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S1_1 A Floating World

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Abstract

As in the film *2012*, we proposed geological disasters to cause global flooding in the year 2030 causing human survival to depend on arks for one year. We calculated the size of the three arks needed to be 12612 m x 4204 m x 4204 m to support the weight of the projected population size and its food supply. Using Archimedes Principle, we concluded the arks will be of sufficient buoyancy, sitting at a depth of 636 m in the water.

Introduction

In Roland Emmerich′s film *2012*, the world is struck by cataclysmic events leaving the human population scrambling to board giant arks before being wiped out. We considered the problem of whether such arks could carry the mass of humans and proper food supply in the year 2030 with the aim of zero human casualties. We used a flood period of one year and a years food supply for all passengers. What dimensions would the arks require to house such a population? At what depth would the arks float? With appropriate population estimates and Archimedes Principle we explored the human race′s chance of survival.

Theory

In Equation (1), Archimedes′ Principle states that, for a fully or partially submerged body, the weight of the liquid displaced is equal to the upward buoyant force and acts at the centre of mass of the displaced liquid.

$$\rho_w g V_d = mg, \tag{1}$$

where ρ_w is the density of seawater, 1025 kgm^{-3} [1], g is the acceleration due to gravity, V_d is the volume of the liquid displaced and m is the mass of the ark and its contents.

For simplicity, we modelled our arks as cuboids made of steel, as seen in Figure 1.

Figure 1: Ark dimensions.

To investigate the buoyancy of the arks, the masses of the population, food supplies and ark structure were calculated. Once all the masses were found, V_d was substituted by the volume of the ark submerged, $A_s d$, where $A_s = 3x^2$ is the base surface area and d is the depth the ark is submerged.

To calculate the mass of the population in 2030, a projected growth of 15.5% was applied to the current population [2]. The population was split into closely sized age groups and masses among each group were averaged.

Age Group	Current Population	2030 Population
0-4	648,398,688	642,045,759
5-10	748,760,672	771,412,647
11-17	835,625,101	894,790,012
18+	5,115,406,313	6,022,277,203

Table 1: Age group divisions used with current and projected population sizes.

Age Group	Average Mass(kg)
0-4	11.69
5-10	24.68
11-17	50.40
18+	70.30

Table 2: Average mass in kg for each age group [3].

Results

From Table 1, one third of the total population for 2030 was found to be 2.78×10^9 with mass, $m_p = 1.65 \times 10^{11}$ kg. We found the ideal living space for an individual to be 32.1 m^2 [4], assuming a room height of 2.50 m, giving a volume of 80.3 m^3 per person. Hence, each arks total volume must be 2.23×10^{11} m^3. x was found to be 4204 m, giving the ark dimensions of 12612 m x 4204 m x 4204 m.

To find the mass of the ark, we multiplied the density of steel, $\rho_{steel} = 7715$ kgm^{-3} [5], by the surface area of the ark and an estimated steel thickness of, $t = 5 \times 10^{-2}$ m.

$$m_a = \rho_{steel} V_{steel} = \rho_{steel}(14x^2t). \qquad (2)$$

Mass of floors, m_{fl}, was found using using the surface area of the floors, $3x^2$, ρ_{steel} and t. Using a room height of 2.5 m combined with floor thickness, the ark height divided by 2.55 m gave the number of floors in the ark.

$$m_{fl} = 3x^2 t \rho_{steel} \frac{x}{2.55}. \qquad (3)$$

Mass of food per person per year was estimated as 230 kg [6], giving a supply, m_f, of 5.62×10^{11} kg to be stored in the living space.

To find the depth the ark is submerged we rearranged Equation (1) then substituted in $V_d = A_s d$ and the masses to give;

$$d = \frac{m_a + m_p + m_f + m_{fl}}{\rho_w 3x^2}. \qquad (4)$$

This gave us a depth of 636 m.

Conclusion

To conclude, we investigated the dimensions of three arks needed to support a total population of 8.33×10^9, in the year 2030, for a period of one year. We also found the depth at which the arks would be submerged to determine whether they would be buoyant. The dimensions of each ark were found to be 12612 m x 4204 m x 4204 m with a submerged depth of 636 m. With such a small submersion depth, it is clear that the arks will float and support the combined weight of the population, its food supply and the ark's frame. Multiple assumptions were made, including ark shape, ark material and volume per person, which could contribute to a notable error. However, given the unsubmerged height, a large error could still be compensated for. Future investigations could consider a more accurate perception of a ship and the maximum length of time the population could survive aboard them.

References

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