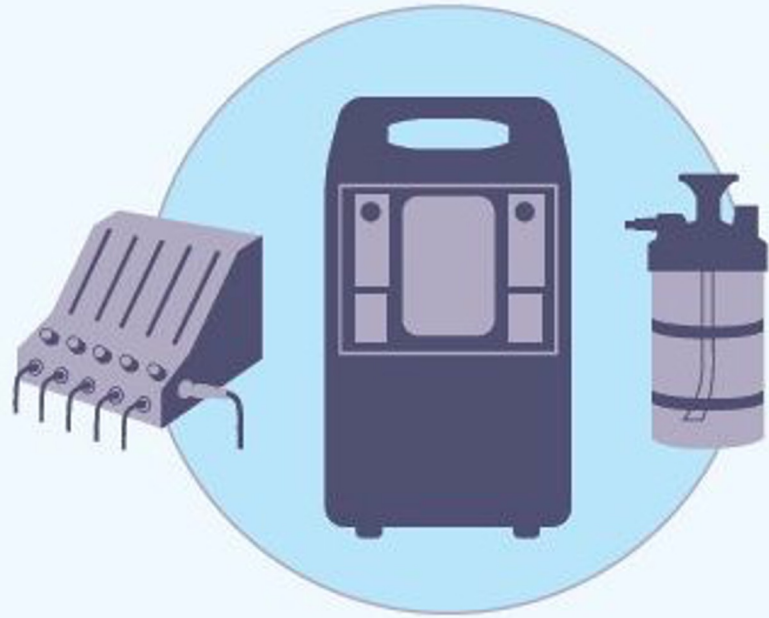
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## Opportunity

Redesign the bubble humidifier bottle from a semi-disposable to an affordable, reusable device.





Improve device design  
and labelling for LMICs



Reduce the burden of  
training and service in  
LMICs



Scale access to safe and  
effective oxygen therapy  
in LMICs

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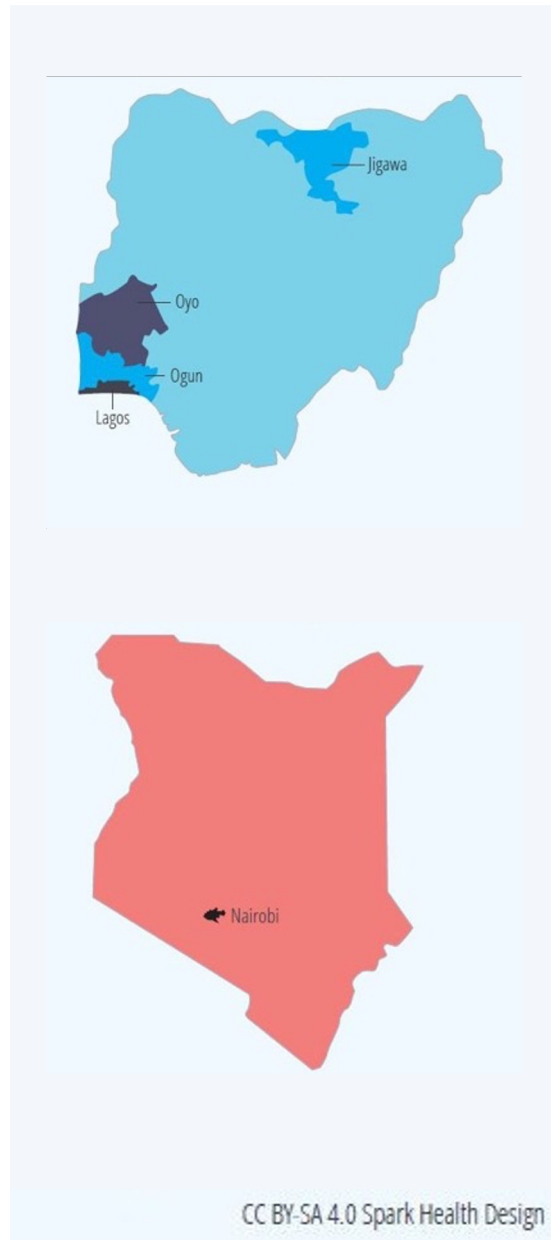
# Lessons for Practitioners

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# Select Countries with Strong Partners

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1. Potential future markets.
2. Ideally at least two countries to see differing use patterns, intended users, and intended use contexts for the medtech of focus.
3. **Select countries with strong partners**; there are many shared challenges between healthcare systems in different low- and middle-income countries, partners matter most.

# Select Partners in LMICs

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1. The activity advances the LMIC org's mission.
2. Experts with relevant clinical and technical experience.
3. Healthcare system relationships with facilities reflecting intended users and contexts.
4. Experience in conducting studies that require ethical and regional approval.
5. People trained in human-centered design or human factors - or - there is organizational interest in building capacity.

# Local Ethical Approval is Gold Standard

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Oyo State University  
Ministry of Health  
Nigeria



Maseno University  
Kenya

1. Enables a culturally-sensitive approach. For example, informed consent and remuneration customs.
2. University, government, or healthcare system ethics boards.
3. Regional and healthcare system approvals often also required.
4. Plan for translation into various languages.
5. Know the schedule; typically monthly cycles.

# Learn from Your Partners

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1. Early input on intended uses, users, and use contexts.
2. Identified most common technologies in-use locally.
3. Identified the most common failure modes of similar technologies.
4. Provided expertise in training healthcare professionals.

# Co-Create the Protocol

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## Moderator's Guide

Facility Tour

Photo Checklist

Interview

Nurse Interview Guide

Part A: Background & R

Part B: Simulated Use

Part C: Product Feature

BMET Interview Guide

Part A: Background & R

Part B: Simulated Use

Part C: Product Feature

Preferred Product Feature

1. First draft protocol from Spark Health Design.
2. Discussed with partners what is feasible for healthcare facilities and participants.
3. Discussed with partners whether the most important topics are covered.
4. Spark Health Design updated protocol.
5. Partners reworked protocol to appropriate format and content for local ethics approvals.

# Virtual Moderator Training

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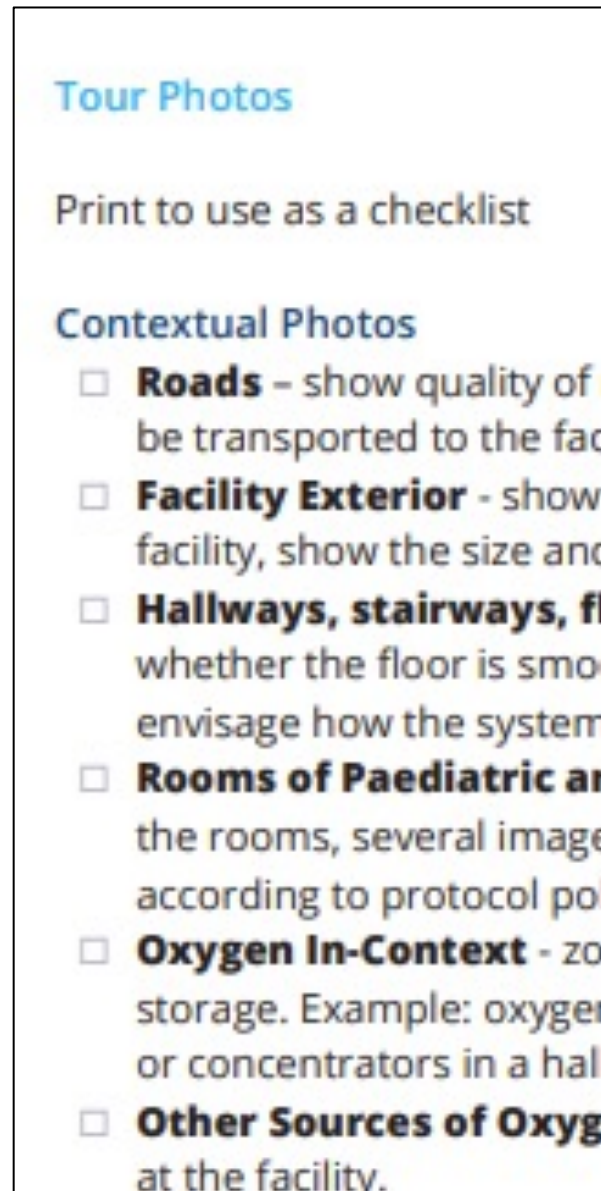


1. Virtual moderator training led by Spark Health Design.
2. Moderators performed practical run-through with stand-in participant, recorded on video.
3. Spark Health Design reviewed video.
4. Follow-up virtual moderator training with Spark Health Design to address any observation and questions from moderators.
5. WhatsApp group with moderators and Spark Health Design to answer questions ongoing.



# Contextual Inquiry for Those Not Present

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1. Moderators toured each facility.
2. Provided a list of photos to take.
3. Spark Health Design provided moderator training in what makes a good storytelling photo.

# Simulated Use Testing in Ad Hoc Spaces

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1. Visiting the context is key in early stages; healthcare professional participants more easily engaged if at their healthcare facility.
2. Partners performed simulated use testing in clinician offices, hallways, empty patient rooms, and instruction rooms.
3. Described what should stay consistent:
  - Patient bed against a wall
  - Bed proximity to power outlet
  - Medical supplies set out on a surface in the room



# Conclusion

# Conclusion

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1. The need is great.
2. Human factors practitioners are uniquely trained to help.
3. Ideal: people from LMICs trained in human factors.
4. More of us could make a big difference in **designing more medical devices for more people.**

## Design for Oxygen Concentrator Usability in Under-Resourced Healthcare Settings

An evidence-based guide to designing oxygen concentrators, humidifier bottles, and flow splitters to address the oxygen gap in healthcare settings in low and middle-income countries.

Version 1.0 July 2022



Find the oxygen concentrator design guide on UNICEF's website: <https://uni.cf/3oFolwN>



Johansen, E., Bakare, A.A., Sogbesan, A., Olojede, O., Bakare, D., Mate, M., Eleyinmi, J., Kendi, C., Njuguna, M., Onyango, E., Olatunde, O., Loring, B., Gheorghe, F., Ruddick, L., Subbaraman, K., Graham, H., Olayo, B., Falade, A.G. (2022, July). Design for Oxygen Concentrator Usability in Under-Resourced Healthcare Settings. Spark Health Design, Oxygen for Life Initiative, and Center for Public Health and Development. <https://www.unicef.org/supply/documents/design-oxygen-concentrator-usability-underresourced-healthcare-settings>.