European Cave Rescue Association

Foul Air

The Gases

- There is an accompanying document that can be provided
- Much of the information presented here comes from that document
- So no need to rush taking notes.

The Atmosphere

- By volume, dry air contains
  - 78.09% nitrogen,
  - 20.95% oxygen,
  - 0.93% argon,
  - 0.039% carbon dioxide,
  - and small amounts of other **gases**.

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Oxygen

- Lack of oxygen is probably most dangerous situation we may face
- A person will find it difficult to detect
  - it is not the lack of oxygen that makes you want to breath it's the CO_2 build up in the blood that triggers this reflex
- But lack of oxygen is often accompanied by an increase in CO_2
- For example in a passage where the air is not moving
- The situation where there is oxygen deficiency without high CO_2 is most likely to occur where it has developed over a long time

Oxygen

- 21% - Normal proportion in air on the surface
- 17.5% - ok to work in for several hours provided CO_2 level is not dangerous
- 13% - considerable increase in breathing rate needed to sustain work level
- 10% - lips turn blue and headaches gradually develop, becoming severe
- 8% - complexion is blue/grey, breathing is very rapid and disablement occurs after about 15 minutes
- 6% - unconsciousness is rapid and acute danger to life
- 2% - rapidly fatal – eg after about 45 seconds with no warning

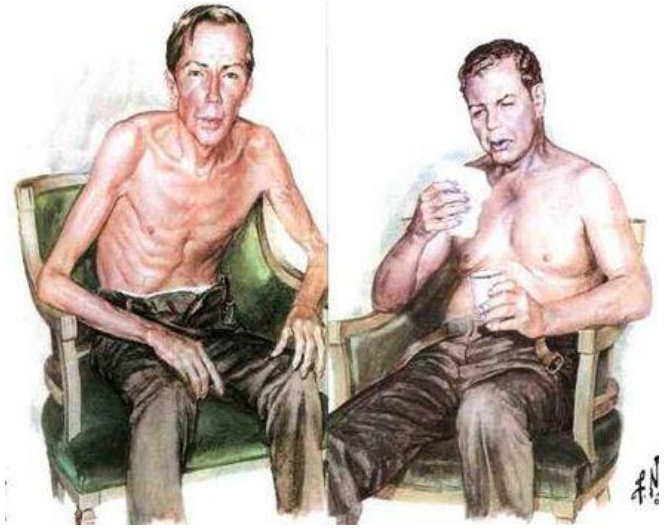
BUT remember the above all assume the CO_2 levels are not dangerously high, in most rescue situations where the problem is developing (eg due to the number of people in a blind passage) it will be the CO_2 build up that will be critical.

Carbon Dioxide

- This is perhaps the problem gas we can most expect to encounter.
  - It can be caused where the air has been ‘used up’ usually the build up of CO_2 is the critical factor rather than the oxygen deficiency.
- Can survive in relatively high concentrations of this gas.
  - We can work moderately in up to about 2% to 3% without a major problem but breathing rate will increase, making hard work impossible at the top of this concentration range.
- However, there can be bigger problems above 3%.
- The effects of the excessive gas can come on slowly and thus not be immediately noticeable to a caver suffering unless trained to recognize the effects.

Carbon Dioxide

- Different people can react in different manners to exposure above about 3%
  - ‘Red puffers’ will go red in the face but cope relatively well
  - whilst the more rare ‘blue bloaters’ may well collapse in lower concentrations.
- On a rescue we need to keep the level as low as possible below 1% and no higher that 2%



Carbon Dioxide

- Is heavier than air and can form a pool in lower passages
  - so short people may be first to be effected
- Will also be dissolved in the water in some mines
  - so the double effect of going into deep water with your face at water level (ie as low in the passage as you can get) and stirring up the sediment to release more CO_2 may result in a potentially lethal situation – ie if the person goes unconscious they will drown!
- When lights are observed along a long length of passage the shorter wavelengths of light are “filtered” out leaving the light looking red, as you get closer to the light it will revert to its normal colour.

Carbon Dioxide

- Remember base line of 0.039% carbon dioxide
- 1% CO_2 results in an increased rate of respiration
- 3% CO_2 results in a two-fold increase in the rate of respiration at rest, hard work will be impossible
- 5% CO_2 results in more than a four-fold increase in the rate of respiration – only slow walking/moving may be possible, not possible to work to any useful effect on a rescue
- 3 to 6% CO_2 produces either “red puffers” or “blue bloaters”. The former go red in the face but cope relatively well (60% of people) whilst the latter may collapse.

Carbon Monoxide

- Produced by incomplete combustion
  - Can occur where machinery such as generators have been used underground or too near an entrance with an inward draft
  - Bonfires underground
  - Coal mines and other mines where coal seams are present – due to slow combustion of the coal
  - May be one of the products of some explosives, but main risk is with poorly mixed proportions of home made explosives
- Can be quick acting and fatal if not recognized and dealt with
- Is lighter than air and may be at higher concentration near roof and at head height

Carbon Monoxide

- CO is toxic and even a small amount is a risk to life
- This risk increases the longer the exposure – there is no really safe level
- 30 to 50 ppm is about the maximum level we should ever work in.

Hydrogen Sulphide

- Hydrogen sulphide is the most renowned toxic gas because of its “bad egg” smell, which can be smelt down to less than 0.1ppm.Can be formed by rotting vegetation
- Often found during tunneling and deep drilling (oil etc) and in sewers
- Rare in caves and most mines
- If found very dangerous and action to evacuate and ventilate etc must be immediate

Hydrogen Sulphide

- A maximum safe exposure limit is 10ppm, but beware high concentrations cannot be smelt as the sensors in the nose are made ineffective.
- 0.1 ppm – smell just detectable
- 100ppm (0.01%) – eyes affected and become sore rapidly, and with increased exposure the following symptoms will occur - rapid breathing, headaches, coughing, and if exposure continued - palpitations, muscular weakness, cold sweats, and unconsciousness
- 1,000ppm (0.1%) – unconsciousness followed fairly rapidly followed by death
- 6,000ppm (0.6%) - instant paralysis followed by rapid death

Sulphur Dioxide

- Sulphur dioxide is a colourless gas with a pungent irritating odour, which is noticeable at 3-5 ppm. Mainly formed on burning sulphur and sulphurous oils and coal. It is highly acidic giving sulphurous acid in water – one of the main causes of acid rain.
- Unlikely to find this in caves – could be a problem in some mines, coal mines that have a spontaneous combustion problem. But other production will be evident and the need to take action will not depend on SO_2 measurement.

Sulphur Dioxide

- Below 2ppm – safe to work in for extended periods
- 3-5ppm – irritating smell noticeable
- 5ppm – dryness of nose and throat and increase in breathing resistance (tightness in chest)
- 6-8ppm – significant decrease in lung tidal volume may limit work load
- 10–50 ppm more acute effects including coughing, bronchial secretions and increased effort required to breath – heavy work not possible
- 400-500 ppm – pulmonary oedema and respiratory arrest may occur followed by death
- 1000ppm – death within 10 minutes

Sulphur Dioxide

- There are normally no lingering effects from the irritation effects cause by a single exposure of up to about 10ppm. However possibility of more severe effects on people who suffer from asthma.

Nitrous Oxides

- In caves and mines, this will invariably be the product of explosives
- The gas can also be found in silos (silo gas) due to the fermentation of fresh plant material.
- Nitrous fumes are heavier than air and are extremely toxic:
- NO_2 fumes in high concentrations are brown, but at the level they can cause serious health damage they will appear colourless.

Nitrous Oxides

- Can be encountered whenever explosives have been used, even from Hilti caps and snappers
- Can form a severe hazard in places with little or no ventilation if even only small amounts of explosive have been used.
- Has caused a multiple fatality in Wharfedale in the past
- No clear detection by rescuers at levels that can damage health and pose a risk of death, must measure if explosives are involved.

Nitrous Oxides

- NO_2 is the more toxic gas so this determines the figures below.
- Below 1ppm – generally accepted safe maximum limit for extended work (eg 8hrs)
- 1ppm - 3ppm – acceptable to work in for occasional periods if an emergency
- Up to 5ppm – only acceptable for very short term (15 mins max) exposure in an emergency.
- 15 ppm and above - nasal irritation and pulmonary discomfort may occur as concentration increases,
- above 20ppm increasing risk of health damage leading to death some time later
- 200ppm – acute danger to life
- The main risk of death and major illness is not immediate but may occur up to 48hrs or more after exposure due to pulmonary oedema – for this reason rescue teams should aim to get the level well below 1ppm as fast as possible and only work at around this level for short times to save life.

Nitrous Oxides

- After any suspected exposure to levels above about 3ppm close observation of health, particularly pulmonary condition should be done, with higher exposure and where ill effects were felt during exposure, this should be in hospital.

Methane

- Most likely where coal measures are present
- Can also be formed from decaying vegetation and timber in anoxic conditions

- The main danger is from explosion and not to health!
- Explosive in air, lower explosive limit is 5%, above 15% it will not explode but is still dangerous as it may start to disperse bringing it into the explosive range. Ignition can be by naked light, electrical spark, rusty steel on aluminum etc.

Methane

- At levels above the explosive range the following symptoms can occur
  - Rapid respiration
  - Impaired muscular coordination
  - Impaired judgment
  - Emotional instability
  - Fatigue
  - Nausea
  - Coma and even death
- However, in laboratory condition with levels of oxygen maintained at normal levels people have endured levels of up to 80% methane.