Single Diver Fatality in Cenote Nariz on 3 February 2024
CREER (Comité Regional de Espeleobuceo, Ecología y Regulación)
Line and Safety Committee Report

This report is based on interviews with divers, analysis of dive computer data and examination of equipment. Names of those involved in the incident, recovery and investigation have been omitted deliberately. As always with responsible accident analysis, the focus is on learning, improving systems and encouraging changing behaviours within the community to reduce the chance of any future incident, rather than attributing any blame. Please be respectful when discussing these events and act with humanity and civility.

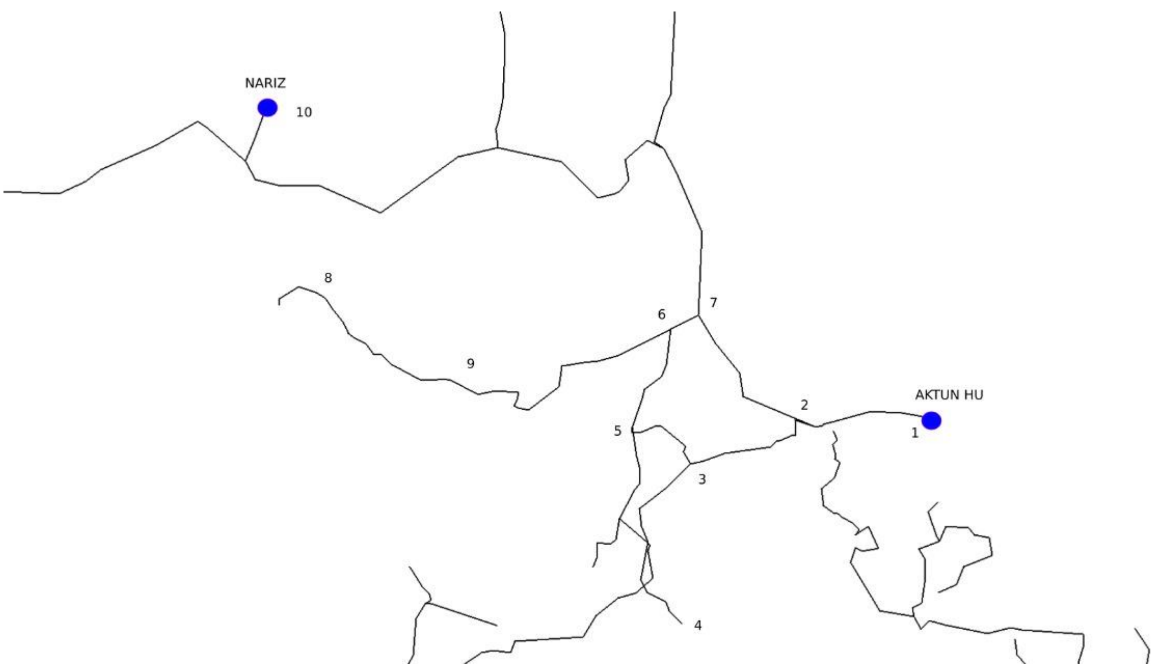
Location

Cenote Nariz is part of Sistema Sac Actun near Tulum, Quintana Roo, Mexico. The average depth is approximately 9m (30ft) and there is little to no flow.

Summary of Event

Three divers planned on resurveying an area downstream near Aktun-Hu. They were:

Diver 1 (Deceased): Local cavern instructor and cave/cavern guide, KISS Sidewinder CCR
Diver 2: Local diver, KISS Sidewinder CCR
Diver 3: Visiting diver, open circuit sidemount with a single stage



The three divers began their first dive at Cenote Nariz at 1411 local time. They swam to Cenote Aktun Hu, which took approximately 33 minutes. They surfaced at the cenote and had a conversation. The team of three divers then started their survey dive at 1451. They made their way from Cenote Aktun Hu (Point 1) and installed a jump at Point 2 approximately five minutes later.

The team started the dive to survey the lines in the area around Point 3. After approximately 10 minutes the team navigated the T left (Point 3) and swam to the end of the line (Point 4) where the cave pinches down.

They turned around and swam back past Point 3 until the other end of the line (Point 5). They installed a jump and turned right on the line, swimming towards the T at Point 6 and arrived at 1511, around 60 minutes of dive time.

At this point in the survey dive, Diver 3 (the OC diver) hit turn pressure and communicated this to Diver 1. Diver 3 returned to the exit alone, while Diver 1 and Diver 2 (CCR divers) continued to survey. Diver 1 and Diver 2 surveyed the line towards Point 7, leaving a REM on the line to indicate it was a shorter route towards the exit at Cenote Nariz. They returned to the T (point 6) and carried on their survey towards Point 8. They swam down this line, surveying for 15 minutes before they turned and started to swim towards their exit. This section of cave is slightly deeper than the rest of the dive (around 13m/40ft rather than 10m/30ft). Five minutes into their swim out they passed from the slightly deeper section back to 10m/30ft, at around 85 minutes dive time.

Diver 2 was checking a lead around Point 9 when he noticed rapid light movement behind him. Diver 2 turned to respond to the light signal, and as he approached Diver 1, he noted wide eyes, a flushed face and what appeared to be up and down light signalling. Diver 2 attempted to communicate with the casualty that he should bailout and purged the bailout regulator around Diver 1's neck to encourage him to switch to his open circuit gas supply.

These attempts were not successful, and Diver 1 seemed to move backwards away from Diver 2, appearing to resist attempts at assistance. Diver 2 persevered with attempts to assist until the loop came free of Diver 1's mouth, when he discontinued rescue attempts and made the decision to exit. The time from the initial light signal until the loop coming out of Diver 1's mouth was approximately one minute.

Diver 2 started to swim out, passing the T at Point 6. As he approached the mainline at Point 7, he encountered Diver 3 who was investigating the side passage on his way out. Diver 2 communicated the fatality to Diver 3, and they returned to Cenote Nariz (Point 10) together. They surfaced at 1652 without further incident and sought assistance.

Search and Recovery

The recovery of Diver 1 was conducted successfully on 4 February by two local cave instructors from the CREER Rescue Team, with additional divers acting as surface support. Civil authorities, including Police and Civil Protection were also in attendance and an initial examination of Diver 1's rebreather was completed, including photographing all equipment.

Details of Casualty

The casualty was a 33 year old male who was an active cavern/cave guide and Cavern Instructor in Quintana Roo. He was certified as a Mod 1 (Air Diluent) diver on the KISS Sidewinder in August 2023, but was not CCR Cave trained. He had logged approximately 21 dives and 25 hours on the unit after training. All his overhead environment and rebreather training took place with local instructors in Quintana Roo.

Details of Equipment

The equipment being used by Diver 1 on 3 February was as follows:

- KISS Sidewinder CCR purchased used from a previous owner and first dived by Diver 1 on 10 October 2023. It was configured with:
    - Auto Diluent Valve disconnected and capped.

    - Overpressure Valve shut.
    - Single PO_2 monitor, Shearwater Petrel 3 (Firmware v95) on Fischer connection.
    - Dual Button Manual Add Valve Assembly.
    - Oxygen in a butt-mounted Steel 2L cylinder. It was empty when recovered as would be expected with a constant mass flow rebreather.
    - COAX oxygen sensor conversion. Cells were PSR-11-39-SMB from Dive Gear Express and marked as installed on 31 October 2023. They had an expiry date of 5 October 2024.
- X-Deep Stealth Rec sidemount wing and harness.
- Drysuit.
- Bailout/diluent of 32% nitrox in two standard Sidemount Al80 cylinders.
- Apeks Regulators.
    - The regulator on the left-hand cylinder had a short hose regulator on a necklace. There was no dedicated low-pressure hose to inflate the wing, just a single low-pressure hose that was connected to the diluent manual addition valve (MAV), but could be disconnected from the MAV and connected to the wing if required.
    - The regulator on the right-hand cylinder had a 7ft/2.1m hose and a low-pressure inflator connected to the drysuit.
- Standard Cave Diving equipment, with various spools and markers clipped to butt D-ring.
- Mnemo survey device.

Analysis

It is not possible to be completely certain what physiological events led to the death of Diver 1. Initial reports from the only witness indicated that the victim suffered a seizure or cognitive impairment that led to drowning. Precisely what caused the issue is unknown, but historical data from similar rebreather incidents suggests that hypercapnia and or hyperoxia are the most likely triggering events leading to the fatal outcome. Seizures can also result from an underlying medical condition, but neither the autopsy nor medical history of the deceased indicates this was likely.

Hypercapnia

Hypercapnia is the condition of having too much CO_2 in the blood. Symptoms include dyspnea (shortness of breath), and neurological symptoms which can include confusion, disorientation, or paranoia. Causes of hypercapnia in rebreather divers can include incorrect assembly of the rebreather equipment, over exertion, flooding of the CO_2 absorbent material (scrubber), or re-using the scrubber material after it has been exhausted. The likelihood of hypercapnia can also be increased if the removal of CO_2 from the breathing loop (which includes the lungs) is impeded by technical/mechanical issues.

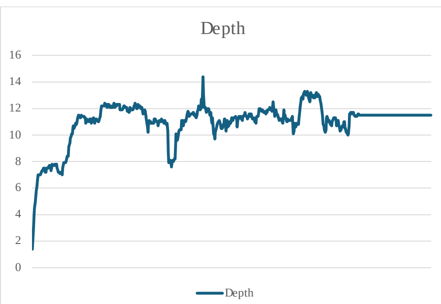
In this incident, the CO_2 absorbent material was found to be partially flooded because Diver 1's loop was open. It is therefore hard to be certain of the absorbent's condition, age and ability to remove CO_2. Analysis of the rebreather did not reveal any faults or abnormalities that were likely to cause hypercapnia. One hypothesis is that Diver 1 could have used the scrubber material for longer than recommended, which would have increased the likelihood of hypercapnia. This practice is known to exist in the diving community, especially when operating in warm water environments.

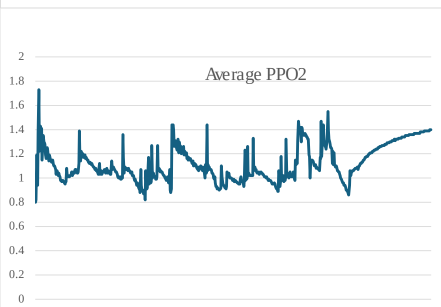
Hyperoxia

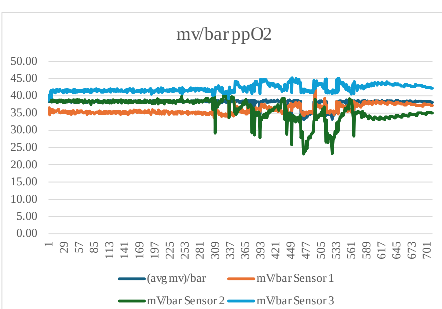
Hyperoxia is a state of excess supply of oxygen in tissues and organs. High pressure O_2 poisoning, also known as Central Nervous System Oxygen Toxicity, is caused by high partial pressures of oxygen. This can be a single “spike” of a PO_2 of 2.0 or higher, or slightly elevated PO_2 (above 1.6) for an extended period. Typical symptoms include convulsions, visual disturbances, ringing in the ears, nausea, tingling or muscle twitching, irritability, and dizziness or disorientation.

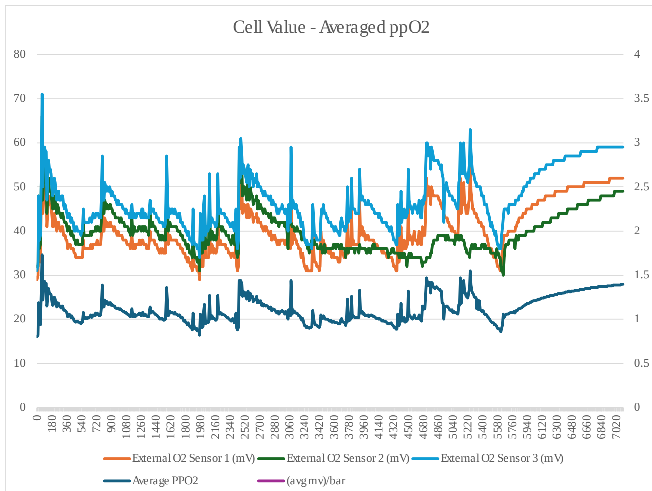
Hyperoxia and a CNS oxygen toxicity “hit” in rebreather divers is caused by an excess partial pressure of oxygen in the rebreather loop. This can be the result of too much oxygen entering the loop or a rapid descent. Failed oxygen sensors can cause an excess of oxygen when they become current limited and do not accurately measure high levels of O_2, which leads to more oxygen being added (by the diver in this type of CCR), resulting in a higher PO_2 in the loop than indicated. Inaccurate calibration of sensors before the dive can also result in breathing a different PO_2 to that indicated.

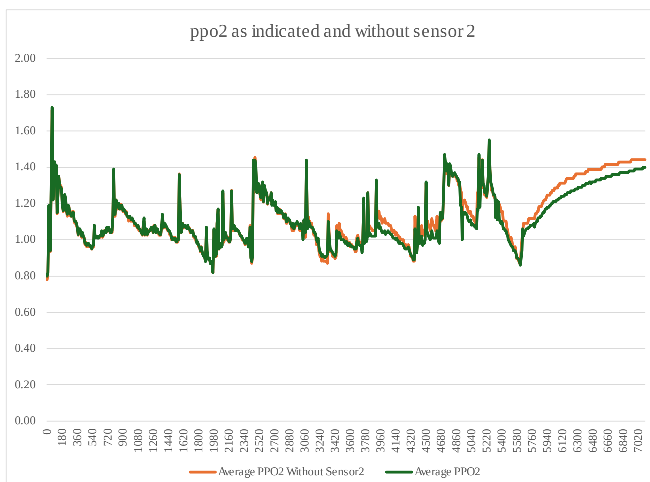
The dive computer log shows an average PO_2 of around 1.14, with a series of spikes corresponding to a manual addition of oxygen or a change in depth. This is usual for a constant mass flow rebreather. Some of the spikes approached a PO_2 of 1.6, and on one occasion at the beginning of the dive reached 1.73, but the indicated PO_2 alone is unlikely to be high enough to cause a CNS oxygen toxicity hit, unless these readings were erroneous.











Analysis of previous dives logged indicates some erratic cell behaviour and data indicates Diver 1 potentially conducted some shallow test dives to validate cells. One cell appears to stop working on a dive on 30 January

2024. It is possible that Diver 1's rebreather could still have been experiencing intermittent cell issues, but the data from the dive does not indicate high PO_2 as the sole triggering factor for unconsciousness or convulsions.

Hypercapnia and hyperoxia have a tendency to exacerbate each other. Increased metabolism due to hyperoxia can increase CO_2 production. Hyperoxia can also decrease sensitivity to elevated CO_2 levels, leading to inadequate ventilation and a further build-up of CO_2 in the bloodstream. Hypercapnia can cause vasodilation, leading to increased blood flow to the brain and increased likelihood of CNS toxicity symptoms when PO_2 levels are elevated. Increased metabolism due to hypercapnia can lead to higher oxygen consumption by tissues, including the CNS. This exacerbates CNS oxygen toxicity by increasing oxygen use in neural tissues. In summary, the presence of elevated levels of both CO_2 and O_2 increases the likelihood of either convulsions from CNS oxygen toxicity or dizziness and stupor from hypercapnia.

Analysis of Broader Causes and Human Factors Involved

Diving fatalities are rarely attributable to a single cause, and when conducting accident analyses, it is important to examine the systems, procedures and actions that contributed to the event. It is critical to understand not just what happened in an incident, but how it made sense for those involved to do what they did. Looking at the 'why it happened' often leads to focusing on individual behaviours, rather than understanding why decisions were made. If we adopt a learning focussed approach, which does not attribute blame, the likelihood of changing behaviours and preventing future accidents is greatly increased.

In this incident there are a number of contributory factors and performance influencing aspects that present a valuable learning opportunity.

Diving beyond the level to which divers are certified greatly increases risk factors, especially in a challenging overhead environment. The minimum standard for starting training to be a Rebreather Cave Diver with most training agencies is 50 hours. This gives time for divers to build up some experience with diving and operating a complex piece of equipment in a more benign environment, before taking it into a cave. It also provides the opportunity to make minor mistakes or errors of judgement within an environment that is more tolerable for failure and where the margin for recovery is greater.

Fostering a psychologically safe environment where divers are encouraged to question decisions and dive plans is important. If a diver feels that they or another member of the team is not prepared for a dive, or if they are concerned about the dive plan, they should feel able to speak up without fear of criticism. This can be challenging within an unfamiliar group that has not completed many dives together. The well-known cave divers' rule that any diver can thumb any dive at any time for any reason, without question, is critical.

Goal orientated or task focussed diving can narrow a diver's field of attention, especially when the task is complex and unfamiliar. This narrowed focus can lead to missing critical signals within the environment as a consequence of reduced situational awareness. Undertaking complex tasks such as cave survey, without formal training or building capacity and experience, is an example of limiting the sensing and processing capabilities of the diver and dive team.

Allowing a dive team to separate during a dive significantly reduces the resources available to each member of the team. This includes equipment redundancy, gas volume and decision-making capacity. This is not an issue if everything goes well, but if something goes wrong, this additional capacity will likely be critical to the success of the team. Solo diving, whether part of the dive plan or when a team splits up during the dive, significantly reduces the chances of dealing with a failure successfully.

Starting a dive with a known fault, or any question about equipment reliability, should be avoided, especially in an overhead environment. This is especially applicable to rebreathers that generally have more complex and nuanced failure modes.

Normalisation of deviance is a common phenomenon within diving and happens when accepted standards are not followed, and this behaviour becomes tolerated and accepted. It involves a gradual drift from established safety practices until rule-breaking becomes the norm. When instructors or other role models take shortcuts or dismiss safety protocols, it subtly endorses such behaviours as acceptable or even desirable. This can erode safety cultures and encourage risky practices among less experienced divers. The normalisation of deviance is insidious because it often goes unchecked until a significant incident occurs. When divers bend rules without immediate negative outcomes, it sets a new and riskier normal standard of behaviour.

Using rebreather scrubber material for longer than recommended by training agencies and manufacturers increases the risk of hypercapnia. The CE testing data on scrubber durations is based on greater CO_2 production and lower temperatures than the conditions in which many rebreather divers operate, however any extension of scrubber time leads to uncertainty. The CO_2 scrubbing capability of the stack is not linear, and if a high workload is needed in the later part of the dive to resolve an emergency, there is a greater risk of scrubber breakthrough, creating another issue in a system that already has reduced capacity. The normalisation of risk is present in many aspects of diving, and this includes extending scrubber duration in apparently benign conditions. Scrubber material should always be replaced if in any doubt.

One of Sheck Exley's ten recommendations for safe cave diving in "A Blueprint for Survival" was "Practice emergency procedures with your partner before going diving and review them often". Some cave courses do not include diver lifts or rescues, and there are many cave divers who do not practice these skills often enough. Divers who participate in demanding dives in the overhead environment should practice cave rescue skills regularly.

The use of formal checklists dramatically improves safety in high-risk environments. All CCR training agencies and manufacturers recommend the use of formal build and pre-dive checklists for all rebreather dives.

Conclusion

Diver 1 suffered a seizure or cognitive impairment and drowned. It is impossible to be certain of the triggering event leading to the fatality. Oxygen toxicity is difficult to predict and is exacerbated by high CO_2, therefore a CNS oxygen seizure cannot be completely ruled out. Based on the computer data, hyperoxia is considered to be less likely than hypercapnia, which could be made more likely by an elevated partial pressure of oxygen.

It is natural to focus on the apparently direct causes, such as hypercapnia or hyperoxia and look for ways to reduce the likelihood that they occur. At the same time, it is important to focus on the wider systems, cultural and behavioural issues and what cave divers can learn from the context to reduce the chances of similar incidents occurring in future. As always, please treat the information in this report with respect and remember to act with humanity and civility when discussing any diving incident.

Report prepared on behalf of the CREER Line and Safety Committee
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