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P3_2 Don't smoke and drive!

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Abstract

This paper investigates the consequences of smoking tobacco cigarettes in a car. With an average smoking rate of 5 minutes per cigarette and with no air exchange in the car, we calculate that you would have to smoke approximately 15 cigarettes in 75 minutes for the level of CO to reach levels of 1000ppm. This is enough to make you fall unconscious. Furthermore by considering the air flow out of the car we find that opening a window would make it safer for you to smoke in a car due to the exchange of air.

Introduction

Smoking cigarettes poses a serious health concern and causes over 100,000 smoking related deaths in the UK [1]. There are also over 4,000 chemical compounds which are released by smoking cigarettes, one of which is carbon monoxide (CO). Depending on your smoking topography, (puff duration, inter-puff interval, maximum puff velocity, etc.) the amount of carbon monoxide released per cigarette varies. In this investigation we consider the smoking behaviour investigated in a study [2], from which we find that the average mass of CO released per cigarette is 145mg. Furthermore we consider the pressure difference inside and outside of the car and determine the air flow rate out of the car. We can then calculate how long it would take to completely replace the amount of air of air in the car.

Theory

The first step in this investigation requires us to work out the ratio of CO in comparison to air inside the car. We can assume that the majority of air in the car is mainly composed of N_2, O_2 and CO; therefore the total mass of air in the car is taken to be 2.205kg, using the density of air as 1.204kgm^{-3} at 20°C [3] and the volume of the inside of the car as *V= 1.2mx1.5mx1m*. Since we know the mass of CO released per cigarette is 0.145x10^{-3}kg, the proportion of harmful CO in the car is calculated below.

Using equation (1) we can convert the number of grams of the substance to molecules for both air and carbon monoxide molecules. From this we can directly use the figures in table 1, to calculate the level of CO in the car which would make you fall unconscious.

$$n = \frac{m}{M} N_A \qquad (1)$$

Here n is the number of molecules, N_A is Avogadro's number, m is the mass of the substance and M is the molar mass which equals 28.97g/mol and 28.01g/mol for air and CO respectively [4]. Therefore n_{air} is calculated to be 4.58x10^{25} in the car, and after one cigarette is smoked the number of molecules of n_{CO} equals 3.12x10^{21}. The proportion of molecules of CO to air in the car is 0.0068% which is a very tiny proportion, so smoking 1 cigarette in a car is not very harmful to us. Table 1 shows the percentages of CO in ppm, which are harmful to the human body [5].

Level of CO	Health Effects, and Other Information
0 PPM	Normal, fresh air.
100 PPM	Slight headache after 1-2 hours.
400 PPM	Headache and nausea after 1-2 hours of exposure.
1000 PPM	Loss of consciousness after 1 hour of exposure.
12,800 PPM	Immediate physiological effects, unconsciousness. Death within 1-3 minutes of exposure.

Table 1. Shows some of the health effects of prolonged exposure to carbon monoxide [5]

If we now assume that the car now has one window open, causing a pressure difference inside and outside of the car, air will flow out of the window. Pressure difference can be calculated using Bernoulli's equation (2)

$$P_0 = P_S + 0.5\rho v^2 \quad (2)$$

where P_0 is atmospheric pressure inside the car, P_S is the pressure outside the car, ρ is the density of the fluid and v is the velocity of the wind. The change in pressure can then be used to calculate the volume flow rate out of the window given by equation (3)

$$Q = C_D A\sqrt{\frac{2\Delta P}{\rho}} \quad (3)$$

where $C_D = 0.6$ is the discharge coefficient for a rectangular window [6], A is the area of the opening (0.5m x 0.5m) and ΔP is the change in pressure. The air change rate, q, in the car is then given by equation (4).

$$q = \frac{Q}{V} \quad (4)$$

Discussion

Firstly to fall unconscious from CO poisoning in the closed car scenario, we would require 1000ppm or 0.01% of the air in the car to be composed of CO molecules, $n_{CO}=4.58\times10^{22}$. Considering that the mass of CO released per cigarette is 145mg and the number of CO molecules released, we calculate that we would need to smoke a total of 15 cigarettes to achieve the required CO level in the car. If it takes 5 minutes to smoke one cigarette, then it would take at least 75 minutes to fill the car with this amount of harmful carbon monoxide and cause you to lose consciousness.

On the other hand with the window open the volume flow rate of air out of the car can be calculated using equation (4). This yields a flow rate of $0.75m^3s^{-1}$, assuming a wind speed of $v=5ms^{-1}$ and a pressure change of 16.2Pa. This gives an air change rate of $0.4h^{-1}$ which suggests that the entire volume of air in the car would take 2.5 hours to completely change. As a result, due to the continuous circulation of air, if a window was open the carbon monoxide in the car would not be fully removed, but may still be quite harmful as even lower levels of CO in the car can be damaging for your health [5].

Conclusion

In conclusion we would advise that when smoking in a car you should always open a window to reduce the risk of carbon monoxide poisoning. Even a small concentration of CO in the air is harmful and could cause you to feel a slight headache. Of course for the first part of this investigation we assume that no air can escape or enter the car, however this is impossible. In addition we assume that the cigarettes are smoked at a constant rate of 1 cigarette every 5 minutes and that the puffs all emit the same concentration of CO. However the way in which people smoke differ largely and therefore this can only be used as a rough estimate. Furthermore there are thousands of harmful chemicals released by smoking cigarettes so the actual danger from smoking far greater than calculated above.

References

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