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P4_1 Dead Sea Walking

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Abstract

The paper investigates the possibility of walking on the water of the Dead Sea under the assumption that salt can be added to the lake. The current salinity is not sufficient to enable a person to walk on the water. Theoretically, this feat would be achievable if the lake contained 6.77×10^{15} kg of salt. Practically, this amount of salt would not dissolve in the volume of water present in the Dead Sea.

Introduction

The Dead Sea is a salt lake located at the boundary between Israel, Jordan and the West Bank. It has a very high salinity which can vary between 30% and 40% for the water in the upper part of the lake and remains approximately constant in the bottom layers of the lake [1]. Salinity is defined as the ratio of salt to water in a sample. The high salinity of the lake increases the density of the water to 1240 kgm^{-3} as a result of which the water becomes more buoyant. The aim of this paper is to investigate whether it is possible to walk on the Dead Sea water, assuming that more salt can be added to the lake. Alternative approaches enabling to walk on liquids will also be discussed.

Can a person walk on the Dead Sea?

The salt content of the Dead Sea is approximately nine times higher compared to the salt content of the oceans [1]. If the increase in salinity is sufficiently large, it is feasible that a person could float to the extent that they may walk on the water. This can be investigated by applying Archimedes' principle. According to the principle, an object fully or partially immersed in fluid is buoyed up by a force equal to the weight of the displaced fluid. The following equation describes the buoyancy force B of the Dead Sea water:

$$B = \rho_{DS} V_W g \, , \qquad (1)$$

where ρ_{DS} = 1240 kgm^{-3} is the Dead Sea density [1], V_W is the volume of the displaced water and g is the acceleration due to gravity.

In the case where a person floats on the water the buoyancy force must equal the weight of the person. Combining the balance of forces with equation (1) allows us to obtain V_w:

$$V_W = \frac{m_P}{\rho_{DS}} \, , \qquad (2)$$

where m_P is the mass of the person, assumed to be 70 kg for the purpose of this investigation. Therefore, the volume of water displaced by a floating person is 0.056 m^3. This can be directly compared with the volume of the person, modelled as a cuboid of dimensions 1.75 × 0.46 × 0.24 m (height, shoulder width and depth respectively [5]), calculated to be 0.19 m^3. This suggests that 29% of the person would be submerged before floating occurs. However, for the person to be classified as walking on the water we require a maximum of 3% of the person to be submerged. This calculation is based on a cuboid model of a foot of dimensions 0.05 × 0.10 × 0.30 m (depth up to which a person is considered to be walking on water, width and length respectively [5]) which results in a volume of approximately 0.0015 m^3. Therefore, the current density of the Dead Sea water does not allow a person to walk on it.

Can a person walk on the Dead Sea if the salt content is changed?

Equation (1) suggests that if the density of the Dead Sea water is increased sufficiently then the buoyancy should be able to support a person walking on the water. The value for the desired density is referred to as ρ_{DS}'. The volume V_{DS} of the Dead Sea is taken to be 1.47 × 10^{11} m^3, as was measured in 1974 [2]. Assuming that all the salt in the lake is dissolved, the combined mass m_{DS} of the water and the salt can be found using the following equation:

$$m_{DS} = \rho_{DS} V_{DS} \,. \qquad (3)$$

The total mass of m_{DS} = 1.82 × 10^{14} kg is obtained. The current average salinity of the lake is approximately 33% [1]. Therefore, the total mass of salt in the lake is:

$$m_s = 0.33 \times \frac{m_{DS}}{1.33} = 0.45 \times 10^{14} kg$$

and the mass of water is:

$$m_W = \frac{m_{DS}}{1.33} = 1.37 \times 10^{14} kg \,.$$

The required density ρ_{DS}' of the water can be found by rearranging equation (2) and substituting ρ_{DS}' for ρ_{DS}:

$$\rho_{DS}' = \frac{m_P}{V_W} \,. \qquad (4)$$

Following Archimedes' principle, V_W = 0.0015 m^3 which is the volume calculated for the foot in the previous section. The required density ρ_{DS}' is approximately 47,000 kgm^{-3}. This value of density is unrealistically high for a liquid in normal conditions. Mercury, one of the highest density liquids occurring naturally, has a density of 13,579 kgm^{-3} [3]. However, if the calculated density was achievable by assuming that any amount of salt could be dissolved in a fixed volume of water, it would become possible for a person to walk on the Dead Sea. The required mass of salt m_s' that needs to be added can be found as follows:

$$m_s' = \rho_{DS}' V_{DS} - m_W \,. \qquad (5)$$

The above equation further assumes that the volume of the water-salt solution does not change in this process. The final value of the required mass of salt is m_s' = 6.77 × 10^{15} kg which is 49 times the mass of the water. This amount of salt would certainly not dissolve in the given amount of water, especially that the solubility of salt is 35.7 g per 100 mL of water at the temperature of 298 K [6].

It appears that the only type of liquid that has the properties required for a person to walk on it is a non-Newtonian fluid. The viscosity of such fluid depends on the flow conditions, for example forces acting upon it and the flow geometry [4]. This implies that if enough force is applied to the fluid, a person could walk on it.

Conclusion

This investigation shows that while the salinity of the Dead Sea water makes it possible for a person to comfortably float in it, it is not possible to walk on it. Realistically, adding more salt to the lake would not increase the buoyancy force by a sufficient amount because the required mass of salt, 6.77 × 10^{15} kg, is 49 times the mass of the water available in the lake. This leaves no possibility for the salt to fully dissolve and therefore a person cannot walk on the Dead Sea water. Alternatively, walking on a fluid could be achieved by utilising the viscosity-force relationship present within a non-Newtonian fluid.

References

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