CAVES, CARBON DIOXIDE and YOU

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Carbon Dioxide (CO_2) often occurs in high concentration at the bottom of deep caves. It is a colourless, odourless and non-combustible gas which is over one and a half times denser (heavier) than air.

EFFECT OF CO_2 ON THE HUMAN BODY.

Although carbon dioxide is not a poisonous gas, it can be dangerous and even life threatening by causing suffocation.

CO_2 is the body's regulator of the breathing function. It is normally present in the air at a concentration of 0.03% or 300 parts per million (ppm) by volume. Any increase above this level will cause accelerated breathing and heart rate. A concentration of 10% can cause respiratory paralysis and death. In industry the maximum safe working level recommended for an 8 hour working day is 0.5% (5000ppm by volume). (CIG Gases Catalogue, Dec 1991).

Are you placing yourself at risk by going caving?

Before answering this question we should study certain aspects of the CO_2 cycle dealt with in the following text.

HOW CO_2 GETS INTO CAVES.

Carbon Dioxide exchange is the dominant mechanism for carbonate deposition in most caves. In well ventilated caves the level is about 10 times higher than that of the outside atmosphere, and approximately 25 to 250 times lower than the CO_2 content of the ground water before reaching the cave. This is because plant roots and soil microbes give out carbon dioxide as part of their life processes, adding it to the air in the soil through which the rain water passes. When the ground water enters the cave, it looses carbon dioxide to the cave air until equilibrium is reached.

It is a popular belief that if the level of CO_2 increases in a cave, it conversely displaces an equivalent quantity of air, ie. oxygen (O_2) and nitrogen. In many caves this may be true however there are caves where the nitrogen level stays constant while the oxygen level decreases and CO_2 increases.

At Bungonia Caves (NSW), CO_2 levels of up to 6% have been linked to micro-organisms (i.e. fungi and bacteria) which depend on the nutrition present in organic material leached down from the soil or washed into the caves by floods. These organisms produce CO_2 as a by-product of their digestion process. This mechanism was observed to correlate with the reduction in O_2 accompanied by the increase in CO_2 concentrations. (Crawshaw and Moleman 1970)

At Bungonia it is generally agreed that foul air accumulation by loss of CO_2 from saturated ground water was not the major source, but a contributing factor. High levels in some caves can be attributed to micro-organisms and/or large bat colonies.

In 1958 members of S.U.S.S. confirmed that readings of up to 13.5% CO_2 at Wellington and Molong Caves were at the expense of oxygen. ie. the sum of CO_2 and O_2 was constant and the percentage of inert gases was reasonably constant. They also concluded that this was due to organic decomposition. ("Bungonia Caves" 1972, article E. Halbert).

Although caves naturally breath due to changes in surface temperature and changes in atmospheric pressure, CO_2 is heavier than nitrogen and oxygen, so it tends to congregate at the bottom of deep caves which do not have through ventilation to a lower entrance.

WHAT PERCENTAGE OF AIR DO WE USE ?

To get a complete insight into what actually occurs when a caver is exposed to a cave atmosphere, which contains higher than normal levels of CO_2, we should examine the mechanism by which our own body expels this unwanted by-product of metabolism.

The human body under average conditions inhales air which contains approximately 21% O_2 and 0.03% CO_2. The air breathed out of the lungs contains approximately 15% O_2 and 5.6% CO_2.

A person at rest inhales and exhales approximately 6 litres of air per. minute but in times of stress, this may increase to more than 100 litres per minute.

The lungs do not expel all of the air with each breath. The volume of air that moves in and out of the lungs during each breath is known as the tidal volume. The maximum possible tidal volume is equal to the vital capacity. The vital capacity is the amount of air that the lungs can hold after trying to force out as much air as possible and then taking the deepest possible breath. The amount of air left in the lungs after trying to breath out as hard as possible is the residual volume. It is impossible to empty the lungs of all air in this manner.

For an average adult, approximately 500 milli litres (ml) of air is drawn into the lungs with each breath during normal breathing. But of this 500 ml of tidal volume, only 350 ml is fresh air as the first 150 ml is 'dead' air already in the nose, trachea and bronchi. The 350 ml of fresh air represents only approximately 6% of the lungs maximum total capacity which is about 6000 ml (6 litres).

HOW THE HUMAN BODY GETS RID OF CO_2.

Normally a person is unaware of the complex mechanisms of breathing which are regulated and controlled by the respiratory center of the brain and the nervous system.

The carbon dioxide level in the blood is an important stimulus to respiration. Nerve receptors in the aorta near the heart and in the carotid artery that goes to the brain, monitor changes in the CO_2 in the body. If the amount of CO_2 in the blood increases, both the rate and depth of breathing increases. Changes in O_2 levels are also monitored, but the receptors are not as sensitive to changes in O_2 as to CO_2.

The exchange of the two gases (CO_2 and O_2) takes place in the lungs by diffusion across the walls of the air sacs (alveoli). O_2 from inspired air diffuses across the lining of the air sacs and enters the circulation, while CO_2 moves in the opposite direction. Then the gases are transported between cells and the lung by the blood circulation.

The principle by which diffusion occurs dictates that a gas in high concentration will move to an area of relatively low concentration, until an equilibrium is reached. This enables CO_2 in the body at a higher concentration to diffuse to the inhaled air.

HOW THE BODY REACTS TO HIGH CO_2 LEVELS.

As each persons body has a slightly different reaction and tolerance to stressful situations the following symptoms are general, however nobody is immune to the dangers of CO_2. It should be noted here that in many cases involving foul cave air, it is not the lack of O_2 which is the danger but moreover the critical factor is the high level of CO_2.

Exposure to levels of CO_2 in excess of 0.5% will cause a cavers breathing and pulse rate to increase. Other symptoms may begin to occur in areas containing 1% and greater. These include feeling hot and clammy, lack of attention to details, fatigue, anxiety, clumsiness and loss of energy which is commonly first noticed as a weakness of the knees (jelly legs) may occur.

Long term exposure to levels of between 0.5 and 1% as may be experienced by personnel on a submarine, is likely to increase calcium deposition in body tissues such as the kidney.

Exposure at 1.5% will result in a noticeable increase of breathing and pulse rate. Several hours at this level may cause severe headaches.

Accumulation of carbon dioxide in the body after prolonged breathing of air containing around 2% or greater will disturb body function by causing the tissue fluids to become too acidic. This will result in

loss of energy and feeling run-down even after leaving the cave. It may take the person up to several days in a good environment for the body metabolism to return to normal.
Other symptoms may occur such as severe headaches, dizziness and possible vision disturbance such as speckled stars.
However if the concentration in the cave atmosphere reaches 5% the bodies ability to get rid of its own CO_2 waste, is severely impaired. Shortness of breath and severe headaches are most common. The CCH Australia Ltd. Laboratory Safety Manual indicates that exposure to a concentration of 5% for a period in excess of 30 minutes will cause irreversible effects to health.
If the cave atmosphere reaches 6% and the caver remains in this environment for any length of time the levels of waste CO_2 in the body would reach an extremely dangerous level and could lead to suffocation.
Exposure to 10% CO_2 concentration for a few minutes will result in unconsciousness and suffocation without warning. Extremely high concentrations of 25 to 30 percent will cause coma and convulsions within one minute of exposure.

SIMPLE METHODS OF TESTING FOR CO_2.

A naked flame is a simple method of testing for a low level of O_2 which would indicate an elevated concentration of CO_2 in the cave atmosphere.
The naked flame tests uses any one of the following fuels:- matches, cigarette lighter, candle or carbide lamp. If any one of these items will not light or remain alight, then it is time to get out of the cave. Tests reveal that below approximately 15% concentration by volume of O_2 a flame will not continue to burn. *For more information on this subject, refer to "Naked Flame Tests for CO_2 in Limestone Caves & The Effect of CO_2 and O_2 on Humans", (Smith, G.K., 1997) printed in this conference proceedings.*

WHAT TO DO WHEN ENCOUNTERING CO_2.

A test should be made as soon as foul air is suspected and if a match will not strike or burns only briefly, all members of the party should immediately exit the cave in an orderly manner without panicking. Inexperienced cavers in the group should be especially watched and guided to the entrance.
When undertaking vertical pitches in caves suspected of foul air the first person down should make thorough checks for CO_2. Besides carrying ascenders, a safety belay is a wise option in the event that the first person down may be overcome when suddenly descending into an area of high concentration.
A safety belay should be mandatory with all pitches where a ladder is more than just a hand-hold.
Cavers should only enter areas of foul air during special circumstances, such as search and rescue operations, exploration and scientific work. Under these circumstances special precautions should be taken to ensure the safety of the group. For more information regarding safety precautions refer to ASF Cave Guidelines.

CONCLUSION.

By now you're probably bewildered as to whether the carbon dioxide in caves is harmful to you. The best advice is if you have any of the common side affects of CO_2, carry out a simple match test. If this indicates a high level notify the party leader and the group should vacate the cave.
Carbon dioxide when treated with respect is no worse than the other dangers in caves such as infections of cuts and abrasions, histoplasmosis, hypothermia, equipment failure, becoming wedged in a tight squeeze, trapped or drowning by rising flood waters, sustaining injury from a loose rock dislodged overhead, and loosing your footing or grip on small climbs.
Despite the seemingly endless list of possible dangers, caving is still safer than driving a motor vehicle, which most of us take for granted.

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CARBON DIOXIDE IN CAVES

CAVE SECTIONS SHOWING THE MOST LIKELY CONDITIONS UNDER WHICH, CONCENTRATIONS OF CARBON DIOXIDE IS FOUND IN CAVES.