

Reducing Carbon Monoxide Content in Surface-Supplied (Hookah) Air Sources of Artisanal Fishermen of the Yucatan Peninsula

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Background

Over 300 fishermen in the Yucatan Peninsula utilize primitive hookah dive systems (HDS) supplied by poorly-filtered gas compressors. Each year 75% of this population experiences decompression illness (DCI).

Gas engine exhaust is located in close proximity to air compressor intake which allows carbon monoxide (CO) and carbon dioxide (CO₂) to directly enter the volume tank air supply of the HDS.

Conservative safety standards permit a diver’s air supply to contain 10 ppm of CO and 500 ppm of CO₂.

Exposure to excessive amounts of CO and CO₂ can lead to symptoms similar to DCI. This makes distinguishing injury and designing interventions to prevent future injuries difficult.



Purpose

This study quantified the levels of CO and CO₂ from the fishermen’s air supply both before and after physical separation of engine exhaust from air compressor intake.

Eliminating the threat of potential CO and CO₂ poisoning could help clarify symptoms of DCI

Materials

Samples

This observational study was full reviewed and approved by the UCLA IRB (#13-00532). Eight consenting fishermen volunteered their volume tanks for CO and CO₂ analysis. Fishermen also consented to the implementation of an intervention that separated air compressor intake from gas engine exhaust. Data was not collected from one participant.

Measuring Instruments

A C-Squared® CO Analyzer (±1 ppm) calibrated with a Praxair 70 ppmv CO-N₂ gas (±5%) and an Analox® Aspida CO₂ Analyzer (±1%) calibrated according to the manufacturer’s standards were used to analyze gas samples.

An aluminum panel (12” X 16”) was designed to serve as a gas sample manifold. Measuring instruments were fitted into custom cut-outs and bolted into place on the panel. The manifold was leveled and bolted onto a wheeled Oxygen cylinder holder for ease of transport.

Procedure

Gas samples were obtained while the engine was idling and after the volume tank was fully pressurized (100-160 PSIG).

4 CO and 4 CO₂ values per each of the seven volume tanks analyzed were collected before and after the intervention according to the following procedure:

Gas Sample Procedure

1. Flush with O₂
 - 0.5 L/min for 15 sec
2. Turn 3-way valve to CO/CO₂
 - 0.2 L/min for 25 sec
 - Record CO/CO₂ (1)
 - Wait 10 sec
 - Record CO/CO₂ (2)



Gas Sample Manifold

Tanks were drained and allowed to re-fill before post-intervention measurements were acquired.



A 0.25” Swagelok hose connected volume tank gas samples to the sample manifold via quick disconnects.

Intervention

1. Air compressor intakes of each participating HDS were fitted with a custom-designed rectangular high temperature aluminum plate (0.25 X 4.00” X 1.75”).
2. High temperature gasket rubber created an air-tight seal between the plate and the compressor intake.
3. A 1-1/4” polyethylene hose (200°F) was inserted into a circular cut-out in the metal compressor plate and secured by a stainless steel hose clamp.
4. A customized aluminum 1.5” wide bracket was bolted onto the compressor body; the bracket created a 90 degree angle with a base of 4.0” and a height of 10.0.”
5. A 5.0’ PVC pipe was bolted to the bracket.
6. The hose was elevated above the gas engine exhaust and secured to the pipe in 3 separate locations with either zip ties or a carabiner keychain.
7. A large particle filter was secured to the distal end of the hose with another hose clamp.



Variables

- CO
- CO₂
- Volume tank size (1-1.5 ft³)
- Compressor intake dimensions (3.5-63 cm²)
- Engine horsepower (5.5-6.5 HP)

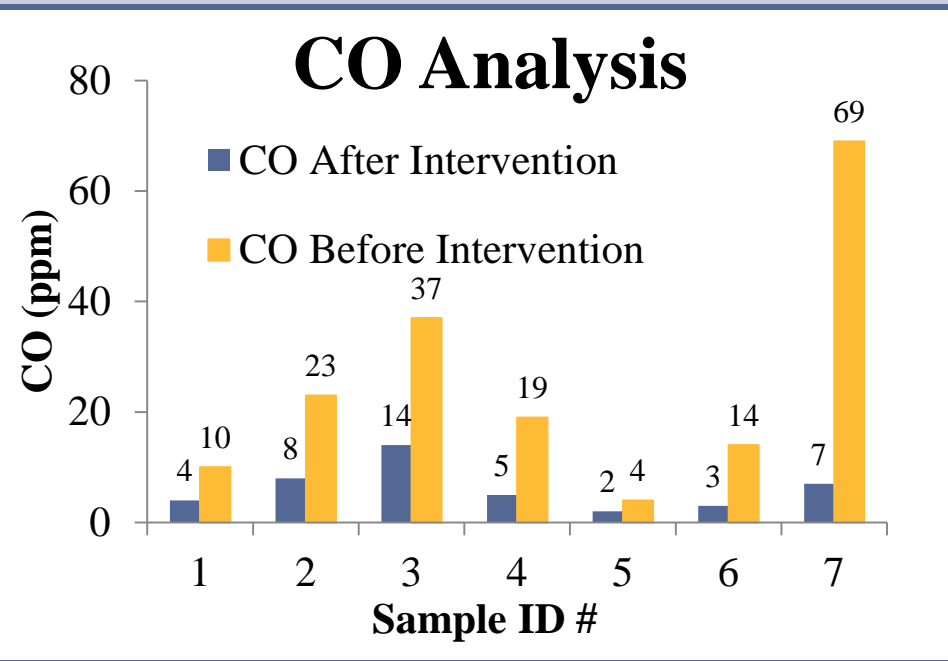
Data Analysis

Mean CO and CO₂ values were compared before and after the intervention was applied. Means were tested for differences using a paired samples *t*-test.

Results

Mean difference for CO levels before and after the intervention was significant, *t*(6) = 2.622, *p* = 0.04 whereas the CO₂ levels were not significantly different, *t*(6) = 2.066, *p* = 0.084

Gas	Pre- Intervention (N = 7)		Post-Intervention (N= 7)	
	Mean (ppm)	Range (ppm)	Mean (ppm)	Range (ppm)
CO	25.5	4.0-68.0	7.0	2.0-17.0
CO ₂	430	400-500	400	400



Conclusion

The intervention reduced CO in the fishermen’s air supply by 75% to acceptable diving levels. CO₂ levels do not appear to be at detrimental levels to these divers

Discussion

This intervention could be applied to additional members of the fishing cooperative.