Scuba air quality

Part 2: How do we analyse the air we are breathing?

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IN THIS PART, WE LOOK AT COMMON CONTAMINANTS AND THE VARIOUS TESTING OPTIONS AVAILABLE TO DIVE OPERATORS, FILLING STATIONS AND INDIVIDUAL DIVERS.

IN Part 1 on this topic, we discussed the contaminants we are concerned about, how to determine appropriate limits for these contaminants and we noted that the South African regulations have become a little less clear on this subject, pending a revision of SANS 532.

We know that sophisticated laboratories are able to test air for practically any constituent let alone the wide array of potential contaminants. However, to be practical, the measurements need to be performed real-time, on-site and should be limited to those contaminants that are both likely to be entrained and harmful if present. Otherwise, by the time a laboratory report comes back, many cylinders might already be filled with some undesirable or unsafe pollutant.

In Part 2 of this series, we will look at how we actually determine the level of contaminants in our compressed breathing air. We will review the available techniques for the various constituents and common contaminants and then we will discuss field testing options that are available to dive operators, filling stations or even individual divers filling their own cylinders or wishing to test their breathing gas before use. Finally, we conclude with what we can do when test results approach or exceed the set limits of safety and quality.

> “THERE ARE THREE FUNDAMENTAL WAYS TO DETERMINE AIR QUALITY.

WHAT ARE THE USUAL ANALYSIS TECHNIQUES?

The available analytical methods range from very basic, inexpensive, field testing devices to very sophisticated laboratory equipment. Most of the time, the former is enough to ensure that the compressors and filter packages are working within specification without excessive pollutants being entrained from the surrounding environment. Lower testing costs also encourage more frequent testing, which is more important in an operational setting. Usually, highly-accurate laboratory methods are reserved for forensic or accident investigations. As scuba divers, however, we do need to have some idea of how to assess the “usual suspects” of CO_2, CO, water vapour and oil. The table below summarises the various field-testing options versus accuracy trade-offs. Basically, with the exception of the detection of oil, the other stated contaminants can be field tested either using once-off detector tubes or using an electronic analyser.

In addition to the common contaminants, there is a range of other potential toxic and debilitating compounds that may enter scuba cylinders during filling. Awareness of “environmental” hazards is therefore essential and may include cleaning, industrial or even more natural compounds (such as methane produced by cows).

WHAT ARE OUR GUIDING LIMITS?

Physiological safe limits for gas contaminants are determined by their partial pressure according to Dalton’s Law. Therefore, the concentration (i.e. f_{gas}) must be considered in relation to the maximum diving depth (i.e. the ambient pressure or P_{amb}). Air diving is restricted to 50 m and therefore surface equivalent values (i.e. the maximum concentration as measured at 1 ATA that would not be toxic at 6 ATA).

The limits represented in the Contaminant Safe Limits table indicate the effect on human physiology (health). In the case of oil, methane (CH_4) or moisture (H_2O), the limiting factors are determined by fire risks and risks to equipment.

WHAT ARE THE FIELD TESTING OPTIONS AVAILABLE TO US?

Irrespective of whether you are testing the gas in a scuba cylinder or the gas delivered by a filling station, there are three fundamental ways to determine air quality:

- Single-use detector tubes
- Electronic sensors
- Laboratory analysis

None of these are cheap, but health and safety are at stake. This means that in the end, an appropriate compromise must be made between convenience, cost and accuracy.

Typical Field Analysers

		CO_2	CO	H_20	Oil
Detection methods	Manual Electronic	Detector tube Infrared sensor	Detector tube Electro-chemical sensor	Detector tube Dew-point metre	“Detector” N/A*
Typical accuracy	Tube Electronic	± 50 ppm_v ± 25 ppm_v	± 1 ppm_v < 1 ppm_v	± 5 mg/m^3 < 1 mg/m^3	N/A** N/A**
Typical range	Tube Electronic	0 – 3 000 ppm_v 0 – 5 000 ppm_v	0 – 150 ppm_v 0 – 100 ppm_v	0 – 450 mg/m^3 0 – 2 500 mg/m^3	0.1 – 1.0 mg/m^3 N/A*

*Oil vapour content (mist) is usually only measured in a laboratory (using either gravimetric or spectroscopic techniques) and is not suited to field-use.

**Oil content measurement by detector tube or equivalent either provides a simple pass or fail outcome, or a specific, discrete value such as 0.1, 0.5 or 1.0 mg/m^3 only.

Contaminant Safe Limits

	Safety		Local Regulations		Best Achievable Practice
	Limit	Consideration	SABS 019	SANS 532	
CO_2	$\leqslant$ 833 ppm$_v$	Safe SEV of $\leqslant$ 0.5%	< 500 ppm$_v$	< 500 ppm$_v$	< 500 ppm$_v$
CO	$\leqslant$ 10 ppm$_v$	Safe SEV of $\leqslant$ 60 ppm$_v$	< 10 ppm$_v$	Not stated	$\leqslant$ 5 ppm$_v$
H_20	$\leqslant$ 50 mg/m^3 $\leqslant$ 35 mg/m^3	Equipment: $\leqslant$ 200 bar Equipment: > 200 bar	$\leqslant$ 50 mg/m^3 $\leqslant$ 35 mg/m^3	$\leqslant$ 100 ppm$_v$ or $\leqslant$ 80 mg/m^3	$\leqslant$ 50 mg/m^3 $\leqslant$ 35 mg/m^3
Oil	$\leqslant$ 5 mg/m^3 $\leqslant$ 0.1 mg/m^3	Health Fire: mixing with oxygen	$\leqslant$ 5 mg/m^3 Not stated	Not stated Not stated	< 0.5 mg/m^3 < 0.1 mg/m^3
Particles	$\leqslant$ 5 mg/m^3	Fire	< 0.5 mg/m^3 particles > 5 µm	Not stated	< 0.5 mg/m^3 particles > 5 µm
Odour	None	N/A	None	None	None
		Where deemed to be an environmental issue:			
VOC	$\leqslant$ 5 ppm$_v$	Health	Not stated	Not stated	$\leqslant$ 5 ppm$_v$
CH_4	$\leqslant$ 5 000 ppm$_v$	Fire	Not stated	Not stated	$\leqslant$ 10 ppm$_v$
H_2S	$\leqslant$ 50 ppm$_v$	Health	Not stated	Not stated	$\leqslant$ 1 ppm$_v$
SO_2	$\leqslant$ 5 ppm$_v$	Health	Not stated	Not stated	$\leqslant$ 1 ppm$_v$
NO_x	$\leqslant$ 10 ppm$_v$	Health	Not stated	Not stated	$\leqslant$ 0.5 ppm$_v$

Detector tubes and other non-reusable indicating devices

This is the age-old, tried and tested method. It is relatively simple, but not entirely fool-proof and there is always some degree of uncertainty. In recent years it has become a bit more user-friendly and the accuracy is quite acceptable as shown in the first table (Typical Field Analysers). In simple terms, detector tubes are chemical reagents that are exposed to a given sample (i.e. quantity or volume) of the gas to be tested. Depending on how much of the reagent becomes discoloured as the volume of gas is passed through it, an assessment of the concentration of contaminant can be made. Detector tubes offer a visual indication of the level of contamination; easily read by even the untrained eye.

The tools needed to conduct this in the field may be as simple as some silicon tubing, a few basic flow-meters, a stop-watch and the detector tube; more sophisticated and less "hands-on" devices are available too – at a price.

The new CO-Pro device, soon to be made available through DAN and some dive shops, will be an inexpensive and user-friendly "safety indicator" that can be packed into the travelling diver's luggage without any space or safety concerns.

Detector tubes: the age-old method

CO ≈ 5 ppm$_v$
Tube: Green-brown

CO_2 ≈ 1 700 ppm$_v$
Tube: Violet

H_2O ≈ 500 mg/m^3
Tube: Brown

Electronic analysers

With the increased use amongst recreational divers of nitrox and other blended gases, we have seen a host of hand-held oxygen and even helium analysers enter the market. Prices in real-terms have come down pretty dramatically over the past 10 years, as popularity and application have increased. Driven primarily by safety concerns, contaminant analysers have entered our market in the same way, with prices dropping steadily: Simple-to-operate, hand-held versions of CO and CO_2 analysers are now coming within the reach of individual divers. There are even products entering the fray that combine these with oxygen, moisture and helium, but these are still too expensive for the average travelling diver.

What we would really like to see is that our scuba filling stations invest in some of these instruments, so that regular spot checks can be made on CO, CO_2 and moisture levels during everyday fills. Oil vapour assessments are still a bit finicky for real-time use although at least one US-based air quality analysis company has a product that can be used on-site. Located at the local scuba-filling facility, this device communicates with the company's laboratory over the internet and produces a result in real time that includes oil vapour determination.

> LOWER TESTING COSTS ALSO ENCOURAGE MORE FREQUENT TESTING, WHICH IS MORE IMPORTANT IN AN OPERATIONAL SETTING.

Sending a sample to an accredited air-testing laboratory

Lastly, we have a variant of the analytical method used for a highly-accurate determination of gas constituents and contaminants: ready access to a special testing laboratory for breathing gases. While not easily accessible in Southern Africa – given the high courier or postage fees – this style of assessment is popular in Europe and the US. Many dive centres make use of this service by sending in specially-prepared and easy-to-conduct test samples for their quarterly or semi-annual air quality tests. A simple process then captures the "quality" of the air on a specific date and this is then sent in to a sophisticated testing laboratory. Results are sent back via email or mail. Very effective, although the results usually only appear around seven to 10 days after the sample was taken. This option is excellent for routine assessments or for a diving accident investigation, but it does not address the concerns of a dive customer who is not happy with the "smell" or "taste" of the air in their cylinder!

For facilities using this method, we would recommend that they ask for the actual contaminant values rather than just a pass or fail certificate. This would enable the facility to monitor trends or changes in breathing air quality, which in turn might prompt timely filter changes or compressor maintenance before air quality becomes unacceptable.

For the greatest level of confidence, filling stations should be well-managed with regular air quality tests of which the results are readily visible to prospective customers who are about to buy their life-support gas from them. However, dive operations are rarely ideal settings and as we travel the diving regions of the world, this becomes readily apparent in more isolated and less developed parts of the globe. CO, moisture, CO_2 and oil often exceed the safety limits, and environmental hazards like methane (CH_4) and nitrogen oxides (NO_X) become a real concern. Costs are of course an important aspect in deciding which of the three methods to employ.

The individual, safety-conscious diver who has been alerted to reported incidents in certain dive spots might well choose to invest in a CO-Pro, disposable detecting device or even a hand-held electronic CO monitor, ready for the day when they are concerned about their cylinder contents. This is not a significant investment all things considered and certainly better than the complications!

The quality conscious scuba-filling facility has a wider choice and a simple assessment of ongoing sampling costs (on-site or by laboratory) versus an on-site electronic, real-time analyser would be the way to make the sensible decision.

WHAT DO WE DO IF THE LEVELS APPROACH OR EXCEED THE SAFE LIMITS?

The second table (Contaminant Safe Limits) provides an overview of the safe, regulated and ultimately, desired limits. Where regular testing shows that air quality is approaching these limits, there are two options:

- If it is CO, CO_2 or some environmental pollutant that is on the rise, the compressor intake may need to be moved or secured away from the source of pollution.
- If it is primarily oil, moisture or an associated odour, the compressor and its filtration package should be assessed to decide whether the current maintenance or change-out intervals are adequate. (Note: CO can also be the product of an over-heated compressor.)

Air filtration is a topic for another day, but we do know that as a general rule moisture, oil and CO can and should be removed by the filtration package, whereas CO_2 will pass through without any real reduction in level. If the filtration system is not coping, it may be time to consider investing in one of our industry's recent and long-overdue developments: a high-pressure refrigerant dryer. The upfront cost is quickly amortised through a significant reduction in filter replacements. Better still, there will be greater assurance of the highest quality air when it comes to oil and moisture control.

A FINAL NOTE

A recent assessment of the quality of scuba air in South Africa concluded that, as a general rule, our local scuba filling stations are doing a pretty good job. This provides some assurance closer to home, but all bets are off when travelling to remote locations. Still, by simply being more aware of the relevant issues, together with an eye on product developments, divers can make better choices on what to expect, what to ensure and what to measure before sinking below the surface on oxygen-enriched exhaust fumes. Jokes aside, sub-standard air can be harmful and even fatal as was reported extensively in the media during 2012.

Science and technology have brought both knowledge and tools within our reach; we should avail ourselves of both and give ourselves a little more assurance and security.