Scuba air quality

Part 1: What do the limits really mean?
SAFETY

IN THIS FIRST OF TWO PARTS, THE RATIONALE BEHIND SET CONTAMINANT LIMITS FOR ACCEPTABLE SCUBA AIR QUALITY IS EXPLAINED.

Our knowledge-base on air quality for scuba diving has traditionally been driven by commercial and military diving practices. These empirically derived requirements were typically based on experience; either on what can realistically be achieved, or on accidents or the lack thereof.

Over the past 50 years or so, medical investigative work has been performed to determine the human impact of common contaminants in breathing air. In addition to this, occupational health and safety approaches, commonly referred to as Hazard Identification and Risk Assessment (HIRA), have been applied where other notable toxic or debilitating elements have found their way into breathing systems.

The first part of this two-part series offers some rationale behind the contaminant limits. In Part 2, a discussion will follow on how breathing air is analysed.

WHAT ARE THESE CONTAMINANTS?

Contaminants can be divided into three levels that represent the likelihood of them occurring in a compressed-air cylinder intended for the diver, namely:

- Those most commonly found in compressed air (carbon dioxide \([\text{CO}_2]\), carbon monoxide \([\text{CO}\]), moisture \([\text{H}_2\text{O}\]), condensed oil, particles and odour)
- Those found in certain geographic locations (volatile hydrocarbons and organic compounds such as methane \([\text{CH}_4]\))
- Relatively rare but reported toxic substances (for example vapours from cleaning products and halogenated solvents, emissions from motor vehicles, sulphur, and nitrogen-based products and fumes)

The air compression process can only introduce oil (vapourised or condensed), particulates and some amounts of \(\text{CO}_2\) and \(\text{CO}\). All other contaminants, including larger amounts of \(\text{CO}_2\), \(\text{CO}\) and especially moisture, must be available in the environment in order to be present in the filled cylinder.

As a general rule, occupational health practices require that we analyse environmental conditions in the vicinity of where we are aware of potential hazards. Compressors used to produce breathing air require a thorough risk analysis prior to site selection of the compressors’ intake, with consideration of weather conditions, potential local toxic fumes and exhaust from buildings or internal combustion engines.

Lubricating oils for breathing air compressors are selected on the basis of their high temperature stability, inertness and acceptability for human exposure.

Finally, it remains an accepted fact that we do not monitor or analyse the air that we breathe unless we have reason to be concerned.

We therefore need to be pragmatic in our assessment of limits and, as a general rule, we know that exposure to contaminants in compressed air has mainly occurred due to a loss of controls, external influences and incidents, and where equipment has been neglected.

Studies have determined the human impact of contaminants on breathing air.
## SAFETY ASSESSMENT

The following table indicates the primary safety concerns (namely human, fire and equipment safety) that apply to the contaminants we are concerned with.

<table>
<thead>
<tr>
<th>Group 1: Contaminants always potentially present in compressed air</th>
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<tbody>
<tr>
<td><strong>Compound:</strong> Carbon dioxide (CO₂)</td>
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<tr>
<td><strong>Sources:</strong> Ambient environment, internal combustion and cooking processes, human and animal respiration, microbial breakdown of organic matter, conversion of CO to CO₂ in compressor filters, and motor vehicle exhaust systems.</td>
</tr>
<tr>
<td><strong>Sources:</strong> Ambient environment, internal combustion processes, furnaces, gas burners, cigarette smoke and overheated compressor oils.</td>
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<tr>
<td><strong>Sources:</strong> Ambient environment (humidity), drying processes (laundry), some combustion and other processes.</td>
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<tr>
<td><strong>Sources:</strong> Ambient environment (micro-particles of dust and pollens); breakdown products in compressors, piping systems and filtration media; as well as post-construction debris in pipes and controls.</td>
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Compound: **Odour**

Sources: Ambient environment and cleaning compounds used on air supply systems.

Human safety: It is generally only related to comfort levels. Odours from volatile, toxic or otherwise harmful substances indicate potential safety issues related to these contaminants.

Fire safety: There is no concern from odour. Contaminants with fire risks (oils, volatile organic compounds [VOC], etc.) are discussed under the relevant contaminant sections.

Equipment: No concerns.

PATIENTS WITH HIGH PaO₂ ARE AT GREATER RISK OF OXYGEN-INDUCED SEIZURES WITH ELEVATED PaCO₂.

Group 2: Contaminants present in specific areas

This group may be significantly larger than discussed here, but the following analysis serves to indicate where potential hazards may exist for clinical hyperbaric facilities.

Volatile hydrocarbons include organic compounds. However, methane is the most commonly occurring compound of these compounds and is separated from the analysis.

Some standards require that all hydrocarbons be grouped as a total hydrocarbon (THC) limit. This does not allow for easy identification of potential sources.

Contaminant: **Volatile hydrocarbons and VOC**

They include, but are not limited to, toluene, xylene, benzene, ethane, styrene and acetone.

Sources: Ambient environment as a result of exposure to building materials, plastic materials, industrial chemicals, and cleaning compounds, adhesives, furniture, flooring, heating and combustion processes. Overheating compressors are reported as a potential source.

Human safety: Generally hazardous in terms of carcinogens, neurological and narcotic effects, organ damage as well as general distress. Initial symptoms include fatigue, headaches, confusion, numbness, cardiac irritation and depression.

Fire safety: There are significant fire concerns in terms of low ignition temperature and low flashpoint fuels.

Equipment: There is no significant concern at the expected levels.

Compound: **Methane (CH₄)**

Sources: Ambient environment, especially in certain geological areas and near decaying or fermenting organic matter, landfills or domestic animals (cattle). CH₄ may permeate buildings and enter the compressor intake.

Human safety: It is not toxic (may be an asphyxiant where oxygen is reduced to below 16%).

Fire safety: There are significant fire concerns with CH₄ because it is a highly flammable fuel.

Equipment: No concerns.
PARTICLES SMALLER THAN 10 MM HAVE THE POTENTIAL TO CAUSE SHORTNESS OF BREATH.

Group 3: Rare but reported contaminants
This group is too diverse and extensive to discuss in a similar fashion to the previous two groups.

Typical contaminants include vapours from cleaning products or solvents that are not covered under Group 2 as well as environmental compounds including hydrogen sulphide (H\textsubscript{2}S), SO\textsubscript{2}, NO, N\textsubscript{2}O, NO\textsubscript{2}, fumes, ozone, lead compounds, asbestos and many others.

Each of these has specific deleterious effects on humans, but there are neither significant fire issues nor equipment issues – at least not in the concentrations expected in the air.

Nitrogen oxide products, loosely referred to as NO\textsubscript{x}, are associated with decreased lung function, increased severity of respiratory problems, chronic inflammation and irreversible structural changes, amongst other related respiratory conditions and complications.

Most occupational health and safety regulations for any public enterprise provide regulations, limits and guidelines for identification and exclusion. In terms of this article, we will exclude several of these from the requirements for acceptable air quality for scuba diving and accept that they will be controlled by occupation HIRA practices.

WHAT ARE SAFE LIMITS?
The limits depicted in the table below are based on the effect on the human physiology, the fire risks and the risks to equipment.

All human exposure limits are expressed as the surface equivalent value (SEV) and for the purposes of air diving a maximum depth of 50 metres of seawater (MSW) is assumed. Limits tabulated are generally stated as the “no-effect level” which is the dose with no known toxic or debilitating effects.

FINALLY, A NOTE ON SOUTH AFRICAN REGULATIONS
Traditionally, our local regulations were contained in a standard known as SABS 019, the code of practice for transportable compressed gas containers. This regulation contained a table listing limits for impurities in compressed air for breathing. However, the latest revision of this standard no longer contains this table and instead we are referred to SABS 532 (issued in 2009 as SANS 532) which is the standard for industrial, medical, propellant, food and beverage gases, refrigerants and breathing gases.

We have lost some of the required guidance in this process and DAN-SA, together with the Compressed Gas Association of South Africa, has requested the SABS to provide an update to SABS 532 to include limits for the common contaminants of concern to scuba divers. We have hopefully provided practical, achievable and realistic limits for their consideration.

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<tr>
<th>Contaminant Safe Limits</th>
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<tr>
<td>Human exposure</td>
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<tr>
<td>CO\textsubscript{2}</td>
</tr>
<tr>
<td>CO</td>
</tr>
<tr>
<td>H\textsubscript{2}O</td>
</tr>
<tr>
<td>Oil</td>
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<tr>
<td>Particles</td>
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<td>Odour</td>
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<td>CH\textsubscript{4}</td>
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<td>H\textsubscript{2}S</td>
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<tr>
<td>SO\textsubscript{2}</td>
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<td>NO\textsubscript{2}</td>
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