



International Journal of

# Young Scientist Research

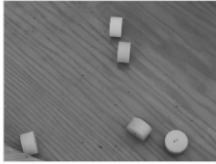
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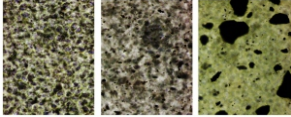


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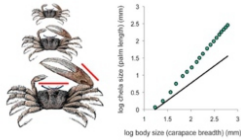
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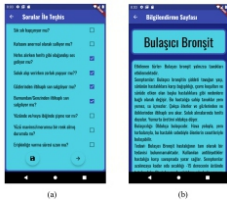
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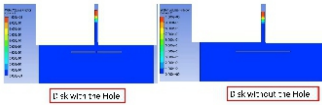
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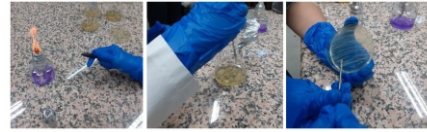
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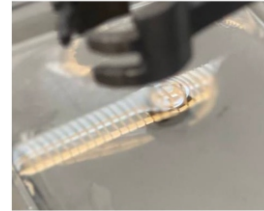
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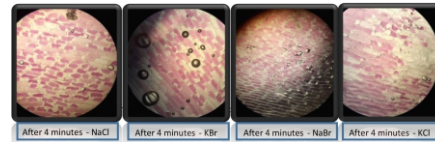
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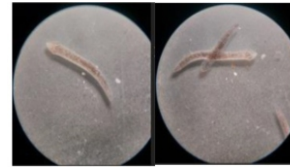
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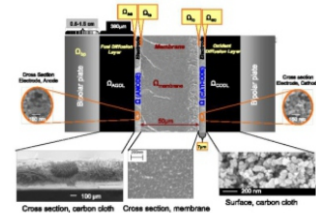
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# THE PROBABILITY OF A CYLINDRICAL DICE TO BE LUCKY

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## ABSTRACT

A coin is a circular disk so when its flipped it lands on either its heads or tails but technically it's really thin cylinder so there's a tiny chance for it to land on its edge. Dice are generally used to generate a random outcome in which the physical design and quantity of the dice thrown determines the mathematical outcome used mostly for different games all around the world but in this research we are going to find the most important factors in a cylindrical dice when we flip it to land on each one of the faces.

**Keywords :** Cylindrical Dice, Probability, Mass Theory

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## 1. Introduction

The problem states that to land a coin on its side is often associated with the idea of a rare occurrence. What should be the physical and geometrical characteristics of a cylindrical dice so that it has the same probability to land on its side and one of its faces? (Fig.1).

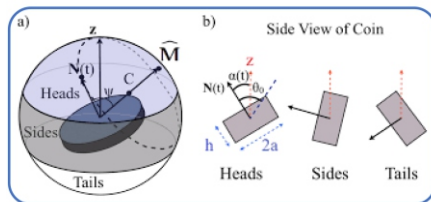


Fig.1: Paper spiral suspended above a candle

A coin is a circular disk so when its flipped it lands on either its heads or tails but technically it's really thin cylinder so there's a tiny chance for it to land on its edge but that's such a small probability that it doesn't even matter but there's also something like a pen which is the other extreme a very long cylinder if we flip it, it would land on its edge and if the pen was to be a coin the chance of the landing on its faces would be so little. So somewhere between the coin and the pen there's a cylindrical thick enough which makes it as likely to land on its edge and one of its faces and can be used as a three sided dice.

Dice is generally used to generate a random outcome in which the physical design and quantity of the dice thrown determines the mathematical outcome used mostly for different games all around the world. A cylinder on the other hand doesn't have an abundance of symmetry for various reasons least of it being the edge face doesn't have the same shape as the other two faces.

## 2. Theories and Methods

we inscribe the circular in a sphere. A cylindrical dice is made of two pieces; the smaller part is denser than the bigger one and they have equal masses, this moves the center of mass from the middle closer to the edge of the cylinder. The important way and variables such as height and angular velocity directly affect the throw's outcome. The number of throws is 1500 which the probability of

getting an edge,  $P$ , is a third and  $1-P$  is the probability of not getting an edge ( $2/3$ ). Using these values, we can get a probability based on a normal approximation.

### 2.1. Center of Mass Theory

In this theory, considering that the center of mass is right in the middle of the cylinder, we divide the cylinder into 3 parts from the inside, each of which represents one of the faces. This theory states that all 3 parts should have the same mass (Fig. 2).

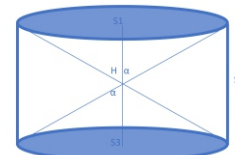


Fig.2: The cylinder is divided into 3 parts from the inside

### 2.2. Sphere theory

In throwing a sphere shaped ball the probability of it landing on any point on it is equal and this is where the idea comes from. This thick coin is embedded in a sphere where it fits the idea is that if we throw the sphere which has the thick coin inside of it one third of the area of the surface of the sphere is associated with one face one third a it is associated with the other face and the third associated with the band around the middle which is the edge (Fig.3) (Eqs. 1-4).

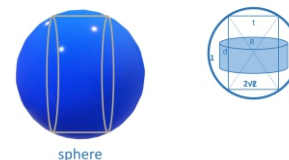


Fig.3: Thick coin is embedded in a sphere

$$S = 2\pi tR \quad (1)$$

$$S = \frac{4\pi R^2}{3}$$

$$t = \frac{2R}{3} \Rightarrow 2R = 3t \quad (2)$$

$$D^2 + t^2 = (2R)^2 = (3t)^2 \quad (3)$$

$$D^2 + t^2 = 9t^2 \quad (4)$$

$$D = 2\sqrt{2}t$$

**2.3. 2D Version**

Now let's look at it from a 2d perspective. The coin is now fitted in a circle so taking the rectangular cross section of the disk and doing essentially the same technique but it 2d which means dividing the perimeter of the circle into third which means dividing the perimeter of the circle into thirds (Eqs. 5-7) (Fig. 4).

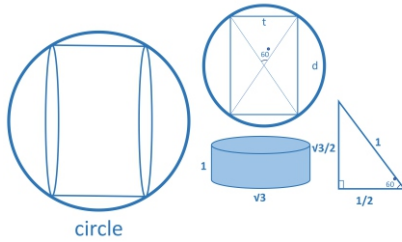


Fig. 4: The coin is now fitted in a circle

$$D = 2R \sin 60^\circ = R\sqrt{3} \tag{5}$$

$$t = 2R \cos 60^\circ = R \tag{6}$$

$$D = \sqrt{3}t \tag{7}$$

So with the first 2 theories we found the shortest and the tallest extremes then with the third theory we got ratio diameter to thickness but they are both super theoretical and non-might be right so the only way to prove that they are right is an experiment repeated hundreds of times keeping all the factors except the ratio diameter to thickness constant in order to find the ideal ratio that gives the third probability.

**3. Experiment**

First I did 3D Printed Cylinders with ratio diameter thickness of route two and route 3 with the same mass and material.

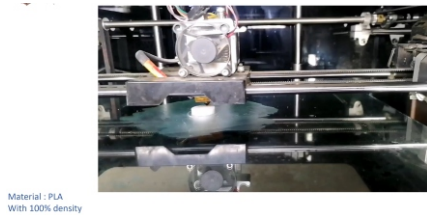


Fig. 5: 3D Printed Cylinders

Random Throw :then I figured out a way to a random throw . It's important the way the cylinders are thrown cause it has a direct effect on the outcome . The throw has to be random but not every single parameter has to be random in the throw . Variables like height and angular velocity directly affect on the throw's outcome . The angle which the cylinders are thrown at , is the random parameter in this method .

**4. Statistical Analysis**

Here we assume that the probability of a third landing on each side is correct with the given ratios and then calculate the likeliness of our data if that's true (specifically the edge). What is the chance of seeing 395 edges if it's got probability of third?

we can calculate that using binomial distribution which says from our 1500 throws we got 395 edges if the probability of success ( an edge ) is a third what is the chance of that happening ? The answer is a very tiny

probability but this isn't surprising considering that this is the probability of exactly 395 edges so what we do instead is saying what is the probability of getting less than or equal to 395 edges ; we'd need to calculate the probability of 1 + the probability of 2 + all the way to the probability of 395 which with the binomial distribution that would take lots of time and is unnecessary so instead we approximate it using the normal distribution . Our expectation is 500 if we're right ( that's from our binomial distribution ) . We also get our variance from binomial distribution ( the number is 1500 that's how many throws , P is a third ( probability of getting an edge ) and 1-P is the probability of not getting an edge (2/3) (Fig. 6). We can use these numbers to see how wide this bell curve needs to be . Using these values we can get a probability based on a normal approximation .

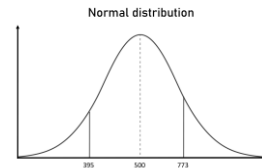


Fig. 6: Variance from binomial distribution

We got our average value here ( this is what we would expect if it was a third ) and we are saying what is the probability of 395 and how far away is it ? And it's still really tiny ; and even if we took a 2 sided test to see if it's in the extreme it would still be tiny . So we wouldn't have gotten these numbers if the ratios were correct . The probability of getting an edge is statistically different from a third with the 2 ratios. Although both the ratios were incorrect , they provided upper and lower bounds on the answer ; so I made cylinders with ratio diameter to thicknesses between  $2\sqrt{2}$  and  $\sqrt{3}$  ( started with the  $2\sqrt{2}$  ratio and made each cylinder 1 millimeter thicker to  $\sqrt{3}$ ) (Fig.7a & b).

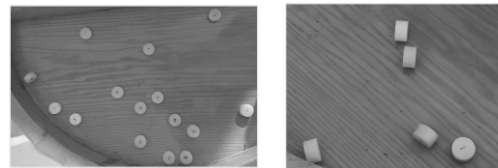


Fig. 7: a)Thinnest cylinder  $2\sqrt{2}$  b) Thickest cylinder

From the chart the closest ratio to the third probability is 2.4. As shown the probability is a big number , and the difference from the third probability is less than 2% (Tables 1 &2).

Table 1: Ratio  $2\sqrt{2}$ for total number of throws 1500

Number of	The results number	The expected number	The difference	Percentage
landing on one of its faces	1105	1000	105	73.66%
landing on its edge	395	500	-105	26.33%
landing on face 1	553	500	53	36.86%
landing on face 2	552	500	52	36.81%

Table 2: Ratio  $\sqrt{3}$  for total number of throws 1500

Number of	The results number	The expected number	The difference	percentage
landing on one of its faces	727	1000	-273	48.47%
landing on its edge	773	500	273	51.53%
landing on face 1	351	500	-149	23.41%
landing on face 2	376	500	-124	25.06%

With an experiment like this it's about having the result close enough and 2.4 can be considered close enough but we can get even closer than that.

I made a cylindrical dice of two pieces ; the smaller part is denser than the bigger one and they have equal masses , this moves the center of mass from the middle closer to the edge of the cylinder .This cylindrical dice is landed and the percentage of landing on the edge, the heavier side, is more and this is where the idea of the mass theory comes from .

Then we experimented with 3D printed dice and the mass theories cylinders with ratio diameter to thicknesses of  $2\sqrt{2}$  ,  $\sqrt{3}$  and 2.4 with following results (Eqs. 8-13).

$$n=1500 \quad P=1.3$$

Probability of Edge for  $2\sqrt{2}$  :

$$P(X = 395) = \binom{1500}{395} (1.3)^{395} (2.3)^{1105} = 1.78 \times (10)^{-342} \quad (8)$$

Probability of Edge for  $\sqrt{3}$  :

$$P(X = 773) = \binom{1500}{773} (1.3)^{773} (2.3)^{727} = 7.42 \times (10)^{-267} \quad (9)$$

$$P(X \leq 395) = P(X=1) + P(X=2) + \dots + P(X=395)$$

$$P(X \geq 773) = P(X=773) + P(X=774) + \dots + P(X=1500)$$

$$\phi\left(\frac{395 - E(x)}{\sqrt{V(x)}}\right) E(x) = nP = 500, V(x) = nP(1-P) \quad (10)$$

$$P(X \leq 395) = P(X=1) + P(X=2) + \dots + P(X=395) \quad (11)$$

$$\phi\left(\frac{773 - E(x)}{\sqrt{V(x)}}\right) E(x) = nP = 500, V(x) = nP(1-P) \quad (12)$$

$$P(X \geq 773) = P(X=773) + P(X=774) + \dots + P(X=1500) \quad (13)$$

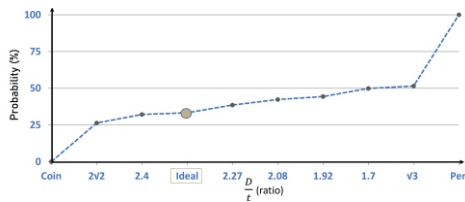


Fig.8: Probability of landing on the side

Table 3: Ratio 2.4 for total number of throws 600

Number of	The results number	The expected number	The difference	percentage
landing on one of its faces	407	400	7	67.83%
landing on its edge	193	200	-7	32.16%
landing on face 1	204	200	4	34%
landing on face 2	203	200	3	33.83%

They brought the results closer to the ideal so not only the geometric characteristics should be considered in this cylindrical dice but the physical properties play important role . There are lots of other physical properties that affects on the outcome of throwing variables like material , initial angular velocity , mass , the angle which the coin is thrown at , friction of the pieces , bounciness and more and the best way to study the effect of each of these variables and get closer than 1.57% to the third probability is a simulation (Fig. 9).

Finding how it works we throw thousands of cylinders while iterating over the cylinders thicknesses then find the

thickness at which the coin is equally likely to land on each side then experiment is done a lot of times for different values of different physical properties to find how they affect on the outcome.



Fig.9: Simulation

### 5. Conclusions

The mass of the cylinder doesn't seem to make a big difference ; it's pretty much steady at a thickness of 0.43 - 0.45 times the diameter . Initial angular velocity shows the more the cylinder spins in the air initially the thicker it has to be it increases between 0.42 and 0.46 (isn't a large difference) (Fig. 10).

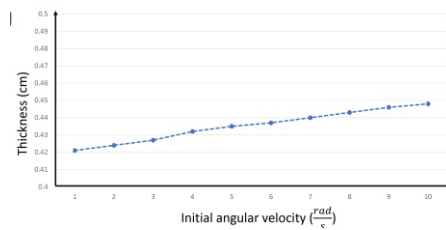


Fig.10: Thickness vs initial angular velocity of dice

The angle which the cylinder is thrown at the surface makes a huge difference ; in this experiment it's the random parameter but I calculated the ratios with different given angles from 90 degrees to 270(Fig. 11) .

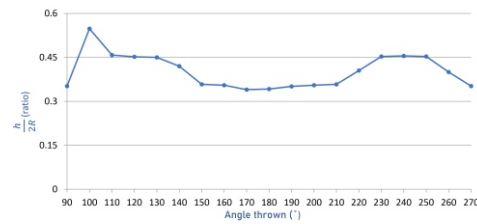


Fig.11: Angle of thrown effect on the results

Friction changes the results a lot and we need a much thicker coin when the coefficient of friction is between 0.1 and 0.18 but after that it decreases (Fig. 12) .

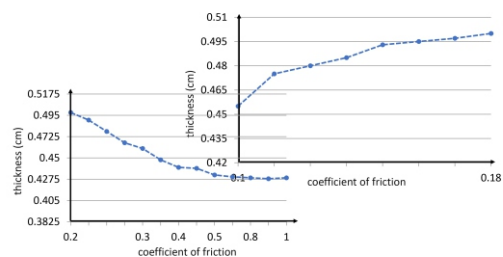


Fig.12: Friction changes on the results

After collecting data with the simulation the best ratio diameter to thickness was found which resulted in exactly third on each face lots of times and generally the probability of it landing on the edge is 2.4655 only 1.23%

further from 33.33%.

The 2.4655 ratio makes the closest to a perfect 3-sided dice but since this is a cylindrical and considering it doesn't have so many symmetry, with exaggerated changes on our physical properties the best cylindrical dice wouldn't be fair anymore so the best 3 sided fair dice would be a cube that has 2 obs 2 twos 2 thres on it.

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# SYNTHESIS AND DETERMINATION OF DRUG RELEASE BEHAVIORS OF SHAPE MEMORY MAGNETIC NANOCOMPOSITE FILMS

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## ABSTRACT

Developing efficient drug delivery systems ensure that the drug reaches the target tissue at the highest rate without damaging other tissues. Since magnetic nanoparticles can be controlled externally by magnets, and shape memory polymers can be adapted to any tissue, they are both often used in drug delivery systems. In this study,  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> nanoparticles and a PVA/regenerated cellulose-cotton solution were combined to develop a more advantageous system that is aimed to be effective to use in target-oriented release of cancer drugs.

**Keywords :** *Magnetic nanoparticle, Shape memory polymer, Drug release*

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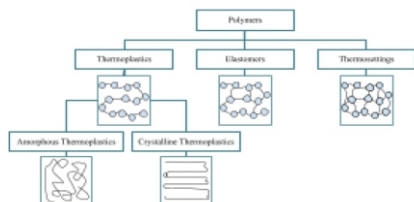
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## 1. Introduction

### 1.1. Polymers

Polymers, also known as macromolecules, are large molecules that are formed by the repetition of one or a group of small chemical units called monomers. The word polymer is formed by the combination of the Latin words “poly” meaning numerous and “meros” meaning piece [22, 23].

Polymers are divided into three groups according to their chain forms: thermoplastics, elastomers and thermosettings (Fig. 1). Thermoplastics, by means of the linear or branched chains in their structure, can be softened, melted and reshaped by the application of heat. They can be easily dissolved with the use of an appropriate solvent.



**Fig. 1:** Classification of polymers depending on the chain structure

The second type of polymers, elastomers which are also known as rubbers, are highly flexible and elastic. Due to the small number of crosslinks between the polymer chains, they can temporarily elongate at a high rate with the tensile effect. The tensile effect causes the polymer chains to slide over each other, but the crosslinks prevent permanent flow, so the molecules return to their original positions when the force is removed.

The third and last type of polymers, thermosettings, are defined as three-dimensional rigid polymers that contain a lot of crosslinks in their structure (network polymers). At high temperatures, they cannot be melted or reshaped, they break down and decompose by breaking the chains and bonds in their structure [19].

Polymeric composites, which are generally obtained from petroleum-derived materials, are materials with a high loading capacity per unit mass, corrosion resistant,

easy to process and shape, and suitable for long-term use. There are two types of polymeric composites, the first being thermoset and the second being thermoplastic matrix composites. Thermoset matrix composites are found in liquid form and are first gelled by adding a solidifier and then solidified in order to be shaped. They are frequently used in fibre-reinforced composite making, and during this process, it is often required for them to have a low viscosity. With the effect of heat, can be melted, cooled and solidified, thereby obtaining the ability to be remodeled [11, 12, 16].

### 1.2. Magnetic Nanoparticles

The word nano means “dwarf” in Greek and denotes one billionth of a unit. Therefore, a nanometer corresponds to one billionth of a meter. Nanostructures are systems consisting of 10-100 atoms, and nanoparticles are nanostructures that are generally between 1-100 nanometers in length [20]. It can be said that there are many subgroups of nanostructures such as nanotubes, nanocrystals, nanowires, nanorods, nanoparticles, and nanofilms. It is seen that nanoparticle production is of great importance for new developments in the field of nanotechnology, owing to its wide application area and superior properties [5, 15].

Nanoparticles could contain materials with different chemical structures such as metals, metal oxides, silicates, organic and carbon materials and biomolecules [17]. The fact that their movements can be easily controlled externally using a magnetic field and their high surface area/volume ratio make magnetic nanoparticles suitable for use in biology, medicine and many more fields, including diagnosis and treatment of numerous diseases, drug delivery, bio-labelling, separation or purification of biomolecules, and medical imaging [3, 24].

Essentially, two approaches are followed for the production of nanoparticles, namely top-down and bottom-up. The top-down approach is based on the separation of the material into nano-sized pieces by energising the volumetric material from the outside by mechanical, chemical or different processes (Fig.2). The bottom-up approach, on the other hand, is the opposite of the top-down approach, aiming to create particles by growing atomic or molecular structures through chemical

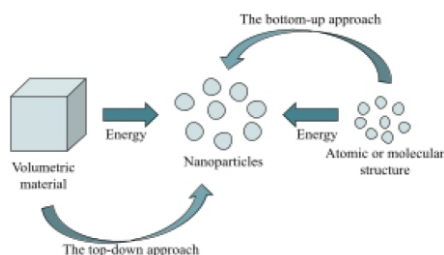


Fig. 2: Procedures used in the production of nanoparticles

One of the main contents of nanoparticles, iron oxides are formed as a result of the chemical combination of iron and oxygen, and approximately 16 types of iron oxide have been identified to date [4]. Since iron oxides, which can be found in many geological and biological processes, are not very sensitive to oxidation, they can maintain the stability of their magnetic effects [20].  $\text{Fe}_3\text{O}_4$ ,  $\alpha\text{-Fe}_2\text{O}_3$  and  $\gamma\text{-Fe}_2\text{O}_3$  are the most common forms of iron oxides in nature. Among these three forms,  $\text{Fe}_3\text{O}_4$  and  $\gamma\text{-Fe}_2\text{O}_3$  nanoparticles have attracted more attention with their superparamagnetic properties, low toxicity, and high surface area/volume ratios. Iron oxide nanoparticles can be used in various biomedical applications such as drug delivery, magnetic resonance imaging (MRI), and protein immobilization, as well as in coating, concrete and paint production [1, 13].

### 1.3. Smart Materials

Such as diodes and photovoltaics colour or phase-changing, light-emitting piezo materials are defined as smart materials. There are also smart materials that are designed to respond to a stimulating source or that provide optimum interaction by changing the geometry, electromagnetic character and mechanical/physical properties of the molecule [21]. With the current technology, it is possible to produce polymer-based smart materials with different properties that are sensitive to various conditions such as humidity, pH, temperature, light, magnetic field and solvent in the environment [6, 8].

Shape memory polymers, which have the ability to change shape depending on various variables in the environment and then return to their permanent shape, are one of the most frequently used smart polymer types. In recent years, thermosensitive shape memory polymers have been given importance in studies on shape memory polymers due to their wide application area, especially in materials engineering, textile and biomedical devices. In the structure of thermosensitive shape memory polymers, there are often physical or chemical cross-linked points such as various crystals, intertwined chains or amorphous hard segments, which allow their permanent shape to be retained in memory [9].

In addition to their shape memory properties, smart polymers also have the ability to carry about a thousand times their weight. This is due to the high energy released during some property changes. The usability of these polymers, which can easily return to their original shape at body temperature, in the biomedical field is an important research topic. Smart polymers are especially preferred in different biomedical applications such as artificial skin, surgical sutures and drug release. One of the areas where smart biomaterials are frequently used is drug release systems that enable the active substance to be delivered to the target in the body. The sensitivity of smart polymers to properties such as temperature and pH allows the desired

change to be made in the desired area of the body, even when a slight difference occurs [21].

## 2. Method

### 2.1. Synthesis of Iron (III) Nanoparticles

For this method, after weighing 6.06 and 11.75 grams of ferrous sulfate heptahydrate ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ) and non-hydrated ferric chloride ( $\text{FeCl}_3$ ), they were first mixed in 100 mL of distilled water in an ultrasonic environment and then in the ultrasonic water bath without applying heat. 25 mL of 25% ammonium hydroxide solution was added dropwise to the clear solution obtained, and then the resulting precipitated solution was stirred and heated in an ultrasonic environment for 60 minutes. After the resulting brown precipitate was filtered, it was washed with distilled water until  $\text{pH}=7$ . Afterwards, the precipitate was dried at  $70^\circ\text{C}$  for 12 hours and prepared for the analysis [10].

### 2.2. Preparation of Shape Memory Polymers

In order to prepare the RC-C (regenerated cellulose-cotton) solution, necessary amounts of NaOH, urea and distilled water with a weight ratio of 7:12:81 were used to obtain an aqueous solution in a 250 mL beaker and the resulting solution was cooled. After the cotton, which was previously decomposed in  $\text{H}_2\text{SO}_4$ , was added to this solution, the solution was mixed vigorously. Then, this solution was centrifuged to remove bubbles and insoluble substances and was taken to a  $4^\circ\text{C}$  environment [7, 14] (Fig. 3).

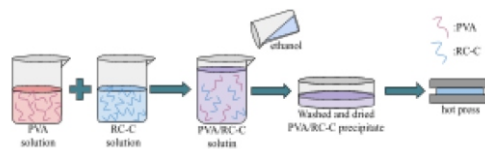


Fig. 3: Preparation of PVA/RC-C composites

The solution consisting of 8 g PVA and 92 g distilled water was heated to  $98^\circ\text{C}$  and mixed to obtain 8% by weight PVA solution. Afterwards, the PVA and RC-C solutions were mixed for 30 minutes, and the resulting solution was co-precipitated by adding more ethanol. The precipitate was washed with water, then soaked and dried for several days at  $60^\circ\text{C}$  for 4 hours to remove any remaining NaOH and urea. After drying, the PVA/RC-C precipitates were hot pressed at  $110^\circ\text{C}$  for 3 minutes [7]. At the end of these processes,  $\gamma\text{-Fe}_2\text{O}_3$  nanoparticles were placed into the shape memory polymer at 1%, 2.5% and 5% ratios, and the preparation of shape memory nanocomposite film samples was completed.

### 2.3. Characterisation of Nanocomposite Films

At this stage, the determination of morphological characteristics of shape memory magnetic nanoparticles were carried out by examining the samples containing 1%, 2.5% and 5%  $\gamma\text{-Fe}_2\text{O}_3$  nanoparticles and no nanoparticles with a light microscope.

After that, a dynamic mechanical analyzer was used to analyze the mechanical properties of shape memory magnetic nanocomposites. The tensile strengths of each sample under a force of 1N were calculated.

In order to examine the drug release behaviour of nanocomposite films, a certain amount of samples were transferred into 50 mL buffer solutions, then the solutions were placed in a shaking water bath. Drug release tests lasted for 120 hours in  $\text{pH}=1.2$  HCl acid solution and  $\text{pH}=7$

phosphate buffer. To determine the amount of clarithromycin released from the nanocomposites, 0.5 mL samples were taken from the solutions per hour and to calculate the concentrations of the samples, absorbance values at 760 nm wavelength were determined and the calibration chart was used [18].

### 3 Conclusion and Discussion

#### 3.1. Determination of Morphological Characteristics of Shape Memory Magnetic Nanocomposite Films

As a result of the investigations to determine the morphological properties of the prepared nanocomposite films, as shown above, it was seen that the magnetic  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> nanoparticles showed a homogeneous distribution in the shape memory polymer (Fig. 4a-c).

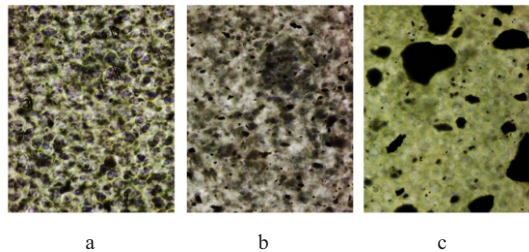


Fig. 4: Microscopic image of nanocomposite film samples containing a) 1, b) 2 and c) 5% magnetic nanoparticles, respectively

#### 3.2. Determination of Mechanical Endurance of Shape Memory Magnetic Nanocomposite Films

It is seen that the mechanical endurance of the samples containing nanoparticles is prominently higher than the mechanical endurance of the control sample without magnetic nanoparticles (Table 1). Additionally, it was determined that among the nanocomposite films containing nanoparticles, the sample with the highest mechanical endurance was the sample with 5% nanoparticles, and the sample with the lowest mechanical endurance was the sample with 1% nanoparticles. When the table is examined, it can be seen that the mechanical endurance of the sample with the least amount of nanoparticles increased by 173%, and the sample with the highest amount of nanoparticles increased by 227% compared to the sample without nanoparticles. It was observed that the mechanical endurance of the sample containing 5% nanoparticles reached approximately 3.5 times that of the sample without nanoparticles. The high mechanical endurance ensures that the drug delivery system is not damaged until the drug is delivered to the required tissue, therefore significantly increasing the efficiency of the drug delivery system.

Table 1: The mechanical endurance increase percentage of the samples containing nanoparticles compared to the control sample

Sample	Mechanical Endurance (MPa)	Mechanical Endurance Increase (%)
control	18.38	-
1%	50.15	173%
2.5%	55.86	204%
5%	60.15	227%

#### 3.3. Determination of Drug Release Behaviors of Synthesized Shape Memory Magnetic Nanocomposite Films

It can be easily seen that samples containing nanoparticles have much higher drug loading capacities

than the control sample. It was determined that the drug loading capacities of nanoparticle-containing samples are twice the sample without nanoparticles (Table 2) (Fig. 5).

Table 2: Drug loading rates for nanocomposite films with 1%, 2.5% and 5% magnetic nanoparticles

Sample	Drug Loading Rates
control (0%)	48.75%
1%	97.15%
2.5%	99.8%
5%	95.6%

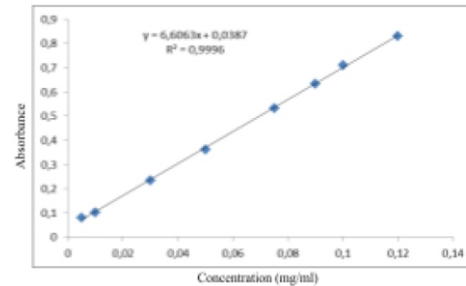


Fig. 5: The standard calibration chart prepared for clarithromycin

In figures (6-9), the drug release amounts of nanocomposite films in the first 10 and 120 hours in environments with pH levels of 1.5 and 7 are given. In both graphs, it is seen that the drug release rates of the samples containing nanoparticles are higher than the samples that do not contain them. Considering that the drug release amounts of the samples containing 5% nanoparticles reached 100% at the end of the 120th hour, it was revealed that the prepared drug release system was more efficient in terms of drug release amount from the shape memory polymer. The fact that the samples containing nanoparticles released at high rates and close to each other in both environments with different pH levels indicate that the synthesised nanocomposite films are compatible with different environments. When the samples containing nanoparticles are compared with each other, it can be concluded that the increase in the nanoparticle ratio will positively affect the drug release, based on the fact that the highest release rate is observed in the sample containing 5% nanoparticles in both samples.

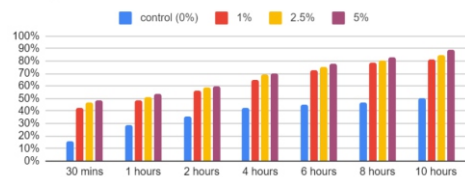


Fig. 6: First 10-hour release graph for pH=1.5

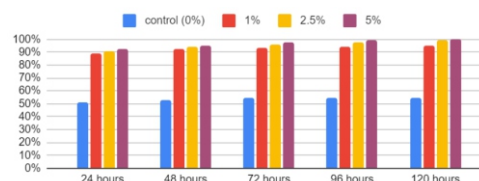


Fig. 7: First 120-hour release graph for pH=1.5

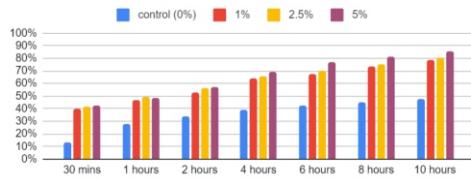


Fig. 8: First 10-hour release graph for pH=7

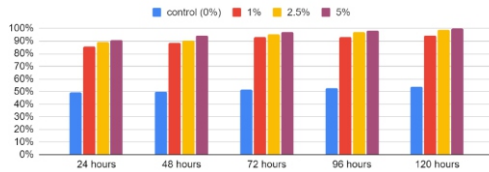


Fig. 9: First 120-hour release graph for pH=7

#### 4. Conclusions

In this study, shape memory magnetic nanocomposite drug carrier polymeric systems, which have not been encountered before in the literature, have been developed. Since it is a fairly new field of study in the scientific world, our study has been very promising in terms of developing new generation drug delivery systems after its biocompatibility has been proven by testing it in cells and tissues in the next stages. Besides, it is known that magnetic nanoparticles have the advantage of being able to control with magnets. It is predicted that the nanocomposite films that we have synthesized using this advantage will be very successful, especially in the controlled and target-oriented direction of cancer drugs. Likewise, since these magnetic nanoparticles are excellent heat conductors after they are delivered to the target tissue, they can be brought to the desired temperature from the outside and used to release the drug at the desired temperature.

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# ALLOMETRY

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## ABSTRACT

If we want to create a new creature (by stimulation of new stem cells), we should apply allometric scaling and equations in designing processes. For example, if the target be the creation of a human, her/his skull should become approximately twofold after the puberty period. Allometry helps us to guess the size of different parts of the body in different ages that is how the doctors find out how much our stature will grow. Here, we show the allometric scaling of different kind of animals which shows a logarithmic behaviors.

**Keywords :** Stem Cell, Allometry, animals, logarithmic

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## 1. Introduction

It is clear that the body of animals and humans is made of different parts and organs. These parts and organs grow during time gradually and everything about the biology of an animal is influenced by its body size, including its physiology (e.g., heartrate, respiratory rate, total metabolic rate, mass specific metabolic rate, growth rate), anatomy (e.g., organ mass, blood volume, surface area, cross-sectional area of limbs), and ecology (e.g., diet, home range size, reproductive strategy, life span, population density) [1]. But the question is that “what happens to these different parts when an animal grows?” and to answer this question many tries have been done [2]. There are many researches which show when the body becomes more massive, different parts become larger. These studies are the subjects of allometry science. Hence, Allometry is the study of how these processes scale with size of the body. In its broadest sense, it describes how the characteristics of living creatures change with size. The term originally referred to the scaling relationship between the size of a body part and the size of the body as a whole, as both grow during development. However, more recently the meaning of the term allometry has been modified and expanded to refer to biological scaling relationships in general. In this research, we searched to find the charts that shows how much the different important parts of the human body (such as bones, brain and heart) or body of animals (such as legs, antennae or horns) relate to each other [1]. One of the most general concepts that you are likely to find in biology is that of the relationship between body size and the rest of an organism's biology, a relationship that is often referred to as allometry. Therefore, an exploration of this topic is important if we are to understand the relationship between form and function in vertebrates. The purpose of learning allometry study is to explore for ourselves the relationship between two important biological traits: volume (a function of mass) and surface area, and how this relationship influences other aspects of an animal's biology. Allometry literally means “of other or different measures” (allo = other or different; metry =measure). The goal of its study with respect to biology is to describe the differences in magnitude in form or function that are correlated with changes in form or function of another variable [3].

## 2. Experiment

Allometry does not have any direct experiment. Therefore, the only thing that we should do is: search and read the gathered data in the libraries, websites and published papers. We've also investigated the documents about the dinosaurs in museums and national parks and got information about allometry equation. We've also investigated allometric scaling in different parts of different animals bodies. We realized that allometry is not always additive for example Our heads are almost a quarter of our body size when we are born, but when we grow to become adults our heads are only 1/8 or so (or heads grow slower than the rest of our body) and it is negative allometry (Fig. 1).

We found it ourselves by investigating the table of height, weight and height and weight of head growing during gestational period.

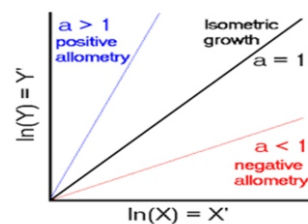


Fig. 1: The chart which shows negative and positive allometry[5].

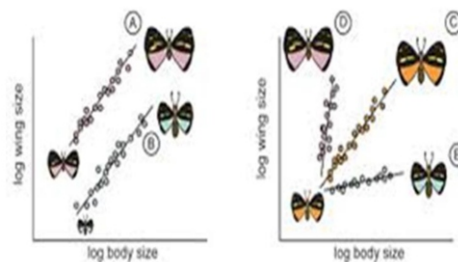
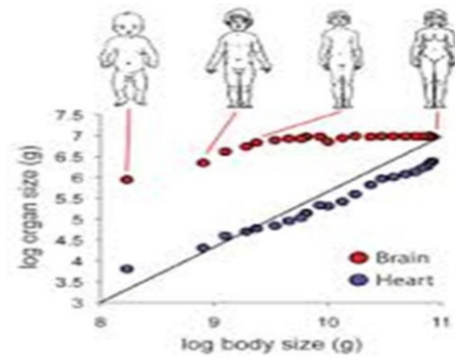


Fig. 2 : Allometric scaling of butterfly wings [1]

We also found many charts about allometric scaling of different parts of the body of different animals (Figs. 2 to 5) and Table (1).

**Table 1:** Mass and length of a baby inside the mothers [3]

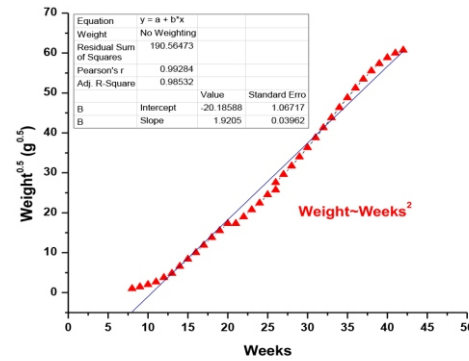
getational age	length(us) (crown to rump)	weig(us) (crown to rump)	length(cm)	mass(g)
8weeks	0.63inch	0.04 ounce	1.6	1
9weeks	0.90inch	0.07 ounce	2.3	2
10weeks	1.22 inch	0.14 ounce	3.1	4
11weeks	1.61inch	0.25 ounce	4.1	7
12weeks	2.13inches	0.49 ounce	5.4	14
13weeks	2.91 inches	0.81 ounce	7.4	23
14weeks	3.42 inches	1.52 ounce	8.7	43
15weeks	3.98 inches	2.47 ounces	10.1	70
16weeks	4.57 inches	3.53 ounces	11.6	100
17weeks	5.12 inches	4.94 ounces	13	140
18weeks	5.59 inches	6.70ounces	14.2	190
19weeks	6.02 inches	8.47ounces	15.3	240
20weeks	6.46 inches	10.58ounces	16.4	300
21weeks	10.08 inches	10.58ounces	25.6	300
22weeks	10.51 inches	12.70ounces	26.7	360
23weeks	10.94 inches	15.17ounces	27.8	430
24weeks	11.38 inches	1.10 pound	28.9	501
25weeks	11.81 inches	1.32 pound	30	600
26weeks	13.62 inches	1.46 pound	34.6	660
26weeks	14.02 inches	1.68 pound	35.6	760
27weeks	14.41 inches	1.93 pound	36.6	875
28weeks	14.80 inches	2.22pounds	37.6	1005
29weeks	15.2 inches	2.54pounds	38.6	1153
30weeks	15.71 inches	2.91pounds	39.9	1319
31weeks	16.18 inches	3.31pounds	41.1	1502
32weeks	16.69 inches	3.75pounds	42.4	1702
33weeks	17.20 inches	4.23pounds	43.7	1918
34weeks	17.72 inches	4.73pounds	45	2146
35weeks	18.19 inches	5.25pounds	46.2	2383
36weeks	18.66 inches	5.78pounds	47.4	2622
37weeks	19.13 inches	6.30 pounds	48.6	2859
38weeks	19.61 inches	6.80 pounds	49.8	3083
39weeks	19.96 inches	7.25 pounds	50.7	3288
40weeks	20.16 inches	7.63pounds	51.2	3462
41weeks	20.35 inches	7.93pounds	51.7	3597
42weeks	20.28 inches	8.12pounds	51.5	3685



**Fig. 5:** Allometric scaling of brain and heart of humans [1]

**3. Results**

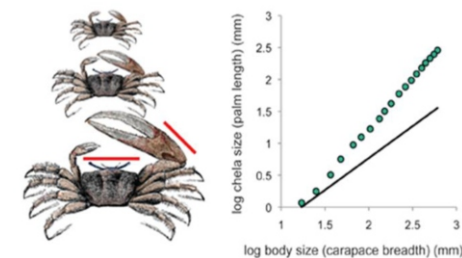
More simply, it is the study of what happens to Variable Y when you change Variable X. This is basically a qualitative description and only allows us to speak of correlated changes in qualitative ways; for example, Y gets bigger as X gets bigger, Y slows down as X speeds up, Y gets wider as X gets heavier, and so on. As biologists, however, we want to be able to describe things in a more precise way.



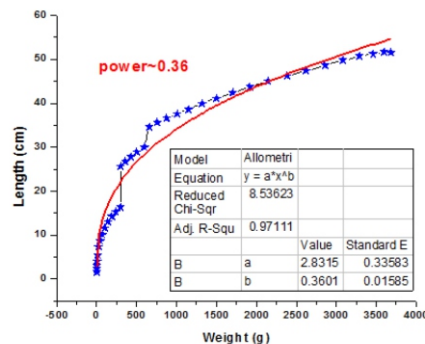
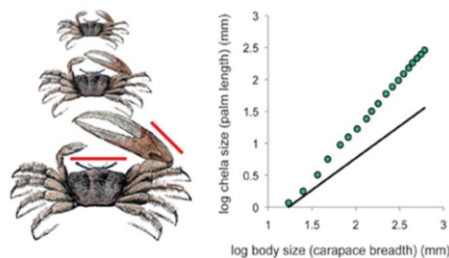
**Fig. 6 :**Chart of weight growing during time (OUR MODELING)

Does Y get bigger (or slow down or get wider) at the same rate as X? At a faster rate? A slower rate? To satisfy our need for quantification, we resort to mathematical equations that precisely describe the relationship between two variables. We investigated the table of humans head growing during gestational period\* and found out my own equations. We've also drawn the charts of these information ourselves (Figs. 6 to 9).

**Fig. 3 :** Information of different animals and human [5]



**Fig. 4:** Allometric scaling of chela and carapace of crab [1].



**Fig. 7 :** chart of length growing relating to the weight (OUR MODELING)

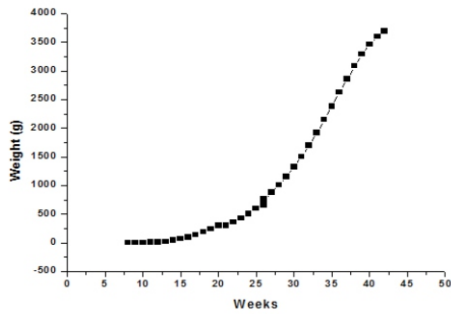


Fig. 8: Chart of weight growing during time (OUR MODELING)

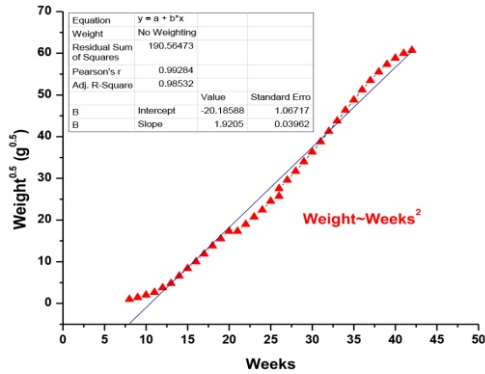


Fig. 9: Chart of  $(\text{weight})^{(0.5)}$  growing during time

#### 4. Conclusion

Allometry scaling shows that when an animal or human grows up, different parts of its body become larger and all of these parts grow relating to the whole body size. We are not always able to measure the size of different parts of the body such as inner parts like brain or heart and we can figure it out by the allometric equations that describe the relationships between two variables (like weight of the whole body and length of the crown in humans). Allometry is not always positive and it's sometimes (like humans head) negative when a particular part of the body grows slower than the rest of the parts.

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# COLORED FIRE

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## ARTICLE INFO

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## ABSTRACT

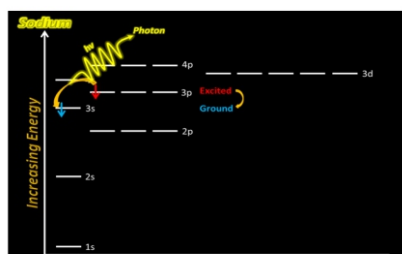
The flame can be easily painted using different chemicals. To identify the chemicals needed to obtain a particular color and check what color is obtained if a combination of these chemicals are used, several experiments have been done. All colored flames with different chemical substances are captured to compare with each other.

**Keywords:** Flame, Chemical Substances, colored Fire

## 1. Introduction

Are electrons excited by heat? Electrons can also be excited by electrical excitation, where the original electron absorbs the energy of another, energetic electron. The simplest method is to heat the sample to a high temperature. The thermal energy produces collisions between the sample atoms causing the atom's electrons to be excited.

When an electron in an atom has absorbed energy it is said to be in an excited state. An excited atom is unstable and tends to rearrange itself to return to its lowest energy state. When this happens, the electrons lose some or all of the excess energy by emitting light (Fig. 1).



<http://ircamera.as.arizona.edu/Astr2016/lectures/spectroscopy.htm>

Fig. 1: Radiation from excited atom

## 2. The Origin of Flame's Colors

We should know that the color of each flame is determined by the temperature of the material is used.

The temperature ranges from Red to White:

### Red

Just visible: 525 °C (980 °F)  
Dull: 700 °C (1,300 °F)  
Cherry, dull: 800 °C (1,500 °F)  
Cherry, full: 900 °C (1,700 °F)  
Cherry, clear: 1,000 °C (1,800 °F)

### Orange

Deep: 1,100 °C (2,000 °F)  
Clear: 1,200 °C (2,200 °F)

### White

Whitish: 1,300 °C (2,400 °F)  
Bright: 1,400 °C (2,600 °F)  
Dazzling: 1,500 °C (2,700 °F)

As shown, the lower the color temperature is and the warmer more reddish the color of the light will be and the higher the color temperature is the cooler more bluish the color of the light will be.

The white light source with a high proportion of red and a low color temperature will appear warmer.

The white light source with a high proportion of blue and a higher color temperature will appear cooler.

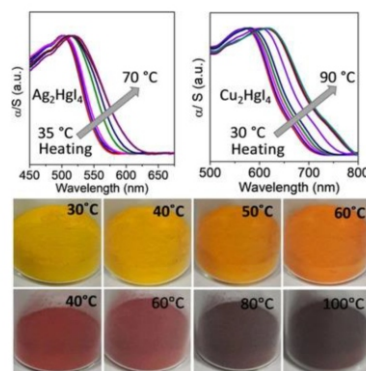


Fig. 2: The concepts of color temperature

## 3. Materials and Methods

All materials in this research are in Table (1).

Table 1: Chemical substances in our experiments

Material	Chemical Formula	color
1-Magnesium sulfate	$MgSO_4$	White
2-Potassium chloride	$KCl$	White
3-Copper chloride	$CuCl_2$	Green
4-Boric acid	$H_3BO_3$	White
5-Copper sulfate	$CuSO_4$	Blue
6-calcium chloride	$CaCl_2$	White
7-Strontium chloride	$SrCl_2$	White
8-Barium chloride	$BaCl_2$	White



#### 4. Experiment

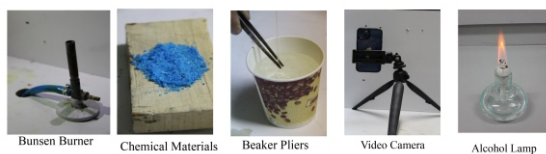


Fig. 3: Experimental Setup

All experiments have been done with different chemical substances and the flame's colors are observed in Bunsen burner and Alcohol lamp.

Flame's Color of Magnesium sulfate,  $MgSO_4$ , is Blue and  $KCl$  is Purple,  $CuCl_2$  is Green and boric acid flame's Color is light green so  $CuSO_4$  flame's Color is Green also  $CaCl_2$  flame's Color is Orange and  $SrCl_2$  is Red.

Experiments are compared in different temperatures (Fig. 4).



Fig. 4: Flame's color with different chemical substances

Experiment with combined substances resulted in new color which depends on percentage of mixture of each substances. Combining the 33% magnesium sulfate + 66% boric acid and making blue and green color is one of the experiments but the green color is more than the blue color because the percentage of boric acid is more than that of magnesium sulfate. Measuring the temperature of materials with a laser thermometer is recorded.

The results of all materials in my tests are in Table (2).

Table 2: The results

Material	Chemical Formula	Material color	Real color	Observed color	Bunsen Burner Flame temperature	Alcohol lamp Flame temperature	color temperature	Wavelength
1-Magnesium sulfate	$MgSO_4$	White	Blue	Blue	1500°C	260°C	1400 – 1500°C	450 – 495
2-Potassium chloride	$KCl$	White	Purple	Purple	1500°C	260°C	1200 – 1400°C	380 – 450
3-Copper chloride	$CuCl_2$	Green	dark green	dark green	1500°C	260°C	1400 – 1600°C	495 – 570
4-Boric acid	$H_3BO_3$	White	light green	light green	1500°C	260°C	1400 – 1600°C	495 – 570
5-Copper sulfate	$CuSO_4$	Blue	Green	Green	1500°C	260°C	1400 – 1600°C	495 – 570
6-calcium chloride	$CaCl_2$	White	Orange	Orange	1500°C	260°C	1000 – 1200°C	590 – 620
7-Strontium chloride	$SrCl_2$	White	Red	Red	1500°C	260°C	800 – 1000°C	620 – 750
8-Barium chloride	$BaCl_2$	White	light purple	light purple	1500°C	260°C	1200 – 1400°C	380 – 450

#### 5. Conclusion

Different types of substances were tested to find temperatures and the excitation of materials on different

flames. The best visible spectrum was on the Bunsen Burner because it had a high flame temperature. But in the alcohol lamp, because the flame temperature was very low, the substances couldn't excite well and the visible spectrum was not produced as well as the Bunsen-Burner.

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# DISEASE DETECTION FROM CHICKEN FECES ON A MOBILE PLATFORM USING DEEP LEARNING METHODS

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## ABSTRACT

The demand for poultry, which has been an important economic activity for humanity for thousands of years, is increasing due to many reasons. One of the most important factors that negatively affect poultry farming is pathogenic animal diseases. The detection of diseases in poultry is usually done through laboratory tests, the disease progresses and causes mortality in the time required for laboratory examinations. In this study, a mobile application was developed to minimize the mentioned problems and to enable poultry producers to obtain fast and reliable information about diseases that occur in their animals.

**Keywords:** *Chicken diseases, Deep learning, Mobile application.*

## ARTICLE INFO

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## 1. Introduction

In this study, a mobile application was developed to minimize the mentioned problems and to enable poultry producers to obtain fast and reliable information about diseases that occur in their animals. To be used in this mobile application, a deep learning model has been developed that can distinguish pseudo-plague (Newcastle strain), salmonella, and coccidiosis diseases in chicken feces through the data collected by processing the photographs taken from the feces of chickens with the help of tools such as artificial intelligence, machine learning, and image processing, which are widely used today. To train the deep learning model used, a dataset of 6812 photos consisting of chicken droppings was prepared for training deep learning models and models previously used for various purposes were trained through transfer learning. After the training, the models were evaluated comparatively and the model with the highest accuracy and efficiency ratio was selected for use in the mobile application. In addition, a panel has been developed in which users can get information about possible diseases that may be found in their chickens as a result of answering questions about the symptoms that can be observed in their chickens.

Poultry farming, which has been shown as one of the main economic activities of humanity for thousands of years, gains importance every year due to the advantages it provides for producers and consumers, and as a rapidly growing economic sector on a global scale, it is closely related to a large part of the world's population. Poultry farming, which stands out as an economic activity with a high-profit margin due to the competitive advantage that can be achieved even at local scales due to the low opportunity cost for the producers, is also frequently preferred by consumers due to its high nutritional value and relatively more economical conditions. Considering these reasons, it is seen that the demand for poultry farming is already increasing at exponential levels all over the world, and it is predicted that this trend will gradually accelerate in the future as well. So much so that since 1995, the demand for chicken meat in the world has doubled every 10 years; the egg and other poultry products market has achieved a growth of around one hundred and fifty percent on a global scale [2]. At the same time, the waste

and other by-products generated after production are rich in elements such as nitrogen, phosphorus, calcium, and potassium that are necessary for soil quality and will increase product yield, a chicken produces 5 kilograms of waste that can be used as fertilizer annually, chemical agents rapidly pollute the currently limited resources. and due to reasons such as commercial fertilizers do not produce sustainable solutions for ecological balance, the poultry farming sector; gains a position that directly or indirectly affects the basic economic activities in many countries. In particular, the use of chicken manure in agricultural activities is expanding in Asia Minor and many African countries such as Pakistan, and Iran, where access to chemical fertilizers and reinforcing agents is limited [3].

As a sector that affects the entire food web in the ecosystem, poultry farming, like all other livestock sectors, is critically adversely affected by emerging animal diseases. As in many countries of the world, these diseases are viewed as the most important obstacle to sectoral development and competitiveness for Turkey. Although the breeders in Turkey do not have difficulty in reaching a certain quality in the final products to be exported, they lose their potential export opportunities due to widespread zoonosis and animal diseases and there are economic losses that will deeply affect the sector [1]. In addition, poultry diseases transmitted to other foods and water sources through agricultural processes in which the wastes produced by chickens are used as fertilizer pose a high danger to public health, especially to the people living in rural areas. Considering that poultry farming is in a more complex relationship with other economic activities, especially in developing countries where access to health services and protective measures is relatively inadequate, it is seen that this situation constitutes a major deficiency in terms of preventing epidemics that are currently on the agenda of the whole world. So much so that typhoid fever, which is a common chicken disease and a disease caused by Salmonella bacteria, has lost its power in countries such as the USA, Denmark, and Turkey, where the sanitary infrastructure has developed since the 2000s, but only in the border regions of Pakistan and Iran in 2017-2018. It has caused the death of hundreds of people by developing new mutations with a high mortality rate and antibiotic

resistance even within the range [4].

In addition to diseases caused by bacteria, viral infections transmitted from poultry to humans also cause major problems both locally and globally. Avian Influenza, which is known as "bird flu" among people, has deeply affected many countries, including Turkey, in the 2000s. In addition to new viruses such as H7N9, which are currently circulating in countries such as China, Vietnam, and Thailand and can be transmitted from person to person [5], studies conducted in Western and Sub-Saharan Africa regions draw attention to a new H5N1 danger [6]. Considering the incurable viruses such as HIV, which can transmit from other vertebrates to humans through mutations, and SARS-CoV-2, which has been affecting the whole world for more than 2 years, biosecurity is of high importance today, and solutions that can detect pathogenic diseases of poultry origin at the earliest and the lowest cost are considered. It is seen that the need is increasing day by day. Considering the damage caused by many poultry diseases to the intestinal and digestive tracts, it is thought that chicken droppings may be a good indicator for the most common poultry diseases such as coccidiosis (coccidiosis), pseudo-plague (Newcastle strain) and Salmonella-related diseases.

Coccidiosis, which is a deadly disease seen in many vertebrates due to protozoa of the *Eimeria* genus, adversely affects the intestinal tract of the infected creature and causes problems such as tissue damage, diarrhea, decreased resistance to other diseases, and in some cases death [7]. Coccidiosis disease causes great harm to the poultry industry, considering the negative effects on animals that die due to the disease and producers who come into contact with live, feces, and other wastes. So much so that, according to 2016 data, coccidiosis caused a loss of over £100 million in the UK alone; It has been found to cause damage to the poultry farming industry in developing countries such as Brazil, Egypt, Guatemala, India, and Nigeria at a level of over £10 billion that could be classified as devastating [8].

Although drugs and vaccines have been developed for the prevention and early diagnosis of coccidiosis disease, due to the high cost of drugs and the logistical barriers to establishing the necessary infrastructure for widespread vaccination in developing countries, they could not be easily made available to poultry producers, prompting the producers to seek more natural, economical and effective solutions. [9].

Newcastle strain (false plague), another common poultry disease in the world, is reported as a deadly and contagious disease affecting many domestic and wild animal species. The only known diagnostic method for the diagnosis of this disease, which is seen in Asia, Africa, and parts of North and South America, is high-cost and long-term laboratory tests. Many producers do not seek medical help except in very urgent cases due to the high cost, even though symptoms are observed and the disease is suspected, and this situation endangers public health as well as causes financial damage. Another dangerous situation related to pseudo-plague is that it is a disease with a high ability to cross-transmission between species. For this reason, vaccine makers and laboratory workers are the most affected by the Newcastle strain, which can infect bird species as well as spread among humans, and resistant mutations that are more difficult to treat can be seen. [10]

Salmonella-based diseases have been followed as an international public health threat since the 2000s, as a

disease with high mortality. According to 2015 data, Salmonella bacteria, which causes 93.8 million food-borne diseases and 155,000 annual deaths [11], continues to be effective in many countries, especially in African countries, East Asia, and Asia Minor, although it has lost its effect in countries such as Turkey and European countries [12]. Salmonella Enterica, one of more than 2000 different serotypes, tends to cause systemic diseases in humans. Although progress has been made in the fight against Salmonella with today's technology, the immunity of pathogens against the substances used and the fact that it is a pathogen that can be transmitted to humans through food makes a full-scale control in poultry difficult without effective early diagnosis methods [13]. This situation causes great economic damage to the chicken farming sector.

As one of the biggest common points of poultry diseases, which are pregnant with such great economic problems and cause harm to the ecological balance, changes in the appearance of chicken droppings can be shown due to the effects of diseases on the digestive system [14]. In particular, detecting the apparent differences in stools with the help of computer vision algorithms, which have recently played a role in the detection of many diseases and problems, will be able to eliminate the logistical impossibilities and cost problems, which are one of the most fundamental problems in the diagnosis of diseases. Today, computer vision technologies are used in quite different fields such as health [15], agriculture [16], and livestock [17]; It is used for purposes such as image classification, image recognition, and image segmentation. To perform the image classification process used in this study, firstly, the images to be classified are named with appropriate classes, and a data set is created. Then, a deep learning model, which is thought to be suitable, is trained with this data set and a model trained on that data set is obtained. This model is tested by using the test set separated from the data set before the training process and the accuracy of the model is obtained. For example, the working group led by Ranjbarzadeh [18] developed a deep learning model that can segment brain tumor images with an accuracy of 92%, and Konstantinos P. Ferentinos [19] identified 58 different plant diseases with an accuracy of 99.53%. has developed a deep-learning model that can diagnose.

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## 2. Method

Deep learning algorithms, which are a sub-field of machine learning algorithms, can reach very high accuracy rates in areas of use such as classification, object detection, and segmentation in computer vision. Deep learning algorithms, which use artificial neural networks created by imitating the cognitive process of humans, are widely used in the construction of autonomous vehicles, the development of chatbots, and image processing. Although artificial intelligence networks used in deep learning have a convolutional neural network (CNN), generative contentious network (GAN), recursive neural network (RNN), and similar network structures, each is used by researchers in line with different requirements. In this study, we have used the CNN structure, which enables deep learning to transform images into digital matrices. In line with the aforementioned purposes, (i) a suitable development environment has been established in the computer environment, (ii) operations have been made on the dataset, (iii) appropriate deep learning models have been trained, and (iv) a mobile application has been developed to ensure that the work done is accessible to all segments.

### A. Creating the Development Environment

One of the issues that the researcher should decide before starting any artificial intelligence study is to choose the artificial intelligence software framework to be used. Tensorflow and PyTorch are the most popular artificial intelligence and deep learning frameworks used worldwide today. The Keras API, which works on these software frameworks and facilitates their use, is widely used in today's deep learning research. In this research, it was decided to work with the TensorFlow software framework using the Python software language, due to a large number of users in the world and the rapid application development. After the software framework has been determined, it has been deemed appropriate to work with the Conda package manager to use different versions of the libraries at the same time, to make experiments, and to provide environmental management easily.

In the first stage, artificial neural networks were run on the CPU to make the experiments, but with the growth of the data set, the use of GPU, which is hardware that can run more than one process in parallel, was needed. For this, the first artificial intelligence models were created with the NVIDIA GTX 1650Ti GPU, and GPU acceleration processes were configured using the NVIDIA CUDA Toolkit. Due to the growth of the network architectures used in artificial intelligence models to reach higher accuracy values and the limited video memory (VRAM) of the GPU used accordingly, the Google Colaboratory, which is offered to researchers free of charge, has been switched to the Colab platform. The Colab notebook, which is accessed through the browser, allows the codes written using the Python programming language to run in the cells it contains. Colab offers access to GPUs in servers located in data centers for free with no extra configuration

required for use in machine learning. In this study, it has been actively used and the power of the hardware in the data centers has been used in training artificial intelligence models.

### B. Applied Operations on the Dataset

The dataset contains a total of 6812 photographs, of which 2057 are healthy, 2103 are coccidiosis, 376 are Newcastle strains, and 2276 are salmonella disease. Some of these photos were collected by us using the ODK (Open Data Kit) mobile application. ODK is a mobile application that allows quick tagging of photos taken while taking a photo. Data were collected and labeled under the supervision of a veterinarian from a small poultry farm (Fig.1).



Fig. 1: Data Collection and Labeling Using ODK Application

The photos in the dataset are of different resolutions because they were taken by different mobile phone cameras. However, the requirement that all photos fed to the artificial intelligence model must be of the same resolution (for example, 299 pixels x 299 pixels) necessitated the application of intelligent cropping and resizing to each photograph. While doing this, attention was paid to the aspect-width ratio and the value of the data was tried to be preserved as much as possible. Examples of data are shown in Figure (2).

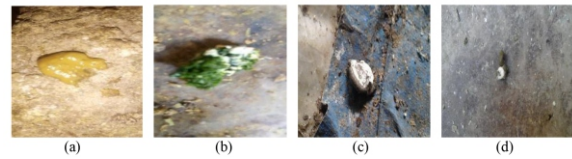


Fig.2: Examples of Data (a) Coccidiosis (b) Newcastle Strain (c) Healthy (d) Salmonella

The data duplication method, which is another of the preprocessing methods applied to the data set, was used both to increase the number of high-quality data to be fed to the model and to avoid the problem of data imbalance between classes, which is one of the factors affecting the performance of the model.

Table 1: Duplication Operation on Dataset

Classes	Number of Data Before Duplication	Number of Data After Duplication
Healthy	2057	4114
Coccidiosis	2103	4206
Newcastle Strain	376	2256
Salmonella	2276	4552
<b>Total</b>	6812	15128

In the data duplication process, techniques such as random enlargement, vertical or horizontal rotation of the photo, random amount of zoom in/out, and a random

amount of clockwise/counterclockwise rotation were applied to each photo, and the number of photos in the dataset increased to 15128. However, more replication was performed in Newcastle Strain disease, which has fewer data than other diseases and causes an imbalance between classes, compared to other classes. Since it would cause poor quality of data in the Newcastle strain class, which reached almost half the number of other classes, no further replication was performed and the imbalance problem between classes, which was the first step towards a solution after preprocessing, was solved during the training phase of the model. The results of this duplication process are shown in Table 1. At the same time, examples of photographs formed after duplication are shown in Figure (3).



**Fig.3:** Salmonella Class Data Before (a) and (b) After Replication Process

After duplication, the dataset was divided into 3 parts (80%-10%-10%) for (i) training, (ii) testing, and (iii) validation of the model. The results of this separation process are shown in Table(2).

**Table 2:** Segmentation of the Dataset into Training-Test-Validation Parts

Classes	Training	Test	Validation
Healthy	3291	411	411
Coccidiosis	3365	421	421
Newcastle Strain	1804	226	226
Salmonella	3642	455	455
<b>Total</b>	<b>10899</b>	<b>1363</b>	<b>1363</b>

### C. Training the Deep Learning Models

To feed the data set to the network, which is the first stage of training deep learning models, a software pipeline should be established. The tf.data module in TensorFlow has been preferred to be used for importing the data set due to its high speed and easy application. In other data input generation modules, while the artificial neural networks wait for the data to be processed first and then enter the network, the tf.data data processing module divides the data set into data stacks and queues them in the RAM region, and feeds the incoming data stacks to the network. This module, which is 38 times faster than other data entry creation modules, benefits from the advantages of parallel processing.

After the data set is transferred to the program, before the data set is divided into training and test parts, the problem of imbalance between classes still needs to be resolved in the results obtained by preprocessing. To overcome this problem, it was decided to use the class weights method. The class weights method ensures that certain weights are assigned to each class during the training of the model and that classes with a small number of data in the back-propagation process affect the model more, thus preventing the accuracy rate decreases, which are caused by the unequal distribution of the classes in the data set and

especially affecting the F1-score.

Research has been carried out on which network architecture can be used by the artificial intelligence models that will be created when the data set is ready to be fed to artificial neural networks as a training and test set after the preprocessing processes. The performance levels of network architectures achieved in previous studies were examined and studies were started to create models from prominent architectures. While some of the most advanced architectures are readily available within the Keras API, the architectures used to make the first trials were built manually from scratch using object-oriented programming techniques, again over the Keras API. Some of the readily available architectures can be seen in Table 4. The first 1 accuracy rate and top 5 accuracy rate columns are the performance data obtained by testing the model trained using the specified architecture on the ImageNet dataset. Depth refers to how many layers the network has topologically, such as the activation layer, the batch normalization layer, the pooling layer, and similar layers.

**Table 3:** Data on Different Deep Learning Models

Model	Size (MB)	Top 1 Accuracy Rate	Top 5 Accuracy Rate	Number of Parameters	Depth
Xception	88	0.790	0.945	22,910,480	126
VGG16	528	0.713	0.901	138,357,544	23
VGG19	549	0.713	0.900	143,667,240	26
ResNet152	232	0.766	0.931	60,419,944	-
InceptionV3	92	0.779	0.937	23,851,784	159
MobileNet	16	0.704	0.895	4,253,864	88
MobileNetV2	14	0.713	0.901	3,538,984	88
DenseNet201	80	0.773	0.936	20,242,984	201

Our work in this research started with Mini VGGNet, which uses fewer resources and has lower complexity than advanced architectures. MiniVGGNet;It is an architectural structure inspired by the VGGNet [23]architectural family, with much less complexity than the architectures in the VGGNet architecture family. As the studies progressed, it was decided to increase the complexity of the architecture to increase the accuracy of the model on the data set and to reach a model structure that can generalize real-world scenarios. At the end of the study, considering the mobile application to be developed, Xception[24], which is very popular today, VGG16 from the VGG architecture family, MobileNetV2[25], and Resnet 50[26] optimized for mobile, each model has been started to be trained to compare each model.

The VGGNet architecture, which won the 2014 ImageNet competition, outperformed its predecessors by using a 3x3 Convolution Filter consisting of 16 or 19 layers. Developed by François Chollet, the designer of the Keras deep learning library, Xception is inspired by the Inception architecture. While standard convolutional layers perform spatial computation in one step, depth-wise separable convolution divides the computation into two steps. Developed by Mark Sandler and his colleagues in 2019, MobileNetV2 outperformed many of its predecessors produced for mobile use, taking the state of the art one step further using existing popular datasets. The Resnet architecture, developed by Kaiming He and his colleagues, which won the ImageNet competition in 2015,

has been designed to have much less complexity, although it uses 8 times more layers than the VGGNet architecture family.

Transfer learning, another method used with the architectures mentioned above, is a method developed to take the features learned in a problem and use them on a new problem. In this study, previously learned features of different classes were transferred to the models developed by the transfer learning method by using the models created on the ImageNet data set.

Hyperparameters are various parameters that are adjusted according to certain rules and trial-and-error methods when training deep learning models.

**Table 4:** Hyper Parameters Used in Training the Deep Learning Model

Parameters	Value
Learning Rate	0.0001
Epoch Number	20
Batch size	32
Optimization Algorithm	SGD

The explanations of the parameters mentioned in Table 4 are given below:

(i) Learning Rate: This parameter determines how much the weights of the model will change depending on the margin of error.

(ii) Epoch Number: This parameter determines how many times a data batch (batch) will be learned by the model.

(iii) Batch size: This parameter determines how much data will be learned by the model in each round.

(iv) Optimization Algorithm: This parameter determines which optimization algorithm will be used during the training of the model. Among the most used optimization algorithms, SGD (Stochastic Gradient Descent)[27], Adam[28], and Adagrad [29] can be given.

The sample hyperparameters used for this research took their final form as shown in Table 4 after various attempts were made to train the models. Finally, the training of the models was carried out using the GPU in the Colab notebook.

**Table 5:** Data on Training Different Deep Learning Models on the Created Dataset

Models	Training Accuracy	Validation Accuracy	F1 Score
Xception	0.93	0.88	0.91
VGG16	0.76	0.72	0.7
MobileNetV2	0.85	0.83	0.82
Resnet 50	0.74	0.66	0.69

The statistical evaluations (Table 5) obtained after the models were trained were compared. Even if the Xception network structure has reached the highest accuracy rate, since the model will work on the mobile device, the MobileNetV2 network structure, which is a more optimized model for working on the mobile device, has been preferred.

#### D. Mobile Application Development

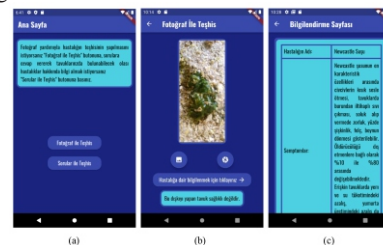
It has been decided to develop a mobile application so that everyone can benefit from the artificial intelligence models obtained as a result of the studies. Necessary optimizations have been made to enable the artificial intelligence model

to work on mobile so that every person with an Android smartphone can analyze whether there is a disease in their chicken.

Flutter is used for the development of the mobile application of this project; It is an open-source UI software development kit created by Google. It uses the Dart programming language created by Google for mobile and web development purposes. Among the reasons for deciding to use the Flutter mobile development kit in this project are Flutter's open-source code, its speed compared to its peers, its ability to easily design impressive interfaces, and its detailed and explanatory documentation. After the decision to use the Flutter mobile development kit, the Flutter development environment was established and the general design of the mobile application was made. Using the TensorFlowLite library, which was developed to use the trained deep learning models in the mobile application, the deep learning model with the best results was optimized and made ready for use in the mobile application.

With the increase in information and data, different methods were needed to store data. One of these methods is databases. Databases work according to the principle of putting the data that wants to be stored in the appropriate row and column under a table. In this study, a database that can only be used for reading (no data transfer from the application to the database), does not need any network connection, and can run on a local device is needed. The necessary literature review was made and it was seen that the SQLite database met the desired features so it was decided to use the SQLite database in the mobile application. Using SQL (Structured Query Language) language, SQLite is an open-source SQL database engine that can be used in many different languages and does not need an external server, that is, can run on a local device. In this study, the SQLite database was used to store information about diagnosed diseases. In this way, diseases added to the database in the future, and their explanations will be able to be used without any changes in the code of the mobile application.

Users who open the mobile application encounter the first page called the "Home Page", where the diagnosis of diseases can be made as "Diagnostics by Photo" or "Diagnostics with Questions" (Figure 4(a)). When the user clicks the "Diagnose with Photograph" button, on the page titled "Diagnose with Photograph" (Figure 4(b)), the user is expected to enter a photo via gallery or camera. The result obtained by processing the input given to the system by the deep learning model is "Click here for information about the disease." On the page titled "Information Page" (Figure 4(c)), which can be accessed with the help of the button, the name of the disease, the symptoms of the disease, the actions to be taken against the disease, and general information about the disease are examined under 4 headings.



**Fig. 4:** Screenshots of Mobile Application While Working on Android Virtual Device (a) Home Page, (b) Diagnosis by Photo, (c) Part of Information Page

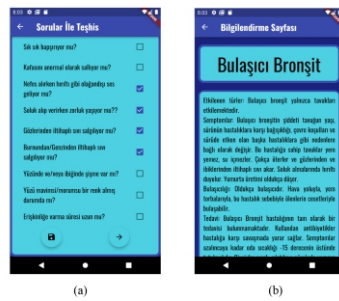


Fig. 5: (a) Diagnosis with Questions, (b) Part of the Information Sheet

When the user clicks on the "Diagnostic with Questions" button on the page titled "Home Page", he will be greeted with the questions directed to him on a page titled "Diagnostic with Questions" (Fig. 5a). After giving the necessary answers to the questions, they should record their answers. After clicking on the Save button and clicking on the button to go to the next page, the page titled "Information Page" (Fig. 5b), you will see information about possible diseases/diseases that can be seen in your chickens.

### 3. Results

After obtaining the necessary data and performing "duplication" and clipping operations on the data, a data set that can be used for training the models was obtained (Table 1). Then, the obtained dataset was divided into 3 parts training-test-verification (Table 2). The models were trained with the parameters specified in Table 3 on the created dataset. Although XceptionNet performed better among the deep learning models that were trained, the MobileNetV2 model, which can work more optimized in the mobile application, was found suitable for the use of the mobile application to be developed (Table 5) and it was made ready to be integrated into the mobile application with the help of the TensorflowLite library. Then, two panels of the mobile application, "Diagnostic by Photo" and "Diagnose with Questions" were developed. After the integration of the database and deep learning model into these panels, the user-friendly interface of the mobile application was improved and the mobile application became ready.

### 4. Conclusion and Discussion

When the accuracy rates obtained from the trained models were examined, it was seen that the 82% accuracy rate obtained for disease detection from the feces of chickens was suitable for use in the mobile application, and the MobileNetV2 model, which will work in the most optimized way in the mobile application, was integrated into the mobile application after the necessary preparations. Then, the "Diagnostics with Questions" panel of the mobile application was developed, and a connection was established with the database of the mobile application to display information to the user in line with the received data.

### 5. Suggestions

While doing this study, it was considered that the dataset and database could be expanded with different diseases in the following stages, and the structures created were established to serve this purpose. Therefore, by training different deep learning model structures through the new

dataset obtained by expanding the dataset, a higher accuracy rate than the models obtained in this study can be obtained and the newly trained model can be used in the developed mobile application. In addition, the number of questions in the "Diagnosis with Questions" panel of the mobile application can be increased and the database containing data on diseases can be expanded by adding new diseases.

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# FLOATING OF A METAL DISK ON THE WATER SURFACE

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## ABSTRACT

When a metal disk is placed in a vessel of water it shall sink due to its higher density but the water jet impinges on the center of the disk may cause it to be floated. The hydraulic jump is formed in the edges of the disk by the water jet that passes radially away from the center of the disk to the edges. This jump causes a difference in the level of the height above and under the disk which will increase pressure under the disk. Water above the disk is moving with higher velocity compared to its velocity under the disk so due to Bernoulli's principle, the pressure difference between them increases. pressure difference and then minimum velocity of the water jet.

**Keywords :** Metal disk, Hydraulic jump, Water jet, Stability

## ARTICLE INFO

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## 1. Introduction

In this research a metal disk in a vessel of water is studied. A metal disk with a hole at its center sinks in a container filled with water. when a vertical water jet hits the center of the disk, it may float on the surface. It shall sink due to its higher density but as an external force here the water jet impinges on the center of the disk and it is observed that the disk floats. To find relevant parameters several experiments are designed with qualitative analysis.

## 2. Theories and Methods

In the beginning there are two possibilities:

1- The radius of the water jet is smaller than the radius of the hole so the whole flow of the water jet passes through the hole.

2- In the second scenario radius of the water jet is bigger than the radius of the hole so that there is a flux of water passing radially away from the center.

Since the first case will not keep every metal disk floated we will observe the second scenario in more details (Figs. 1 & 2).

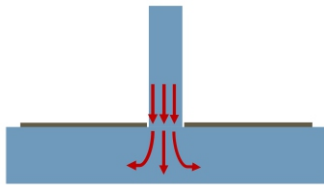


Fig. 1: The whole flow of water passes through the hole

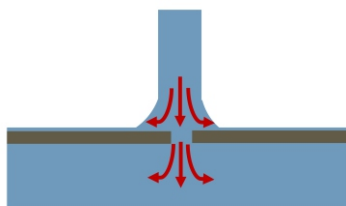


Fig. 2: Part of water flows radially away from the center to edges on the disk

To illustrate forces acting on our disk there is a free body

diagram. Gravity force is pulling our disk downward then as the water jet impinges to the center there is an extra force acting downward but still we see our disk stays floated so there must be an upward force acting against our downward forces that prevent our disk from sinking now we want to find the origin and minimum amount of this upward force (Fig. 3).

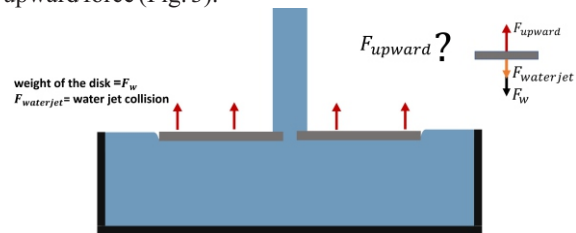


Fig. 3: Forces are applied on the disk

Before moving on to the theoretical framework there are some concepts that we need to understand. First hydraulic jump which as our jet impinges to the center of the disk it flows radially away from the center to the edges with higher velocity and makes the super critical flow then at the edges of our disk there is a jump formed with this super critical flow which collides with the subcritical flow with less velocity. To observe characteristics of this jump we defined two Froude number one refers to outer film depth being outer Froude number and one refers to inner film depth as inner Froude number (Figs. 4 & 5) (Eqs. 1-3).

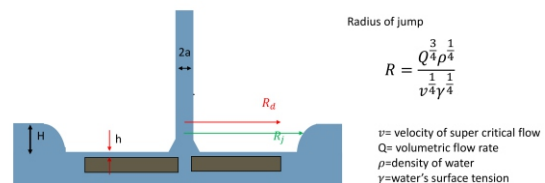


Fig. 4: Hydraulic jump and its radius

$$Froude number : \quad F_{ro} = \frac{Q}{2\pi R_j \sqrt{gH^3}} \quad (1)$$

$$F_{ri} = \frac{\lambda Q}{2\pi R_j \sqrt{gh^3}} \quad (2)$$

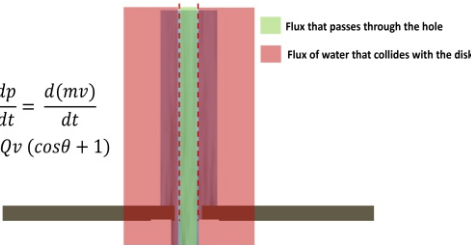
$Fr_o$  = outer Froude number based on outer film depth  
 $Fr_i$  = Froude number based on inner film depth

$$H = \left( \frac{-1 + \sqrt{1 + 8Fr_i^2}}{2} \right) h \quad (3)$$

Since the velocity of the thin layer of water above the disk is not uniform and constant we have a correction factor to be calculated also the height of the jump can be measured by using inner Froude number and depth of water inside the jump. There is a circular hydraulic jump in this phenomenon, radius of the jump can also be calculated proportional to velocity of super critical flow, volumetric flow rate, density of water and surface tension (Eq. 4).

Since system is in equilibrium  $\Rightarrow \Sigma F = 0$   
 $F_{downward} = F_{mg} + F_j$   
 $F_{up} = F_p$   
 $F_p = F_w + F_j$   
 $F_j = \rho Q v$   
 $F_w = mg$  (4)

By Newton's second law and equation of momentum the water jet force is calculated but we have to note that the volumetric flow rate is not the whole water coming out of water jet. To have a better approach, there is an approximate illustration of the water jet. Two fluxes in the edges represented by red collide with the disk and the flux of water in the middle represented by green passes from the center of the hole (Fig. 5) (Eqs. 5&6).



█ Flux that passes through the hole  
█ Flux of water that collides with the disk

$$F = \frac{dp}{dt} = \frac{d(mv)}{dt} \quad (5)$$

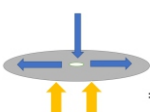
$$F_j = \rho Q v (\cos\theta + 1) \quad (6)$$

Fig. 5: Flux passes through or collide the disk

The other concept is Bernoulli's principle, when the water jet impinges to the center there is a part of water moving above the disk with higher velocity compared to the velocity of water under the disk leads to a difference in pressure above and under it and by higher pressure under the disk there is an upward force (Eq. 7).

Dynamic Pressure  $\rightarrow$   
 $p_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2 + \Delta p$   
 Static Pressure  $\leftarrow$  (7)

$v_1 > v_2$   
 $p_1 < p_2$  } Higher pressure under the disk  $\rightarrow F_{upward}$



Since our system is in equilibrium sum of all forces should equal to zero, downward forces of weight of the disk and water jet force. Upward force is caused by the difference in pressure which minimum amount of this force can be measured. On the other hand, there is another way to calculate this upward force which is multiplying the difference in pressure to the area of the disk in order to do that we have to find the difference in pressure above and under our disk (Fig.6) (Eq.8).

Using Bernoulli's principle that  $p_1$  stands for pressure under the disk and  $p_2$  stands for pressure above it and since the velocity of water under the disk is almost zero that component will be omitted also the height of water above the disk is negligible so that component would also be omitted lastly we can find the difference in pressure as this equation.

$F_p = mg + \rho Q v$  }  $p_1 + \rho g h_1 = p_2 + \frac{1}{2} \rho v_2^2 + 0$  (8)

Pressure under the disk  $\rightarrow$   
 Pressure above the disk  $\leftarrow$

on the other hand  $F_p = \Delta P A$   
 Therefore:  $\Delta P = \frac{1}{2} \rho v^2 - \rho g h$

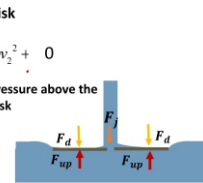


Fig. 6: Forces applied on the disk

Thickness of the thin layer of water above the disk should be measured to find characteristics of hydraulic jump and due to Watson's determination we defined Reynold's number and proportion of radius of the disk to the radius of the water jet and found this equation to calculate the thickness of thin layer but we still have to find the velocity of non-uniform film of water above the disk (Eq.9) (Fig. 7).

$Re = \frac{2Q}{\pi a v}$  }  $h = \frac{2\pi^2 v (R_j^3 + 0.286 a^3 Re)}{3\sqrt{3} Q R_j}$  (9)  
 $\frac{R_d}{a} = 0.366 Re^{\frac{1}{3}}$

$R_d$  = radius of the disk  
 $a$  = radius of the jet  
 $v$  = velocity of jet

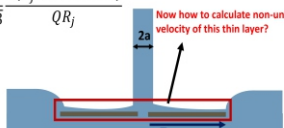


Fig. 7: Non-uniform velocity of the thin layer

Going back to the inner Froude number that we defined here we need to find the correction factor which by integrating from the velocity of the thin layer of water the equation above and by applying the boundary conditions final we can define the Froude number and due to Watson's solution we defined a delta here which represent the proportion of vertical location relative to the surface which Watson gave a solution to find the correction factor (Eqs.10-13).

$$Fr_{ri} = \frac{\lambda Q}{2\pi R_j \sqrt{g h^3}} \quad (\lambda \text{ is the correction factor}) \quad (10)$$

Inner Froude number can be written as :

$$Fr_{ri} = \frac{\sqrt{\frac{1}{h} \int_0^h u^2 dz}}{\sqrt{g h}} \quad (11)$$

If  $u = f u_{z=h}$ ,  $R_j > R_d$  and  $Q = 2\pi R_j \int_0^h u dz$

$$Fr_{ri} = \left( \frac{\int_0^1 f^2 d\delta}{\int_0^1 f d\delta} \right) \frac{Q}{2\pi R_j \sqrt{g h^3}} \quad (12)$$

$u$  = velocity of thin film  
 $Z$  = vertical location relative to surface

$\delta = \frac{z}{h} = 1$  (free-surface of inner film)

Watson also suggested a solution  $\Rightarrow c\delta = \int_0^f (1-x^3)^{-0.5} dx$   
 $\Rightarrow c = 1.4$

If  $R_j > R_d$ ;  $f(1) = 1$ ,  $f(0) = 0$  (boundary condition)

The correction factor :

$$\lambda = \frac{\sqrt{\int_0^1 f^2 d\delta}}{\int_0^1 f d\delta} = \frac{3c^{\frac{3}{2}}}{\sqrt{2\pi}} = 1.12 \quad (13)$$

### 3. Experiment

A supply tank with an adjustable nozzle was used and water jet impinged to the center of various disks which for experimental data we varied radius of the water jet, radius of the hole, mass of the disk, radius of the disk and also the existence of hole in the center and for all experiments distance between nozzle and disk were constant.

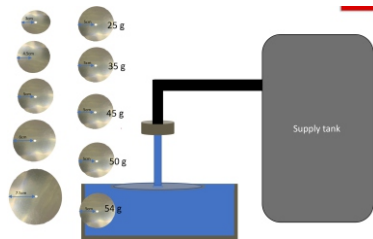


Fig. 8: Experimental Setup

### 4. Results

By analyzing the data it is observed as the radius of the disk increases the minimum velocity that was necessary for the disk to stay floated would also increase similarly. As the disk gets heavier minimum velocity of the water jet would also increase (Figs. 9&10).

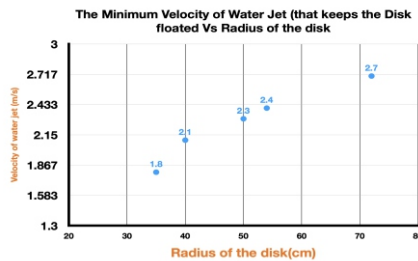


Fig. 9: The velocity of water jet versus radius of the disk

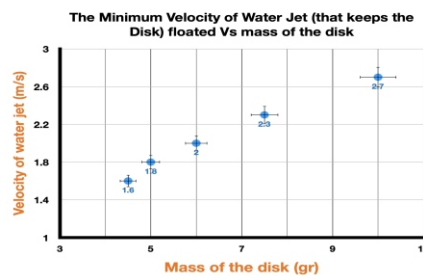


Fig. 10: The velocity of water jet versus mass of the disk

A color-coded chart is used to find how the proportion of radius of the disk and radius of the hole affect on the phenomenon qualitatively which the best floating was possible when the radius of water jet was bigger than the radius of the hole (Fig. 11).



Fig. 11: Color-coded chart in analyzing data

Another color-coded chart is used to show how increasing each parameter changes the floating of the disk which green represents stable floating, yellow stands for floating with oscillation and red stands for sinking (Fig. 12).

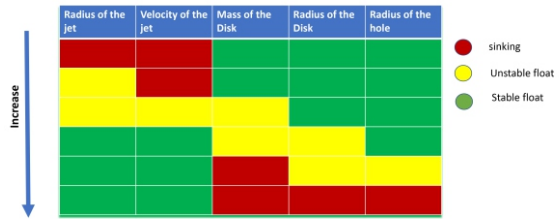


Fig. 12: Another color-coded chart in analyzing data

The next thing in our experiment was simulating the disk and impingement of water jet on the disk with and without the hole. In both cases hydraulic jump was observed but what is the reason that we don't see floating of a disk without the hole in the center (Fig. 13)?

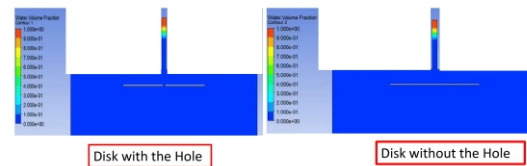


Fig. 13: Simulation results

we even tried to investigate this experimental that the disk with a dent in the center is floated in stable position but for the disk without the hole floating was possible in the beginning but within less than a second it started sinking. Because when the water jet is applied to a disk without any dent on the surface the reaction force is vertically upward and since the disk is placed in water it can move horizontally away but for the second case that has a dent in the center, the reaction force from the edges of that dent can be divided to its x and y components which x components cancel each other and that is the reason that our water jet stays in the center and floating is stable.

By comparing the theory with experimental data we found the force caused by the difference in pressure in two ways and by putting them as equals, also the minimum velocity of the water jet that each disk needs in order to be floated.

### 5. Conclusions

The relation between minimum velocity and radius/mass of the disk also the radius of the hole in the center of the disk are found by the experiments.

The fact that upward force which is keeping our disk floated is mainly due to Bernoulli and hydraulic jump. The hole in the center of the disk works as a system stabilizer.

In order to see this phenomenon, radius of the water jet must be bigger than the radius of the hole in the center. The first scenario that we suggested only works for very light disks. By equations minimum velocity of the water jet that keeps our disk floated was calculated too.

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# COOKING OIL BIOFILTER BASED ON TABOA FIBER (THYPA DOMINGENSIS)

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## ABSTRACT

In Brazil, oil consumption is about three billion liters per year and it is estimated that for every four liters consumed, one is discarded incorrectly, representing more than 700 million liters released into the environment without proper care annually. The present project seeks to create and evaluate the functionality of a biofilter made from Taboa (Typha domingensis) fiber for the adsorption of oils thrown in residential sinks. To achieve the objectives, comparative tests were performed with two hydrophobic materials: Paina and Taboa fibers, seeking to show the efficiency of Taboa compared to other material already researched as an oil adsorbent.

**Keywords :** TBiofilter, Vegetable Oil, Taboa, Adsorption, Water Pollution

## ARTICLE INFO

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## 1. Introduction

Water is one of the essential elements for life to exist, being present in 70% of the human body's composition and also covering 70% of planet Earth. However, the distribution of this resource is quite uneven among the different regions of the planet. In this sense, and considering only fresh water in liquid form, the most adequate and most used for human consumption, about 13% is found in Brazilian territory. Therefore, we are well served by this vital element (OECD, 2015; UN, 2021).

Despite all the amount of water in the country, it is not available to all due to geographical and economic factors, and even in places where water exists abundantly, it is not suitable for human consumption, which occurs more evidently in urban centers, as in the case of Recife, which despite having about 99 urban channels and five major river has a system of water rotation for its inhabitants. (GALINDO, 2009; SOUZA, et al, 2018).

According to the World Water Resources Development Report, 2021, conducted in cooperation, by different UN Agencies, water consumption on the planet has increased 6 times in the last century and continues to increase about 1% per year, resulting from population growth, economic development and changes in consumption patterns among different societies. At the same time that the demand for the resource increases, the quality of the water drastically increases the reality of water scarcity, which already affects more than 2 billion people around the world and Brazil is one of the countries that stand out in this regard. Still according to the UN (2021), it is estimated that water consumption will increase by 25% by 2030.

In addition to the physical or economic scarcity of water, the lack of this resource also occurs due to the increasing degradation of water sources and bodies of water, mainly as a result of human actions. Among the forms of water degradation, the discharge of different types of oils causes great concern, because they produce adverse effects on fauna, flora, and human life, and when it occurs on a large scale, it also affects the economy, tourism, and even daily activities. It is important to highlight that oil is one of the wastes that has a high power of contamination when thrown directly into river courses through disposal in the trash or in the drains of sinks. (BRASIL, 2010; SOUZA, et al, 2018; SILVA et al, 2021)

Given the above, this research seeks, from laboratory experiments, to evaluate the use of the taboa fiber (Typha domingensis), to create a mechanism for filtering oils dumped in household sinks.

In the history of evolution of human society, oils represent an extremely relevant resource and considering vegetable oils, their importance is not only for their use in gastronomy, but also for economic, political and biological reasons. From the Mesopotamian and Ancient Greek peoples to the present day, the use of oil plays a relevant role, since it has the most diverse applications, whether for heating, illumination, food, cosmetics production or even energy production (SANTOS, 2020).

Considering only the edible oils, according to data from the German consulting company, Oil World, the world per capita consumption of domestic oil is, on average, fifty milliliters per day. As far as Brazil is concerned, oil also plays an important role, since about three billion liters are consumed per year, according to the Brazilian Association of Vegetable Oil Industries (ABIOVE, 2022).

However, it is important to highlight that oils are highly polluting substances and with great capacity to degrade ecosystems, especially aquatic ones, because due to its chemical composition, oil is immiscible with water, i.e., they do not mix, and oil is lighter (less dense) than water and when they mix, oil stays on top of water.

On a scale of environmental impact, edible vegetable oil is less polluting than oil of fossil origin such as petroleum, however, the contamination of water by edible oil causes damage to the functioning of the 9 water and sewage treatment plants and makes waste treatment more expensive by up to 45% and the part that remains in rivers may cause soil sealing, this still contributes to the occurrence of floods. (SOUZA, 2018).

Despite causing great negative impact on one of the vital elements for life, the disposal of oils in household sinks is still a silent problem that deserves more attention, debate and environmental awareness, with a view to finding solutions that add up to the protection of water resources

## 2. Aim and Problem Question

Lately, news about oil spills in aquatic environments has become more and more frequent and society as a whole has turned its attention to this environmental problem. In this

sense, it is important to include in this debate the problem of edible oils being thrown into the sewage system through domestic sinks.

Research data from SABESP 2022 indicate that only 1 liter of oil can contaminate 25 thousand liters of water. The oil substances are not dissolved in water and, if discharged into river courses, they cause oxygen depletion and the death of aquatic species. In contact with the soil, the oil also causes contamination, not to mention the enormous damage caused by the accumulation of oil residues in the pipes of domestic sinks, which can cause serious problems for the maintenance of the networks and higher costs to make repairs and repairs (SABESP, 2022). (Fig.1).



Fig. 1: Release of edible oils in sinks Source: Alves & Araújo (2016)

In this sense, among the residues discharged into the collecting networks, lipids occupy the place of greatest pollutant of the sewage among the other materials, with about 60% of the contamination. In this context, the oil that has as final destination streams, rivers, and seas, promotes processes of environmental imbalance such as the eutrophication of water bodies and aquatic contamination in coastal areas. The discharge of oil into water bodies can also impede gas exchange and the passage of sunlight, impair breathing and photosynthesis of life submerged in a river, leading to the reduction of aquatic life or even the extinction of some of them.

In addition, oil pollution makes water treatment up to 45% more expensive, and aggravates the greenhouse effect, since the contact of water polluted by oil when flowing into the sea generates a chemical reaction that releases methane gas, a much more aggressive component than carbon dioxide. This is extremely serious when we analyze that the Brazilian federal government spends more than 600 million dollars on water treatment (ARCOVERDE, 2022).

Despite being a long-debated topic, the solutions presented are still palliative or not very efficient, as in the case of storing oil in containers for later disposal and recycling, a solution that is still not very common among most Brazilians (SABESP, 2022).

Data from the report of the Brazilian Association of Vegetable Oil Industries (ABIOVE) indicate that only 10% of the oil consumed in Brazil is recycled. One of the possible reasons for the low household oil recycling numbers may be the need to always have a pet bottle handy and also that the consumer has to store and deliver the product later to collection environments. Thus, the disposal process for possible reuse does not correspond to the population's perspectives and ends up being an inefficient measure since it is neglected by most users of cooking oils (ABIOVE, 2022).

Also, according to Abiove, the consumption of edible vegetable oils in Brazil is around three billion liters per year and for every four liters consumed, one is discarded incorrectly, which represents more than 700 million liters per year thrown into the environment without proper care and control (ABIOVE, 2022).

Regarding legislation, the National Policy on Water Resources (PNRS) defines cooking oil as solid waste. For, although the oil has a liquid consistency, in contact with water it solidifies. Also, because it is a discarded waste from human activities, which is contained in a container and because it is not feasible to dispose of it in the public sewage system or in water bodies (BRASIL, 2010) (Fig.2).



Fig. 2: Flow of incorrectly discarded oil Source: Siqueira & Pleske (2021)

Aiming to solve the environmental problem exposed, it is believed that the creation of a portable mechanism, capable of retaining the oil dumped in household sinks may present itself as an efficient solution. Thus, the hypothesis of this project is that the taboia fiber may be the ideal product for production in a biofilter for adsorption of cooking oil.

The objectives of the work are to produce and evaluate the use of a biofilter based on *Typha domingensis* (Typha domingensis) fiber for the adsorption of cooking oil thrown into household sinks and, consequently, into rivers. Analyze the viability of the taboia as oleophilic material for adsorption of lipids; Create prototypes of biofilter based on the taboia fiber with low-cost material for absorption of edible oil. Comparing the efficiency of the taboia fiber as an adsorbent of edible oil in comparison with the Paina fiber (Ceiba Pentandra), are part of the research needs.

As a theoretical basis, we took as reference the work developed by Oliveira (2010), in which the author conducted experiments to evaluate the solvent capacity of plant fibers from different species, including the aquatic macrophyte taboia (*Typha domingensis*).

The cattail (*Typha domingensis*) is a macrophyte that occurs naturally in freshwater environments. It is a perennial, herbaceous plant native to South America, with a cylindrical stem, averaging 1.5 m in height. It is quite abundant and produces about 7,000 kg of fruits (rhizomes) per hectare. Despite reproducing in a degraded environment, its rhizomes are edible, possessing protein value equal to that of corn and carbohydrates equal to that of potatoes (MOGROVEJO, 2019) (Fig. 3).



Fig. 3: Taboia plants in a construction site cavity Source: Authors (2022).

Aquatic macrophytes plants, such as Taboa, are widely used for the purpose of reducing contaminant loads and improving the quality of wastewater, because they act as biofilters in the removal of pathogenic microorganisms from the water and in the treatment of water with high load of pollutants, presenting high absorption of organic matter. The aquatic macrophytes also play the role of primary producers, providing habitat and refuge for several species of animals and also act as a substrate for algae, supporting the chain of detritus and herbivory and serving as a nutrient storage compartment (KREBS et al, 2021).

In addition to acting in water purification, Taboa is also considered an excellent adsorbent of oils, mainly from its fruit. This functionality of the plant is due to its high degree of hydrophobicity, buoyancy and high content of lipids 2.41% in its structure, providing significant surface adsorption of different types of oils, considering that the fruit has few empty spaces in its structure (OLIVEIRA, 2010).

The taboa fiber contains about 33.95% cellulose, 33.24% hemicelluloses, between 1.62% lignin, 2.06% ash and a moisture content of 9.33%. Taboa fruit has about 46.6% carbon, 5.96% hydrogen and 1.11% nitrogen and these properties contribute to lipid adsorption. (KHAN et al, 2004; Oliveira, 2010; MOGROVEJO,2019). Research attests the efficiency of the taboa fiber as an adsorbent of oils, however, tests and application of this fiber as a biofilter for sorption of edible oil were not found in the literature, which increased the interest in developing the present work. Thus, and considering that the main alternatives used to reduce the impacts resulting from the degradation of aquatic environments by edible oil spills still do not present significant results, it is expected, with this research, to contribute to the debate about the importance of developing alternative and low-cost methods that can reduce the damage caused by the release of oils in river courses using the taboa fiber.

### 3. Materials and Methods

Three stages were defined for the execution of the project, specified below.

Stage I: Data survey and creation of biofilter models.

The data was researched on sites of agencies and entities that work in the search for solutions to the problem of degradation of water sources and its causes, especially from the release of oils.

Based on the theoretical research, an oil sorption biofilter model was developed, considering the dimensions of different types of domestic sink drains used in Brazil. Two types of drains were chosen to create the biofilter prototype.

Stage II: Selection of the oleophilic filter material.

The choice of the Taboa tree fiber was based on the results obtained by other researches regarding biodiesel sorption and also because it is abundant and easy to find in nature. In order to carry out comparative tests, besides the Taboa tree, it was also selected Paina fiber (Ceiba Pentandra), a material already tested for the sorption of different types of oil, including vegetable oil (Fig. 4).



Fig. 4: Test material. Source: Authors (2022)

Stage III: Prototyping and testing with the use of taboa and kapok fibers and tulle fabric.

The biofilters were tested in reused coffee capsule containers, pet bottles, and disused sink drains.

For each filter half of a Taboa fruit was used. The fruit was loosened, crushed, and the fiber was placed inside each prototype. In the filter with the kapok fiber, half a fruit fiber was used. The fibers received lemon drops, were placed for drying and in perforated containers simulating sink drains (Fig. 5).



Fig. 5: Containers used to support the biofilter. Source: Authors (2022)

To analyze the functionality of the biofilters, five types of tests were performed, as described below (Table 1).

Table 1: test objectives performed, Recife. Source: Authors (2022)

experiments performed in the laboratory	
test 1	analyze water circulation
test 2	comparison of efficiency between diferent fibers
test 3	comparison of efficiency between different layers
test 4	comparison with the use of lemon additive
test 5	evaluation of biofilter reuse

In experiment 1, the circulation of water through Taboa and Paina biofilters prototypes was verified (Fig. 6).



Fig. 6: Prototypes of the biofilter. Source: Authors (2022)

In experiment 2, preliminary tests showed the adsorption of oil - pouring 200 ml of water and 50 ml of oil over each biofilter, the one with the Paina and the one with the Taboa fibers (Fig. 6), simulating the discharge of oil into sinks.

In experiment 3 the biofilter with a double layer of Taboa, without inserting lemon juice, was tested, seeking to verify the real capacity of oil adsorption by Taboa, the substance chosen for the biofilter.

In experiment 4, tests were performed at the Federal University of Pernambuco to compare the Taboa biofilters with and without the use of lemon (Fig. 7).



Fig. 7: Comparative test between double taboa filters with and without lemon at UFPE, Recife. Source: Authors (2022)

In experiment 5 the reuse of the Taboa biofilter was evaluated, after the oil adsorbed by the fiber was removed and the material was dried (Fig. 8).



**Fig. 8:** Water and oil solution after filtration. Source: the authors, (2022)

#### 4. Results and Discussion

The tests indicate that the use of two layers of taboa fiber, forming a double filter, was more effective than the use of a single layer, being also more efficient than the biofilter of kapok fiber. The results obtained matched the results achieved by Oliveira (2010), when using the taboa fiber to absorb diesel oil. It is worth noting that the experimentation process cost only the value of one kilogram of lemon and 1m<sup>2</sup> of tulle to produce the biofilter prototypes.

After the experiments it was observed that the double Taboa fiber filter adsorbed about 49 ml of the 50ml poured and the water flowed without difficulty. Thus, the biofilter showed an average efficiency of 99% absorption, confirming the oleophilic property and hydrophobicity of Taboa, while the millet biofilter obtained an oil adsorption of about 60%. The part of oil (10 ml) that managed to pass through the Taboa filter presented a different coloration and the water had a clearer appearance (Table 2).

**Table 2:** corroborative results performed at UFPE, Recife. Source: Authors (2022)

Tests	Liquid Volume (ml)	Oil Retention Volume (ml)	Percentual Retention
1: biofilter with lemon	Oil(50 ml) Water(200 n 45 ml)		80% of retention
2: biofilter without lemon	Oil(50 ml) Water(200 n 49 ml)		98% of retention

These results indicate that the double biofilter made of woven wattle without the use of lemon has a higher efficiency than the others. It is important to emphasize that tests were also performed with the taboa fiber after the first use, attesting to the possibility of reusing the material, after cleaning and removing the absorbed oil.

The corroborating results attest to the effectiveness of the biofilter produced, being a viable and sustainable solution to the serious problems arising from the discharge of oil into river courses from households. After being used in the biofilters, the fibers of the Taboa and Kapok were stored in a container for later removal of the adsorbed oil. The plant material will be sent to Sempre Viva, a non-governmental organization that performs the separation of oil for soap production and the introduction of plant compounds in a biodigester system in order to synthesize fertilizer and biogas.

#### 5. Conclusion

In view of the tests performed and the corroborating

results achieved, it can be concluded that the taboa is a viable alternative as a material for making the oil filter for adsorption of household oils. For being an ecologically sustainable material, of low cost and easy to obtain, the taboa has its viability confirmed. So far, the experimentation has shown results within the authors' expectations and, as a further step, it is planned to introduce the use of the biofilter in 10 homes in order to monitor the performance of the biofilter in a real situation.

It is believed that an accessible, practical and innovative solution to the issue of domestic oil disposal is possible with the use of the Taboa biofilter. Thus, it is also expected that the research can contribute to the development of a sustainable alternative of easy development and application and low cost, aiming to considerably reduce serious socio-environmental problems such as the improper disposal of oil into the sewage system.

Finally, it is noteworthy that this research is innovative, considering that no literature has been found about the possible production of a biofilter made of Taboa bean. It is hoped that the product created will contribute to reduce the damage caused by the discharge of oil into rivers and contribute to a healthier environment for all, in close accordance with the Sustainable Development Goals proposed by the UN.

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# SPINNING OR SLIDING OF A WASHER ON A VERTICAL ROD

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## ABSTRACT

The motion of the washer on a vertical steel rod is investigated which may start spinning instead of simply sliding down. Terminal velocity of this movement and other affective parameters are considered by different experiments. It is possible to observe the washer will start to rotate on the rod by an initial velocity and rotate till it reaches a maximum angle and a steady state for the washer's rotation and finally reaching to the point that we can perceive a free fall motion for the washer's movements.

**Keywords :** Terminal Velocity, Washer, Kinetic Energy

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## 1. Introduction

The problem states that a washer on a vertical steel rod may start spinning instead of simply sliding down. To study the motion of the washer and what determines the terminal velocity with the most parameters that would affect on it, several experiments are designed.

To find the optimum conditions different rods and washers are studied.

## 2. Theories and Methods

Starting with initial observation and introduction of the phenomenon, the main purpose of the statement is to investigate the terminal velocity and the parameters that would affect the terminal velocity of the washer, it is possible to observe that the washer will start to rotate on the rod by an initial velocity and it will rotate till it reaches a maximum angle and a steady state for the washer's rotation and finally reaching to the point that we can perceive a free fall motion for the washer's movements.

To start the basic theory and to have a better intuitive view of the phenomenon, amplitude of the sound that is possible to hear by the washer's movements on the rod is recorded (Fig. 1).

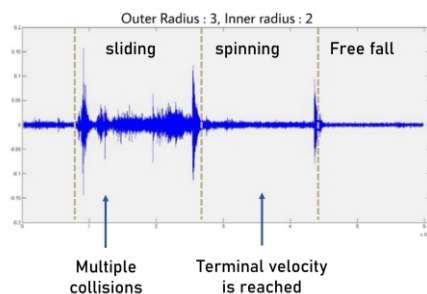


Fig. 1: Recorded sound of washer movement on the rod

The basic transition between the motion of the washer will be sliding motion which involves acceleration and tilting of the washer around the rod. It is expected to be a free fall motion but will turn into a spinning motion which is possible to observe different types of angular velocity in different conditions.

Terminal velocity of the system leads us to a maximum

tilt angle. By tracker the change of the angle per time and the maximum tilt angle are measured. Having a schematic observation of the contact points, 3D printed washer designed to see that there are two contact points.

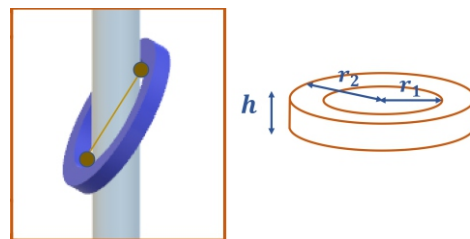


Fig. 2: Washer's dimensions and its contact points on the rod

The main motion of the washer will be rotating around the rod that we can divide this motion to two different motions one in z direction and the other one in "x,y" which makes the phenomenon more clear.

A theory based on energy determines the velocity of the system but this theory will be in the steady state condition that the angular velocity of the system is stable. Each term of the equation is investigated and we will start with the air resistance which by estimation is negligible.

Now to divide each kinetic energy that affects on the washer's movements, there are two kinetic energies. One of them is based on the angular velocity in different directions z and x, y. The other kinetic energy is based on terminal velocity of the washer, but because the rotational energy, this formula represents the equation for inertia in z and x, y components (Eqs.1-5).

$$k_1 + k_2 + \frac{1}{2}mv_z^2 - mg(v_z t) + \mu N(r\omega_{xy}t) + W_{air} = cte \quad (1)$$

$$E = k_1 + k_2 + \frac{1}{2}mv_z^2 - mg(v_z t) + \mu N(r\omega_{xy}t) \quad (2)$$

$$E = \frac{1}{2}I_{xy}\omega_{xy}^2 + \frac{1}{2}I_z\omega_z^2 + \frac{1}{2}mv_z^2 - mg(v_z t) + \mu N(r\omega_{xy}t) \quad (3)$$

$$I_{xy} = \frac{1}{12}m(3(r_2^2 - r_1^2) + h^2) \quad (4)$$

$$I_z = \frac{1}{2}m(r_2^2 - r_1^2) \quad (5)$$

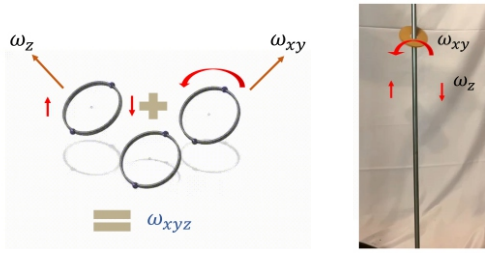


Fig. 3: The angular velocity of the washer in different directions

The equation for energy of the system involves the terminal velocity in z component due to the change of velocity based on change of washer's, and we obtain the terminal velocity in z component by this equation. By observing the motion in steady state from the experiment we can get a better intuitive view of the condition that the energy stays constant and why the equation from the qualitative theory is based on the fact that the motion is stable in the steady state (Eqs. 6-8).

$$v_z = \frac{D_{rod}}{2\pi} \cdot (\omega_{xy} + \omega_z) \tag{6}$$

$$D_{rod} = 1\text{cm}$$

$$\frac{D_{rod}}{2\pi} \cdot (\omega_{xyz} + \omega_{xy}) - \mu N r \omega_{xy} = 0 \tag{7}$$

$$E = k_1 + k_2 + \frac{1}{2}mv_z^2 - mg(v_z t) + \mu N(r\omega_{xy}t) \tag{8}$$

$0.8 \swarrow$   
 $mg \cos \alpha$   
rotation time in  $\alpha_{max}$  condition

### 3. Experiment

In our experimental setup 64 different sizes for washers are used.

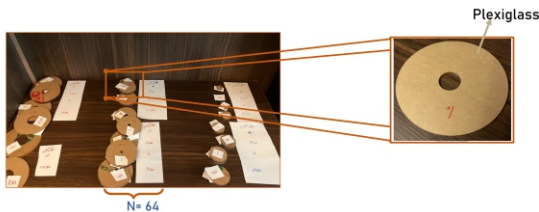
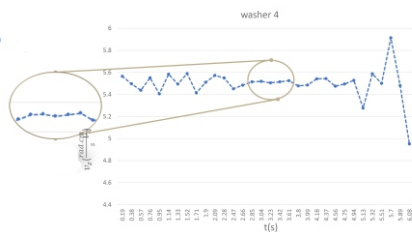
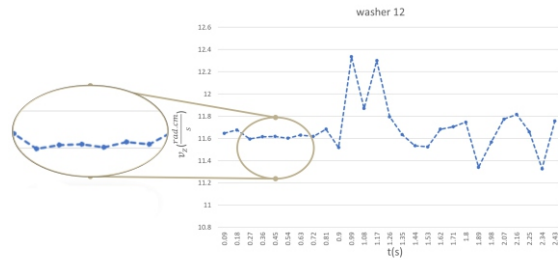


Fig. 4: Plexiglass washers in 3 mm thickness

The energy and terminal velocity in steady state for different washers and the time range of movement are calculated according to the theory for 25 different plexiglass washers that the longest time for the washer rotation belongs to washer number 9 (Diameter 6 cm and hole diameter 3 cm) (Figs. 5-7).



(a)



(b)

Fig. 5: Terminal velocity of washers in two samples a) washer No 4, b) washer No12

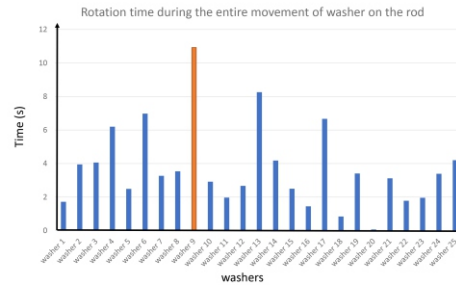


Fig. 6: Rotation time of different washers

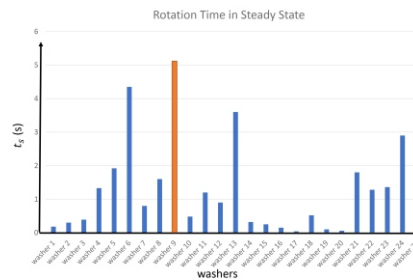


Fig. 7: Rotation time of different washers in steady state

The same experiment goes for the velocity of each washer in z component, and by the result of the experiment, the most displacement in z direction belongs to washer No17, but as the main investigation in steady state, as much as the terminal velocity in z axis decreases for instance the washer No3, the time that the washer stays in steady state increases (Fig. 8).

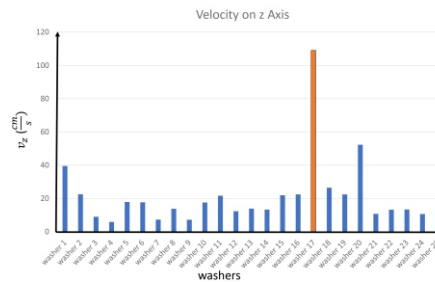


Fig. 8: Velocity of different washers on Axis Z

### 4. Conclusions

In this research we found several parameters regarding different washers movement on the rod including time range in steady state, which clarifies the time of start of the

state till the end of it.

To start the basic of the theory and to have a better intuitive view of the phenomenon, we used amplitude of the sound that is possible to hear by the washer's movements on the rod and a basic transition between the motion of the washer will be sliding motion which involves acceleration, tilting of the washer around the rod and it will turn into a spinning motion and after that we expect a free fall motion and it is possible to observe different types of angular velocity in different conditions. Tracker and 3D printed washer is used to measure the change of the angle per time and the maximum tilt angle. To determine the velocity of the system theory based on energy is used. But this theory is in the steady state condition that the angular velocity of the system is stable for different washers. The comparison between theory and the experiment shows a good agreement.

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# HOW TO MAKE A CANDLE POWERED TURBINE

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## ABSTRACT

As demonstrated in this research, to make a turbine by a candle under a spiral it starts to rotate above the needle that is attached to the tip of the rod so, we can say the spiral above the candle rotates by the air flow that comes from the heat that is given to it by the candle. But to investigate this phenomenon, different experiments have been done and the most important parameters related to the characteristic of spiral, candle and heat transfer are studied.

**Keywords :** Candle, Turbine, heat Transfer, Spiral

## ARTICLE INFO

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## 1. Introduction

The problem states that a paper spiral suspended above a candle starts to rotate optimize the setup for maximum torque (Fig. 1).



Fig.1: Paper spiral suspended above a candle

The candle under the spiral lit up, spiral starts to rotate above the needle that is attached to the tip of the rod so, we can say the spiral above the candle rotates by the air flow that comes from the heat that is given to it by the candle. The candle heats the surrounding air heated air causes the air particles to go farther apart. Thereby, making the air less dense and less dense air always rise above the dense air.



Fig.2: Heat transfer around the spiral

## 2. Materials and Methods

To analyze this setup in a theoretical way initially we're going to start with the spiral itself that is divided into 3 parts we can name:

1. Number of the spiral cycles
2. Radius of the spiral circle
3. The paper width

As the second part of the theory analyzing, we will

discuss about the convection mechanism and the effects on the phenomenon, then the candle that is divided into three parts:

1. candle wax combustion
2. candle flame
3. the causes effect from the distance between candle and spiral

Moving to the division between our theories we can distribute them to two different viewpoints which are the macroscopic view and the microscopic view. First we start with the microscopic view to discuss the partial forces applied to the spiral and the transition between energies.

The heat conduction makes the burning fuel releases CO<sub>2</sub> and Water and the steam as well as the heat radiation causes the air molecules to run parallel to the spiral (Fig. 3).

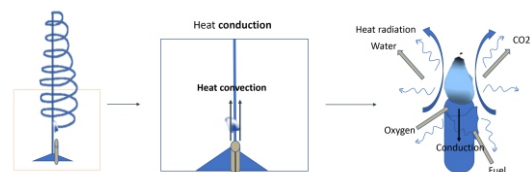
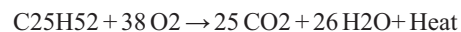


Fig.3: Burning fuel and heat radiation

Wax combustion makes turning thermal energy into kinetic energy of the air particles.



So to divide each applied force to the system the definition of the drag force is needed. The applied force by the particle is an action force and a reaction force is from the opposite direction. The air particles begin to rotate in the direction of motion (Fig. 4).

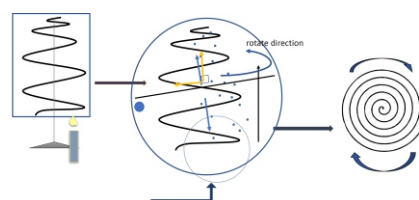


Fig.4: Rotation of spiral

To name each force that is applied to the strip part of the spiral, we can see as the laminar flow runs through the strip it goes up with a turbulent form, and the force from air flow is divided into one in the direction of motion and one perpendicular to the strip which makes a total force which applies into the torque according to the changes of spiral radius (Eqs. 1-3).

$$\tau = Fr \sin \theta \tag{1}$$

$$\Delta\tau = r\Delta F \sin \theta \tag{2}$$

$$\tau = \sum \Delta\tau = \sum r\Delta F \sin \theta \tag{3}$$

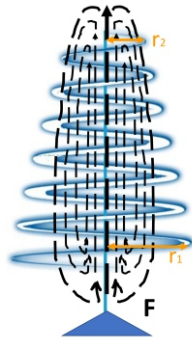


Fig. 5: Applied forces on spiral

Also there is a maximum torque by air transfer and friction which works on the opposite direction of motion (Eqs.4-6).

$$\tau = Fr \rightarrow \tau = I\alpha \tag{4}$$

$$F \sim v$$

$$\tau' = Fr \sim r^2\omega \tag{5}$$

$$\tau' = \tau \tag{6}$$

The macroscopic view which is the definition of air transfer and starts with convection is the circular motion that happens when warmer part of fluid rises while the cooler part of fluid drops down.

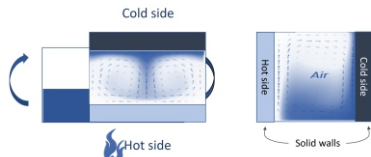


Fig. 6: Microscopic view of convection

As the warm air rises upward the paper begins to spin, the process keeps working because the cooler surrounding air keeps coming towards the candle and warms up. But of course, there is a difference between two parts of the spiral from down to upside part and that is where the area of air flow starts to increase and the velocity of the movements decreases (Eq. 7) (Fig.7).

$$A_1V_1 = A_2V_2 \tag{8}$$

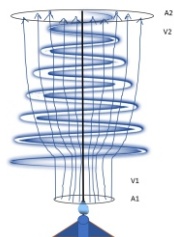


Fig. 7: Modeling of air flow around the spiral

Having an intuitive view of the Continuity equation a simulation of velocity for each air particle is done. If we have an imaginary closed area around the spiral to avoid other effective parameters such as wasted air flow that gets out of the spiral area, as the solution for air particles velocity, we can observe the movements of the particles are not the same in every part of the spiral and the velocity streamline divided these speeds into different colors is possible to see in the model itself (Fig. 8).

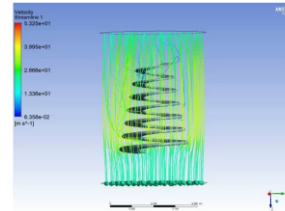


Fig. 8: Simulation of velocity for each air particle

### 3. Experiments

The microscopic view of the theory in our experiment proves the reason for the spiral to rotate regularly with almost constant speed which helps to find a version of transition between airflow.

The schlieren photography shows there are two different types of air flow, laminar and turbulent. As the experiment shows as the spiral appears the laminar flow transforms into turbulent flow including the air currents or we can say turbulent flow moves around the spiral (Fig. 9).

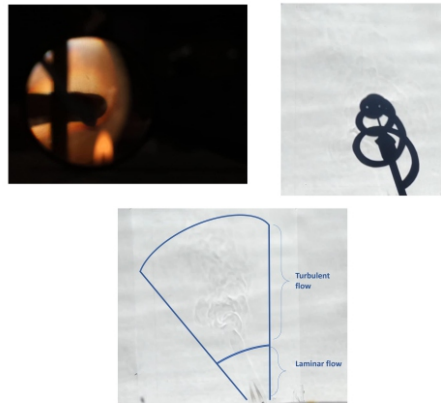


Fig. 9: The schlieren photography

In our Experiment the spiral is divided into a 4 different number of cycles and 4 different densities for each number of cycles with a needle is attached to the rod to keep the friction as less as possible. The candle is in three different distances from the rod to see the result. Further, we used tracker to measure the radiation of the spiral and it is analyzed by the Fourier transformation (Fig. 10).

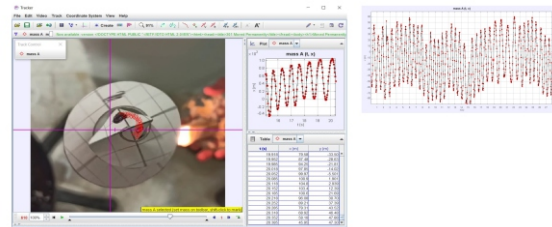


Fig. 10: Tracker to analyze data

For the next part of the experiment, density and angular velocity of the strip from 1 cm to 2.5 cm are investigated. In each experiment by the change of number of rounds, when the density/width of the strip for paper spiral increases, there is a decreasing trend in the graphs which occurs for each number of rounds from 4 to 7 (Fig. 11).

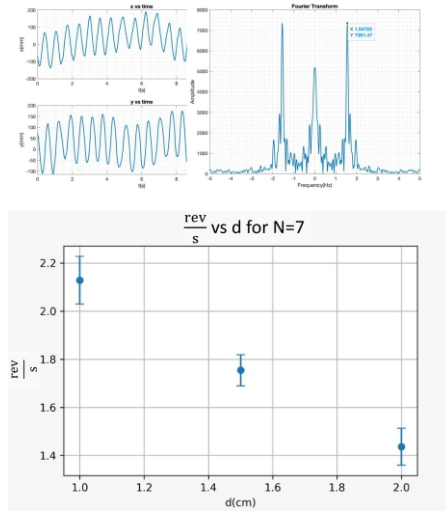


Fig. 11: Changing density and angular velocity

4. Results

It can be reported that by increasing the density of the strip, rotating per second for that specific spiral is decreasing. The same thing happens for the number of rounds, five, and the change of the density in the same way and there is almost an decreasing trend by increasing the density. Best change and almost close to the theory is given in the diagram for number of rounds six with the least error of the experiment which is possible to observe a more logical decrease of angular velocity of the system, the same experiment goes for number of rounds 7 but to mention that density, 2.5 cm couldn't be investigated for this spiral because of the weight of the strip which I couldn't measure. Each experiment for each density of the spirals is done four times to make sure that the variation of angular velocity for the same spiral has a little error.

As the result of the experiment, the color-coded version is used to show 9 different number of rounds by the different density and divergent number of cycles. The velocity will decrease by increasing the number of rounds or density for each number of rounds.

A color-coded approach from the experiment represents the state of the rotational speed for each spiral. The green stands for the best and the fastest ones as it is possible to see in the intuitive view of the experiment, the light green section is consider as the well rotation and between the time range of 1.5 to 1.7 for each rotation in this phenomenon, and the yellow section is representation of the 1.7 to 2.5 seconds for each rotation of the spiral (Fig.12).

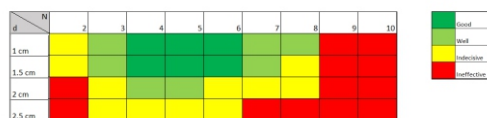


Fig. 12: Color coded approach

An optimization for the best setup in this experiment I

reached to two best setups that the speed of the rotation had the best result, and it is possible to observe by the experiment in the video of each spiral for maximum torque. (Fig 13).

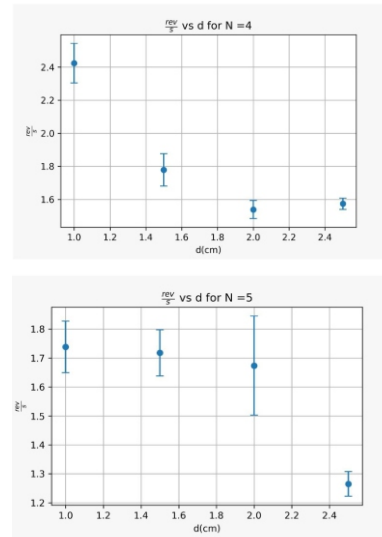


Fig. 13: The best spiral for maximum torque

5. Conclusions

This research by the theory in energy transition and the division between forces applied to the system and obtaining each force. Total torque equation and the factors to have a maximum torque and the study of airflow that causes the force were studied. For the experiment to measure the maximum torque four number of rounds with different densities of the strip for each spiral have been used. The result of the experiment by a color-coded version for the diagrams and optimized the setup for maximum torque between the best experiment and angular velocities have been presented that was gotten from the green code experiments.

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[2] [https://stemfellowship.org/iyppt-references/problem13/Cross,Rod.‘‘RotatingRingonaVerticalRod.’’PhysicsEducation56,no.2\(2021\):023003.https://doi.org/10.1088/1361-6552/abd992](https://stemfellowship.org/iyppt-references/problem13/Cross,Rod.‘‘RotatingRingonaVerticalRod.’’PhysicsEducation56,no.2(2021):023003.https://doi.org/10.1088/1361-6552/abd992)

# BIORESTORATION

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## ABSTRACT

### ARTICLE INFO

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The cement production causes global warming, environmental pollution and climate changes. Also this production is too costly. Especially the cracks of buildings cause collapsing of them. The demolition pollutes the environment and restructuring durations are costly. This project aims to develop bond to reduce environment pollution about cement. The research showed that "the biomineralization" method can be effective. Cement includes %60-70 of calcium carbonate. That is if CaCO<sub>3</sub> is produced with microorganisms, it can be eco-friendly bond.

**Keywords :** Fine-grained soil, Mechanical properties, Biomineralization, *B. megaterium* (ATCC 14581), Calcium Carbonate (CaCO<sub>3</sub>)

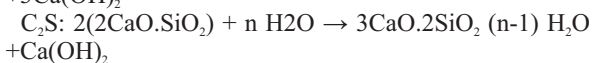
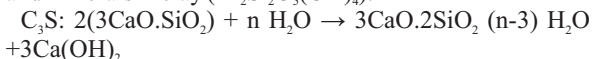
## 1. Introduction

There is a very rapid population growth in the world. As of 31 December 2021, the population residing in Türkiye increased by 1 065 911 people compared to the previous year and reached 84 680 273 people (TUIK, 2022).

Rapid population growth has led to the need to build housing and business areas. This situation has led to an increase in investments in the construction sector and the use of more cement. Increasing cement production is both costly and brings along various environmental problems (Gürtuğ, Sesalı, Yıldırım, 2016). In addition, due to factors such as earthquake and building age, cracks may occur in the structures. As the buildings become uninhabitable due to cracks, the building must be completely demolished. This causes both environmental pollution and high costs.

### 1.1. Cement Production

Cement whose raw materials are limestone and clay; sand, gravel, etc. used to bind materials. Calcium hydrates (C<sub>3</sub>S, C<sub>2</sub>S, C<sub>3</sub>A) and calcium ferrite (C<sub>4</sub>A) form the composition of cement. When cement interacts with water, hydrated calcium silicate (C<sub>2</sub>SH<sub>x</sub>, C<sub>3</sub>S<sub>2</sub>H<sub>x</sub>), hydrated calcium aluminate (C<sub>3</sub>AH<sub>x</sub>, C<sub>4</sub>AH<sub>x</sub>) and slaked lime Ca(OH)<sub>2</sub> are formed, which is the primary cementitious product. Hydrated calcium silicate and hydrated calcium aluminate are formed by the reactions between Ca(OH)<sub>2</sub> and minerals in clay (Al<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>(OH)<sub>4</sub>).



### 1.2. Problems Due to Cement

During the production of a bag of cement, approximately 25 kg of coal is burned. As a result of the burning of coal, the increase in CO<sub>2</sub> in the air causes global warming; NO<sub>x</sub>, SO<sub>x</sub> gases cause acid rain, which in turn causes climate change and environmental pollution. (Udara et al., 2019). The fact that 5% of the worldwide CO<sub>2</sub> production is caused by cement production shows the worldwide impact of the problem (Kara, 2020). Acid rain affects the chemical and biological structure of the soil. It causes significant damage on historical artifacts and buildings. (<https://www.mgm.gov.tr/FILES/genel/brosurler/asit->

[yagmurlari.pdf](#) Access Date: 18.12.2022)

High temperature, dust, toxic and allergic chemicals and heavy metals (Cd, Cr, Cu, Hg, Pb, Se, Zn etc.) released during cement production also mix with soil, streams and underground waters and adversely affect minerals and living things living there. Cement contains high amounts of materials such as Mn, Mg, TiO<sub>2</sub> (Marlowe and Mansfield, 2002; EIA Guide, 2009). Cracks, especially in old buildings, can cause buildings to collapse. Demolition pollutes the environment and rebuilding processes are costly.

### 1.3. Biomineralization and Microbial CaCO<sub>3</sub> Formation Mechanisms

The product that is frequently used in cement-based products is calcium carbonate. CaCO<sub>3</sub> is a fairly solid compound. 65-70% of the cement component is CaCO<sub>3</sub>, while the remaining part is composed of clay components (Yıldırım, 2019). Biomineralization is defined as the mineralization created by living things (Knoll, 2003). Various biopolymers are formed as a result of biomineralization. Calcium carbonate precipitation takes place by various microorganisms in soil, water and marine environments (Cura et al., 2001). This event occurs in various ways depending on the type of microorganism: cyanobacterial photosynthesis, sulphate reduction, denitrification, ammonification, urea hydrolysis (Gürtuğ et al., 2016) (Table 1).

**Table.1:** Microbial CaCO<sub>3</sub> formation mechanisms due to bacterial groups (Gürtuğ et al., 2016)

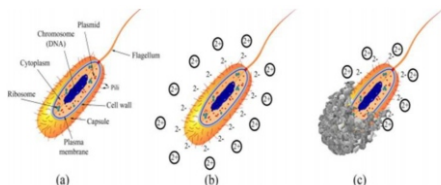
Bacteria Group	Types of Bacteria	Metabolism	Reaction	Spin off
Cyanobacteria and alg	<i>Nostoc calcicola</i>	photosynthesis	$3HCO_3^- + C^{2+} \rightarrow CH_3O + CaCO_3 + O_2$	$O_2, CH_3O$
	<i>Oscillatoria salina</i>			
urolytic bacteria	<i>Acetobacter cyathoides</i>	urea hydrolysm	$CO(NH_2)_2 + 2H_2O + C^{2+} + Cell \rightarrow 2NH_4^+ + Cell-CaCO_3$	NH <sub>4</sub> <sup>+</sup>
	<i>Bacillus pasteurii</i>			
	<i>Bacillus megaterium</i>			
nitrate reducing bacteria	<i>Diphtherobacter nitroreducens</i>	Denitrification	$CH_3COO^- + 2H^+ + 1.6NO_3^- \rightarrow CH_3CO_2 + 0.8N_2 + 3.8H_2O$	CO <sub>2</sub> + N <sub>2</sub> + NO <sup>-</sup> + N <sub>2</sub> O
	<i>Nitrobacter species</i>			
myxobacteria	<i>Mycrococcus xanthus</i>	Ammonification	$NH_4^+ + H_2O \rightarrow NH_3 + OH^-$ $Ca^{2+} + HCO_3^- \rightarrow CaCO_3 + H^+$	NH <sub>3</sub>
	<i>Desulfosporospora denitrificans</i>			
sulfate reducing bacteria	<i>Desulfobacterium autotrophicum</i>	sulfate reducing	$SO_4^{2-} + 2CH_3OH + OH^- + Ca^{2+} \rightarrow CaCO_3 + CO_2 + 2H_2O + HS^-$	CO <sub>2</sub> , HS <sup>-</sup>



**1.3. Urolytic Bacteria and Bacillus megaterium (ATCC 14581)**

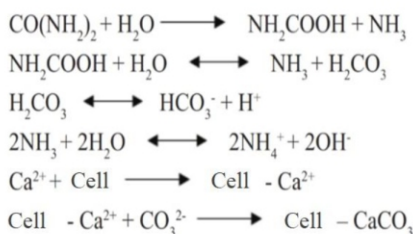
Microorganisms with urease enzyme attract calcium ions in the environment electrostatically, thanks to their negatively charged membranes, and cause the formation of calcium carbonate (CaCO<sub>3</sub>) precipitation (Gürtüğ et al., 2016). The resulting CaCO<sub>3</sub> precipitation can provide self-healing by filling cracks in cement-based materials (De Muynck et al., 2010).

The mechanism of urea hydrolysis and CaCO<sub>3</sub> formation is given in Table (2), and the calcium carbonation process in the bacterial wall is given in Figure (1).



**Fig1:** Calcium carbonation process in the bacterial wall. (a) bacterial structure, (b) negatively charged bacteria attract positive structures, (c) biomineralization (Seifan et al. 2016).

**Table 2:** Urea hydrolysis and CaCO<sub>3</sub> formation (Gürtüğ et al., 2016)



Tezer and Başaran Bundur (2021) conducted experiments using *Sporosarcina pasteurii* bacteria in their study. They used diatom and pumice in their work. However, silt and clay were used in this project. In addition, in this study, the effect of CaCO<sub>3</sub> formed by *B. Megaterium* (ATCC 14581) bacteria on the binding of the building material was investigated. The effect of binding was seen with SEM images.

**2. Material and Method**

**2.1. Materials and Devices Used**

The materials used in the experiments were of analytical purity and were obtained from Sigma Aldrich, Fluka companies. The devices used are of high sensitivity (Table 3).

**2.2. Preparation of Medium and Growth of Bacteria**

*B. megaterium* (ATCC 14581) was used in this study. *B. megaterium* (ATCC 14581) obtained from Ege University Science Faculty Biochemistry Department Biotechnology Laboratory culture collection was first line inoculated on Nutrient agar and then inoculated into Nutrient broth, which is a liquid medium.

Nutrient agar was prepared in distilled water as 20.0 g/L, then sterilized in autoclave at 121 °C 1.5 ATM for 15 minutes, cooled to 45-50°C and poured into sterile petri dishes 12.5 mL each. The nutrient agar divided into Petri dishes was expected to freeze. On the other hand; 3 g Nutrient Broth, 5 g urea, 0.7 g CaCl<sub>2</sub> (calcium chloride) were added to 250 mL pure water and dissolved and a

liquid medium was formed.

Bacteria inoculation was carried out after the medium was brought to room temperature. In order to prevent microbial contamination during sowing, the sowing surfaces were sterilized with 70% ethanol. The loop, which was turned into incandescent in a spirit stove, was used for the inoculation of *B. megaterium* (ATCC 14581) cells in nutrient agar after cooling (Fig. 2).

**Table 3:** Materials, Devices and Media Components Used

MATERIAL	COMPANY
Nutrient Broth	Fluka
Urea	Sigma Aldrich
Calcium chloride	Bio Basic Inc.
Yeast Extract	Oxoid
Peptone	Fluka
Beef Extract	Fluka
Bacterium ( <i>B. megaterium</i> (ATCC 14581))	Ege University Faculty of Science Department of Biochemistry Biotechnology Laboratory Culture Collection
Low plasticity silt (Maximum diameter) 63x10-6 m)	Aydınlı madencilik
Clay (kaolin)	UTELKA Ltd. Şti.
DEVICE	COMPANY
Precision Scale	Daihan Biomedical
Autoclave Device	Hmc
Shaking Incubator	New Brunswick Scientific
Spectrometer	Perkin Elmer
pH Meter	Hanna Instruments
Free Pressure Device	Multiplex 50
Weighing	Adventurer Ohaus
Magnetic Stirrer	VELP Scientifica
Coating Device	Leica EM ACE600
SEM (Scanning Electron Microscope)	Thermo Scientific Apreo S



**Fig2:** Calcium carbonation process in the bacterial wall.

*B. megaterium* (ATCC 14581) was inoculated for 120 hours at 37 °C with a stirring speed of 120 rpm. Bacterial growth was monitored spectrophotometrically every 24 hours, and an absorbency value of 1.5 was observed at OD600, which determined the transition to log phase. The sample, whose transition to the log phase was detected and CaCO<sub>3</sub> formation did not occur yet, was kept in the incubator for 120 hours and studied with two different cultures with CaCO<sub>3</sub> formation.

Bacteria were divided into 2 groups in order to examine the effectiveness of the growth stages of the bacteria on the building materials. Bacteria that have just entered the log phase have just started the CaCO<sub>3</sub> generation process. *B. megaterium* (ATCC 14581) bacteria entered the log phase after approximately 24 hours and therefore the first group of bacteria was incubated in the incubator for 24 hours. The other group is the bacteria in the group where the log phase has ended, that is, the CaCO<sub>3</sub> formation has been completed. Since the bacteria formed CaCO<sub>3</sub> after an average of 4 days, the bacteria in the second group were also incubated for 4 days. In order to examine the effect of the substances formed as a result of the metabolic activities of *B. megaterium* (ATCC 14581) on the pH value of the medium, which is 7.4, measurement was made with a pH

meter. No significant difference was observed in the pH measurement.

**2.3 Use of Bacteria in Soil Stabilization-Free Pressure Tests**

It was thought that the bacteria could easily create CaCO<sub>3</sub>, and at the same time, it would be appropriate to use materials with large macro-cavities. For this purpose, the material classified as SP (poorly graded medium sand-D50=0.4 mm) according to the Unified Soil Classification System was chosen because it could not hold itself and its unconfined compressive strength was zero. For the preparation of samples with a relative density of 50%, 400 g of sand (0.5-2.0 mm in size) and 50 ml of *B. megaterium* (ATCC 14581) culture (Log phase start and CaCO<sub>3</sub> formation completed) were used and the first samples were prepared. The prepared molds were cured 7 day. At the end of the period, they were dispersed during the demoulding process with the Sample Extraction System. Because CaCO<sub>3</sub> could not sufficiently bind the sand used and frictions affected the sample during demoulding. For this reason, it was decided to change the material used. In the second experiment, samples were prepared by adding 50 ml of *B. megaterium* (ATCC 14581) culture to a mixture of 70% silt and 30% clay. The clay-sand mixture prepared with log phase bacterial cultures could not be removed from the mold and dispersed. The sample, which was prepared and cured with the cultures whose CaCO<sub>3</sub> formation was completed, could be removed from the mold and the unconfined compressive strength was measured. However, the compressive strength was as low as 65 kPa. It was decided to perform an optimization process for the log phase and for the CaCO<sub>3</sub> formation phases.

**2.4 Optimization Process for Bacteria to Generate CaCO<sub>3</sub>**

The effect of *B. megaterium* (ATCC 14581) on CaCO<sub>3</sub> formation was investigated by changing the content of the medium with optimum reference values for the growth of bacteria. CaCl<sub>2</sub> and urea were added to support the formation of CaCO<sub>3</sub>.

The amount of only one substance at a time was changed in the media to observe the optimization. No changes were made in the procedures applied in bacterial sowing (Table 4).

**Table 4:** Substance Components and Amounts to be Used in Optimization (For 1 L medium)

	Substance	Reference Quantities(g)	Quantities Used in Optimization (g)			
Nutrient Broth Content	Peptone	5	1	2.5	10	15
	Yeast Extract	2	0.25	1	4	6
	Beef Extract	1	0.1	0.5	2.5	5
	NaCl	5	1	2.5	7.5	10
Additions	CaCl <sub>2</sub>	3	0.1	1	6	9
	Urea	20	5	10	40	60

For the bacterial cultures obtained, samples were formed with 0.63 mm, 350 g sand and 50 mL medium. It was compressed into 196 cm<sup>3</sup> molds at Standard Proctor Energy (592.7 kJ/m<sup>3</sup>). In this context, it was compressed in 3 layers with 25 blows to each layer with the hammer released from a height of 30.5 cm. The mold was separated from the lower part and the upper and lower surfaces were smoothed with the help of a knife. The mold was removed with the help of a sample extractor. The prepared molds

were kept at room temperature for 14 days (Fig. 3).



**Fig.3:** Preparation of Molds and Demoulding Process

The unconfined compressive strengths of the samples were determined according to the ASTM D2166/D2166M standard. The experiments were carried out at a loading speed of 1.27 mm/min. The dimensions of the unconfined pressure test instrument used are 500 x 500 x 1470 mm. The load cell of the free pressure device has a capacity of 5 kN. In the simplest terms, the unconfined compressive strength is the ratio of the applied load at the time of failure to the cross-sectional area at the time of failure. For example, assuming that the volume does not change (Eq. 1).

$$q_u = \frac{P}{A_0} (1 - \epsilon) \tag{1}$$

In this formula, q<sub>u</sub>, A<sub>0</sub> and ε show the unconfined compressive strength, cross-sectional area and unit deformation before the test, respectively. The secant modulus (E<sub>50</sub>), which reflects its resistance to elastic and plastic deformation, is an important parameter that contains information about deformation behaviour (Wang et al., 2013). The stress-strain ratio, which corresponds to 50% of the unconfined compressive strength in the stress-strain graph obtained from the unconfined compression test, is defined as the secant modulus (Lorenzo and Bergado, 2006).

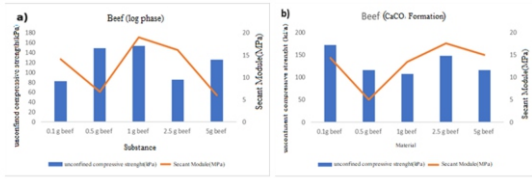
Two controlled trials were conducted in this project. In the first experiment, the optimum amount of medium required for the survival and reproduction of the bacteria was taken as reference. However, the desired result could not be obtained in the prepared samples. For this reason, optimization has been made. The amount of substances contained in the medium has been changed. Thus, CaCO<sub>3</sub> production of *B. megaterium* (ATCC 14581) bacteria and its effect on the building material were observed. In the second experiment, the amount of substance was kept constant and the effect of the bacterial phase on the strength was investigated. The sample was created with the media in which the bacterium had just entered the log phase and the media where CaCO<sub>3</sub> was formed. The strengths and stiffness (secant modulus) were examined with a 14-day curing period. The measurement results were graphed and the samples with the highest strengths were determined (Table 5). Bacterial mineralization products in these samples were examined using scanning electron microscopy (SEM). Mineral formations were determined by SEM images and it was investigated whether bacterial cells combined with carbonate crystals.

**Table 5:** Variables

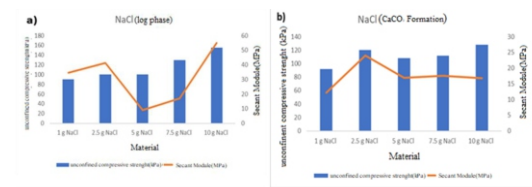
TABLE OF VARIABLES		
Independent variable	Dependent variable	Control Group
The amount of any substance in the medium	Strength of the obtained sample	Sample waiting temperature, ambient Other component amounts of the medium
Bacterial phase added to the sample (log phase and CaCO <sub>3</sub> formation states)	Strength of the obtained sample	Sample waiting temperature, ambient Other component amounts of the medium

**3. Results and Discussion**

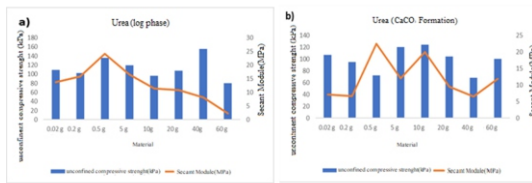
The unconfined compressive strength and secant modulus results are given in the graphs below, which are drawn according to the crimping results. In each graph, samples with the medium removed from the incubator (a) at the beginning of the log phase of the bacterium and (b) removed from the incubator when CaCO<sub>3</sub> formation of the bacterium is completed are included. Graphs are named according to the amount of items changed for optimization (Fig. 4- 8).



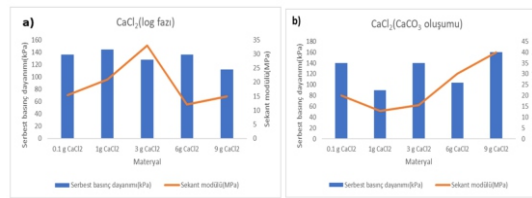
**Fig.4:** Graphs of unconfined compressive strengths and secant modulus according to different beef extract amounts. a) Log phase b) CaCO<sub>3</sub> formation



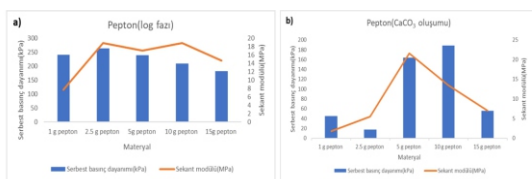
**Fig. 5:** Graphs of unconfined compressive strengths and secant modulus according to different NaCl amounts. a) Log phase b) CaCO<sub>3</sub> formation



**Fig. 6:** Graphs of unconfined compressive strengths and secant modulus according to different Urea amounts. a) Log phase b) CaCO<sub>3</sub> formation



**Fig. 7:** Graphs of unconfined compressive strengths and secant modulus according to different CaCl<sub>2</sub> amounts. a) Log phase b) CaCO<sub>3</sub> formation



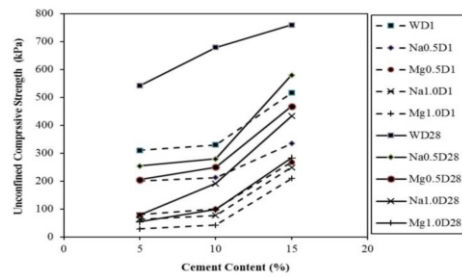
**Fig. 8:** Graphs of unconfined compressive strengths and secant modulus according to different Yeast extract amounts. a) Log phase b) CaCO<sub>3</sub> formation

All graphics were examined and samples with high unconfined compressive strength were determined. 2.5 g

peptone (log phase); 10 g peptone (CaCO<sub>3</sub> formation); 4 g yeast extract (log phase); 0.25 g yeast extract (log phase); 6 g yeast extract CaCO<sub>3</sub> formation); 0.1 g beef extract (CaCO<sub>3</sub> formation); Free compressive strengths were higher in 40 g urea (log phase) samples.

*B. megaterium* (ATCC 14581) is a carbonate-precipitating bacteria. It produces urease, which catalyzes the hydrolysis of urea resulting in the formation of carbonate and ammonium ions. In the presence of Ca<sup>2+</sup>, CaCO<sub>3</sub> is formed due to the precipitation reaction of calcium and carbonate ions. Bacterial urease activity directly determines the productivity of biogenic CaCO<sub>3</sub>, which is the main crack healing material in the bacteria-based healing system. The amount and rate of decomposable urea were affected by the urea and Ca source (Wang et al., 2017). In this system, urea is the source of carbonate. If more urea is supplied, more CaCO<sub>3</sub> can be formed provided that sufficient calcium ions are present, although it has been shown that bacterial growth and autolytic activity are inhibited when the urea content is excessive.

The strength value of the fine grain silt-clay mixture at the optimum water content of 51 kPa has increased to a maximum of 5-6 times after the optimization studies with the effect of calcite rain. It has been concluded that a strength performance will be seen. The increased rigidity of the material, which evolved from a ductile structure to a brittle structure, again stood out as an increase in performance at low amplitude deformation levels. Strength values, for example, were obtained as a result of cement stabilization and in previous studies (Kalıpcılar et al., 2016) show that the strength of fine-grained soils reaches strength values slightly above the levels obtained with biocalcite in this study, after durability effects such as sulfate effect, even when the cement amount is increased to a very high value such as 15% (Fig. 9). In this context, promising results were observed in the improvement of the mechanical properties of the soils after the optimization of the study.



**Fig. 9:** Strength values obtained after curing of cement stabilized floors up to 28 days (time is indicated by the letter D) after the effect of water (W), Na- and Mg-sulphate (Kalıpcılar et al., 2016; Sezer et al., 2017)

**4. SEM Results**

Scanning electron microscopy (SEM) analysis performed on powder samples taken from the fracture surfaces of the samples subjected to the unconfined pressure test reveal the reasons for the increase in strength and stiffness. In Figures (10) and (11), bacterial formations, bonding with calcite, especially the bonding of silt particles and matrix structure are clearly seen, thus improving mechanical properties. The better results of the culture samples added in the log phase compared to the CaCO<sub>3</sub> formation phase samples show that *B. megaterium* (ATCC 14581) can produce CaCO<sub>3</sub> even underground formation

(Dhami et al., 2013). These images are the proof that there is  $\text{CaCO}_3$  in the structures formed by silt and clay. While the sample, which we consider as blind, where only the medium is placed, cannot even be removed from the mold, the strength of the mold as a result of  $\text{CaCO}_3$  production being produced in the ground material shows that  $\text{CaCO}_3$  is inside the structure.

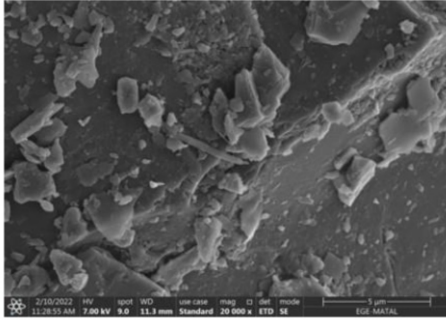


Fig. 10: SEM image of samples prepared using 4g yeast extract (log phase)

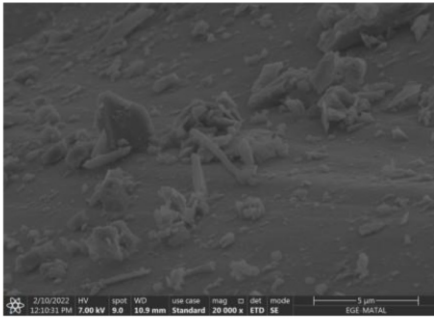


Fig. 11: SEM image of samples prepared using 0.1g beef extract ( $\text{CaCO}_3$  formation)

The setup of the project is to move away from the use of cement and to use environmentally friendly biomolecules. It can also be used in the biological repair of potentially damaged columns, floors or structures in construction, which is one of the most important parts of this project. Thus, the structures can be restored and reused at a lower cost without demolition.

## 5. Conclusion

It has been concluded that biocalcite can be used to add strength to the soil instead of cement. Optimization studies will be carried out in order to further increase the strength. By using this method, environmentally friendly biomaterials will be produced and it will be possible to get rid of the damages of cement. Due to the high cost of cement production, the production of buildings is also costly. This problem will also be solved. In addition, serious contributions will be made to the economy by saving the buildings that have to be demolished due to cracks.

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# STRANGE MOTION

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## ABSTRACT

**S**prinkle small floating particles on the surface of water in a bowl. Bring a strong magnet above and near to the water surface. Explain any observed motion of the particles. The main purpose of the problem is explaining any observed motion of the particles. Experiments on this project show that in paramagnetic fluids, first adsorption and then excretion occur. This phenomenon also occurs if the liquid changes to alcohol, because alcohol is also diamagnetic, so it shows the same behavior as water.

**Key Words :** Moses effect, particles, diamagnetic, laser

## ARTICLE INFO

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## 1. Introduction

Normally there are three types of material in terms of magnetism: ferromagnetic, diamagnetic and paramagnetic. Different liquids and materials exhibit different behaviors in the presence of magnets. Water is one of these materials that shows an interesting behavior in the presence of a magnet because it is one of the diamagnetic materials that is repelled against the magnet. Temperature has no effect on this material because in general, unlike para-magnetic materials, temperature has no effect on diamagnetic materials (Fig.1).

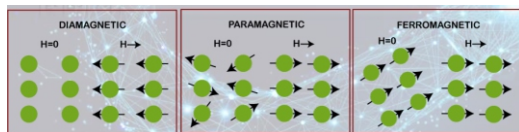


Fig.1: Three types of material in terms of magnetism

Deformation of the surface of a diamagnetic liquid by a magnetic field is called the "Moses Effect". This deformation in water attracts particles and create a current in the direction of the magnetic field. By calculating this deformation, we can also measure the magnetic energy density and the gravitational potential energy density, which according to the law of conservation of energy must be equal.

Due to the behavior of water, which is related to its non-bonding electrons, a Moses effect is created when a magnet is held above or below a container containing a liquid, the liquid will show different magnetic behaviors depending on its type. If it is diamagnetic, a dome is created inward and if it is paramagnetic, it is created upward.

In this question water is diamagnetic so a semicircle is created downward. This phenomenon helps us to justify the behavior of particles (Figs. 2).

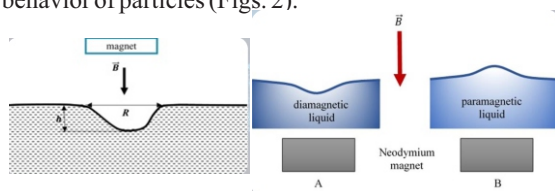


Fig 2. Comparison of phenomena in diamagnetic and paramagnetic fluids and their deformation

Moving and positioning small particles and low liquid volumes are important tasks in miniaturized bio-analytical and biomedical systems, where decreased sample sizes can reduce analysis costs and times.

Water is a diamagnetic fluid because it has no unpaired electrons. Also, the specific locations of water molecules are regular due to the orientation of water molecules in the presence of an induced magnetic field.

Due to the above reasons and the diamagnetic nature of water, it can be said that it is expelled from the magnet.

By measuring the depth of water created, we can calculate the magnetic energy density and the gravitational potential energy density.

## 2. Experiments and Theory

To measure the water level, we measure the laser to the water level once in the presence of a magnet and once without the presence of a magnet, and measure the maximum water depth by using the height difference created by the reflection of the laser light on the screen (Figs. 3 & 4) (Eqs. 1-8).

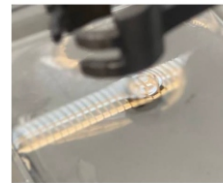


Fig. 3. Deformation created in the water surface in the presence of Neodymium magnets

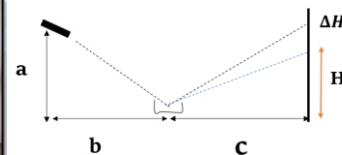


Fig 4. Experimental Setup and Laser test simulation

$$\frac{a + \Delta h}{b} = \frac{?}{c} \rightarrow ? = \frac{c}{b} (a + \Delta h) = H + \Delta H \rightarrow \quad (1)$$

$$\Delta h = \frac{H + \Delta H}{c} \times b - a \rightarrow \Delta \theta \rightarrow \Delta H < 0 \rightarrow \quad (2)$$

$$\frac{a}{b} = \frac{H}{c} \rightarrow (H + \Delta H)/C = \text{tg}(\alpha - 2\Delta\theta) \quad (3)$$

$$\text{tg}\alpha = \frac{a}{b} \quad (4)$$

$$\frac{\text{Distance of laser to water surface}}{\text{The distance from the curtain to the water surface}} \times \Delta H = \frac{\text{Maximum water surface displacement}}{\quad} \quad (5)$$

$$\frac{360\text{mm}}{1540\text{mm}} \times 7\text{mm} = 1.4 \text{ mm} \quad (6)$$

Gravitational Potential Energy Density :

$$\mu = \rho g \Delta h \quad (7)$$

$$\mu = 997 \frac{\text{kg}}{\text{m}^3} \times 9.8 \frac{\text{m}}{\text{s}^2} \times 0.0014\text{m} = 13.7 \text{ kg/ms}^2 \quad (8)$$

Magnetic Energy Density (Eqs. 9-10):

$$\mu = \frac{B^2}{2\mu_0} \quad (9)$$

$$\frac{0.006^2}{2 \times 1.2566 \times 10^{-6}} = 14.32 \text{ kg/ms}^2 \quad (10)$$

By the law of conservation of energy, the two energies should be equal.

### 3. Results and Relevant Parameters

1. With the change of fluid, the performance of the system also changes. If the liquid is diamagnetic (residual alcohol that has been tested), it behaves like water and the particles absorb the magnet. If the liquid is para-magnetic, it is first excreted and then absorbed.

2. If the particles are denser than water, they will settle and the phenomenon will not be observed. Otherwise, the smaller its size and mass, the faster their movement will increase.

3. If the strength of the magnet changes, the stronger the magnet, the clearer and faster the particles move towards the magnet. Also, the strength of the magnet affects the shape of deformation.

### 4. Conclusions

Due to the diamagnetic nature of water and the effect of Moses, a deformation is created in water and attracts particles, and due to the movement of water molecules and the induction magnet, a current is created.

This phenomenon occurs similarly in diamagnetic fluids. By measuring the maximum depth of water, we can also calculate the magnetic energy density and the gravitational potential energy density, which according to the law of conservation of energy must be approximately equal.

$$13.7 \text{ kg/ms}^2 = 14.32 \text{ kg/ms}^2$$

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# THE EFFECT OF DIFFERENT SALTS ON ONION CELL STRUCTURE

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## ABSTRACT

The main structure of the onion cell consists of a cell wall which, with its strength and cellulose structure, forms a polygonal cell, the cell membrane, the cytoplasm which contains organelles, chloroplasts and central vacuole, which is the largest part of the cell and includes water and food. In this paper, we intend to compare the effect of different salts on onion cell structure based on their concentration by comparing the cell's situation before and after the experiment. Finally, the purpose of this research, is to study the factors related to the amount of cell osmosis.

**Key Words :** Salt, Onion Cell, Osmotic Pressure, Plasmolysis

## ARTICLE INFO

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## 1. Introduction

Have you ever thought about the effect of various salts on the onion cell? for investigating and answering the question raised in this study first, we remove the purple epidermis of the onion cell and then take a picture of its previous state under the microscope, in the Next step, we use a dropper, and then pour a few drops of the salt solution over the sample and after that by taking some pictures at different time lapses, the changes would be recorded in the images.

Walter Stiles and Ingvar Jorgensen, who also published an article in 1918 entitled "On the Relation of Plasmolysis to the Shrinkage of Plant Tissue in Salt Solutions" were the first researchers who examined the relationship between cellular plasmolysis and shrinkage of plant tissue . A few years after Nobur, Kamiya, and Masashi Tazawa in 1955 published an article entitled "Studies on Water Permeability of a Single Plant Cell by Means of Transcellular Osmosis", which in that time this paper developed a new method for the measurement of permeability of the cell to water and other research by different scientists.

But up to now, the factors affecting cellular osmosis have not been discussed precisely, and we intend to investigate this subject more precisely in this article. Other reasons include inappropriate technology, inaccuracy in hygiene conditions, the onion product packaging and storage conditions do not allow the proper use of this product. Osmotic dehydration is a storage method that delivers the highest possible quality by transporting water out of the foodstuff tissue. and by determining the factors related to the amount of cell osmosis, the amount of product osmosis can be controlled so then by using osmotic dehydration, the characteristics quality of the processed product can be improved.

Various factors such as temperature, concentration of osmotic solutions, proportion of sample to solution, time and physical and chemical properties of an onion are effective in the osmotic process.

## 2. Research Method

For doing the experiments, first, we remove the purple epidermis of the onion cell and then take a picture of its previous state under the microscope, in the Next step, we

use a dropper, and then pour a few drops of the salt solution over the sample and after that by taking some pictures the changes would be recorded.

We used purple onions to study the effect of different salts on the structure of the onion cell because it contains the anthocyanins pigment molecule which is purple and make the visibility of the vacuole better under the microscope. We used four types of salts, NaCl, NaBr, KBr and KCl to study the effect of salts because, these are soluble in water and also the number of particles in each molecule of those salts are equal with each other.

## 3. Experiments

Our experiments are divided into three parts:

Part one: In this section, the variable is type of salt, we used NaCl, NaBr, KBr and KCl solutions with the same mass concentrations (5 percent). We recorded the vacuole changes by taking pictures in this section for all of our salt solutions after 4 minutes we dropped the solution on the onion cell.

Part two: In this section, the variable is type of salt and we used NaCl, NaBr, KBr and KCl solutions with the same molar concentrations (1 molar). We recorded the vacuole changes in this section for all steps in three time lapses of 3, 4 and 5 minutes after we dropped the solution on the onion cell.

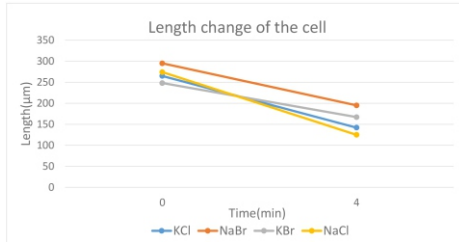
Part three: In this section, the variable is the salt concentration for which we used sodium chloride. We used different concentrations of 0.5%, 1%, 2%, 5% and 10%. We recorded vacuole changes in this section for all steps in three time lapses of 3,4 and 5 minutes after we dropped the solution on the onion cell.

Finally, in this paper, the approximate range of hypertonic, isotonic and hypotonic sodium chloride solutions equal with the red onion cell are measured and also the effect of different type of salts on the amount of plant cell osmosis is also examined.

## 4. The Results

The results of the first part of the experiment:

The diagram shows the plasma membrane length changes before and after the experiment. It should be noted that the cell wall length has not changed (Fig.1).



**Fig. 1:** Changes of the cell wall length Vs time

According to the figure (1), the cell length has decreased in all salt solutions because of the cell plasmolysis which means, the water has exited from the cell. Comparison of the amount of plasmolysis in the salt solutions:

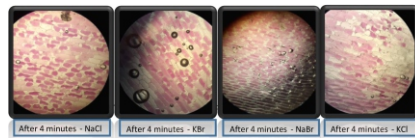
KBr solution < NaBr solution < KCl solution < NaCl solution

According to the table and figure (1), salts with lower molar mass, have higher plasmolysis

**Table 1:** The molar mass of the salts

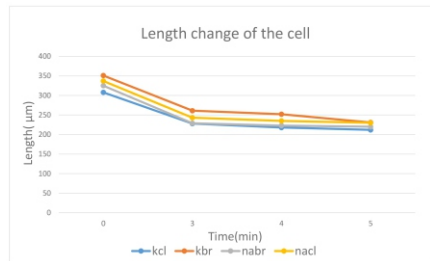
NaCl	KBr	NaBr	KCl
58.44 g/mol	119.002 g/mol	102.894 g/mol	74.551 g/mol

The pictures of the cells after the experiment are in figure (2).



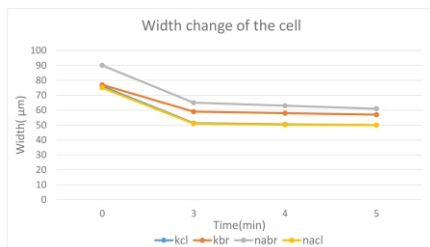
**Fig. 2:** Different salts on onion cells after 4 Min.

The plasma membrane length changes before and after the experiment are in figure (3). It should be noted that the cell wall length has not changed.



**Fig. 3:** Changes of the plasma membrane length Vs time

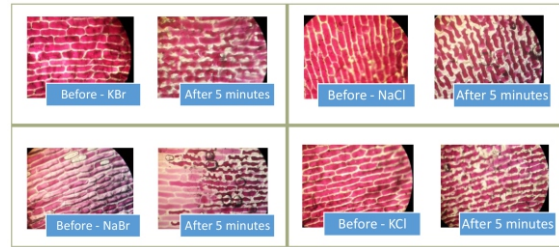
The plasma membrane width changes before and after the experiment are in figure (4). It should be noted that the cell wall length has not changed.



**Fig. 4:** Changes of the plasma membrane width Vs time

According to figure (3), the trend for all salt solutions was decreasing, so the cell length was reduced, because of the plasmolysis. Also the decreasing trend of cell length for almost all salt solutions has been the same, which can tell us that the type of salt was not effective in the amount of osmosis.

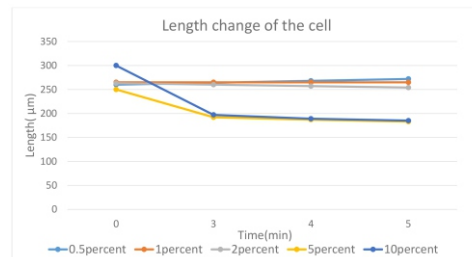
According to figure (4), the trend for all salt solutions was decreasing, so the cell width decreased from its previous state because of the plasmolysis. Also the decreasing process of cell width for almost all the salt solutions has been the same. As a result, the type of salt was not effective. The pictures of the cells before and after the 5 minutes are in figure (5).



**Fig. 5:** Different salts on onion cells after 5 Min.

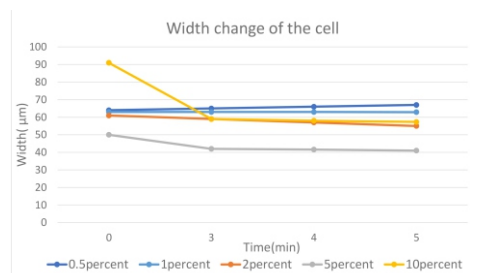
The results of the third part of the experiment:

The plasma membrane length changes before and after the experiment (Fig. 6) (by different percentage of salts). It should be noted that the cell wall length has not changed.



**Fig. 6:** The plasma membrane length Vs time in different percentage of salts

The plasma membrane width changes before and after the experiment (Fig. 7) (by different percentage of salts). It should be noted that the cell wall length has not changed.



**Fig. 7:** The plasma membrane width Vs time in different percentage of salts

According to these figures, in 0.5 percent NaCl solution, a small amount of turgency has occurred, meaning that water has entered the cell, thereby the length and width of the cell has increased slightly. Also, in 1 percent NaCl solution, the length and width of the cell has not changed. In 2 percent NaCl solution, the width and length of the cell has decreased a little so a small amount of plasmolysis occurred, meaning that the water was exited from the cell.



In 5 percent NaCl solution, Plasmolysis occurred, meaning that water was exited from the cell, thereby cell length and width has reduced. In 10 percent NaCl solution, a lot of plasmolysis has occurred, which means that the water was exited from the cell and the length and width of the cell has decreased Sharply (Fig. 8).

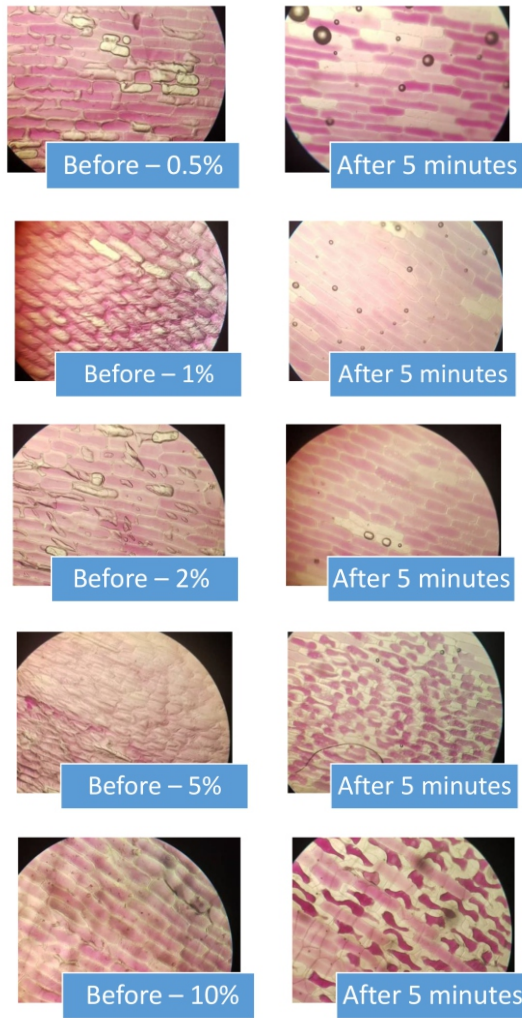


Fig. 8: Different changes in onion cells by different percentage of salts

### 5 Discussion and Analysis

The cause of cell plasmolysis:

The concentration of the solutes outside the cell is higher than the inside of the cell, and this is true for all the salt solutions we have used. This type of solutions is called hypertonic solutions. As a result, the osmotic pressure of the salt solution is higher than the osmotic pressure inside of the cell.

Osmosis occurs when two solutions, containing different concentrations of solute, are separated by a selectively permeable membrane. Solvent molecules pass preferentially through the membrane from the low-concentration solution to the solution with higher solute concentration. The transfer of solvent molecules will continue until equilibrium is attained so the water molecules will move from the cell to the outside of it. Both salt ions used in each of the four salts are large in size so they can't pass through the cell membrane and also the cell membrane has selective permeability because it is a semipermeable membrane and the cell membrane doesn't

let the ions to pass, in fact the system of transportation in our experiments is osmosis because every salt ion doesn't have the necessary conditions to pass through the cell membrane by other transportation systems. so the osmosis occurs and Osmosis only permits water to pass and for balancing the pressure on both sides of the membrane, the water moves from inside of the cell to outside of it so, the cell would shrink.

The largest part of the cell is vacuole where most of the cell's water is stored so most of the water would exit from this organelle and the shrinkage of vacuole affects the shape of cytoplasm so the size of cytoplasm will be lower with the size of vacuole but the size of cell wall wouldn't change (Fig.9).

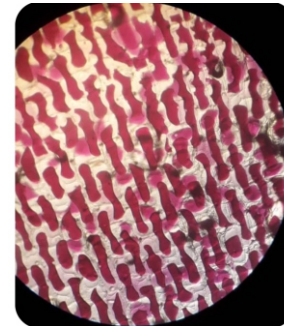


Fig. 9: The shrinkage of vacuole affects the shape of cytoplasm

Analysis of the results of the first part of the experiments:

As mentioned cells placed in salt solutions with lower molar mass had more plasmolysis. This results are because in this section the mass concentrations of our solutions are equal so the molar concentrations of them are different. The mass of one mol of those salts which have less molar mass, is lower. So in the same mass concentrations the salts with lower molar mass have higher molar concentration. As a result, the number of salt molecules in those solutions are higher so they attract more water molecules and because of that the plasmolysis in those solutions would be higher too.

Finally, the aim of this project is to understand the effect of the type of salts on the amount of osmosis, so this type of experiment isn't correct because, the molar concentrations aren't equal so it makes experimental errors. In the next section, the effect of different salts is investigated.

Analysis of the results of the second part of the experiments:

According to this part, the downward trend of cell length and width in all four types of salts was close to each other. So from this section it can be concluded that the type of salt is not effective in the amount of cell osmosis. For proving this part, the van't hoff's equation is needed. With this law the osmotic pressure of a solution can be measured.

The osmotic pressure of a solution is the minimum amount of pressure needed to prevent water from flowing into it across a semipermeable membrane.

The van't hoff equation:

$$\Pi = iMRT$$

$\Pi$  is the osmotic pressure in atm

$i$  = van 't Hoff factor of the solute

$M$  = molar concentration in mol/L

$R$  = universal gas constant = 0.08206 L · atm/mol · K

$T$  = absolute temperature in K

Osmotic pressure obeys a form of the ideal gas law and can be calculated provided you know the concentration of the solution in molar and the temperature in kelvin because other factors are constant. In this part of the experiments,

the molar concentrations and the temperature of the solutions are equal with each other and the other factors are constant. therefore, the osmotic pressure of the solutions is equal with each other. Thus, the amount of pressure required to prevent the water from exiting the cell is the same for all of them, therefore the amount of water would exit from the cell for all four types of salts are equal, so the amount of plasmolysis would be equal too and because of that their downward trend on the chart is almost similar to each other.

Analysis of the results of the third part of the experiments:

The purpose of this section was to show that the effect of salt on the onion cell is not just plasmolysis and the shrinkage of the cell, and various effects can be observed by changing the concentration of the salts in the solutions. The effects of it are divided into three cases, depending on the concentration of solution relative to the concentration of solutes in the cell:

Case One: In this case, the concentration of solution is higher than the concentration of the solutes in the cell, so the water exits from the cell to the outside of it therefore, the cell shrinks. This type of solution is called hypertonic solution and this shape of cell is called plasmolysis.

Case Two: In this case, the concentration of solution is lower than the concentration of the solutes in the cell, so the water enters into the cell therefore, the cell swells. This type of solution is called hypotonic solution and this shape of cell is called cytolysis.

Case Three: In this case, the concentration of solution is equal with the concentration of the solutes in the cell, so the shape of the cell wouldn't change. This type of solution is called isotonic solution.

According to the figures in this section the shape of the cell after the experiment was like this:

0.5 percent solution	Turgid
1percent solution	No change
2 percent solution	little plasmolysis
5 percent solution	plasmolysis
10 percent solution	high plasmolysis

Another thing we can conclude from this part is that by increasing the concentration of the salt in the solution, the molar concentration would be higher so the plasmolysis would be higher too (Fig. 10).

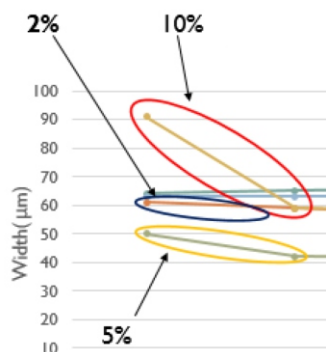


Fig. 10: The molar concentration would be higher so the plasmolysis would be higher too

The approximate range of hypertonic, isotonic and hypotonic sodium chloride solutions are equal with the red onion cell we experimented (Table 2).

**Table 2:** The approximate range of hypertonic, isotonic and hypotonic sodium chloride solutions

	Lower than 0.5% or equal to it	1 percent	Higher than 2 percent
The type of solution	Hypotonic solution	Isotonic solution	Hypertonic solution
cell shape	Cytolysis and turgid	No changes	Plasmolysis and shrinkage

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# NEAR SPACE SATELLITE

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## ABSTRACT

Our project had 2 parts: biological and engineering. The main part of the engineering subset consisted in assembling, programming, and launching the device into the stratosphere, as well as developing, programming a ground-based receiving rotary station, and creating a web application for visualization and analysis of the received data. The biological part consisted of conducting a biological experiment to study the possibility of regeneration of *Dugesia Tigrina* planaria and the development of *Danio Rerio* larvae after exposure to radiation, ultraviolet radiation, temperature changes and mechanical effects during stratospheric flight.

**Key Words :** *Biology, Engineering, Stratosphere, Dugesia Tigrina Planaria*

## 1. Introduction

The stratosphere is a layer of the atmosphere located at an altitude of 11 to 50 kilometers. Rockets fly through it in a matter of minutes, planes very rarely get there, and the people who were there can be counted on the fingers. The stratosphere is very dangerous due to its harsh conditions, such as low pressure and temperature, as well as increased solar radiation, which is why it is often called near space. But this is what attracts researchers - in the stratosphere, you can conduct many experiments with conditions close to real space. Therefore, our goal was to develop a stratospheric satellite as a platform for scientific experiments and directly conduct them.

The zebrafish or *Danio Rerio* is an aquarium fish which belongs to the minnow family of the order Cypriniformes. A distinctive feature of this species of fish is rapid development, which makes it extremely interesting for scientific research. Researchers who studied zebrafish development concluded that «The interaction between UV-B and temperature impaired the development of zebrafish embryos and disrupted their metabolism» [Aksakal, Ciltas 2018]

Planarias *Dugesia Tigrina* are free-living aquatic flatworms that can regenerate cells. Scientists who studied planaria's regeneration and development at different temperatures and at certain doses of ultraviolet radiation UV-B concluded that «Doubt is therefore cast on the hypothesis of an adaptive value of regeneration in view of the fact that several planarian species actually live and reproduce at temperatures well below those necessary for regeneration». [Brøndsted, Brøndsted 1961]

Planarias *Dugesia Tigrina* and *Danio Rerio* larvae became our first passengers.

The purpose of our biological research is to study planarias' *Dugesia Tigrina* regeneration and *Danio Rerio* larvae' development after the influence of irradiation, ultraviolet radiation, low temperatures, and mechanical damage after the stratospheric flight. To successfully conduct the experiment, it was necessary to create a satellite platform and equip a receiving station, as well as create a means of processing the received data.

In addition, we assumed that *Danio Rerio* larvae can fall into state of suspended animation at low temperatures and radiation and ultraviolet exposure adversely affect the

regeneration of *Dugesia Tigrina* planarian cells and we checked it during our flight.

These studies will be useful in the future as they help to find the optimal conditions for transporting living objects from Earth to space station or other planets as the conditions in the stratosphere are quite similar to space.

## 2. Materials and Methods

To conduct the experiment, a satellite platform was developed with a set of necessary sensors and tools necessary for recording environmental parameters: 4 temperature sensors in the main compartments of the satellite and outside (battery, electronics, interior space and one sensor outside the satellite), a GPS sensor (for tracking the satellite and pointing the receiving station at it during flight, and to facilitate the search after landing), barometers and gas analyzers (for dynamic analysis of the composition and pressure of the surrounding atmosphere), as well as an ultraviolet sensor and a Geiger-Muller counter.

The engineers faced several tasks, for example, placing test tubes with living organisms inside and outside the device (additive technologies were used for this purpose) or placing all sensors. For each module, it was necessary to develop a firmware and ensure that they work together through the main board. Specialized libraries were used to work with additional modules, a lot of work was done with microcontrollers.

Also, to monitor the launches of the platform, a rotary receiving station was assembled (metal structures and additive technologies were also used during assembly) and programmed, whose orientation method is described above. Such a mechanism of the station helped to significantly improve the signal quality and dramatically increase the data transmission distance. During the creation of the receiving station, new machine parts for us and methods of complex mathematical modeling were used.

To successfully conduct the experiment, all factors affecting living objects during the flight were studied. The oxygen consumption of each of the creatures was calculated to avoid a fatal outcome because of its shortage. According to the plan, oxygen in the test tubes should have been enough for larvae for 5 hours and for planarians for 7 hours (more than doubled flight duration). Special

transport capsules were found that met all the requirements to ensure a comfortable flight (ability to transmit ultraviolet and radiation, tightness, Impact resistance 5 N). To increase the amount of scientific data obtained and confirm their liquidity, we divided the samples under study into two groups: the first was placed in more greenhouse conditions inside the satellite, and the second had to endure more severe conditions outside the satellite, including temperature differences.

Subsequently, a web application was developed using the Python and JavaScript programming languages, with the help of which the data received from the satellite is visualized. The application can work both with pre-recorded data and with values received directly during the flight.

One of the recent achievements of our programmers was the transition to the Grafana service to improve the quality of visualization, as well as the successful implementation of relational databases in our hardware and software complex.

### 3. Experiment

On June 12, 2022, the first launch of our satellite platform into the stratosphere was carried out near Pereslavl-Zalessky. Our satellite was fixed on the suspension of a helium balloon. At a certain point in time, due to the increased pressure difference between the pressure inside the ball and outside, a planned rupture occurred. During the entire flight, the satellite regularly transmitted up-to-date data about the environment and its location. The duration of the flight exceeded 3 hours, during which time the device covered over 35 km and reached an altitude of over 25.5 kilometers. 4 transport capsules (2 test tubes inside the satellite and 2 outside) with living objects (1 larvae and 2 planarians outside the satellite, 2 larvae and 3 planarians inside the satellite) were launched and successfully returned to the satellite (Figs. 1 and 2).

Larvae and planarians were exposed to:

- 1) Irradiation (Maximum index – 731.1 mcR/h  
The usual indicator on Earth is 15-20 mcR/h)
- 2) Temperature differences (-14°C - 50°C inside the satellite, -45.7°C - 27.6°C outside)
- 3) Ultraviolet radiation
- 4) Mechanical damage

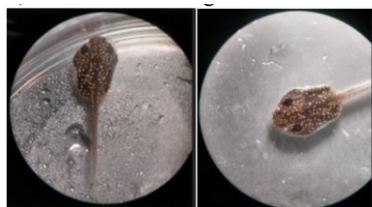


Fig. 1: Test organism №1. Danio Rerio larvae. Henry



Fig. 2: Test organisms №2, №3. Planarians. Sam and Bob

Not all the living objects survived the stratospheric flight. The planarians died from cell destruction, due to mechanical damage by reason of strong impacts on the test tubes.

Not all biological objects survived the stratospheric flight. Subjects 2 and 3 (*Dugesia Tigrina planaria*) stopped functioning due to cell destruction caused by strong mechanical impacts on the walls of test tubes. According to the camera recordings, the larvae, located outside the satellite, finally stopped its motor activity at an altitude of 15 km and a temperature of -20 °C. The probable cause is the influence of extremely low temperatures. 11 days after the launch, the process of decomposition of the larvae's body began. Usually, this process begins 2-3 days after death. The larvae showed no motor activity and did not decompose for 11 days. Based on this, we can say that the larvae has fallen into a state of suspended animation, which probably can confirm the above hypothesis.

Scientists have found out that «The physiological adaptations required by these animals and plants to survive extreme conditions at no detectable metabolic rate are generally complex and specialized» [Withers, Cooper 2008]. On this basis, we can put forward a hypothesis that Danio Rerio larvae probably have «complex and specialized physiological adaptations» to survive such low temperature.

One of the larvae inside the satellite died at an altitude of 20 km and at a temperature of -10°C. The decomposition process began 2 days after launch. The second larvae, located inside the satellite, successfully survived most of the flight, which can be seen from the cameras, but during landing, due to a hard impact, it stopped its vital activity.

All larvae lost the black pigment in melanocytes, acquired a gray-brown translucent color (the alleged reason is exposure to a large dose of radiation and ultraviolet radiation).

The satellite, the receiving station and the application performed well at the first launch. All systems worked correctly and without critical interruptions. In the course of the work, a software and hardware complex of the receiving station was created that performs dynamic reception and processing of data from a satellite platform, the satellite platform itself was implemented, providing the necessary conditions for various scientific experiments, a successful test launch was made with *Dugesia Tigrina planarians* and *Danio Rerio* larvae. During the test flight, it was possible to reach an altitude of 25 kilometers 700 meters and get all the necessary data.

### 4. Results and Discussion

1) For realization of biological experiments in the stratosphere with a lower percentage of deaths, the development of a special capsule protecting against mechanical damage is required.

2) *Danio Rerio* larvae can survive sub-zero and extremely high temperatures (-14°C - -50°C), ultraviolet and radiation exposure (maximum index – 731.1 mcR/h) with a smooth change and in small timespan.

3) The hypothesis that *Danio Rerio* larvae can fall into state of suspended animation at low temperatures (-20°C) is confirmed.

### 5. Conclusion

In the course of work, it was possible to create a fully working receiving station for the satellite and the satellite itself, reach a height of 25 kilometers 700 meters, get all the necessary data, develop a web application with full telemetry of the device and conduct a biological experiment in the stratosphere using the developed hardware and software complex.

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Serapinas B. B. – Geodesic foundations of maps // Lecture 4, geodesic coordinates

# NATURAL TIMING DEVICES AS BIOLOGICAL CLOCK IN LIVING ORGANISMS

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## ABSTRACT

**B**iological clocks are natural timing devices in living organisms such as plants, animals, humans, microbes and many others. They mostly work throughout the day-cycle and react based on the light they receive. Most daily activities are seen in the Circadian rhythms which are 24-hour cycles, but we can see behaviors in other cycles as well, such as Circalunar rhythms which are monthly activities, or the Circannual rhythms which are yearly cycles; we can see behaviors like seed germination, flowering and leaf fall in plants in the Circannual rhythms.

**Key Words :** *Biological Clock, Living Organisms, Circadian Rhythms*

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## 1. Introduction

Biological clocks are natural timing devices that are organized by the day-cycle. They are spread throughout all our body and interact with several kinds of cells.

Biological clocks are fundamental to the functioning of life and to the organization and coordination of behavior. Simple behavioral functions, such as timing active and inactive periods during the day/night cycle to maximize productivity and minimize risk rely on internal clock functions.

The main secretion point of Melatonin is a part of the brain called the SCN inside the hypophysis.

Circadian Rhythms are physical, mental, and behavioral changes that follow a 24-Hour cycle that primarily react to light and darkness and affect lots of living organisms like people, plants, microbes and animals.

Biological clocks in birds are critical components of their physiology and behavior . However, as the properties of the pineal gland's function became clearer and the identification of new pacemakers in the hypothalamus and retinae made the system appear more complex.

Being a derivative of serotonin, melatonin is one of the main hormones affecting many species throughout the day-cycle.

## 2. Method

Examples of timing processes in living organisms are plants opening their flowers at particular times of the day or sleep-wake cycles in humans. To Propose a problem concerning rhythms and timing in the species we have examined in both plants and animals (Fig. 1).

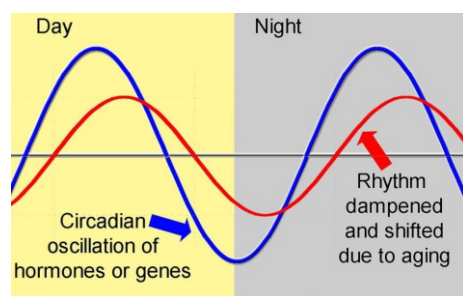


Fig. 1: Circadian Rhythms

## 2.1 Circadian Rhythms in Plants

Because the function of a biological clocks is to anticipate environmental changes they tend to be set to environmental rhythms such as daily, tidal and seasonal changes. While, the behavior or response itself is mediated by the endogenous (internal) biological clock, the clock is set to these exogenous (external) environmental cycles. As a result the following are commonly observed periods for biological rhythms:

Circadian –daily activity (~24hrs) E.g. Sleep movements, the opening and closing of flowers and solar tracking

Circatidal –tidal activity period (~12.4hrs)

Circalunar –monthly activity period (~29days)

Circannual –Yearly activity period (~365 days) Seed germination, flowering, and leaf fall

## 3. Experiments

### 3.1. Comparing Leaves in Plants

Plant A: 6 hours of light and 6 hours of darkness

Plant B: 12 hours of light and 12 hours of darkness

\*Both watered at the same time

\*Both with the same conditions (Fig. 2)



Fig. 2: Two identical plants

Number of leaves in this two identical plants are compared in different times (Fig. 3).

### 3.2. Comparing Stems in Plants

Plant A: 6 hours of light and 6 hours of darkness  
 Plant B: 12 hours of light and 12 hours of darkness  
 \*Both watered at the same time  
 \*Both with the same conditions (Fig. 4)

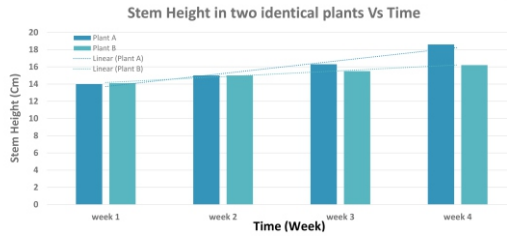


Fig. 4: Stem height vs time

### 3.3. Comparing Flowers in Plants

Plant A: 6 hours of light and 6 hours of darkness  
 Plant B: 12 hours of light and 12 hours of darkness  
 \*Both watered at the same time  
 \*Both with the same conditions (Fig. 5)

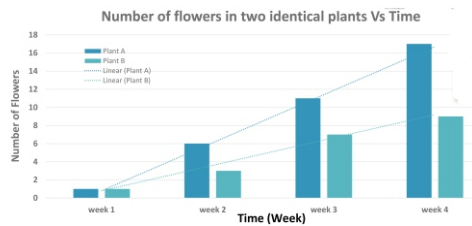


Fig. 5: Number of flowers vs time

### 3.4. Comparing the Amount of Light in Plants

Some of the plants open and close their flowers according to the changes in the amount of light during the day and night. Chinese rose flower was used in this experiment (Fig. 6).



Fig. 6: Changes in plants in front of light and darkness

### 3.5. Comparing the Roots in Plants

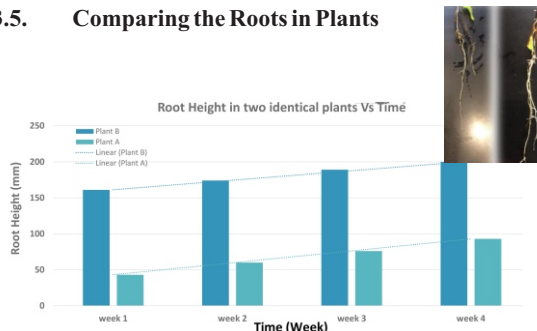


Fig. 7: Root's height vs time

### 3.6. Comparing Biological Clock in Animals

Chicken A: 12 hours day- cycles  
 Chicken B: 24 hours day- cycles  
 \*Both chickens were fed 40 gr a day  
 \*Both chickens grew in the same conditions (Figs. 8 and 9)

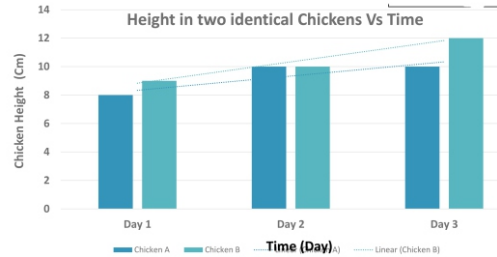


Fig. 8: Height in two identical chickens vs time

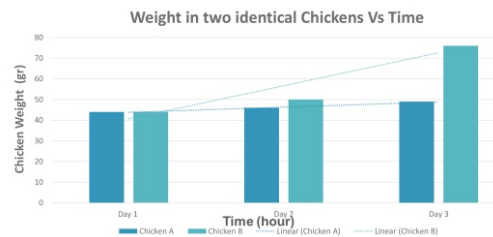


Fig. 9: Weight in two identical chickens vs time

## 4. Results

Comparison in plants resulted in (Figs. 10-12):



Fig. 10: Growing the stem and increasing the number of leaves in plants



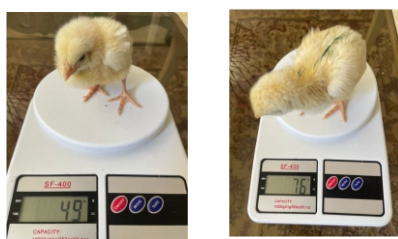
Fig. 11: Increasing the number of flowers in plants



**Fig. 12:** Growing the roots and increasing its height in plants

Results in animals:

Increasing the weight and height of chickens (Figs. 13 and 14).



**Fig. 13:** 12 Hour day-cycles      24 Hour day-cycles  
49 gr                                      76 gr

## 5. Conclusion

In our study we found:

- Circadian rhythms can affect the growth and development of living organisms, both in plants and animals.

- In the study related to plants, the reduction of the circadian rhythm to half of the normal state resulted in an increase in the number of leaves, flowers, and an increase in the length of the roots and stems.

- In the chicken study that was conducted over three days, the chicken with the shorter circadian rhythm was removed from the experiment after three days due to weakness and inability to treat and help him recover. We think the reason why chicks are weaker with a shorter circadian rhythm is jet lag.

- The chicken with a longer circadian rhythm showed more growth and development in the same and equal period of time by receiving sufficient and equal amount of water and food compared to the chicken with a shorter circadian rhythm.

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# CONTROLLED, EFFICIENT HYDROGEN AND FUEL CELL DESIGN FROM SODIUM BORHYDRIDE WITH ACETIC ACID CATALYST IN POLYETHYLENE GLYCOL MEDIUM FOR FUEL CELL

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## ABSTRACT

The aim of this study is to conduct controlled and efficient hydrogen production studies from sodium borohydride with acetic acid catalyst in polyethylene glycol medium for fuel cells. In this study, a literature review was conducted to collect data and the resources related to the subject were examined. Then, experiments related to the subject of the project were carried out. By analyzing the data and information we obtained during the project, controlled and efficient hydrogen production from sodium borohydride with acetic acid catalyst in polyethylene glycol environment for fuel cells was investigated.

**Key Words :** Fuel Cells, Acetic Acid, Sodium Borohydride, Polyethylene Glycol, Hydrogen

## ARTICLE INFO

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## 1. Introduction

### 1.1. Definition of Fuel Cell

Fuel cells are electrochemical devices that convert the chemical energy of the reaction directly into electrical energy. The basic physical structure of a fuel cell consists of a porous anode and an electrolyte layer in contact with the cathode on both sides. A diagram of the fuel cell with the reaction input and product gases is shown in Figure (1). Likewise, the flow directions of the ions through the fuel cell are also shown.

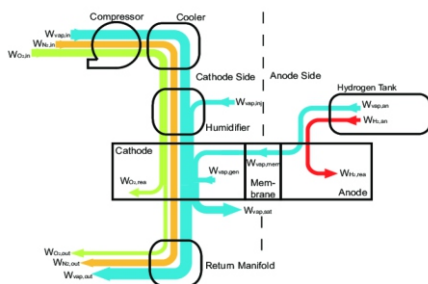


Fig. 1: The flow directions of the ions through the fuel cell

The components of a single-cell fuel cell module and fuel cell system are shown in Figure (2).

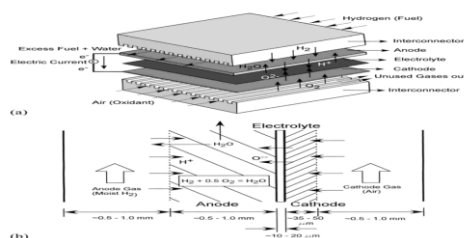


Fig. 2: Schematic representation of a single fuel cell and module

In a typical fuel cell, gaseous fuel is fed continuously to the anode (negative electrode), oxidizer (i.e. oxygen/air) to the cathode (positive electrode). In the fuel cell, while the reduction/oxidation reaction occurs between the fuel and

oxygen, electric current (direct current) and heat are formed. At the cathode, protons combine with oxygen and produce only water vapor or water vapor and CO<sub>2</sub>, depending on the type of fuel used. A fuel cell is an energy conversion device theoretically capable of generating electricity as long as fuel and oxidant are fed to the electrodes. In fact, fuel cells also have a limited operating life (< 10 years for vehicles) due to degradation over time, corrosion, and component life.

### 1.2. Types of Fuel Cells

There are many types of fuel cells under development. These are the type of fuel and oxidizer it uses, the processing of the fuel outside (external reforming) or inside (internal reforming) of the fuel cell, electrolyte type, operating temperature, fuel supply type, etc. can be classified in many different ways. The most common classification of fuel cells is based on the type of electrolyte used in the cell. According to this classification, there are 6 types of fuel cells. These;

1. Polymer Electrolyte Membrane Fuel Cell (PEMFC)
2. Direct Methanol Fuel Cell (DMFC)
3. Alkaline Fuel Cell (AFC)
4. Phosphoric Acid Fuel Cell (PAFC)
5. Molten Carbonate Fuel Cell (MCFC)
6. Solid Oxide Fuel Cell (SOFC)

In addition to its direct use in internal combustion engines, hydrogen is a fuel suitable for flameless combustion on catalytic surfaces. However, the development in the world is in line with fuel cell technology, where hydrogen is used as a fuel. Fuel cells were discovered in 1839, improved in 1932, and used by NASA as an energy provider in space studies in 1952. It was put into use in land transportation with the construction of the first fuel cell tractor in the 1960s, fuel cell train in the 1980s, fuel cell submarines and aircraft in the 1990s, it has been the subject of widespread research and application in land vehicles and power plants. Due to its high efficiency and low emissions, it has been successfully used in industry and service sectors, especially in the transportation (automotive) sector in recent years. Fuel cells are thought to revolutionize clean

vehicle technology. Fuel cells can be designed to produce little power to meet the needs of mobile phones or enough to produce enough power for a city. Therefore, they have a wide usage potential from transportation vehicles to domestic and industrial applications. The size of the fuel cell market is expected to increase to 1-2 billion dollars in the next few years and to 20 billion dollars in the next decade.

Fuel cells are systems that convert chemical energy directly into electrical energy and use hydrogen as fuel. Fuel cells are energy conversion systems that are clean, do not harm the environment and work with high efficiency, in addition to their thermal efficiency over 60%, which is 2-3 times that of gasoline engines. In this system, electrical energy is produced directly without the use of a steam boiler or turbine by the electrochemical reaction between hydrogen (H<sub>2</sub>) and oxygen (O<sub>2</sub>) (the opposite of water electrolysis). Fuel cells are also known as continuously operating batteries or electrochemical machines.

Fuel cells are classified according to operating temperature, electrolyte type and fuel type. If the operating temperature of the fuel cell is lower than 150 °C, it is called "low temperature fuel cell", and if it is between 500-1000 °C, it is called "high temperature fuel cell". Whereas low temperature fuel cells require simple fuel like hydrogen and good and expensive catalyst like platinum, high temperature fuel cells have the potential to use hydrocarbon fuel and cheaper catalyst. The electrolyte used can be acidic or basic. Fuel cell fuels are generally hydrogen, natural gas (methane), methanol and propane. Figure 1.3 shows a schematic of a fuel cell using ambient air and hydrogen. In the battery, potassium hydroxide (KOH) solution is used as the electrolyte and the battery mainly consists of two interlocking porous carbon tubes. As soon as the hydrogen flow from the inner tube starts, electricity production starts in the battery. As it passes through the outer tube in contact with the air, the oxygen separates from the air and enters the battery.

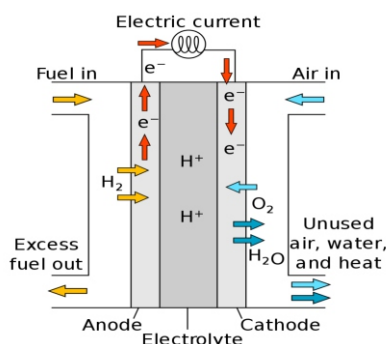


Fig. 3: Fuel cell using ambient air and hydrogen

Fuel cells are small in size, work with high efficiency, can achieve higher conversion than fossil fuels and waste heat can be used, as well as being portable, not containing moving parts, being built close to the user and in a short time, requiring very few environmental restrictions in the area to be built, fuel cells. In addition to pure hydrogen, natural gas, methanol or gas produced from coal can be used, quiet operation, not causing environmental and noise pollution, and no solid waste problems.

### 1.3. Sodium Borohydride and Fuel Cells

The role of sodium borohydride in energy production, which is a boron compound used as a hydrogen supplier in

fuel cells and on which the world works intensively, is gradually increasing. In fuel cells, sodium borohydride can be used in two main ways: 1. In hydrogen production other than the fuel cell, 2. In the fuel cell directly. Apart from the fuel cell, the catalyzed sodium borohydride solution is converted into hydrogen by passing through the hydrogen generation unit and this hydrogen is used in low temperature fuel cells. In this system, sodium borohydride catalytically gives hydrogen in aqueous medium. This technology is especially important in applications where hydrogen transport and storage is a problem such as weight, volume and safety. In direct sodium borohydride fuel cell, on the other hand, sodium borohydride is directly used as fuel without hydrogen production intermediate stage and electrical energy is produced. Direct sodium borohydride fuel cell is especially suitable for portable civilian (telephone, radio, small television, hand vacuum cleaner, etc.) and military (local lighting, mobile radio, telephone, electronic warfare devices, radio, personnel heating, unmanned vehicles, sensor etc.) is important in applications.

The advantages of producing hydrogen from sodium borohydride can be summarized as follows:

- 1) As a result of NaBH<sub>4</sub>-acetic acid reaction, controlled hydrogen release can be achieved.
- 2) The reaction occurs at room temperature and pressure and is exothermic. Therefore, no additional energy is required for the hydrogen to be released.
- 3) The NaBH<sub>4</sub>-acetic acid-PEG system can be an alternative system to other methods for hydrogen production.
- 4) The reaction products and solvent are harmless to the environment.
- 5) NaBH<sub>4</sub> is safe as a hydrogen source, non-flammable and non-hazardous.
- 6) NaBH<sub>4</sub> solution can stand for months without decomposition even in open air.
- 7) Since the freezing point of polyethylene glycol (PEG400) is -10°C, using polyethylene glycol in environments where water cannot be found in liquid form can also provide hydrogen at low temperatures.

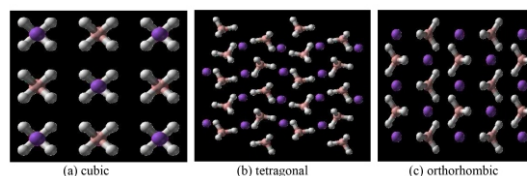


Fig. 4: Crystal structures of sodium borohydride

### 1.4. Fuel Cell Applications

Studies on the use of fuel cells as an automotive energy source are intensifying, especially within the scope of research for solutions to clean transportation. The proposed sodium borohydride fuel cell system for automotive applications is schematically given in Figure(4).

The first vehicle that uses fuel cells and is manufactured for research purposes is a hybrid vehicle that uses fuel cells and batteries. In this vehicle, the fuel cell and the battery are connected in parallel. While the fuel cell is used for stable driving power supply and battery charging; The battery temporarily provides additional power for starting and acceleration. The phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) electrolyte fuel cell, shown schematically in Figure (5), has been defined as the most technologically advanced fuel cell

today. The battery uses ambient air and hydrogen from fuels such as methanol. It is stated that the weight of the 15 kW battery is 237 kg, the volume is 0.25 m<sup>3</sup>, it gives 181 amps at 87 volts at atmospheric pressure and 177 °C operating temperature, and the power level of the battery can be changed by the number of elements or the active surface area.

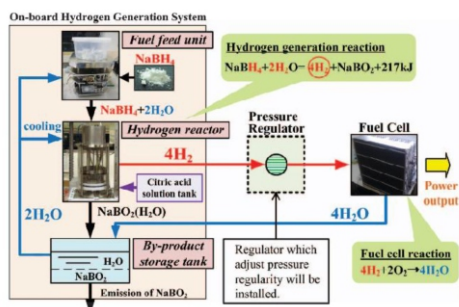


Fig. 5: The use of the H<sub>2</sub> storage system in vehicles via NaBH<sub>4</sub>



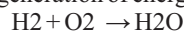
Fig. 6: Two cars powered by a fuel cell

The first vehicle that uses fuel cells and is manufactured for research purposes is a hybrid vehicle that uses fuel cells and batteries. In this vehicle, the fuel cell and the battery are connected in parallel. While the fuel cell is used for stable driving power supply and battery charging; The battery temporarily provides additional power for starting and acceleration. The phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) electrolyte fuel cell, shown schematically in Figure (5), has been defined as the most technologically advanced fuel cell today. The battery uses ambient air and hydrogen from fuels such as methanol. It is stated that the weight of the 15 kW battery is 237 kg, the volume is 0.25 m<sup>3</sup>, it gives 181 amps at 87 volts at atmospheric pressure and 177 °C operating temperature, and the power level of the battery can be changed by the number of elements or the active surface area.

### 1.5. Hydrogen Energy

In the last 100-150 years, the main energy sources have undergone a partial transformation from solid (coal) to liquid (petroleum) and from liquid to gas (natural gas, LPG) in recent years. This transition is expected to continue with hydrogen. Hydrogen is the simplest and most abundant element in the universe, discovered in the 1500s. It is a colorless, odorless, 14.4 times lighter than air and non-toxic gas. The fuel of the heat given by the sun and other stars through the thermonuclear reaction is hydrogen, and it is the main energy source of the universe. At normal pressure, its boiling point is -252 °C, its critical temperature is -234 °C, its critical pressure is 12.8 atm, and its critical density is 0.031 gcm<sup>-3</sup>. The volume of liquid hydrogen is 1/700 of its gaseous volume. Hydrogen has the highest energy content per unit mass of all known fuels (heat of combustion = -242 kJmol<sup>-1</sup> = -121 MJkg<sup>-1</sup>). The energy of 1 kg of hydrogen is equivalent to the energy of 2.1 kg of natural gas or 2.8 kg of oil. However, the volume per unit energy of hydrogen is high. Hydrogen is not found

in free form in nature, it exists in the form of compounds. The most well-known compound is water. It is clean and easy to use in any area that requires heat energy. During the generation of energy from hydrogen,



Except for water vapor and partially nitrogen oxides (NO<sub>x</sub>), no gas and harmful chemical substances (such as CO, CO<sub>2</sub>, C<sub>n</sub>H<sub>m</sub>, SO<sub>x</sub>) that pollute the environment and increase the greenhouse effect are produced. Research shows that under current conditions, hydrogen is about three times more expensive than other fuels and its use as a common energy source will depend on cost-reducing technological advances in hydrogen production. However, the inability to store electrical energy keeps hydrogen on the agenda as a storage medium. As a matter of fact, countries such as Canada and New Zealand, which have abundant hydroelectric energy resources, have started programs in this direction. This approach is based on the continuous operation of hydroelectric power plants at a certain intensity, and the excess energy is evaluated in the production of hydrogen by electrolysis of water and energy is stored in this way.

### 1.6. Hydrogen Production and Storage

It is accepted that the most advanced technology that can provide the world's increasing energy needs without polluting the environment and sustainably is the hydrogen energy system. Every year, 500 billion m<sup>3</sup> of hydrogen is produced, stored, transported and used in the world. The chemical industry, especially the petrochemical industry, has the largest share of users. In our country, gas or liquid hydrogen is produced in pressurized cylinders to be used in the artificial fertilizer industry (25000 m<sup>3</sup>), vegetable oil (margarine) production (16000 m<sup>3</sup>), oil refineries (1200 m<sup>3</sup>), the petrochemical industry (30.000 m<sup>3</sup>) and in various places. There is no commercial hydrogen production for power generation purposes. Production sources of hydrogen are plentiful and diverse. It can be obtained from fossil fuels such as coal and natural gas, as well as by using renewable energy sources such as solar, wind and hydraulic energy, it is possible to produce from water electrolysis, biomass and biotechnological processes. Today, hydrogen is mainly obtained from the reaction of natural gas with water vapor. Perhaps the most important feature of hydrogen is that it is storable. As it is known, there is still no suitable method for storing large amounts of energy today. If it were possible to store the energy obtained from hydroelectric power plants today, it would be possible to solve the energy problem to some extent. However, the best known storage method for electrical energy is still accumulators. Hydrogen can be stored in pure form as a gas or liquid in tanks, as well as physically in carbon nanotubes or chemically in the form of hydrides. The advantages of sodium borohydride over other hydrogen transport media are summarized below:

- ü It can store 20% hydrogen by weight,
- ü It is not flammable/explosive,
- ü The reaction can be easily controlled,
- ü Catalyst and sodium metaborate are reused.

### 1.7. Development of Hydrogen Energy Technology in the World

Fuel cells have proven their role in space, as they have safely provided electricity (and water) on shuttle missions. These achievements led to predictions that fuel cells could be the solution to all of the world's energy problems in the 1960s, and in the 2000s, they started to take an important

place in the energy policies of countries. America is marketing the phosphoric acid type fuel cell that provides 200 kW of energy. The 11 MW power plant in Japan meets the electricity and heat needs of Rokko island, and 40000 kW of the city's electricity needs in Tokyo are provided by hydrogen energy systems. Canada has offered generators with 250 kW of electricity and 230 kW of thermal power, using PEM type fuel cells.

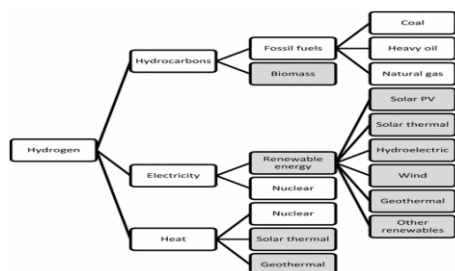


Fig. 7 : Production sources and methods of hydrogen

In the transportation sector, the development of fuel cell-powered vehicles will not only reduce oil consumption, but also minimize air pollution caused by vehicles. In addition to Canada, which produces fuel cell buses, the world's leading automotive companies are trying to commercially produce cars powered by fuel cells. A large number of sample vehicles have been produced since 1993. A new bus running on hytane, a mixture of 15-20% hydrogen and 80-85% natural gas, has been trialled since 1993 in Montreal (Canada). In addition to vehicles, Locomotives for the Canadian railways and submarines for the German, Australian and Canadian navies have also been manufactured for the use of hydrogen through internal combustion engines or fuel cells. Generally, in these vehicles, the system moves with an electric motor, there is no engine, piston, crank and gearbox. Hydrogen has been used as an unrivaled fuel in space shuttles and all other rockets for many years.

### 1.8. Hydrogen Energy and Turkey

Turkey is a country with the richest and highest quality boron minerals reserves in the world with a share of approximately 65%. In order for Turkey to transform its richness of boron ores into added value and to reach a position compatible with this richness in the world boron market, it is necessary to start the production of boron compounds that can be widely used in large quantities. Turkish Boron Research Institute carries out and coordinates R&D activities for the production of boron compounds with high added value and their use in critical technology areas. The production of sodium borohydride and its use in fuel cells are good examples of these compounds. Two projects on "Sodium Borohydride Synthesis and Production" and "Direct Sodium Borohydride Fuel Cell Production and Integration" supported by the Boron Research Institute are carried out at TÜBİTAK MAM. Another pleasing development regarding Hydrogen and Hydrogen Energy is the establishment of the "United Nations International Center for Hydrogen Energy Technologies (ICHET)" in Istanbul. The agreement regarding this Center was signed between Turkey and the United Nations on 21 October 2003 in Vienna. The main purpose of the Istanbul Center for hydrogen energy, which is called the energy of the future, to which the international energy circles attach great

importance, together with our country, is to carry out all kinds of research and development activities related to hydrogen and hydrogen energy, to ensure coordination among investor institutions, to determine the application areas of the future hydrogen technology and industry .

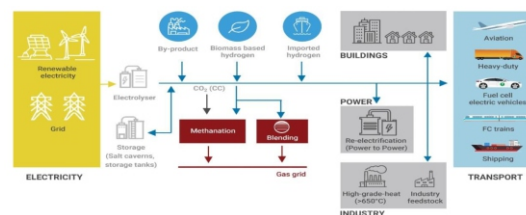


Fig. 8: Hydrogen energy system

### 1.9. Acetic Acid and Polyethylene Glycol

Acetic acid, also known as ethanoic acid or acetic acid, is an organic acid with open formula  $\text{CH}_3\text{COOH}$  and closed formula  $\text{C}_2\text{H}_4\text{O}_2$ . It is the acid that gives vinegar its pungent smell and sour taste. It is the most important and smallest of the carboxylic acids. It is obtained by oxidation of carbohydrates in nature. It can be obtained biologically and synthetically in the industrial sector. The salt and ester of acetic acid, completely soluble in water, is called "acetate". It is referred to as ethanoic acid in the chemical industry. Pure acetic acid has a sharp, colorless, acrid odor and boils at 118 degrees Celsius and freezes at 16.7 degrees Celsius. When mixed with water, it absorbs water, irritates the skin and corrodes metals. The main ingredient of vinegar, which is obtained by fermenting wine or yeast, is acetic acid. Acetic acid, which has a wide use in industry, is evaluated as a raw material in the production of chemicals. It is used extensively in the production of vinyl acetate. Wood glue is obtained from this. It is also used in the production of acetic ester and acetic anhydride. It is also used as a solvent. It is used as a solvent in the production of terephthalic acid, which is used in pet plastic production. This accounts for about 5-10% of the use of acetic acid. Since it has a buffer feature in the food industry, it is used as an additive as E260. Its derivatives are also used in different fields. Sodium acetate is used as E262 in the weaving industry and as a food additive.

Polyethylene Glycol (400) (PEG) is colorless, odorless, viscous. Polyethylene Glycol is the most important glycol commercially available and produced in the world. It can be used in the production of an antifreeze and coolant, hydraulic fluids and low-freezing dynamites and resins. Polyethylene glycol is a polyether compound with many applications. It can be used in industrial and pharmaceutical production. Polyethylene glycol is produced through the interaction of ethylene oxide with water, ethylene glycol or ethylene glycol oligomers. PEG is used as an excipient in many pharmaceutical products. Low molecular weight variants of Polyethylene Glycol are used as solvents in oral liquids and soft capsules. Solid variants of Polyethylene Glycol are used as ointment bases, tablet binders, film coatings and lubricants. It can be used to create very high osmotic pressures with the flexible, water-soluble polymer property of Polyethylene Glycol. There is no possibility of specific interaction with biological chemicals in Polyethylene Glycol.

### 1.10. Problem Status

In the research, during the interview, the problem situation was determined as follows:

In this study, "Controlled, Efficient Hydrogen Recovery

from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" constituted the problem of this research.

#### 1.11. Purpose of the Research

The aim of this study is to conduct "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells". In this study, a literature review was conducted to collect data and the resources related to the subject were examined. Then, experiments related to the subject of the project were carried out. By analyzing the data and information we obtained during the project, "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" was examined.

#### 1.12. Importance of the Research

It is seen that there is limited research in our country and internationally on the subject of "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells". For this reason, it was found important to conduct a research on this subject. The findings of this research,

1. The importance of "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" will be revealed,
2. "Controlled, Efficient Hydrogen Recovery and Fuel Cell Design from Sodium Borohydride with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" will help to be more constructive and permanent,
3. It will provide opportunities for reflection, discussion and new research on "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells",
4. It will provide preliminary information to the persons or organizations that will carry out the studies to be carried out on the "Controlled and Efficient Hydrogen Recovery from Sodium Borohydride with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells",
5. "Controlled, Efficient Hydrogen Recovery and Fuel Cell Design from Sodium Borohydride with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" will be beneficial to the industry and economy of our country,
6. "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells", it would be beneficial to use polyethylene glycol instead of water as a solvent,
7. In addition, the findings obtained, educators who are interested in this subject; It is thought that it will be useful to researchers who will do research and develop projects in this field.

#### 1.13. Counts

While conducting the research, the following assumptions were made:

1. Experiments of "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells and Fuel Cell Design" within

the scope of the research accurately reflect the findings.

2. The experiments of "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" are of the nature to serve the purpose of the research.

#### 1.14. Limitations

The research is limited to the following dimensions in terms of the area it covers and the data it benefits from:

1. This research, with the data of the literature review and experiments conducted in 2021,
2. With the generalization included in the research from the internal and external factors affecting the experiments,
3. The research is limited to the findings of the experiments of "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells".

## 2. Method

In this section, information about the research model, universe and sample, data collection tool, data analysis and interpretation are given.

#### 2.1. Research Model

In this research, which aims at "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells", a literature review has been made and resources related to the subject have been examined. Then, experiments related to the subject of the project were carried out. The data and information we obtained during the project were analyzed and the information obtained from "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" was analyzed and analyzed. The results were edited and evaluated using Microsoft Office programs.

#### 2.2. Universe and Sample

The universe of this research is "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells". Examples in the research universe are "resource scanning" and "observation, experiment and content analysis/text analysis etc." selected by methods.

#### 2.3. Data Collection Tool

In this study, "resource review" and "observation, experiment and content analysis/text analysis etc." were used to collect data. used. The works related to the subject and the libraries where these works are located have been determined.

#### 2.4. Analysis and Interpretation of Data

In order to collect data that will answer the problem and sub-problems of the research, "resource scanning" and "observation, experiment and content analysis / text analysis, etc." The obtained data were collected by the researcher. The results were edited and evaluated using Microsoft Office programs.

## 3. Findings

### 3.1. Materials

All materials used for this experiment were purchased commercially:

NaBH<sub>4</sub>, Polietilen Glikol 400 (C16H34O9), CH<sub>3</sub>COOH HCl, C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, CH<sub>2</sub>O<sub>2</sub>, Schlenk Tube, 50 ml Burette, Micro pipette, Septum, Magnetic heater stirrer, Magnetic fish, Precision balance, Silicone hose, Stopwatch



Fig. 9: Experimental Setup

### 3.2. Experimental Studies

\* NaBH<sub>4</sub> was weighed with a precision balance at the appropriate rates determined in terms of hydrogen yield.

\* 3 mL of Polyethylene Glycol measured with a pipette was added into the Schlenk tube.

\* NaBH<sub>4</sub> was also added to this tube and attached to the assembly with a clamp and placed on the magnetic stirrer.

\* The burette device in the water has been prepared.

\* The burette and the schlenk tube were connected with a silicone hose.

\* Acid was added to the tube closed with a septum at the specified molar ratio.

\* With the added acid, the stopwatch and magnetic stirrer were operated at 500 rpm.

\* The volume of hydrogen released was measured over time.

\* In this study, polyethylene glycol was used as a solvent.

\* The main purpose of this selection is to facilitate the use of PEG in low air temperature environments.

\* NaBH<sub>4</sub>, which reacts very slowly in the alcohol environment, reacts rapidly in the presence of acid and releases hydrogen gas.

\* In the study, the effect of different acids was tested at room temperature.

\* In the research, the effect of acetic acid (CH<sub>3</sub>COOH), hydrochloric acid (HCl), formic acid (CH<sub>2</sub>O<sub>2</sub>) and benzoic acid (C<sub>6</sub>H<sub>5</sub>COOH) on the reaction of obtaining hydrogen gas from NaBH<sub>4</sub> was investigated.

\* Depending on the ratio of the acid used in the reaction of the proton (hydrogen) of the acid used with NaBH<sub>4</sub>, it combines with the proton in BH<sub>4</sub><sup>-</sup> to form hydrogen gas and sodium acetoxyboron hydride (NaBH<sub>3</sub>(OAc), NaBH<sub>2</sub>(OAc)<sub>2</sub>, NaBH(OAc)<sub>3</sub>, or NaB(OAc)<sub>4</sub> sodium mono, di, triacetoxy borohydride and sodium tetraacetoxy boron) compounds are formed.

\* The boron compound reacts (alcolysis) with the PEG used as a solvent to form hydrogen gas.

### 3.3. How does it work?

Fuel cell, with supplied fuel (anode side) and oxidizer (cathode side). When these react in an electrolyte environment, it produces electricity. This reaction takes

place with the effect of a catalyst. The reacting fuel is split into electrons and positively charged ions (anions). Electrolytic material allows anions to pass to the cathode, but does not allow electrons to pass, so electrons are forced to flow through an electronic circuit (electric current (DA)) Electrons recovered by another catalytic process combine with anions and oxidizer to produce waste products (e.g. water, carbon dioxide). With these two catalytic processes, the interior of the fuel cell remains stable, unlike the cells, and they can generate electricity as long as the required material flow is provided.

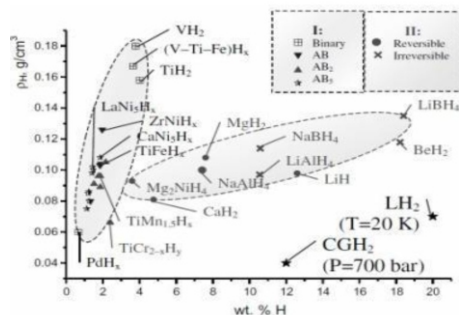


Fig. 10: Hydrogen storage capacities of metal hydrides

## 4. Results

Effect of different acids:

In the study, the hydrogen gas output as a result of the acid reaction with sodium borohydride was measured volumetrically and the results are given in Figure 3.6. The effect of different acids in this reaction was investigated and although formic acid, which provides the highest hydrogen gas output among the acids used, acetic acid was used in the studies because it was more economical in terms of cost.

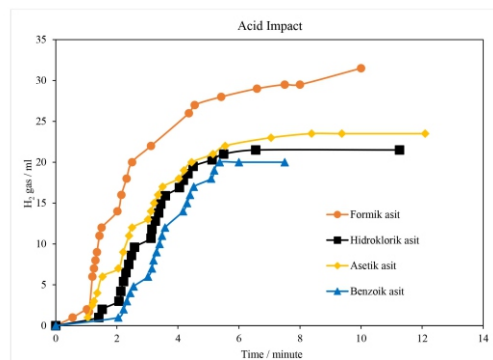


Fig. 11: Different Acid Impact

Reaction Conditions: 20 mg ( $5.2 \times 10^{-4}$  mol); NaBH<sub>4</sub>;  $5.2 \times 10^{-4}$  moles (30  $\mu$ L) Acid; 3 mL of PEG; P=1 atm; T=19 °C; mixing speed= 600 rpm

Effect of water-PEG mixture:

The acid reaction with NaBH<sub>4</sub> in the medium of water-PEG mixture at different ratios was examined and the graph drawn using the results is given in Figure 3.7. Although the H<sub>2</sub> gas output is higher in volume in the presence of water under the studied experimental conditions, the use of PEG provided the regulation of the reaction. In the presence of water, H<sub>2</sub> gas was obtained uncontrollably and rapidly in a short time.

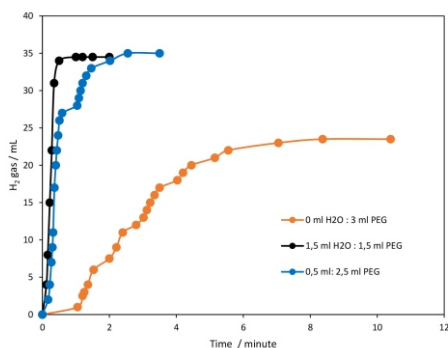


Fig. 12: Obtaining H<sub>2</sub> gas in the presence of water

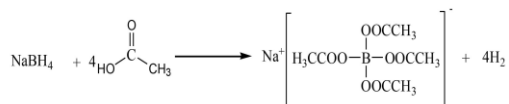
Reaction Conditions: 20 mg ( $5.2 \times 10^{-4}$  mol); NaBH<sub>4</sub>;  $5.2 \times 10^{-4}$  moles (30  $\mu$ L) Acetic Acid; 3 mL of PEG + H<sub>2</sub>O; P=1 atm; T=19 °C; mixing speed = 600 rpm

Effect of the amount of acid:

Figure (13) shows the graphs showing the time-dependent pleasure outputs in the results of the experiment performed by changing only the acid ratios and keeping the other parameters constant.

The reaction requirement shown below is that when NaBH<sub>4</sub> and acetic acid react in a 1:4 mole ratio, 4 moles (50ml) of H<sub>2</sub> gas is theoretically released.

NaBH<sub>4</sub>-acid reaction:



As a result of the experiments, more gas was released than expected in the experiments performed at 1:0.33, 1:1, 1:1.7 and 1:6.7 NaBH<sub>4</sub>:Acid ratios. On the contrary, less gas output than expected was observed in the experiment performed at a ratio of 1:6.7. As a result of these observations, it was decided that an alcoholysis reaction took place between polyethylene glycol and NaBH<sub>4</sub>.

Since the substance that bonds with the hydrogen atom in the structure of NaBH<sub>4</sub> and provides gaseous release is both acetic acid and polyethylene glycol, no definite information about the percent efficiency of the experiment has been reached. However, it was determined that the efficiency of the experiment performed with a ratio of 1:6.7 was not 100%.

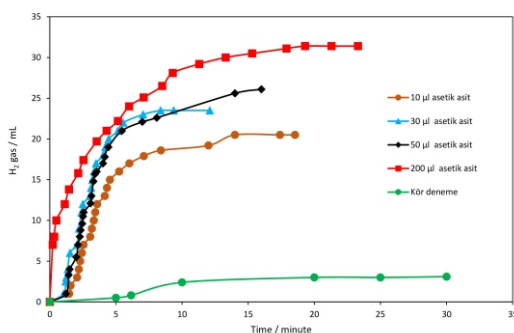


Fig. 13: Effect of the amount of acetic acid

Reaction Conditions: 20 mg ( $5.2 \times 10^{-4}$  mol); NaBH<sub>4</sub>;  $5.2 \times 10^{-4}$  moles (30  $\mu$ L) Acetic Acid; 3 mL of PEG; P=1 atm; T=19 °C; mixing speed = 600 rpm

Table 1: Theoretical and experimental hydrogen gas outputs in sodium borohydride-acid reaction

NaBH <sub>4</sub> : Acetic acid (mol)	H <sub>2</sub> (mL) (THEORIC)	H <sub>2</sub> (mL) (EXPERIMENTAL)
1:0,33	4,17	20,5
1:1	12,5	23,5
1:1,7	20,9	26,0
1:6,7	50,0	31,0

Temperature influence:

NaBH<sub>4</sub>-acid reaction was investigated at two different temperatures (0 °C and 19 °C). In these experiments, other reaction parameters except temperature were kept constant. (Fig. 3.9). Although the efficiency of the reaction is higher at room conditions, the reaction takes place at 0 °C, albeit at a slow rate.

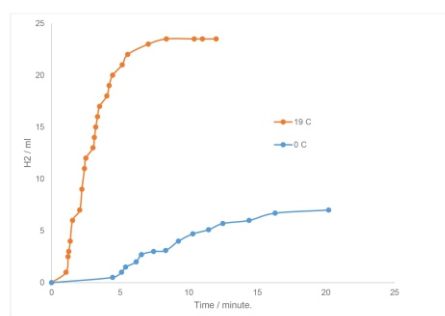


Fig. 14: Hydrogen yield of acetic acid at different temperatures

Reaction Conditions: 20 mg ( $5.2 \times 10^{-4}$  mol); NaBH<sub>4</sub>;  $5.2 \times 10^{-4}$  moles (30  $\mu$ L) Acetic Acid; 3 mL of PEG; P=1 atm; mixing speed = 600 rpm

## 5. Conclusion and Discussion

In this section, the results obtained from the findings related to the research questions are given. Then, the findings and results revealed in the research were discussed by considering the relevant subject. Apart from these, explanations about the theoretical dimensions, method and findings of the study and suggestions for similar researches to be made in the future are included.

### 5.1. Conclusion

The advantages of producing hydrogen from sodium borohydride in a PEG medium can be summarized as follows:

1. As a result of NaBH<sub>4</sub>-acetic acid reaction, controlled hydrogen release can be achieved.
2. The reaction occurs at room temperature and pressure and is exothermic. Therefore, no additional energy is required for the hydrogen to be released.
3. NaBH<sub>4</sub>-acetic acid - PEG system can be an alternative system to other methods for hydrogen production.
4. The reaction products and solvent are harmless to the environment.
5. NaBH<sub>4</sub> is safe as a hydrogen source, non-flammable and non-hazardous.
6. NaBH<sub>4</sub> solution can stand for months without decomposition even in open air.
7. Since the freezing point of polyethylene glycol

(PEG400) is  $-10^{\circ}\text{C}$ , using polyethylene glycol in environments where water cannot be found in liquid form can also provide hydrogen at low temperatures.

As a result;

Electric energy is obtained from hydrogen with fuel cell technology.

In the transportation sector, the development of fuel cell-powered vehicles will not only reduce oil consumption, but also minimize air pollution caused by vehicles.

In addition to Canada, which produces fuel cell buses, the world's leading automotive companies are trying to produce cars powered by fuel cells commercially. Our domestic and national fuel cell, which we developed in our project, can be used in the domestic and national automobile (TOGG) to be produced in our country. (<https://www.togg.com.tr>)

A large number of sample vehicles have been produced since 1993. A new bus running on hytane, a mixture of 15-20% hydrogen and 80-85% natural gas, has been trialled since 1993 in Montreal (Canada).

In addition to vehicles, Locomotives for the Canadian railways and submarines for the German, Australian and Canadian navies have also been manufactured for the use of hydrogen through internal combustion engines or fuel cells.

Generally, in these vehicles, the system moves with an electric motor, there is no engine, piston, crank and gearbox. Because the most important factor that determines the competition in electric cars is not design, but also production. It is "Fuel Cell" technology.

Hydrogen has been used as an unrivaled fuel in space shuttles and all other rockets for many years.

In the last 100-150 years, the main energy sources have undergone a partial transformation from solid (coal) to liquid (petroleum) and from liquid to gas (natural gas, LPG) in the last years. This transition is expected to continue with hydrogen.

Fuel cells are systems that convert chemical energy directly into electrical energy and use hydrogen as fuel.

Fuel cells are energy conversion systems that are clean, do not harm the environment and operate with high efficiency, in addition to their thermal efficiency over 60%, which is 2-3 times that of gasoline engines.

In this system, electrical energy is produced directly without the use of a steam boiler or turbine by the electrochemical reaction between hydrogen ( $\text{H}_2$ ) and oxygen ( $\text{O}_2$ ) (the opposite of water electrolysis).

Considering the boron ore potential of our country, the importance of sodium borohydride fuel cells in our country's energy production increases even more.

As a result of our project work on obtaining controlled and efficient hydrogen from acetic acid and sodium borohydride for fuel cells, it will be a very important guide in future project studies.

## 5.2. Argument

In the research, "Problems in fuel cells; in hydrogen energy; Hydrogen production systems that are economical, controlled, efficient, can be obtained even at low temperatures and do not harm the environment are still the subjects of intensive research. We have contributed to this field with the work we have done, and from the results obtained, it is understood that our work is open to development and that it should be continued and developed.

## 5.3. Suggestions

1. Since the biggest problem of the last century, which emerged as a result of developing technology and increasing population, will reduce the energy problem, systems for "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" should be established.

2. Since fossil fuels will be depleted in the near future and the main cause of environmental pollution is largely due to the use of fossil fuels, systems for "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells" should be developed.

3. Since the use of fuel cells is seen as the most appropriate solution within the scope of finding new, renewable energy sources that are harmless to the environment and developing new technologies, the systems for "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst for Fuel Cells in Polyethylene Glycol Environment" The financial and moral support needed for the establishment should be provided.

4. The regional and national reasons for "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride with Acetic Acid Catalyst and Sodium Borohydride for Fuel Cells in Polyethylene Glycol Environment and Fuel Cell Design" should be revealed and studies should be carried out to eliminate these reasons.

5. This study will make a positive contribution due to the lack of such studies on "Controlled, Efficient Hydrogen Recovery from Sodium Borohydride and Fuel Cell Design with Acetic Acid Catalyst in Polyethylene Glycol Environment for Fuel Cells".

6. With the development of fuel cells, types that use hydrocarbon fuels and air, which still meet the power needs in some limited areas, it can be a serious competitor to today's traditional power sources in automotive and other fields in the near future, "For Fuel Cells Controlled from Sodium Borohydride with Acetic Acid Catalyst in Polyethylene Glycol Environment" Our "Effective Hydrogen Recovery and Fuel Cell Design" project should be evaluated carefully as it will provide added value to our country.

7. In order for Turkey to transform its richness of boron ores into added value and to reach a position compatible with this richness in the world boron market, it is necessary to start the production of boron compounds that can be widely used in large quantities.

8. R&D activities should be carried out on the production of sodium borohydride and its use in fuel cells.

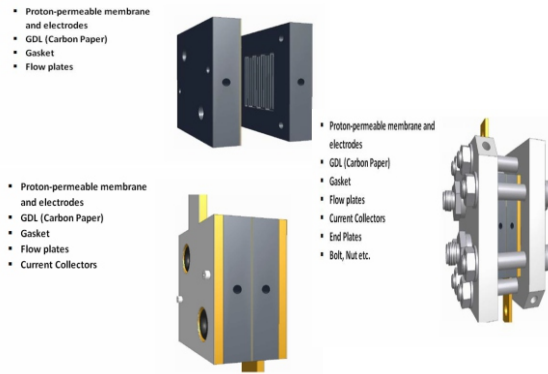
9. It is thought that carrying out our project work at the national and international level will produce beneficial results.

10. Our domestic and national fuel cell, which we developed in our project, can be used in the domestic and national automobile (TOGG) to be produced in our country. Because the most important factor that determines the competition in electric cars is not design, but also production. It is "Fuel Cell" technology. (<https://www.togg.com.tr>)

11. With these suggestions, the results of our project work can be evaluated.

## 5.4. Design of Fuel Cell

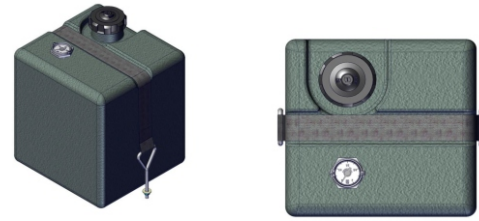
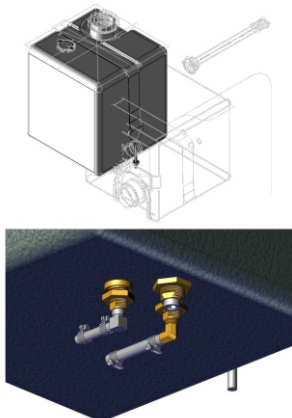
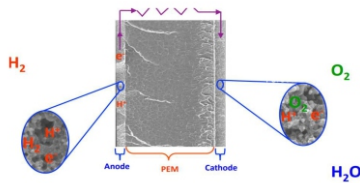
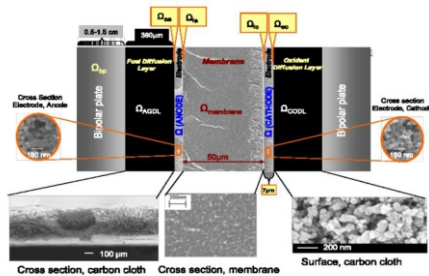




### 5.5. 3D Modeling of Fuel Cell Design



### 5.6. Structure of Fuel Cell



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