**Oxygen Therapy - Introduction**

**WHAT**

Use Scuba tanks, existing kit, and SCUBA industry as an alternative to supply respiratory support and oxygen therapy in emergency scenarios such as field hospitals. Or free up capacity by removing those with lower requirements from the main feed.

Either with 100% oxygen sourced from industry or up to ~40% oxygen, and manpower sourced from dive shops independent of industrial oxygen as a force multiplier.

OXY-SAI: Oxy SCUBA Adaptor (Improvised)

OXY-WAI: Oxy Welding Adaptor (Improvised)

https://youtu.be/PKuD_cVHFm0

**WHY**

Potential Benefits

- Portable & independent from plumbed hospital oxygen
- Alternative O2 sources reduce drain on industrial sources providing 100% O2 by using Scuba Shops to fill tanks to ~40% using Oxygen Concentration from the air
- Industry of Scuba technicians available to support to fill tanks & modify regulators. Dive shops & private equipment may be called on.
- Minimal training at point of use ~10mins to learn regulator
Emergency portable respiratory support

Supporting Information

GLOSSARY

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>O2</td>
<td>Oxygen</td>
</tr>
<tr>
<td>FiO2</td>
<td>Enriched Oxygen Air (usually with % O2)</td>
</tr>
<tr>
<td>Regulator</td>
<td>A pressure reducing valve</td>
</tr>
<tr>
<td>Demand Valve</td>
<td>A regulator that feeds gas automatically as the user inhales</td>
</tr>
<tr>
<td>PADI</td>
<td>Professional Association of Diving Instructors</td>
</tr>
<tr>
<td>BSAC</td>
<td>British Sub-Aqua Club</td>
</tr>
<tr>
<td>Nitrox</td>
<td>Enriched Air Nitrox</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN</td>
<td>The DIN is a threaded valve, wherein you screw the regulator into the tank valve.</td>
</tr>
<tr>
<td>A-clamp / Yoke</td>
<td>The yoke is a clamp-type mounting, which is placed over the tank valve and then tightened into place. Some can be converted to DIN by removing an insert, others may need a yoke to DIN adapter.</td>
</tr>
</tbody>
</table>

DIN thread

A-Clamp
Aka Yoke
Use Scuba tanks, existing kit, and SCUBA industry as an alternative to supply respiratory support and oxygen therapy in emergency scenarios such as field hospitals. Or free up capacity by removing those with lower requirements from the main feed. Either with 100% oxygen sourced from industry or up to ~40% oxygen, and manpower sourced from dive shops independent of industrial oxygen as a force multiplier. OXY-SA1 Oxy: SCUBA Adaptor (Improvised). OXY-WAI Oxy: Welding Adaptor (Improvised)

https://www.youtube.com/PKuD_cVHFM0

The Need
- Extensive need for respiratory support & field hospitals being set up UK wide.
- Ventilators for worst cases, therapy sets may be required for others.
- Some suggest early basic support may prevent worsening, some may need continued after care.
- Risk of supplies of O2 from industrial supplier being limited, or shortage of portable units.

Potential Benefits
- Portable & independent from plumbed hospital oxygen
- Alternative O2 sources reduce drain on industrial sources providing 100% O2 by using Scuba Shops to fill tanks to ~40% using Oxygen Concentration from the air
- Industry of Scuba technicians available to support to fill tanks & modify regulators. Dive shops & private equipment may be called on.
- Minimal training at point of use ~10mins to learn regulator.

Changes to protocol in pandemic are highlighted in this quote from a New Orleans Medic
"I had never discharged multifocal pneumonia before, now I personally do it 12-15 times a shift. 2 weeks ago we were admitting anyone who needed supplemental O2. Now we are discharging with O2 if the patient is comfortable and oxygenating above 92% on nasal cannula. We have contracted with a company that sends a paramedic to their home twice daily to check on them and record pulse ox. We know many of these patients will bounce back but if it saves a bed for a day we have accomplished something"

HOW & WHO

- **Option 1** assume available std medical regulators – so only need standard adaptors available to buy (although low volume assumed, so manufacture). Connector in UK AP diving @ £36. https://www.apdiving.com/shop/scuba-to-medical-oxygen-adaptor.html May need extra manufacture – CNC shops

- **Option 2** assume shortage of medical regulators. Simpler solution than option 1, could be quicker and cheaper. Oxy-Sai prototype created, being tested / improved. < £1 to 3D print could open source. **Option 3** same scenario – for welding kit.

- **All options** Scuba industry support – Technicians fill compressors. Locations UK wide. Check tanks & fill.

- SCUBA tanks & poss regulator. Some ready to buy. Dive Centres, businesses & volunteers may lend tanks if system to return / reimburse. Within 2hrs of asking an Australian dive group nearly 200 tanks and 24 regulators were offered. **NB Not all tanks ideal, but may be useful or convertible. Those not easily cleaned for O2 can be used with 39% O2 Enriched Air (Nitrox) still useful for upping the O2 saturation of Conscious breathing casualties. Based on the use of Nitrox for emergency dive situations to provide extra oxygen to a sick diver in remote areas.

- **Possible other sources** of O2 kit - Airplane sets & regulators. Welding Sets. Commercial Oil & Gas Diving industry. Other.

NEXT

- If interested we can investigate plans: Test Scuba Industry, orgs (BSAC & PADI), and dive group buy in, ask for drawings and source suppliers for adaptors, find out numbers of components available, further work on prototype for Option 2 or look into stocks / making adaptors for Option 1 to demonstrate or get some made with help.

- This is an open source idea on a voluntary basis. Additional skills and materials will be needed to make some parts, and government support to manage, deploy and fund it.

- Further detail, and possible other options in following slides.
CONSCIOUS BREATHING PATIENT - "ON DEMAND"

- Can use unmodified SCUBA gear with 39% O2 breathing from the regulator's demand valve just like a diver. 39% is much cheaper and takes much less time to fill.
- Put in mouth, add nose clip and just breathe - OR - Make an adaptor to fit to a Medical Pocket mask or CPAP Mask that seals to the face (or the Snorkel mask shown in the media).
- This is equivalent to simple O2 a new patient gets - the current medical system gives a little pure O2 (4pm) and mixes it with air at the mask to give equivalent of 30-40% in the lungs.
- With this dive system - No gas comes from the air you set the mix to 39% when you compress it at the Dive Shop and each breath the user gets nearly 40% - direct from the tank.
- The "demand valve" simply feeds them 39% O2 Enriched Air as they breath, if they sigh or take a deep breath it feeds them what they need. Low difficulty of breathing and is easier than breathing through an N95 facemask.
- Minimal use of gas, only delivers gas when breathes in.
- Can use with 100% O2 also but less useful, usually want to keep FiO2% low as too long on high % not good for lungs.

CONSCIOUS BREATHING PATIENT - WITH DIFFICULTY BREATHING OR UNCONSCIOUS PATIENT - FREEFLOW OF OXYGEN

- Low Flow, 100% O2 - Freeflow - In this case any one of the options in the picture could be used to supply 100% on a low 4-5lpm flow rate but tanks and regs would need to be O2 clean
- Using a scuba regulator to deliver a constant flow of O2 instead of a medical oxygen regulator.
- Scuba Technician can adjust regulator to freeflow
- 3D Print a simple clamp with a screw that pushes on the "purge" button at a fixed depression. A medical flowmeter (ball) can be put in line. Additionally a 3D printed adaptor (or a simple $10 rubber ball) can be made to fit tightly over the scuba mouthpiece instead of a divers lips.

SEPARATE SOURCING

This could offer
- A separate source of bottles, and a source of people to clean and service those bottles
- A source of Volunteers to move those bottles, manage them and get them filled - Dive clubs, Dive Industry (Many divers are trained in First aid and would be at least as good a source of Nurse Assistants than retreining Air Hostesses as suggested).
- A separate source of people to fill those bottles.

HOW LONG WILL IT LAST?

- Length of use of the cylinder depends on its size.
- Cylinders are measured by "water capacity" i.e. if you filled them with water how much water (or Air at Atmospheric pressure) they would hold. If you then multiply by the Pressure to which you charge the cylinder this you give you the number of litres "free air" i.e. if you let it all out of the tank into a bag, how big a bag would it fill?
  - 100% O2 can only be filled to 200 Bar
  - <40% O2 can be filled to 240 Bar (1 Bar = Atmospheric pressure)

<table>
<thead>
<tr>
<th>Typical Cylinder</th>
<th>Weight</th>
<th>Replace cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 Litres</td>
<td>14.2kg</td>
<td>~ AUS $500 retail</td>
</tr>
<tr>
<td>15 Litres</td>
<td>16.5kg</td>
<td>~$640 (Retail)</td>
</tr>
</tbody>
</table>

| @ 100% O2 | 200bar * 12 litres = 2,400 litres  |
| At 5lpm Constant flow = 480 mins = 8 Hours |
| @ 39% O2 | 240 bar*12 litres = 2,880 litres  |
| @15 lpm (constant flow) or ~15lpm (demand flow) = 192 mins = 3.2 Hours |

| @ 100% O2 | 200 Bar * 15 litres = 3500 litres  |
| At 5 lpm constant flow - 700 mins = 11 Hours |
| @ 39% O2 | 240 Bar * 15 litres = 3,600 litres  |
| @ 15 lpm (constant flow or demand) = 240 mins = 4 Hours |

- Some smaller cylinders also available: 3 litres (about the size of a typical C size medical cylinder); 7 litre (size of fireman's BA Set); 10 litres (size of medical D cylinder) which could be more portable.
- Where companies such as BOC are only supplying bottled gases on an empty for full basis, this would add extra tanks. Re-fill takes 30-40mins per bottle.
- If the SCUBA tanks are used as O2 tanks – longer times are available.
  - 12 litre 200 bar tank - 100% O2 at 5lpm = 8 hours
  - 12 litre 200 bar tank (can't fill 240 bar tank past 200 bar with O2) - 100% O2 at 15lpm = 2.7hrs
  - 12 litre 240 bar Tank 40% Nitrox at 15 lpm = 3.2 hrs (Using this system you would only use about 30 Bar of a LARGE 50L 200 Bar cylinder so 1 big cylinder is diluted and goes a long way). When empty or half empty - you send it to the dive shop for fill.
- Welding example: Tank D size 2.1l.c.m of O2 - 2100 litres of free O2 @15lpm = 2.3 hrs, @4lpm = 8.75 hrs.

POSSIBLE DEVELOPMENTS - WITH ACCESS TO WORKSHOPS AND TECHS.

- Improved constant flow - A more elegant solution could be to manufacture a simple "nipple" and orifice plate pressure reducer to the medium pressure hose of a dive regulator that gives a fixed flow rate (e.g. my calcs show a 0.25-0.4mm orifice in the 10bar medium pressure port with a nipple for a medical O2 mask would deliver the required flow rates) - Need access to a lathe to develop this.
- Low Gas Whistle - Currently regulators have a clear pressure gauge. For a conscious patient they can monitor gas supply. For unconscious patients in a large busy makeshift hospital a solution already exists - Old style Fire Brigade BA sets had a whistle, a spring allowed a valve to open up when the pressure fell beneath 30 Bar this diverted some flow through a whistle - If these designs or an original (DFES Fire brigade museum) can be copied this could be rapidly implemented.
**VIDEO LINKS**

For this solution:  
[https://youtu.be/PKuD_cVHFm0](https://youtu.be/PKuD_cVHFm0)  
[https://youtu.be/2Fng8-e99Fs](https://youtu.be/2Fng8-e99Fs)  
[https://youtu.be/CeMjeGlOH0Y](https://youtu.be/CeMjeGlOH0Y)  
(Please turn on closed captions / subtitles)

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**IS AN ALTERNATIVE SOURCE OF O2 REQUIRED?**

Media coverage of concerns of oxygen supply.

[https://www.theguardian.com/society/2020/apr/02/london-hospital-almost-runs-out-oxygen-coronavirus-patients?fbclid=IwAR0_I5wJYWnbM_UhlWc4i2JXe2uSNH3joYMk25lypFwRh7TZ-AINTSQVgo](https://www.theguardian.com/society/2020/apr/02/london-hospital-almost-runs-out-oxygen-coronavirus-patients?fbclid=IwAR0_I5wJYWnbM_UhlWc4i2JXe2uSNH3joYMk25lypFwRh7TZ-AINTSQVgo)

[https://www.youtube.com/watch?v=TsNvXerEJuA&feature=youtu.be&fbclid=IwAR2M84NdSy4tWpN9XWigyD7eU0oNXKqzfaGR_r_RMdfRdX4J2HK41r3usc](https://www.youtube.com/watch?v=TsNvXerEJuA&feature=youtu.be&fbclid=IwAR2M84NdSy4tWpN9XWigyD7eU0oNXKqzfaGR_r_RMdfRdX4J2HK41r3usc)

As this article explains

[https://www.gasworld.com/hot-topic-oxygen-supply-shortage/2018697.article](https://www.gasworld.com/hot-topic-oxygen-supply-shortage/2018697.article)

"Karina Kocha, Business Intelligence Manager for gasworld, explained that it seems the challenge with this current outbreak of coronavirus is not so much in the supply of oxygen in the market, but rather the capacity of the hospital supply systems to cope with the sharp increases in demand as they become overwhelmed with stricken patients.

This is, therefore, more of an infrastructure challenge than it is pure product supply. Kocha adds, “The problem here may be in the capacity of the hospital supply systems, which could be not enough for increased consumption. The fastest way to increase it is to bring oxygen in cylinders. Medical oxygen cylinders are technically the same as for technical (industrial) gases, but do need to comply with various government regulations regarding testing and labeling.”

This suggests it may not be needed at hospital level. But reading in USA they are sending patients with mild pneumonia home with a tank of o2 and telling them to stay in and medic visiting 2x a day. Large bottle banks.... that's for the gas companies to sort out.

But there may still be a use for scuba for its **portability and simplicity.**

1. Dive tanks are by definition easily portable. Likely bottlenecks is in man portable tank supply.
2. Nitrox needs more regular filling but is safer to hand out. No explosion risk
3. Small D and E welding o2 tanks may also good. BOC says never ever do this..... but this article says and others you can its just QAQC difference it has to be clean enough to breathe by definition of how its made.. plus welding tanks can be bled down and cleaned. This needs further review – and may be considered differently in worse hit countries.

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**So how can it help?**

- **BIG Hospitals** - Large numbers of less critical patients are using high flow oxygen and causing lines to freeze or heavy demands on the system putting low flow ventilated patients at risk. Hospitals are using more portable O2 for less at risk patients needing high flow.

- **Field Hospitals and outpatients** - In USA its been reported that less critical patients are being sent home with tanks and checked on by roaming nurses / medics. Also field hospitals likely to need portable O2 unlike to have liquid O2.

- **Additionally if a number of Cryogenic O2 tanker drivers get sick this can lead to O2 shortages in Liquid systems as these drivers are specially trained and more bottles likely to be needed. Most commercial bottles are large quad or 50 litre systems rather than “person” portable. SCUBA gear is easily portable.**
ASSUMPTIONS

<table>
<thead>
<tr>
<th>ASSUMPTIONS</th>
<th>VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Lung Tidal Volume</td>
<td>0.5 litres</td>
</tr>
<tr>
<td>Ratio of Inhalation to Exhalation</td>
<td>1:2</td>
</tr>
<tr>
<td>Respiration Rate</td>
<td>12 - 20 breaths / min</td>
</tr>
<tr>
<td>Typically Inspiration</td>
<td>500ml taking 1-1.5 secs</td>
</tr>
<tr>
<td>Peak Flow rate during typical inspiration</td>
<td>20-30lpm</td>
</tr>
<tr>
<td>Non Rebreather Mask</td>
<td>15 lpm gives 80% FiO2 worst case.</td>
</tr>
<tr>
<td>During inhalation Peak flow</td>
<td>30 lpm flow</td>
</tr>
</tbody>
</table>

EMERGENCY OPTIONS USING SCUBA GEAR (Typical 12l tank) BY MASK TYPE

<table>
<thead>
<tr>
<th>Option</th>
<th>Delivery Mechanism</th>
<th>Gas</th>
<th>Flowrate</th>
<th>Est FiO2 delivered</th>
<th>Oxy REG</th>
<th>Oxy-SAi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.a. Nasal Prongs</td>
<td></td>
<td>100%</td>
<td>4/8 lpm</td>
<td>30% / 40%</td>
<td>Yes</td>
<td>Maybe *</td>
</tr>
<tr>
<td>1.b. Basic Mask</td>
<td></td>
<td>100%</td>
<td>4/8 lpm</td>
<td>30% / 40%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1.c. Open Face Mask</td>
<td>40% Nitrox</td>
<td>15 lpm</td>
<td></td>
<td>30%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2.a. Non Rebreather mask</td>
<td>100%</td>
<td>15 lpm</td>
<td></td>
<td>80% - 95%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2.b. Non Rebreather mask,</td>
<td>100%</td>
<td>15 lpm</td>
<td></td>
<td>35%-38%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3. Normal Scuba Demand Regulator with Nose clip (or pocket mask) zero air entrainment.</td>
<td>40% On Demand – no freeflow – 15-20pm but 0lpm between inhalations</td>
<td>40% (Confirmed not estimate)</td>
<td>Maybe **</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See Calculations In Appendices

"*Precise low flow difficult with basic valve fitted to cylinder"

"**Only if using on demand high flow system"

ADDITIONAL INFORMATION FOR WELDING EQUIPMENT

2100 litres of free O2 at 15lpm it will last 2.3 hours
At 4lpm it will last 8.75 hours on a cannula
**ACTIONS TO MOBILISE SCUBA INDUSTRY & DIVERS**

**Conscious Breathing Patient: “On demand”**

- Talk to peak organisations PADI / BSAC (BSAC in UK many clubs have lots of gear).
- Search and identify Dive centres (may be a long way away) who can fill tanks with Nitrox and O2 and Who has Membrane Systems.
- Find Dive networks on Social media in your area - use media and new media to ask for loan cylinders. (S‘sea Sound keen to help).
- Use local dive shop or club to collect cylinders, note tank numbers - label and tag so they can be returned later hospital admin to ensure they get spreadsheet of property and make sure receipts are issued. Dive shop / dive volunteers who are trained e.g. Mixed gas blenders to O2 clean and certify tanks - Needs 3 to 7 days per batch - each tank about 1-3 hours depending on production line and batching.
- In some areas e.g. Swansea Dive there are a few dive clubs and they have a fair few tanks, its not like say Perth (Aus) which is a holiday dive destination. Large cities will have more.
- Also use welding sets, aviation o2 etc.
- If you have different sized valves e.g. Welding O2 - Talk to us to quickly design an OXYSAI adaptor for you. We need photos and measurements. You will also need plenty of PTFE tape to make a seal.
- For HP Oxygen converters - Need to talk to AP Valves and other manufacturing / Small workshops for drawings which can be fabricated quickly but needs some lead time to get drawings and source manufacturers especially because many are shut down.

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**BSAC MAP OF DIVE CLUBS**
SOME NITROX FILL STATIONS

See “Facilities” for fill type. Majority of fill stations use “partial pressure blending” which relies on industrial oxygen meaning equipment will need to be O2 clean. However this still extends the O2 supply and most of the cylinders can be O2 cleaned. This is only a snapshot and there are likely many more around. E.g. Stoney Stanton in leicestershire. Additionally Air Products could ramp up Membrane filter use.

<table>
<thead>
<tr>
<th>Area</th>
<th>City</th>
<th>Name</th>
<th>Facilities</th>
<th>Phone</th>
<th>URL / Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Devon</td>
<td>Plymouth</td>
<td>In Deep</td>
<td>Membrane 40%</td>
<td>01752 405400</td>
<td><a href="http://www.indeep.co.uk/">http://www.indeep.co.uk/</a></td>
</tr>
<tr>
<td>West Midlands</td>
<td>Milwaukee</td>
<td>AC Diving</td>
<td>Nitrox Avail - Method Unknown</td>
<td>01572 868450</td>
<td><a href="http://www.diversair.co.uk/">www.diversair.co.uk</a></td>
</tr>
<tr>
<td>South Wales</td>
<td>Cardiff</td>
<td>Cardiff Scuba</td>
<td>Partial Pressure Blending</td>
<td>02920 615161</td>
<td><a href="http://www.cardiffscuba.co.uk/">www.cardiffscuba.co.uk</a></td>
</tr>
<tr>
<td>South Wales</td>
<td>Swansea</td>
<td>Ocean Quest</td>
<td>Unknown or if even Nitrox?</td>
<td>01792 606500</td>
<td><a href="http://team@ocean-quest.co.uk/">team@ocean-quest.co.uk</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>029 20 303545</td>
<td><a href="http://www.ocean-quest.co.uk/">www.ocean-quest.co.uk</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bay Divers</td>
<td></td>
<td>01656 789344</td>
<td><a href="http://baydivers@live.co.uk/">baydivers@live.co.uk</a></td>
</tr>
<tr>
<td>West Midlands</td>
<td>Milford Haven</td>
<td>Haven Diving services</td>
<td>Nitrox Available – Method Unknown</td>
<td>07581 811240</td>
<td><a href="http://info@havendivingservices.com">info@havendivingservices.com</a></td>
</tr>
<tr>
<td>North &amp; Mid Wales</td>
<td>Wrexham</td>
<td>Divers Air Wrexham</td>
<td>Nitrox Available – Method Unknown</td>
<td>01978661352</td>
<td><a href="http://Sise55@yahoo.co.uk">Sise55@yahoo.co.uk</a></td>
</tr>
<tr>
<td>East Midlands</td>
<td>Oakham</td>
<td>Dive Rutland</td>
<td>Partial Pressure Blending</td>
<td>01572 868450</td>
<td><a href="http://www.diverutland.com">www.diverutland.com</a></td>
</tr>
<tr>
<td>West Midlands</td>
<td>Studley</td>
<td>Scuba School</td>
<td>Partial Pressure Blending</td>
<td>01527 852 555</td>
<td><a href="http://info@scubaschool.org.uk">info@scubaschool.org.uk</a></td>
</tr>
<tr>
<td>Avon</td>
<td>Bath</td>
<td>Vobster Quarry</td>
<td>Partial Pressure Blending</td>
<td>01373 814666</td>
<td><a href="http://info@vobster.com">info@vobster.com</a></td>
</tr>
</tbody>
</table>

SUPPLY

1. Partial Pressure Blending – Requires O2 Clean Cylinders – As tanks are emptied, then receive 30-60 bars of pure O2 then topped off with air – Since it touches >40% O2 the tanks need to be O2 clean, but the regs won’t need to be O2 clean if <40% Nitrox used. But if they are clean then 50 % O2 could be used to extend O2 supplies and boost FiO2.


Industrial Supply

- Prism Membrane Products – Supply industrial Membrane Concentrators – [www.airproducts.co.uk](http://www.airproducts.co.uk) ; 0800 389 0202, apukinfo@airproducts.com

Industrial Supply

- OXY-SAI: New 3D printed prototype – untested in field – see contacts above.
Use of Enriched Air Nitrox (EAN) aka Nitrox

Using Nitrox even just for free flow Masks could greatly increase the capability of giving Oxygen to massive numbers of people. It can be made locally using the same technology as Personal Oxygen Concentrators use i.e. using Nitrogen membrane filters to concentrate and compress the Nitrox mix and store it in large volumes & deliver with existing equipment.

Key Points

i. **Nitrox** is oxygen enriched air which is a mix of Nitrogen and Oxygen but with a higher oxygen percentage than air. In hospitals when patients are breathing from an oxygen mask they are sometimes breathing a low flow of oxygen to raise the amount in their blood. e.g. they may be getting 4 lpm of Oxygen while their natural respiration rate is 10-12 lpm so they are getting about 40%-50% oxygen mix – rather than 100%.

   - Instead of using pure oxygen from a bottle (which could be rare). They may be able to use a pre-blended Nitrox mixture with adapted SCUBA equipment. They could still have up to 40%-50%, without drawing on the scarce supply of medical equipment. It would be stand alone (makeshift hospital without plumbed in O2), and using equipment that already exists in private hands. A 15 litre dive tank could last up to 5 hours at this flowrate (~3.5hrs for a 12litre lighter tank).

   - Any mix of Nitrox from 20% - 40% could be used, a typical diving mix is EAN36 i.e. 36% oxygen. In some cases higher oxygen rates could be achieved but these require more specialist equipment - not as readily available but they do exist. One method of producing Nitrox uses membranes that filter the air and concentrate the oxygen which would prevent drawing on scarce oxygen supplies.

ii. **When O2 >40% touches anything it requires great care to use materials that are O2 Cleaned** (no greases / anything combustible) and O2 Compatible Materials (plastics, metals that can’t combust). However Nitrox 36% does not require special equipment, it’s low enough that risk of O2 saturated bedsheets should not be high.

iii. **Minimal training** - A doctor could prescribe O2 mix required, then a Scuba-tech fills the tank to that %. They analyse it with a simple hand analyser used currently by every dive centre for Nitrox, and marks the tank. So the mix is pre-blended.

iv. **To mix Nitrox many fill centres exist which use several methods** – The BEST is a nitrogen separating membrane (this technology is used at a small scale in Personal Oxygen Concentrators), which can MAKE Nitrox from normal air enriching the air up to about 50% Nitrox WITHOUT STRETCHING EXISTING O2 infrastructure. Even where this isn’t available there is a whole industry of dive shops dedicated to filling peoples’ dive tanks with Nitrox every weekend that is currently idle with plenty of capacity for thousands of people. Click **[here](http://www.nitroxmadeeasy.com/Methods.htm)**

   - There are other ways to mix and blend nitrox that different dive shops will have set up. Where possible the best way is Oxygen Concentrating Filter Membrane as it doesn’t need commercial O2 Plants (BOC, Air Liquide etc.) that create pure O2 and only have a limited stock of Cylinders.

v. **Another option could be to look into the use of welding oxygen**
Supporting information – Basic layout of SCUBA gear

SCUBA gear basic layout

1st stage regulator
240 Bar -> 10 Bar

2nd stage regulator
10 Bar -> Ambient P

Scuba Tank
15 litre 240 Bar

Use of Scuba gear as a basis for respiratory support and designs – ideally with minimum modification

- Portability,
- Independence from plumbed in O2 in a hospital,
- Wide availability,
- Entire industry of Scuba Techs (currently unemployed) who can support.

Supporting information

- Basic layout of SCUBA gear
- Use of SCUBA gear as a basis for respiratory support and designs

With thanks to these and others: Ian Williamson, Euring BEng MSc CEng MIET CGLI; Dr. Barry Doyle BEng PhD; Verma Vitales BEng; Paul Skyrme MEng, BSoc(Hons), IEng, MIET, MSOE, MBES, SiRSM, TechIOSH, CMSE®; Dr. Martin Cross BEng PhD FSEng CEng FIMEchE; Phil Bevan, Chairman BSACWA; Troy Lane MD Perth Diving Academy; Lee Johnston & Joey Pool, Owners Perth Scuba; Groups: FB@SCUBAID; FB Diving Buddies (Perth)
## ASSUMPTIONS

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Lung Tidal Volume</td>
<td>0.5 litres</td>
</tr>
<tr>
<td>Ratio of Inhalation to Exhalation</td>
<td>1:2</td>
</tr>
<tr>
<td>Respiratory Rate</td>
<td>12 - 20 breaths / min</td>
</tr>
<tr>
<td>Typically Inspiration</td>
<td>500ml taking 1-1.5 secs</td>
</tr>
<tr>
<td>Peak Flow rate during typical inhalation</td>
<td>20-30lpm</td>
</tr>
<tr>
<td>Non Rebreather Mask</td>
<td>15 lpm gives 80% FiO2 worst case.</td>
</tr>
<tr>
<td>During inhalation Peak flow</td>
<td>30 lpm flow</td>
</tr>
</tbody>
</table>

## EMERGENCY OPTIONS USING SCUBA GEAR (Typical 12l tank) BY MASK TYPE

<table>
<thead>
<tr>
<th>Method – Typical 12l tank</th>
<th>Oxy REG</th>
<th>OxySAi</th>
<th>Comments &amp; Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal Prongs, 100% O2</td>
<td>Yes</td>
<td>Maybe</td>
<td>Nasal Cannula / Simple Mask - With 100% O2 at 8lpm During inhalation Peak flow = 30lpm flow = 8lpm therefore ~1/4 of the inhaled volume is 100% O2 i.e. 125ml is 100%O2 i.e. O2 = 125ml 375ml is Air and 20% of that is O2 = 75ml and 300ml is N2 Total % O2 is 75ml (O2 from Air) and 125ml (Delivered O2) = 200ml / 500ml = 40% FiO2</td>
</tr>
<tr>
<td>Open Face mask, 100% O2</td>
<td>Yes</td>
<td>Yes</td>
<td>8lpm Nitrox 40 standard mask gives 25% FiO2 in lungs Vs 30% if it was pure o2 delivered</td>
</tr>
<tr>
<td>Open Face mask, 40% O2</td>
<td>Yes</td>
<td>Yes</td>
<td>Simple Mask with - 40% Nitrox at 15 lpm, Peak is 30lpm (not counting that the NR Mask bag makes up for this so FiO2 is for a simple mask) 1/2 of inhaled volume is Air i.e. 250ml is Air, 250ml is 40% O2 250ml * 20% = 50ml O2 from Air; 250 * 40% = 100ml O2 from Nitrox; Total O2 is 150/500 = 30% So Using Nitrox with SIMPLE MASK @ 15lpm = 30% O2</td>
</tr>
<tr>
<td>Non Rebreather mask, 100% 15lpm 80-95% FiO2</td>
<td>Yes</td>
<td>Yes</td>
<td>Non Rebreather Mask (NRM) with 100% O2 worst FiO2 is 80% O2 at 15lpm So 20% is N2 from Air so of 500ml 100ml will be N2. That means 400ml comes from O2 delivered + O2 Air - so N2:O2 is 4:1 so 100ml N2 means 25 ml came from air. O2 from Air = 25ml; O2 Delivered = 375ml. So NRM gives 80%(low end) to nearly 100% in the lungs at 15lpm (likely more due to bag),</td>
</tr>
<tr>
<td>Non Rebreather mask, 40% Nitrox 15lpm 35-38% FiO2</td>
<td>Yes</td>
<td>Yes</td>
<td>O2 from Air = 25ml; O2 Delivered = 40% * 375ml = 150ml; Total O2 = 175 / 500 = 35% O2 SO NRM Mask at 15lpm Nitrox40 gives MINIMUM 35% and maximum 40% FiO2 Normal Mask at 15lpm Nitrox40 gives 30% FiO2 This is similar to a Normal Mask or Nasal Cannula with 100% O2 at 4-8lpm</td>
</tr>
</tbody>
</table>

### Normal Scuba Demand Regulator with Nose clip
Breathing compressed Nitrox @ 40%. Only delivers air when sucked in, no freeflow, no entrained air. But may help if breathing is good slight restriction. Requires Conscious Patient – 40% Nitrox / 40% FiO2 (or if using 100% O2, FiO2 in Lungs 100%) Maybe Only if using on demand highflow system No this is only a low pressure system

**SCUBA Reg - Yes**: This is the best system to use with this option. Either use unchanged scuba reg with bite piece and nose clip OR adaptor to a Pocket mask / CPAP mask or the new SCUBA Masks from Italy.

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**12L Nitrox 40 tank filled from membrane system to 240 bar**

Gives 240 Bar * 12 = 2880 litres @15lpm - lasts for 192 mins - 3hrs 12 mins

12L 100% O2 filled to 200 bar

Gives 200 * 12 = 2400 litres @8lpm – lasts for 300 mins – 5hrs

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**With thanks to these and others:** Ian Williamson; Euring BEng MSc CEng MIET CGLI; Dr. Barry Doyle BEng PhD; Verma Vitales BEng; Paul Skyrme MEng; Mike Cass (Hons); IEng; MIET; MSOE; MBES; SIIRSM; TechIOSH; CMSE®; Dr. Martin Cross BEng PhD FEng CEng FIMechE; Phil Bevan; Chairman BSACWA; Troy Lane MD Perth Diving Academy; Lee Johnston & Joey Pool. Owners Perth Scuba; Groups: FB@SCUBAAid; FB Diving Buddies (Perth)
Possible Alternative Solutions To develop
WHAT

Modify SCUBA Rig to be a CPAP – Positive pressure flow, but also a CPAP that is independent of power AND can provide elevated O2 levels which an electric CPAP can’t do. Could be done with a simple adjustment to regulator, plus gluing the exhaust valve shut and adding a spring controlled back pressure exhaust valve. This could also be relatively quickly implemented in a few days once we work out how.

KEY POINTS

Current regulator

Possible Method
1. Adjust inlet pressure to be higher so valve free flows slightly, if out of mouth
2. Replace simple exhaust mushroom valve with a sprung valve – which can be adjusted for back pressure
3. Use adaptor shown in 3a to go to a CPAP mask and harness. – with mask off face free-flows, mask in place pressure builds up to exhaust level and reg seals (adjust both inlet and exhaust), user breathes in breathes in with about 8 to 20 cm H2S positive pressure.

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**WHAT**

Use scuba tank & regulator adjusted for positive pressure with added in line module. Mechanical or Electromechanical solutions to consider.

Use scuba tank and regulator (1st stage, or possibly both stages, adjusted for positive pressure with a module added in line to make a full ventilator – Could be run off scuba cylinder (air, enriched air nitrox, oxygen (but requires O2 clean and O2 service materials)).

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**KEY POINTS**

**Electro Mechanical Ventilator**

Add Modules to make Mech / Elec Ventilator – Uses portable compressed air / Nitrox / Oxygen – no need to pump uses compressed gas to ventilate – Electromechanical control module (Solenoid, pop-off valve, pressure sensor) uses 240V

**Mechanical Ventilator**

Using Compressed air as sole power source develop from Positive pressure demand regulator resuscitator idea like Oxy-Viva3 / O2 But developed from this to include volume metering or a mechanical feedback system to dump pressure once inflated until lungs empty and ready to start again (exactly how unsure – pop-off valve or exhalation bag which when full triggers valve again? – Portable, not reliant on plumbed Oxygen or Power. Based on this – https://otwo.com/oxygen-therapy-resuscitation-kits/demand-valve-resuscitator/