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NITROX DIVING

Air is a mixture of roughly 21% oxygen and 79% nitrogen (actually 78% nitrogen and 1% argon) and therefore it is a nitrox (nitrogen and oxygen) mixture (with a 1% argon impurity). Our bodies are able to tolerate breathing 16% to 45% oxygen on the surface well and we can breathe 100% oxygen for many hours or even a few days without permanent damage. If we breathe less than 16% oxygen we risk not having enough oxygen for the cells of our bodies to function normally (hypoxia) and if we breathe too much oxygen we will suffer from oxygen toxicity. Therefore, while diving we are limited to breathing oxygen at partial pressures between 0.16 and 1.6 ata. The maximum safe depth to dive air as a result of the toxicity of oxygen is 66 meters (pO_2 = 1.6 ata).

Nitrogen is an inert gas and does not take part in any chemical reactions in our bodies (Argon is also an inert gas). Nitrogen can be thought of as a diluent whose purpose is to reduce the partial pressure of oxygen to a safe level. When we go diving while breathing air, we suffer increasing depression of our brain functions as we go deeper due to the narcotic effect of the nitrogen (nitrogen narcosis). At a depth of 30 meters the effect is similar to having two standard drinks of alcohol on an empty stomach. Most dive training agencies recommend that divers limit their depth to a maximum of 30 meters or less for cold, dark, or challenging dives and 40 meters or less for warm easy dives, primarily due to nitrogen narcosis (limited bottom time before requiring decompression is also a factor).

The second major effect of nitrogen when we go diving is that it is absorbed into our bodies. We can tolerate a limited amount of excess nitrogen without any ill effects but if too much nitrogen is absorbed and we return directly to the surface, we can suffer from problems ranging from trivial to fatal (decompression sickness). This is why decompression stops are required for longer/deeper dives (they allow some of the excess nitrogen in our bodies to leave). If we could reduce the amount of nitrogen we were breathing while diving, we would reduce the level of nitrogen narcosis and increase the amount of time we could spend diving without having to do decompression stops. The bottom line is that air is not necessarily the best nitrox mixture for diving.

If we were to go diving while breathing 100% oxygen, we would never have to do any decompression stops as we would not be absorbing any nitrogen. However, the toxicity of oxygen would limit our maximum depth to only 6 meters (pO_2=1.6 ata). This is too limiting for recreational divers but it has a definite place in military diving. Very simple closed circuit rebreathers can be designed for 100% oxygen diving. They will produce almost no bubbles, will be almost silent, and as a result make it extremely difficult for anyone on the surface to detect the diver in the water, especially at night. There are a large number of military situations where this capability is useful and most militaries conduct this type of diving.

Diving 100% oxygen has a very limited depth capability, but it also presents a serious danger of fire and explosion. Fire requires heat, oxygen, and fuel. When you increase the percentage and the partial pressure of oxygen, fire becomes much easier to start, it burns MUCH faster and hotter, and substances that would not be considered fuel with air will burn in 100% oxygen under pressure (aluminum will burn!).

Heat is commonly generated in diving when gas is compressed. When you open the valve on a full scuba tank, the gas in the first stage of the regulator is compressed from ambient pressure to tank pressure. If this happens in a fraction of a second, temperatures of up to 2,000 degrees F can be generated. Therefore, open valves slowly! If the gas is air this is usually not much of a concern. However, if the gas is 100% oxygen a fire/explosion can result.

Fuel is also relatively common in diving. All compressors require lubrication and most use some kind of oil. There are filters to remove most of the oil that gets into the air before it goes in to the scuba tank, but if the compressor is not maintained properly this vaporized oil can be pumped into your scuba tanks and then get into the regulator. Breathing an oil/air mixture is not good for you and the fire/explosion danger is obvious.

Many years ago I was on a diving expedition in a fairly remote area. We were filling our dive tanks at the local fire hall as there was no dive shop. After three or four days diving I noticed the gas in the tanks tasted odd. My dive buddies agreed so we drained a tank and inspected the inside. It was coated with oil! When we confronted the fire hall we discovered that their compressor had not been serviced for several years. We were preparing trimix and high oxygen nitrox mixtures in the tanks and we were extremely lucky that we had not blown ourselves up!

The danger of fire and explosion is related to the partial pressure of oxygen (percentage and total pressure). The recreational and technical diving community studied this problem and decided that nitrox with up to 40% oxygen can be used with normal, well maintained diving equipment. If any piece of equipment is going to be exposed to more than 40% oxygen, it needs to be cleaned for oxygen use annually (special cleaning to remove virtually all of the traces of oil and other combustibles). Standard rubber O-rings can be used with 100% oxygen but they will wear out faster than O-rings designed for O_2 use. Special oxygen safe lubricants have to be used. Some militaries require cleaning for oxygen use of all equipment exposed to more than 21% oxygen, but this is expensive and not justified by the available data (in my opinion).

NOAA WAS THE FIRST NON-MILITARY AGENCY TO GET INVOLVED IN NITROX DIVING IN A BIG WAY.

Recreational divers are limited to nitrox with a maximum of 40% oxygen. Technical divers use up to 100% oxygen. When you are diving nitrox, your decompression requirements are determined by the amount of nitrogen you are breathing. As a result, different decompression tables are required for every nitrox mixture! The maximum safe diving depth may be determined by either the pN_2 or the pO_2, and these depths will also be different for every nitrox mixture.

NOAA was the first non-military agency to get involved in nitrox diving in a big way. As a result of the above complexities, they decided to limit their divers to only three mixtures, air, Nitrox I (32% O_2) and Nitrox II (36% O_2). This made diving relatively simple. Divers only needed three sets of decompression tables and the maximum safe dive depths because of oxygen toxicity were 40 meters on Nitrox I and 35 meters on Nitrox II (pO_2 = 1.6 ata). The maximum safe depth with air is 30 to 40 meters because of nitrogen narcosis. The critical difference is that depth limitations due to O_2 toxicity should be closely observed to reduce the risk of seizure and death while depth limitations due to nitrogen narcosis are somewhat flexible depending on the nature of the dive and the capability of the diver.

The primary advantage of diving while breathing a nitrox mixture with less nitrogen than air is that it significantly increases the amount of time you can spend at depth before you require decompression. Nitrox with 40% O_2 will approximately double the air no decompression time limits. Nitrox can also be used to reduce your risk of DCS. Most decompression models have been developed and tested on young, fit, healthy, male divers. Most current recreational divers are much older, less fit and less healthy. Therefore they have a much higher risk of DCS. Diving nitrox but using air decompression tables/computers will dramatically reduce your risk of DCS (if you do this never forget the depth limitation of nitrox due to O_2 toxicity).

Several years ago I was surveying an underwater cave and we were doing two dives a day, three hours per dive with an average depth near 10 meters. We would do this for two or three days in a row on several weekends per year (our computers only put us into decompression mode once). My partners and I noticed that we were unusually tired after these dives (some fatigue would have been expected!) so we switched from diving while breathing air to diving Nitrox32. Our fatigue vanished (it was due to decompression stress and we were at risk of developing DCS).

Diving nitrox will also reduce the degree of nitrogen narcosis at a given depth compared to air (the diver will be breathing nitrogen at a lower partial pressure). However, some authorities believe that oxygen is as narcotic as nitrogen. If this is true, the level of narcosis diving nitrox will be the same as diving air. >

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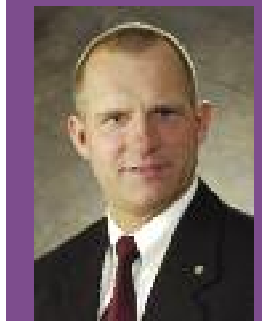

diving medicine

At the present time our ability to measure narcosis is not sensitive enough to determine whether oxygen is as narcotic as nitrogen. The end result is that even if narcosis is reduced while diving nitrox, the reduction will be relatively small.

Divers often comment that they feel warmer when diving in cold water while breathing nitrox compared to breathing air. I don't know of any physiological reason for this to be true.

The bottom line is that diving nitrox will increase your bottom time and/or reduce your risk of developing DCS. Diving nitrox with 40% O2 or less is easy to learn (a course of approximately 4 hours is required) and standard well maintained dive equipment can be used. Nitrox computers are readily available and make it very easy to dive nitrox.

I do not have room in this column to discuss the many ways in which nitrox can be manufactured. Some of them require a significant investment in new equipment and others require a large amount of time and labour. As a result, making nitrox for diving can be relatively expensive. However, in my experience the best method for most dive operations involves buying 100% O2 (gas or liquid), a mixing/blending stick, and two oxygen analysers (a relatively modest initial cash outlay). This equipment can be used with a standard compressor to generate nitrox with up to 40% oxygen quickly and easily at a cost that is usually less than $1 more than air per scuba tank.

It is my personal opinion that if more recreational divers used nitrox, dive safety would be improved.

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