The Dangers of Carbon Monoxide: Part 1

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Recently, the Province of Ontario joined other jurisdictions in making it mandatory to have operational carbon monoxide detectors as well as smoke detectors installed in all residences. Considering that more than fifty deaths occur in Canada each year due to this deadly invisible gas, this law makes incredible sense.

There have been announcements on the radio over the past several months about installing carbon monoxide detectors, or CO detectors as they are more frequently called. I began thinking that although we are told that we must have one of these devices in our home, perhaps we don't really know very much about carbon monoxide itself, and why it is so dangerous. For this and the next article, I'd like to switch my Food Processing hat for a Chemical Engineering hat.

Let's take a look at the sources of carbon monoxide and some of its properties. Then, we can delve into its actual interactions in our bodies - which is where the real dangers arise. To do this, we will use the example of the combustion of gasoline in a car engine.

Gasoline is a mixture of hydrocarbons in a liquid form that burn in the presence of oxygen to give carbon dioxide, water, and heat as the reaction products. It is the rapid expansion in volume that powers our car engines.

The chemical equation for the combustion reaction is shown in Figure 1.

Figure 1: Complete Combustion of Gasoline:

Octane + Oxygen ⟶ Carbon Dioxide + Water

$$2\ C_8H_{18} + 25\ O_2 \longrightarrow 16\ CO_2 + 18\ H_2O$$

The reaction shown in Figure 1 is for the complete combustion of the fuel and carbon dioxide is the gas that is formed. It takes twenty-five molecules of oxygen to react completely with only two molecules of gasoline, which we are representing by the molecules of octane.

Carbon dioxide is dangerous if its concentration in the air we breathe becomes too high, and the concentration of oxygen is too low. The result is asphyxiation. However, there are small amounts of carbon dioxide in the air around us which are not a health danger since it is not a particularly reactive gas. We also need some carbon dioxide in the air to participate in the photosynthesis reaction in plants.

If we have incomplete combustion of fuels such as gasoline, the chemical reaction changes significantly. Instead of forming carbon dioxide, the reaction, which is starved for oxygen, creates carbon monoxide as a one of its products.

The chemical reaction for the incomplete combustion of gasoline is shown in Figure 2.

Figure 2: Incomplete Combustion of Gasoline:

Octane + Insufficient Oxygen ⟶ Carbon Monoxide + Water

$$2\ C_8H_{18} + 17\ O_2 \longrightarrow 16\ CO + 18\ H_2O$$

Now, we can get into the properties of carbon monoxide. But a little bit of basic chemistry might help us out a bit first.

In chemistry, atoms of each element have their own particular weight which is called the “atomic weight”, naturally enough. Carbon has an atomic weight of 12, nitrogen has an atomic weight of 14, and oxygen has an atomic weight of 16. We won’t go into the units of these weights or how they were derived. It’s the actual size of the number that’s important to us.

A molecule of carbon dioxide is composed of one carbon atom and two oxygen atoms. If we take the atomic weight of one carbon atom (i.e., 12) and add the atomic weights of two oxygen atoms (i.e., 2 x 16 = 32), we get a value of 44. This is called its “molecular weight”.

A molecule of carbon monoxide has only one carbon atom and one oxygen atom, so its molecular weight is 28 (i.e., 12 + 16). This tells us that carbon monoxide gas is “lighter” or less dense than carbon dioxide.

If we look at the air around us, it is generally considered to be composed of about 79% nitrogen and 20% oxygen, with some other gases making up the remaining 1% or so.

Nitrogen gas is a made up of two nitrogen atoms. Its molecular weight is 28 (i.e., 2 x its atomic weight of 14). Oxygen is also a diatomic gas made up of two oxygen atoms in the form O_2. Therefore, the molecular weight of oxygen is 32 (i.e., 2 x its atomic weight of 16).

This means that the molecular weight of carbon monoxide is the same as the nitrogen which makes up the bulk of the air we breathe and is not much different than the oxygen which is also present. In fact, these molecular weights are so close that we end up getting a uniform mixture of nitrogen and oxygen in the air. If there is any carbon monoxide present, it can just fit right into the mixture. Because of this, carbon monoxide has a neutral density and travels with the air. We can compare this to carbon dioxide which is “heavier than air” and tends to sink into pockets in low areas.

The question now is, “How does this information help us?”

If you read the instructions that come with your CO detector (there’s a novel idea, right?), you may see that it can be positioned at any height – unlike smoke detectors which need to be at ceiling height. Smoke rises and travels along the ceiling, but carbon monoxide with its neutral density distributes itself through the air and can be detected at any level. The really important thing is where you place your CO detector in your home relative to sources of combustion and bedrooms. For this, you will need to follow the appropriate guidelines recommended by the manufacturer of the CO detector and local regulations.

Carbon monoxide is also colourless, odourless, and tasteless, which makes it impossible for your to detect, unlike smoke which you can often see and smell.

It should be noted that if you buy a combination smoke and CO detector, it should be placed at ceiling height. This will put it in the proper location for sensing smoke as it rises, and will not impair its ability to sound the alarm should there be any carbon monoxide present.

For an “official” look at the rules pertaining to carbon monoxide detectors, you should consult the Ontario Association of Fire Chiefs’ website at www.oafc.on.ca. It also provides an e-mail address, a toll-free number, and links to other relevant sites.

In the next article, we’ll examine the reactions involving carbon monoxide in the body which make it so deadly.