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A3_8 Death by Lecture

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Abstract

This paper explores the time required for the CO_2 levels in a sealed lecture theatre, filled with 100 students, to reach life threatening levels, effectively giving a estimated time limit for a lecture. We found that for the lecture theatre we modelled, it would take 30 hours and 55 minutes for CO_2 levels to rise to deadly levels. Therefore, we estimate that a 31 hour lecture is the maximum lecture length students can endure, in a sealed lecture theatre, before they literally die.

Introduction

For certain lecture courses, some students jokingly say they would rather die than attend the lecture. This paper investigates the time it would take for Carbon Dioxide (CO_2) levels in a sealed lecture theatre to reach life threatening levels, thus causing "death by lecture".

Theory

The atmosphere at ground level is composed of 78.08% Nitrogen, 20.95% Oxygen (O_2), 0.93% Argon and 0.03% CO_2 [1], with the small remainder being made of other gases. When humans inhale we absorb oxygen through the alveoli in the lungs and into the blood. From here it is distributed around the body to our cells, which consume the oxygen. At the same time, CO_2 is released from these cells and into the blood, where it is transported to the lungs and released when we exhale [2]. If the amount of O_2 and CO_2 available in the air is disturbed, it can have deadly consequences to the human body.

In a confined space, a human will replace the O_2 in the air with CO_2 through breathing, which after a period of time becomes highly dangerous. However, the immediate threat does not come from asphyxiation due to decreased levels of O_2, but rather from carbon dioxide intoxication [3] due to increased concentrations of CO_2 in the air. At >5% CO_2 we begin to experience breathing issues, and at 10% CO_2 we suffer convulsions, comas and death [3]. This is the concentration we will use as "deadly" for our sealed lecture theatre.

Method

We will be using the dimensions of the lecture theatre from [4] which are 14.9 m long by 11.5 m wide, with a sloped but constant end height of 2.9 m (as the seating raises with the raising roof). This is essentially a 3D parallelogram, and so we need the height perpendicular to the base to find the volume. Assuming the theatre has an angle of 15^o to the horizontal, we find the perpendicular height to be 2.8 m. We use Base × Perpendicular Height to find the correct area of the parallelogram, which we then multiply by the width to find the volume. This gives us a volume of 480 m^3, as we shall neglect the volume that the students and furniture occupy.

This theatre has a maximum capacity of 100 students, each of which absorb 0.35 to 0.4 litres of O_2 (if healthy) and expel the same amount of CO_2 each minute [5] (we shall use 0.35 l as they are at rest). This means that every minute 35 litres of O_2 (0.35 litres per person × 100 people) is replaced by an equal amount of CO_2. From the composition of air given above and the volume of the room in litres, we have 100800 litres of O_2 and 144 litres of CO_2 initially.

As the concentration of O_2 decreases, CO_2 increases, so the composition of air and the relative percentages will be constantly changing. Also, as O_2 levels in the air decrease, the amount of O_2 absorbed by the body and CO_2 released will decrease. Therefore the absorption rate of 0.35 litres will not be constant. We cannot simply do a calculation up to 10% CO_2, and instead must model the scenario using Python. This allows us to recalculate the concentrations every minute using loops.

We could not find anywhere in the literature that gives a numerical relationship for how absorption scales with availability of O_2. Therefore we will use a step of 1 minute, and after every minute the amount of oxygen absorbed will decrease proportionally with the amount of decreased oxygen in the air, according to equations (1) and (2). We used an equal equation for CO_2, as the amount of CO_2 released will decrease at the same rate. This is because CO_2 release relies directly on the absorption of O_2.

$$\text{Factor Decreased} = \frac{\text{Current Vol. of } O_2/\text{Vol. of Air}}{\text{Starting } O_2 \text{ Concentration}} \quad (1)$$

$$O_2 \text{ Absorbed} = 35 \times \text{Factor Decreased} \quad (2)$$

Results & Discussion

We found from Figure 1 that it took this lecture theatre 30 hours and 55 minutes to reach a CO_2 concentration of 10%. Essentially, it would take a 31 hour lecture for this theatre, if it was completely sealed, to become deadly to the students. They would be suffering health effects as CO_2 rose up to 10%, and would most likely be rendered unconscious before death. Furthermore, we have shown toxic levels of CO_2 are reached before dangerously low levels of O_2 are reached. Reference [6] tells us that issues with breathing are severe and mental functions are impaired at oxygen levels around 10%, followed by certain death at levels of 6% or lower. It takes 60 hours and 8 minutes to reach this level of O_2, at which point the students would already be dead from CO_2 intoxication and so would no longer be absorbing the oxygen.

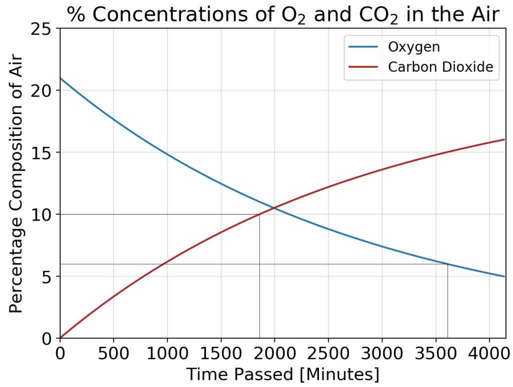

Figure 1: The rate at which O_2 and CO_2 levels change within a sealed lecture theatre containing 100 healthy students. Grey lines represent the deadly levels for each gas.

Conclusion

We found that it takes 30 hours and 55 minutes for a sealed lecture theatre, with a capacity of 100 students, to fill with deadly levels of CO_2. Although no lecture lasts this long, weeks of concurrent lectures in a badly ventilated room could eventually be dangerous. More than anything, this paper highlights the importance of reliable ventilation in such a room, so that levels are never allowed to reach anywhere near dangerous levels. This paper unfortunately does not provide an excuse to skip lectures on the grounds of them being life threatening.

References

[1] https://www.physlink.com/reference/aircomposition.cfm

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[4] K Cheong et al, (2003). *Thermal comfort study of an air-conditioned lecture theatre.* Building and Environment 38, 63 – 73

[5] https://www.sharecare.com/health/air-quality/oxygen-person-consume-a-day

[6] https://sciencing.com/minimum-oxygen-concentration-human-breathing-15546.html

[All websites were last accessed on 19/11/2019]