

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



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Breathing Gas Contamination

- Appears to be rare in recreational diving.
 - suspected to be under-reported
- Contaminants may go undetected.
 - potentially cause death
 - confirmed through breathing gas analysis



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 cases from 2004-2012 in the Divers Alert Network (DAN) fatality database.
 - cases involving U.S. and Canadian recreational divers
 - information 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.
 - Accredited laboratories, autopsy findings, investigative reports and NOK
- Compressed breathing gas testing standards were used to confirm contamination for reported values.

Compressed Breathing Gas Standards

Components	CGA G-7.1-2011 Grade E ³	CGA-E Modified for Nitrox ^{2,3}	IANTD Oxygen Compatible Air ^{2,4}
O ₂ (% vol)	20-22	As required	20-22
CO (ppmv)	10	10	2
CO ₂ (ppmv)	1000	1000	1000
Volatile Hydrocarbons (ppmv)	25	25	25
Oil Particulate (mg/m ³)	5	0.1	0.1
Water Vapor (ppmv)	24	N.S.	N.S.
Odor	N.O.	N.O.	N.O.
N.S.= Not specified		N.O.=Not objectionable	

- Compressed Gas Association (CGA) grade E specific to scuba industry.
 - The US Navy and OSHA base their industrial breathing air standards on CGA G-7.1 Grade D criteria¹
- Compliance with standards is mostly self-regulated by dive industry.
 - dive training and certification agencies
 - standards vary worldwide

Results

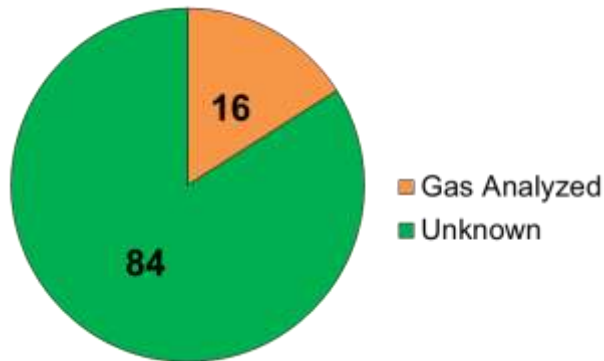


Figure 1. Breathing gas analysis conducted in fatality cases (%) (n=762)

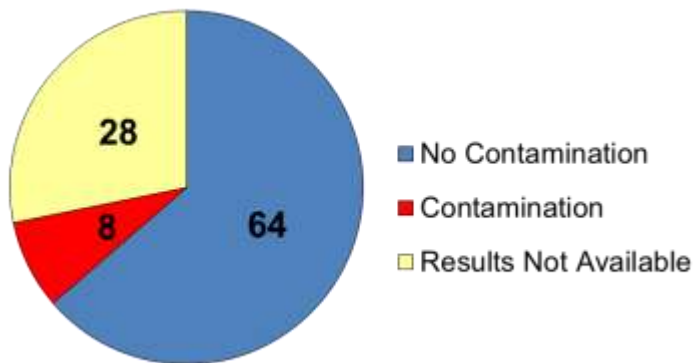


Figure 2. Contamination detected by gas analysis (%) (n=122)

- 762 fatality cases were reviewed (Figure 1).
 - 640 cases (84%) unknown
 - 122 cases (16%) gas analyzed (Figure 2).
 - 78 cases (64%) no significant contaminant levels present
 - 34 cases (28%) results not available
 - 10 cases (8%) positive findings
 - 3 cases of CO
 - 3 cases of pronounced odor
 - 1 case of hypoxic gas & methane
 - 1 case each of CO₂, oil particulate & unidentified

Case Studies

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

Discussion

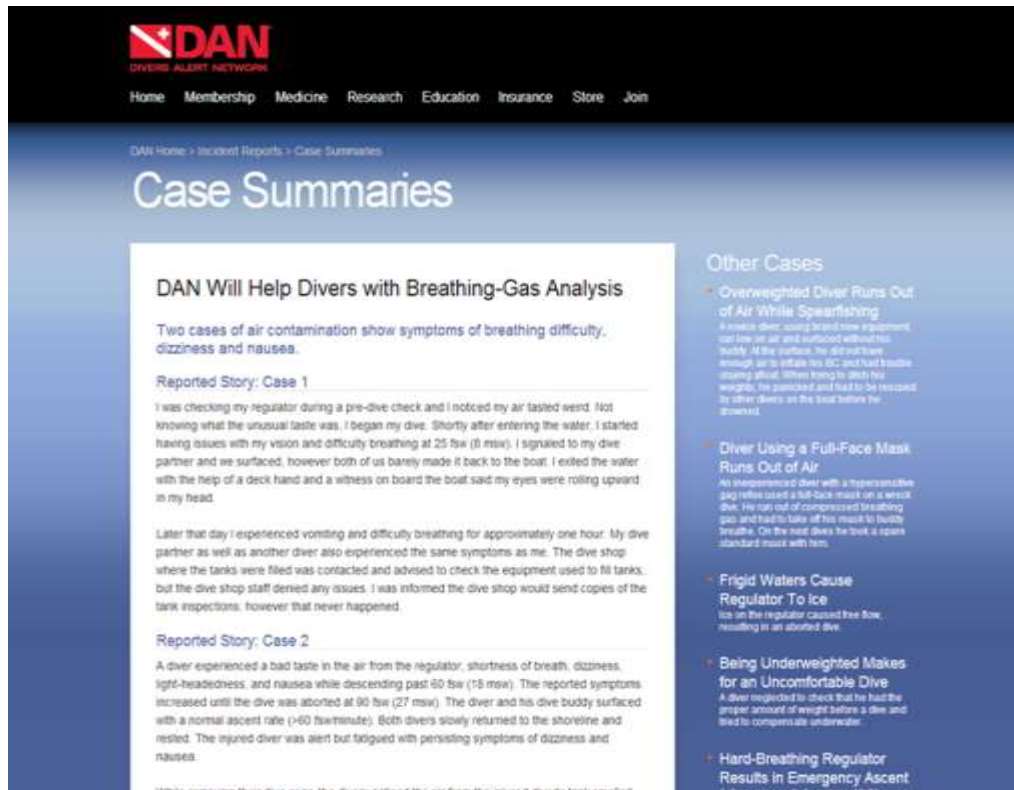
- According to the Florida Department of Health, breathing gas analysis reports submitted from 1999-2011 show no evidence of contamination.⁵
 - Evidence of contamination may exist in other locations
- The recreational diving industry is self-regulated.
 - Responsibility of dive operators, compressor operators and divers to ensure safe breathing gas
- Contamination may be more common in non-fatal incidents.
 - Recognize associated signs and symptoms
 - Confirm contamination through gas analysis

Conclusions

- Breathing gas analysis findings are rarely included in scuba fatality investigations.
 - Reported analyses are often incomplete
 - Reports should include quantitative values of gas analysis
- Contamination is rarely established as cause of death.
 - Excluding contamination as a contributing factor through gas analysis increases the confidence of other established root causes
- Analyses may reveal unsafe gas mixing.
- Maintain awareness of breathing gas quality.

Education & Prevention Efforts

- DAN online incident reporting system.
 - Articles and case summaries
- Assist divers with access to breathing gas analysis in suspected contamination cases.



The screenshot shows the DAN (Divers Alert Network) website. The header includes the DAN logo and navigation links: Home, Membership, Medicine, Research, Education, Insurance, Store, and Join. Below the header, the page title is "Case Summaries". The main content area is titled "DAN Will Help Divers with Breathing-Gas Analysis" and contains two case reports. The first case, "Reported Story: Case 1", describes a diver experiencing breathing difficulties and nausea during a dive. The second case, "Reported Story: Case 2", describes a diver experiencing a bad taste in the air from the regulator, shortness of breath, dizziness, light-headedness, and nausea while descending. To the right of the case reports, there is a section titled "Other Cases" with links to "Overweight Diver Runs Out of Air While Spearfishing", "Diver Using a Full-Face Mask Runs Out of Air", "Frigid Waters Cause Regulator To Ice", "Being Underweight Makes for an Uncomfortable Dive", and "Hard-Breathing Regulator Results in Emergency Ascent".

DAN
DIVERS ALERT NETWORK

Home Membership Medicine Research Education Insurance Store Join

DAN Home > Incident Reports > Case Summaries

Case Summaries

DAN Will Help Divers with Breathing-Gas Analysis

Two cases of air contamination show symptoms of breathing difficulty, dizziness and nausea.

Reported Story: Case 1

I was checking my regulator during a pre-dive check and I noticed my air tasted weird. Not knowing what the unusual taste was, I began my dive. Shortly after entering the water, I started having issues with my vision and difficulty breathing at 25 fsw (8 msw). I signaled to my dive partner and we surfaced, however both of us barely made it back to the boat. I exited the water with the help of a deck hand and a witness on board the boat said my eyes were rolling upward in my head.

Later that day I experienced vomiting and difficulty breathing for approximately one hour. My dive partner as well as another diver also experienced the same symptoms as me. The dive shop where the tanks were filled was contacted and advised to check the equipment used to fill tanks, but the dive shop staff denied any issues. I was informed the dive shop would send copies of the tank inspections, however that never happened.

Reported Story: Case 2

A diver experienced a bad taste in the air from the regulator, shortness of breath, dizziness, light-headedness, and nausea while descending past 60 fsw (18 msw). The reported symptoms increased until the dive was aborted at 90 fsw (27 msw). The diver and his dive buddy surfaced with a normal ascent rate (>60 fsw/minute). Both divers slowly returned to the shoreline and rested. The injured diver was alert but fatigued with persisting symptoms of dizziness and nausea.

While rescuers their dive near, the divers noticed the air from the injured diver's tank smelled

Other Cases

- Overweight Diver Runs Out of Air While Spearfishing**
A male diver, using brand new equipment, ran low on air and surfaced without his buddy. At the surface, he did not have enough air to inflate his BCD and had trouble staying afloat. When trying to shed his weight, he panicked and had to be rescued by other divers on the boat before he drowned.
- Diver Using a Full-Face Mask Runs Out of Air**
An inexperienced diver with a hypersensitive gag reflex used a full-face mask on a wreck dive. He ran out of compressed breathing gas and had to take off his mask to breathe. On the next dive he took a spare standard mask with him.
- Frigid Waters Cause Regulator To Ice**
Ice in the regulator caused free flow, resulting in an aborted dive.
- Being Underweight Makes for an Uncomfortable Dive**
A diver neglected to check that he had the proper amount of weight before a dive and tried to compensate underwater.
- Hard-Breathing Regulator Results in Emergency Ascent**
A diver used a poorly maintained regulator.



Image source: Lawrence Factor Laboratories

References

1. United States Navy. Compressed Breathing Air. 2011. Available from:
<http://www.med.navy.mil/sites/nmcphc/Documents/industrial-hygiene/compressed-breathing-air.pdf>.
2. Trace Analytics, LLC Sport Diving Compressed Air & Gas Testing Specifications. 2014.
3. Compressed Gas Association, Inc. (CGA) G-7 Grade E. 2011: 6.
4. IAND, INC./IANTD Blending Standards. 2003: 142-143.
5. Florida Department of Health, House of Representatives Staff Analysis House Bill 4151 Standards for Compressed Air. (March 24, 2011).
 - Burman F. Scuba air quality. Alert Diver Southern Africa. Autumn 2013: 14-18.