



Divers Alert Network Fatality Database Review For Breathing Gas Contamination: 2004-2012

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Introduction

- Breathing gas contamination appears to be rare in recreational diving but is suspected to be under-reported.
- Contamination can occur if combustion engine exhaust fumes are near the compressor intake while filling tanks, compressor lubricants deteriorate, or improper compressor maintenance.
- Contaminants may be present without the diver being aware and can cause death. The cause of death in such cases may be established only if breathing gas is analyzed.
- The objective of this review was to establish how often breathing gas analysis was included in scuba fatality investigations and the implication of contaminants in dive fatality cases.

Methods

- We reviewed fatality cases in the Divers Alert Network (DAN) fatality database from 2004-2012.
- Database includes cases involving U.S. and Canadian recreational divers. Information is obtained from news reports, law enforcement agencies, medical examiners, witnesses and the decedent's next of kin (NOK).
- Determination of contamination was based on available gas analysis results from accredited laboratories, autopsy findings, investigative reports and NOK.
- Compressed breathing gas testing standards were used for contamination confirmation when values were reported (Table 1).

Table 1. Compressed Breathing Gas Testing Standards^{1,2}

Contaminant	CGA G-7.1-2011 Grade E ³	IAND Blending Standards-2003 ⁴
O ₂ (% vol)	20-22	20-22
CO (ppmv)	10	2
CO ₂ (ppmv)	1000	1000
Volatile Hydrocarbons (ppmv)	25	25
Oil Particulate (mg/m ³)	5	0.1
Water Vapor (ppmv)	24	Not Specified
Odor	None Present	None Present

Compressed Breathing Gas Standards

- Compressed Gas Association (CGA) grade E specific to scuba industry for compressed air.
- Most current version of Grade E standard is CGA G-7.1-2011.
- Modified Grade E for EANX by International Association of Nitrox & Technical Divers (IAND).
- The US Navy and OSHA base their industrial breathing air standards on CGA G-7.1³
- Standards vary worldwide.
- Compliance with standards is mostly self-regulated by dive industry.
- dive training and certification agencies

Results

- 762 fatality cases were reviewed.
- 640 cases (84%) unknown if breathing gas analysis was conducted.
- 122 cases (16%) breathing gas analysis was conducted(Figure 1).

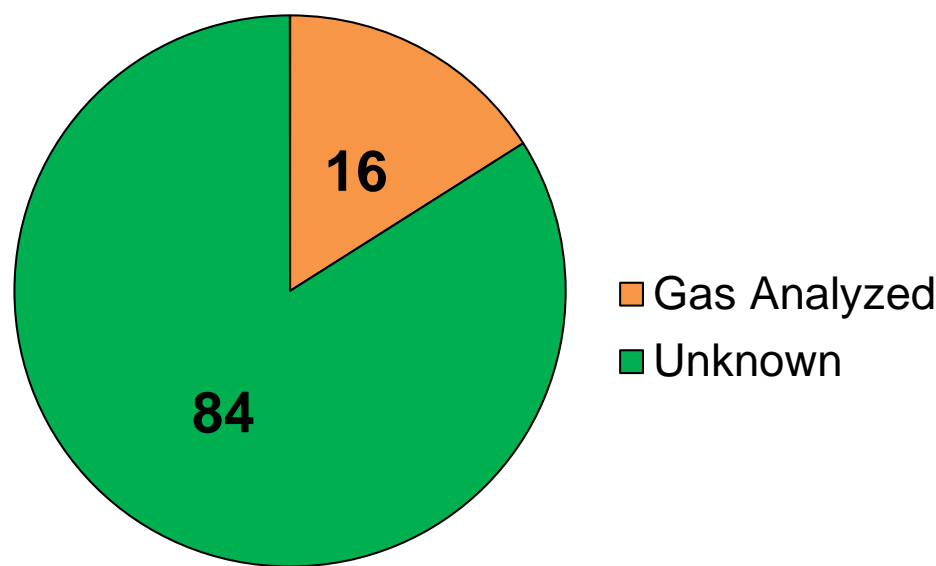


Figure 1. Breathing gas analysis conducted in fatality cases (%) (n=762)

- Of the 122 cases where gas was analyzed, gas analysis results were not available in 34 cases (28%) (Figure 2).
- 78 cases (64%) reported no significant contaminant levels present.
- 10 cases (8%) reported positive findings including CO (n=3), odor (n=3), hypoxic gas mix with methane (n=1), CO2 (n=1), oil particulate (n=1), and unidentified (n=1).

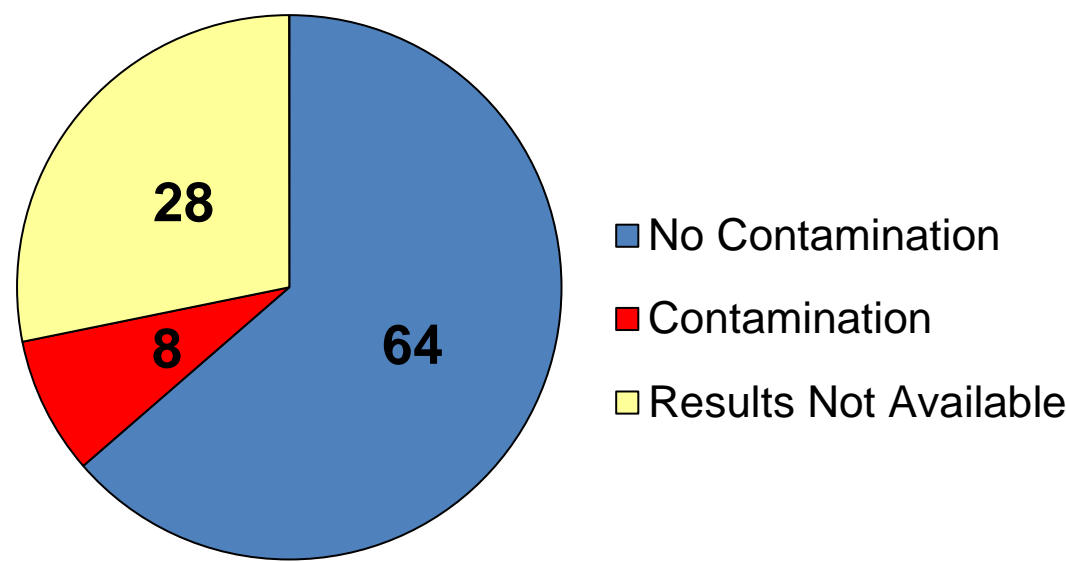


Figure 2. Contamination detected by gas analysis (%) (n=122)

- CO contamination was likely a contributing factor to cause of death in three cases.
 - This was determined by information in news reports, witnesses and NOK.
- Decedents used tanks from the same source (Case 2 & 3). Other divers who also obtained tanks from the same source as decedents reported symptoms like headache and nausea.
- One case of hypoxic gas mix and methane contamination (Case 4).

Case 1	40 yo female, certified and experienced. Maximum depth approx. 75 fsw (23 msw). According to news reports, divemaster and dive buddy surfaced with difficulty breathing, dizziness and chest pain. CO contamination was suspected by investigators. Air testing reported lethal levels of CO according to NOK. Cause of death reported as asphyxia due to drowning.
Case 2	45 yo male, experienced, solo cave dive in Mexico. Body was retrieved, investigation reported tanks were contaminated with lethal doses of CO.
Case 3	Male, unknown age, Experienced. Cave diving with buddy in Mexico. Lost consciousness and brought to surface by buddy. According to news reports, gas analysis detected lethal levels of CO.
Case 4	16 yo male, open water certified, inexperienced. Body recovered in 72 fsw (22 msw). Nitrogen and methane exceed CGA standards according to investigative report. Hypoxic O ₂ level and CO ₂ level. Tank was not properly purged of mixed gas before filled with air.

Discussion

- Dive industry is a self-regulated industry.
- It is the responsibility of dive operators, compressor operators and divers to ensure safe breathing gas.
- According to the Florida Department of Health, since 1999 no submitted breathing gas analysis reports show any evidence of contamination.⁵
- Evidence of contamination may exist in other locations.
- Methane is non-toxic but may be an asphyxiant where oxygen is reduced to below 16%.⁶

Conclusions

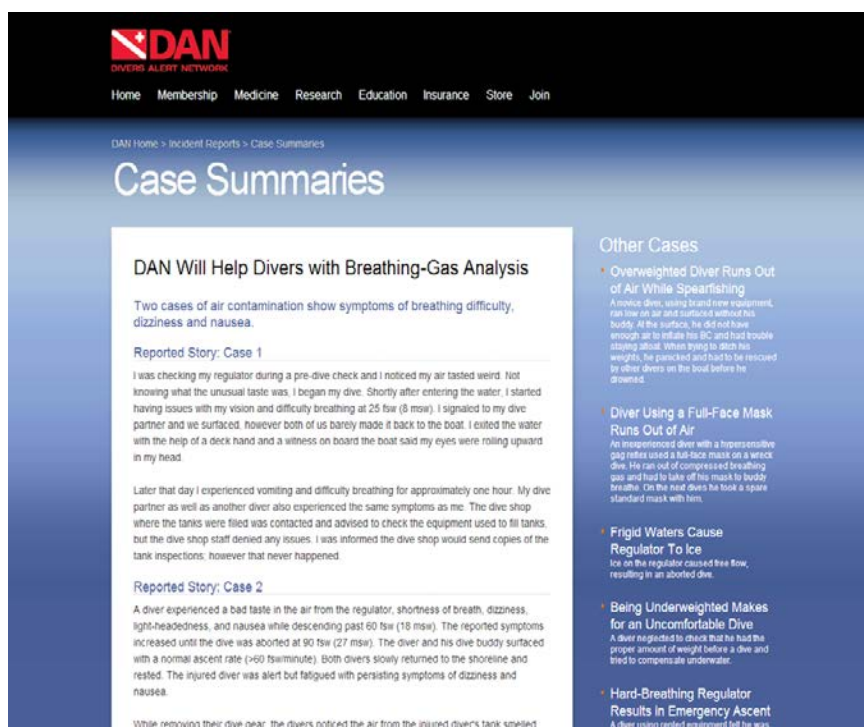
- Breathing gas analysis findings are infrequently included in scuba fatality investigations.
- Causal gas contamination is rarely implied.
- Excluding contamination as a contributing factor through gas analysis increases the significance of other established root causes.
- Breathing gas analysis findings may reveal unsafe gas mixing.
- Breathing gas contamination may be more common in non-fatal dive incidents.

Recommendations

- Breathing gas analysis should be a routine procedure in systematic investigations of scuba fatalities.
- Increase access to autopsy & investigative reports.
- Include values of gas analysis results in investigation report.
- Further research is needed to understand the scope of the issue in both fatal and non-fatal dive incidents.
- Increase prevention efforts to educate divers and operators of breathing gas safety.

Education & Prevention Efforts

- DAN will help divers with suspected incidents of breathing gas contamination.
- DAN online incident reporting system.
- Education & awareness materials
 - case summaries, brochure.



References

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