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Would The Doctor and Martha Have Survived on the Moon with the Judoon?

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Abstract
This paper investigates a Doctor Who episode, Smith and Jones, where a hospital and its inhabitants are transported to the moon by an alien race and whether it was feasible for them to have survived for as long as they did or longer due to a limited air supply. The finding was that they had nearly 105 days of oxygen supply, a considerably longer amount of time than the half an hour of supply shown in the episode.

Introduction
The classic British science fiction television series, Doctor Who, follows the adventures of a time-travelling humanoid alien and his human companion [1]. In a particular episode, "*Smith and Jones*" [2] a hospital in London is transported to the Earth's Moon by an alien police race, the Judoon, who are searching for an alien criminal who is in disguise. The Judoon erect a forcefield around the hospital which keeps the atmosphere the same as on Earth but in a sealed bubble with a limited amount of air. The Doctor is in the hospital and befriends a charming trainee doctor, Martha. The two of them evaluate the predicament and conclude that eventually they will run out of oxygen, O_2, and suffocate to death. Just as people are collapsing due to suffocation the Doctor saves the day and they are transported back to Earth [1, 2].

This paper will look at how long it would take for the O_2 to run out and whether this is comparable to the amount of time it took in the episode.

Assumptions
- Martha estimates that there are 1000 people in the hospital [2].
- That the forcefield is a perfect seal meaning the hospital is airtight with no gas escaping.
- The forcefield is modelled as a cuboid, this is due to the hospital being this shape.
- Plants in the hospital taking in CO_2 and releasing O_2 during photosynthesis will not be considered [3].
- The patients and staff were panicking once on the moon and this would increase their respiration rate. This along with the fact that it being a hospital, an elder demographic of patients will be assumed and therefore the respiration rate per person will be assumed to be 28 breaths per minute (bpm) [2, 4].
- The volume of O_2 inside the force field calculated includes the building and belongings which if considered would decrease the atmospheric volume available and consequently volume of O_2. However, for this model, this filling factor will be disregarded in subsequent calculations.
- Assuming the temperature did not change from after transportation to the moon. The temperature used will be room temperature, 293.15 Kelvin with the pressure being 1 atmosphere (101,325 Pascals) [5].
- The Judoon have their own air supply built into their space suits and therefore are not using up the limited O_2 supply.

Calculations
To calculate the amount of time it would take for the O_2 to run out a few prior calculations are required. Firstly, the volume of air inside the forcefield will be calculated. This was done by using Google Maps to measure the length and width of the building [6].
The hospital was digitally rendered and placed in an area beside the River Thames in London. The hospital did not take up this full area leaving space between

the forcefield and building. This area was found to have a width of 155.00 m and a length of 200.00 m as seen in figure 1.

Figure 1 – An image from Google Maps showing the width of the building [6]

The surface area of the hospital can then be calculated by multiplying the width by the length resulting in the area of a rectangle. A surface area of 31,000 m^2 is found [7].

From a scene the hospital can be counted to have the equivalent of 23 storeys [2]. Using the value of a storey being 3.00 m and multiplying this by the number of storeys a height of 69 m is found [8].

The volume can be found by multiplying the height, 69 m by the area, 31,000 m^2 resulting in a total volume inside the forcefield being found to be 2.14×10^6 m^3, this is the volume of air [9]. Next the amount of O_2 in this volume of air can be calculated. Air's composition is 20.95% O_2. The volume of O_2 in the forcefield is therefore, 448,121 m^3 [10].

Now the number of moles of O_2 in the air can be calculated using the ideal gas law [5]:

$$PV = nRT, \qquad (1)$$

where P is the pressure, V is the volume of, n is the number of moles, R is the gas constant with a value of 8.31 J K^{-1} mol^{-1} and T is the temperature. Using this equation and these values, the number of moles of O_2 is found to be 1.86×10^7. [5]
Next the mass of O_2 can be calculated using the following equation:

$$mass\ (g) = nM, \qquad (2)$$

where n is the number of moles and M is the molecular mass of O_2, 31.20. Using equation 2 the mass of O_2 is found to be 596,121 kg. [11]

In order to calculate how long 591,121 kg of O_2 would last if 1000 people were consuming it, a rate of consumption of 0.14 g of O_2 per breath will be used [12]. As stated earlier it will be assumed that the 1000 patients are all breathing at a rate of 28 bpm. 1000 people at this rate of breathing would consume 235.20 kg of O_2 per hour. By dividing the total mass of O_2 by the consumption rate, the length of time the O_2 would last for is found to be 2,513 hours (104.7 days).

Discussion

From the calculations it can be seen that the inhabitants in the hospital had just short of 105 days of O_2 supply. After this the O_2 would have ran out and they would have all died. However, in real life suffocation occurs before the O_2 levels are depleted due to CO_2 being a product of respiration and so as the levels of O_2 were decreasing the levels of CO_2 would rise. Eventually the CO_2 would reach a harmful level and at this point the humans would suffocate and become unconscious.

From the episode it was found that the hospital was on the moon, with the sealed environment, for just under half an hour at 0.49 hours. The people were all unconscious at this point with O_2 levels severely depleted. This is a colossal 5170 times shorter than the calculated, 105 days in this paper and even with the CO_2 levels considered it seems an infeasibly short amount of time. This paper did not account for the temperature on the moon which would kill people via hypothermia but also have a feedback effect upon equation 1.

Conclusion

It was calculated that the humans would have had enough O_2 for nearly 105 days on the moon, a considerably longer amount of time than the just under half an hour that they seemed to have. As a result of this the patients shouldn't have panicked so readily. Furthermore, for once the very intelligent Doctor assumed incorrectly that they would have a very limited air supply.

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