# INVESTIGATING ACUTE COIN DISCOLORATION BY SOLUTION IMMERSION

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT FOR THE
DEGREE OF BACHELOR OF SCIENCE (HONS) IN FORENSIC SCEINCE

MUHAMMAD FAKHRIY BIN AB.LLAH

SCHOOL OF HEALTH SCIENCES
UNIVERSITI SAINS MALAYSIA
HEALTH CAMPUS
16150, KUBANG KERIAN, KELANTAN, MALAYSIA

2015

# ACKNOWLEDGEMENTS

My gratitude to the Almighty Allah for His blessing and giving me strength and patience to complete my undergraduate research project entitled **"Investigating Acute of Coin Discoloration by Solution Immersion"**.

First of all, I would like to thank my supervisor, Dr. Helmi Mohd Hadi Pritam who gave me guidance and support which helped me a lot throughout the research.

I also would like to thank my examiner, Dr. Noor Zuhartini Binti Md Muslim for her guidance. With her helped, I manage to improvise my thesis especially in term of writing.

I would also like to thank Mr. Mohd Din from BIMB (Pasir Tumboh) for providing the standard 20 sen coins that was really hard to get. Without his help, I would go by myself to Bank Negara Malaysia in Kuala Lumpur which was really a long journey.

I also would like to thank all lecturers, staff and course mates who directly or indirectly helped me in this study.

I also would like to express my indebtness to my parents, Mr. Ab.llah Bin Rashid and Mrs. Saadah Bt. Hj. Ibrahim for their encouragement and support. Thank you.

# CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| BNM | Bank Negara Malaysia (Central Bank of Malaysia) |
| SCC | Stress-corrosion cracking |
| MIC | Microbiologically-induced bacteria |
| NaCl | Sodium Chloride |
| $Cl^-$ | Chloride ions |
| $Na^+$ | Sodium ions |
| $SO_4^{2-}$ | Sulfate ions |
| $Mg^{2+}$ | Magnesium ions |
| $Ca^{2+}$ | Calcium ions |
| $K^+$ | Potassium ions |
| $HCO^{3-}$ | Bicarbonate ions |
| $Br^-$ | Bromide ions |
| $Sr^{2+}$ | Strontium Ions |
| $B^{3+}$ | Boron ions |
| $F^-$ | Fluorides |
| $Mo^{2+}$ | Molybdenum ions |
| $Cu_2(OH)_3Cl$ | Dicopper chlorides trihydroxides |
| $Cu_2O$ | Copper (II) oxides |
| $CuCl_2$ | Copper (II) chlorides |
| S | Sulfur |
| O | Oxygen |
| C | Carbon |
| $OH^-$ | Hydroxide ions |
| Ni | Nickel |
| Zn | Zinc |

| | |
|---|---|
| FTMS | Fourier Transform Mass Spectrometer |
| LAMMA | Laser Microprobe Mass Analyzer |
| EPS | Extracellular polymeric substances |
| $H_2S$ | Dihydrogen sulfide |
| H | Hydrogen |
| sp. | Species |
| $O_2$: | Oxygen |
| $CO_2$ | Carbon dioxide |
| PCB | Pantai Cahaya Bulan |
| WQI | Water Quality Index |
| $K^+$ | Potassium ion |
| SRB | Sulfate-reducing bacteria |

# ABSTRACT

The third series of the 20 sen and 50 sen coins made of nickel-brass are prone to discolouration after few years of circulation. The discolouration causes the brass colour golden coins to change greenish in colour. In order to investigate the discoloration, new 20 sen coins were exposed to various environmental conditions to simulate worst case scenario. New coins morphology and weight recorded and then were submerged in containers containing seawater, river water, well water, bleaching agent, fizzy drink (Pepsi, Root beer and Orange Mirinda), 10g NaCl solution, 50g NaCl solution and 100g NaCl solution with a control coin not submerged in any solution and placed in normal room temperature. Daily observations were made in 30 days by using stereomicroscope to identify the pattern of discoloration of each coin. Results indicate that each solution can caused corrosion and produced different pattern discoloration of the coins. It is hoped that a discoloration timeframe is obtained which would be useful for forensic investigations and that the findings would be useful for future coin design.

# ABSTRAK

Siri ketiga syiling 20 sen dan 50 sen syiling diperbuat daripada nikel-tembaga cenderung kepada perubahan warna selepas beberapa tahun edaran. Perubahan warna telah menyebabkan warna emas tembaga syiling berubah menjadi warna kehijauan. Dalam usaha menyiasat perubahan warna, 20 sen syiling baru didedahkan dengan pelbagai keadaan persekitaran untuk mensimulasikan senario terburuk. Morfologi dan berat syiling baru direkodkan dan kemudian ditenggelamkan di dalam bekas yang mengandungi air laut, air sungai, air telaga, agen pelunturan, minuman bergas (Pepsi, bir akar dan Orange Mirinda), larutan 10g NaCl, larutan 50g NaCl dan larutan 100g NaCl dengan syiling kawalan yang tidak tenggelam di dalam apa-apa larutan dan diletakkan di dalam suhu bilik normal. Pemerhatian harian yang dibuat dalam masa 30 hari dengan menggunakan stereomikroskop untuk mengenal pasti corak perubahan warna setiap syiling. Hasil keputusan menunjukkan bahawa setiap larutan boleh menyebabkan hakisan dan menghasilkan corak perubahan warna yang berbeza daripada syiling. Diharapkan bahawa jangka masa perubahan warna yang diperolehi akan berguna untuk siasatan forensik dan penemuan ini akan berguna untuk reka bentuk duit syiling pada masa hadapan.

# CHAPTER 1

# INTRODUCTION

## 1.1: Background of study

Coins are metal made of nickel brass, an alloy of copper have a tendency to undergo corrosion. Corrosion can be defined as chemical or electrochemical reaction which metal undergoes destruction when attacked by its environment. If the metal is deteriorated by physical means, this metal cannot be described undergoing corrosion but is described as erosion, galling or wearing. Besides, coins are also susceptible to rusting. Rusting is a form of corrosion which undergoes only to iron or iron-base alloys only with the formation of corrosion products consisting largely of hydrous ferric oxide (Revie & Uhliq, 2008).

Generally, corrosion involves electrochemical reaction. Electrochemical reaction is subdivided into oxidation and reduction process. Oxidation and reduction process undergo simultaneously for corrosion to occur. Electrochemical reaction is a reaction in which currents flow from cathode to anode. At the cathode, the reduction process occur involving reduction of oxygen into hydroxyl ion (Revie & Uhliq, 2008). At the anode, oxidation of metal occurs then liberated into the solution as hydrated metal ions or solid metallic compound on the surface (Butler & Ison, 1976). Corrosion of metal usually occurs at the anode.

In this research, the types of corrosion which 20 sen coins undergo are stress-corrosion cracking (SCC). Stress-corrosion cracking is a cracking due to a process involving conjoint corrosion and straining of metal due to residual or applied stresses (National Physical Laboratory, 2000). According to Revie & Uhliq (2008), metal will form cracks when it is subjected to a constanttensile stress and exposed to a specific corrosive environment. Cracks which are formed can be either immediately or after a given time.

According to National Physical Laboratory (2000), basically there are three requirements which must be present for SCC to occur. The requirements are:

I. a susceptible of materials
II. environment for SCC to occur and
III. sufficient tensile stress

## 1.2: History of coins in Malaysia

Bank Negara Malaysia (BNM) has produced three series of coins since 1967. The first series was introduced in 1967 when BNM was replacing The Malaya and British Borneo Dollar. At that time, 1 sen, 5 sen, 10 sen, 20 sen and 50 sen were the denomination in circulation. One ringgit coins were introduced later in 1971. All coins of the first series were made of cupronickel except 1 sen coin which was made of bronze (Wikipedia, 2015).

The second series of coins were introduced in 1989. The second series incorporates Malay culture as the theme. These second series of coins was designed by Low Yee Kheng were made of cupronickel except for the one sen (bronze and copper) and 1 ringgit coins (zinc and tin) (Wikipedia, 2015).

The third series coins were introduced in early 2012 with a theme "Distinctively Malaysia". This theme was inspired from flora and fauna motif which can be found in various cultures in

Malaysia. These third series are made of stainless steel for 5 sen and 10 sen, nickel brass for 20 sen and nickel brass clad copper for 50 sen (Wikipedia, 2015).

### 1.3: Definition and Morphology of 20 sen coins.

Coins can be defined as small, flat and piece of metal which is issued by government as money (http://www.merriam-webster.com/dictionary/coin). The 20 sen coins has evolved drastically so in terms of raw materials, shape, size, color and design since its early establishment. The coin of third series is made of nickel brass with shiny gold-like appearance. Technically, the 20 sen coin has a round shape, yellow in color, coarse edge, has 20.60 mm in diameter with 4.18 g of weight. In general, the 20 sen coin is smaller, lighter and user friendly compared to the previous series (BNM, 2011).

There are common features present in the third series of coins. Each denomination represents different symbols. On the obverse site, 14 dots represents 13 states and the Federal Territory (except 50 sen coin) and five horizontal lines which represent the five principles of the 'Rukun Negara' (national pillars). Unique to 20 sen coin only is presence of 'Bunga Telur' (Jasmine flower) which represents the cultural significant of the three major races in Malaysia. On the reverse side, 'Bunga Raya' (Rosa-sinensis hibiscus) which represents the national flower of Malaysia, numerals which represents the year of minting, the face value of the coin and the words 'BANK NEGARA MALAYSIA' (BNM, 2011)

The gold-like appearance of 20 sen coin and its edge design enable the public to visualize its color as well as to identify and differentiate any impairment in the coins. It incorporates modern, practical features and latest advancements in technology to improve the durability and security.

The nickel brass employed in the process of 20 sen has higher durability and resistance to corrosion (BNM, 2011).

## 1.4: Research Problem

BNM has established Guidelines on Quality Standard for Malaysian Currency which objective is that to provide clear and acceptable requirements and standard for determining the quality of currency in circulation. The coin that has features which render it is not suitable for circulation. This phenomenon is called unfit currency. The coin is said to fit circulation when it meet four requirements; genuine, free from soiling or discoloration, free from defects and not ruins coin (BNM, 2012).

The 20 sen coin of the third series has a tendency to change color from gold-like appearance to greenish color in short period of time compared to the previous series circulated by BNM. The same problem also occurs in the 50 sen coin. According to Guidelines on Quality Standard for Malaysian Currency by BNM, discoloration of coin is one of eight criteria which unfit for circulation (BNM, 2012). The discoloration occurs after few years of circulation. This becomes concern since both 20 sen and 50 sen coins of third series are gradually to replace the previous series of coins in the future.

In order to identify the factors which cause discoloration, the research was conducted with the 20 sen coins were exposed to several types of water which represent several kinds of environment in Malaysia.

## 1.5: Significance of study

Since the coins entered circulation in 2012, BNM noticed some coins discolor rapidly. The discoloration pattern is random and rarely seen in the previous series of coins. It is hoped that, the outcome of this research will aids BNM in designing and developing future coins.

## 1.6: Objectives

### 1.6.1: General Objective

To determine what solution that can cause the discoloration of gold color to greenish color of the surface of 20 sen coin.

### 1.6.2: Specific objectives

1. To determine the specific site surface on coin where changing of color and corrosion occurs on the surface 20 sen coin.

2. The time duration needed for discoloration of 20 sen coin.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1: Nickel Brass Alloys

According to BNM (2011), 20 sen coins are made of nickel-brass alloys. Nickel-brass alloys have magnificent color which has always been adapted as coinage. Nickel-brass alloys are the ternary alloys which are composed of nickel, copper and zinc. Alloy is a mixture of two or more metals or a metal with non-metal which fuse together to form a new solid metal (Kakani & Kakani, 2004). Nickel-brass alloys have characteristics of hardness, corrosion resistant and ductile and no existence of silver elements (Milosev & Kosec, 2007). Due to these properties, nickel-brass is frequently adapted in the making of jewellery, watches and spectacles (Colin et. al., 1997). Although brass is copper-based alloy, zinc is basically higher percentage and predominant compare to the copper. Copper-based alloys commonly selected as coins due to strong and corrosion resistance, easy to mint (sufficiently soft and ductile), difficulty to counterfeit, recyclable and safe to human health, (Callister,Jr., 2007).

## 2.2: Factors that can cause corrosion

### 2.2.1: Metallic corrosion by human hand sweat

Based on a related study regarding copper alloys, copper alloys tend be discolor appearing less attractive when exposed to repeated hand contact (Fredj et. al., 2013). Burton et al. (1976) reported that human hands can tarnish the metals as they touch it. Since sweat contains sodium chloride (NaCl), this NaCl can cause the corrosion on metals. According to Lind et al (1972), NaCl contributes 95% of corrosion of metals by sweat whereas lactic acid and urea contribute only 5% of the corrosion loss.

Lind et. al. (1979) demonstrated that corrosion rates increased as the sweat rates increased. They also mentioned that copper in steel can lower the rates of corrosion of steel in presence of sweat. According to Colin et. al. (1999), they reported that composition of corrosion thickness layer increased with increase of copper amounts. They used a synthetic sweat medium containing 0.5% NaCl, 0.1% lactic acid and 0.1% urea with pH adjusted to 6.5 by using ammonia. The metals they utilised for comparison were 31Cu-66Ni-2Fe, 62Cu-23Ni-12Zn-2.5Sn and 83Cu-2Ni-10Zn-5Sn (wt %) in synthetic sweat medium by using FTMS (Fourier Transform Mass Spectrometer) and LAMMA (Laser Microprobe Mass Analyzer).

Electrochemical potential has high significance on the corrosion of metals. Different potential produce different forms of composition of layer of corrosion product of the nickel brass alloys. At low potential, thin oxide layer formed while at the high potential, thick chloride or oxychloride formed. This result is due to the relying of composition and thickness of the surface layers on the complexes stability of metal ions with the chloride ions and complexing agents which presents in the synthetic sweat. The formation of corrosion products was followed by high releasing of nickel and zinc. The exposure of nickel can cause adverse health effect and can induce dermatitis when contacts with human skin (Milosev & Kosec, 2007).

### 2.2.2: Corrosion due to microorganism

Study on corrosion of metals in industry show that microorganism has a tendency to attach on metal surface and produces extracellular polymeric substances (EPS) which can lead to the formation of cohesive structure known as biofilm (Chen et. al., 2014). The microorganism that can cause corrosion on metal is known as microbiologically-induced corrosion (MIC). Microbiologically-induced corrosion (MIC) is capable to initiate, facilitate and accelerate the corrosion of metal without changing its electrochemical properties (San et. al., 2013). Presence of biofilm can alter the electrochemical properties of metal surface which can lead to degradation of metal (Carvalho et. al., 2013). Biofilm can occur in varieties of metal alloys such as aluminium, stainless steel and copper. According to Chen et. al.(2014), they estimated that 20% corrosion damage of all metals and building materials is because of MIC with total cost around $30-50 billions per year.

The first step in formation of biofilm is bacteria adhering to nonspecific surface to form EPS. This process is governed by long-long range interaction including electrostatic repulsion and Van der Waals attraction (Ong et. al., 2009). Once EPS is formed, bacteria will convert EPS to form a three-dimensional structure of biofilm on substratum with a thick layer in which numerous of cells are embedded. Adhesion of bacteria to the metal surface is a vital step in formation of biofilm process (Razatos et. al., 1998).

Adhesion of bacteria to metal surface is influenced by physiological of bacteria as well as properties of metal surface. The cell surface of bacteria is a complex structure which consists of phospholipids, polysaccharides, lipopolysacharides, proteins and other biopolymer substances which contribute to the bacterial-metal interactions (Walker et. al., 2004).

One of the examples of MIC is sulfate-reducing bacteria (SRB). The sulfate-reducing bacteria (SRB) are anaerobic microorganism which can be considered as one of the main MIC. Many studies already demonstrated the corrosion of steel metal and its mechanism was due to SRB. For example, during SRB metabolism, consumption of cathodic hydrogen catalyzed by hydrogenase enzyme can accelerate corrosion of metal (Angell et. al., 1995). Sulfate-reducing bacteria metabolic product, dihydrogen sulfide ($H_2S$) also accelerates corrosion of metal (Lee & Characklis, 1993). Some SRB trigger metal corrosion by exchanging electron during bacterial-metal interaction (Dinh et. al., 2004).

Generally, copper and its alloys have a broad spectrum of antimicrobial activity which makes them high resistance of corrosion against Gram-positive and negative bacteria, virus and fungi (Sato et. al., 2012). There are some reports in recent years suggesting that a number of microbes such as Pseudomonas fluorescens are able to tolerate to toxicity of copper and survived. These mechanism include removing of copper ion outside the cell (Miller et. al., 2009), energy-dependent efflux of copper ions (Hu & Zhao 2007) and enzymatic detoxification or reduction (Andreazza et. al., 2010). This ability enables them to adhere to copper surface and produce formation of biofilm which lead to corrosion of copper.

Genus Pseudomonas sp. commonly found abundantly in industry and seawater (San et. al., 2013). Pseudomonas sp. secretes organic acids which cause an increasing rate of corrosion of metal and its alloys by facilitating passivity breakdown (Pedersen et. al., 1988). According to Beech et. al. (1999), EPS formation in early stages of formation biofilm, bind to the metal ion will increase ionization of the metal surface and cause metal ions to accumulate within bacteria as well as electrochemical properties of the metal surface.

### 2.2.3: Corrosion in seawater and marine environment

The application of copper alloy as a component in marine structure is due to the low maintenance cost, high service of life, high reliability and high recyclability (Toad, 1991). Basically, the corrosion of metal in seawater is due to high chloride contents in seawater. The presence of MIC plays major role for corrosion to occur. Besides MIC, presence of dissolved organic matter and colloidal substances also contribute corrosion of metal (Bastos et. al., 2008). The formation of protective layer on the surface of metal when exposed to seawater is called patina (Ma et. al., 2014). Basically, they are brown-greenish or green-bluish in color and protect the subsequent metal from continuously degradation (Veleva & Farro, 2012).

Seawater (salinity 35.00%, density1.023 g/cm3 at 25 ◦C) is a harsh environment for metal which can cause serious corrosion damage to metallic structures in short periods of time. Seawater contain various numbers of ionic salts in large amount such as $Cl^-$, $Na^+$, $SO_4^{2-}$, $Mg^{2+}$, $Ca^{2+}$, $K^+$, $HCO^{3-}$, $Br^-$, $Sr^{2+}$, $B^{3+}$, $F^-$, $Mo^{2+}$ and dissolved gases ($O_2$, $CO_2$). Presence of suspended and dissolved substances such as dissolved gases and decomposing organic matter also contribute to metallic corrosion. Average ion abundance in seawater consist of 55.3% chloride, 30.8% sodium, 3.7% magnesium, 2.6% sulfur, 1.2% calcium and 1.1% potassium. All this makes seawater a good complex solution of corrosive agent.

Basically, concentration of chloride ions in seawater plays an important role in corrosion of metal. Chlorides can cause dissolution of copper as well as zinc when selective dissolution of brass is placed is varying chloride concentration and potential (Kharafi et. al., 2014). A previous study regarding copper plates in three different solutions which are sodium chloride, sodium/magnesium, and sodium/calcium chloride solutions shows that the amount of corrosion product including $Cu_2(OH)_3Cl$, $Cu_2O$ and $CuCl_2$ are different in each solution (Chmielova et. al., 2013). According to Zhang et. al., (2010) there is influence of alloying elements in metal alloy on flaking of corrosion product on bare copper sheet and copper-based alloys in high chloride solution.

In this study the corrosion of third series of 20 sen coins were investigated by immersion in several different types of solution. The effects of each type of water on 20 sen coins recorded by taking image of 20 sen coins under stereomicroscope.

# CHAPTER 3

# METHODOLOGY

## 3.1: Materials

The Table 3.1 shows that the material and its quantity used in this experiment.

Table 3.1: The material used

| No. | Material | Quantity |
|---|---|---|
| 1 | 20 sen coins | 31 |
| 2 | Salt ( Halagel, Kedah, Malaysia) | 350 g |
| 3 | Sea water | 1.5 liters |
| 4 | River water | 1.5 liters |
| 5 | Well water | 1.5 liters |
| 6 | Bleaching agent (Clorox) | 0.5 liters |
| 7 | Pepsi | 1.5 liters |
| 8 | Root Beer | 1.5 liters |
| 9 | Orange Mirinda | 1.5 liters |
| 10 | Distilled water | 4.5 Liters |
| 11 | Thread | |
| 12 | Skewers | |

## 3.2: Apparatus

The Table 3.2 shows that the apparatus used and its quantity needed during experiment was carried out.

Table 3.2: The apparatus used and its quantity

| No | Apparatus | Quantity |
|---|---|---|
| 1 | 500ml beakers | 9 |
| 2 | 25 ml beakers | 20 |
| 3 | 50 ml beaker | 1 |
| 4 | Holder | 1 |
| 5 | 500ml beakers | 9 |

## 3.3: Equipments

The equipments used in this experiment were pH meter (pH 211Miroprocessor pH meter, i Hanna Instruments), Salinity meter (556 MPS, YSI), Analytical balance (ATX 224, Shimadzu), Stereomicroscope (MC170 HD, Leica Microsystem), SD card (Micro SD Adapter, Kingston).

The pH meter and salinity meter were used to measure the pH and salinity of the solution prior to experiment. Analytical balance was used to measure the mass of the coins prior to and after day 30 of the experiment. Stereomicroscope was used to capture the image of coins while the images were saved in the SD card.

## 3.4: Methodology

### 3.4.1: Collection of sample

In this study, the solutions which coins will be submerged are seawater, well water, river water, bleaching agent, fizzy waters (Pepsi, Root beer and Orange Mirinda) and NaCl salt solutions. The coins were submerged in various solutions in order to simulate the different kinds of environment. The seawater, river water and well water represented the environment in neutral pH. Bleaching agent represented the basic environment while fizzy water represented the acidic environment. For the NaCl salt solution, three amounts of NaCl salts were used which were 10 g, 50 g and 100 g. This NaCl salts solution represented for the sweat. The sea water sample, river water and well water, each sample were collected by using 1.5 L bottlel. Sea water sample was obtained in Pantai Cahaya Bulan (PCB), river water sample was obtained in Sungai Kelantan while well water was obtained from my house. For the bleaching agent, fizzy waters and NaCl salt solution, all the items were bought in the local market. The new 20 sen coins were obtained from the Bank Islam at Pasir Tumboh (as shown in Fig 3.1, Fig 3.2 and Fig 3.3) which will be used as samples. The samples must be in the same year production in order to standardize the samples.

Fig 3.1: The standard specimen coins prior to experiment

(a) (b)

Fig 3.2: The head (a) and tail (b) of the 20 sen coin under stereomicroscope before experiment was carried out.

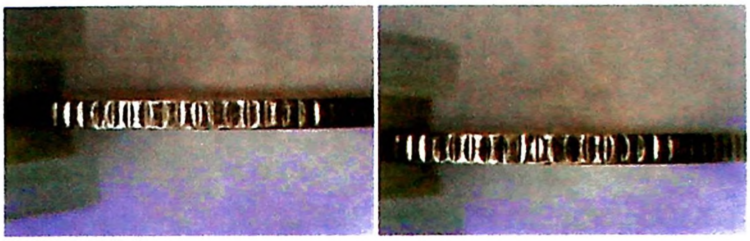

Fig 3.3: The sides of the 20 sen coin under stereomicroscope before experiment were carried out.

### 3.4.2: Sample Preparation and Analysis.

The pH and and salinity of seawater, river water, well water, bleaching agent (Clorox) and fizzy water (Pepsi, Root Beer and Orange Mirinda) and NaCl salt solution (10 g, 50 g and 100 g) were measured by using salinity meter and pH meter respectively which available at the environmental and occupational health laboratory. Seawater, river water, well water, bleaching agent, and fizzy water solution was then poured into three different 25 ml solution with labeled as A, B and C on beakers until solution was enough to submerge the suspended coin. The coin that submerge in beaker A will be referred as sample A, in beaker B will be referred as sample B and beaker C will be referred as sample C. For the different quantity mass of salts, 10 g, 50 g and 100 g of salt was measured using analytical balance and placed into three different 500 ml beakers with labeled A, B and C. 500 ml of distilled water was then added into each beaker and the NaCl salts were dissolved. The coins mass utilized for this study were recorded using analytical balance. The coins were tied and submerged it in the each beaker with the prepared solutions and the coins were suspended without being in contact with the surface of beaker as shown in Fig 3.4.

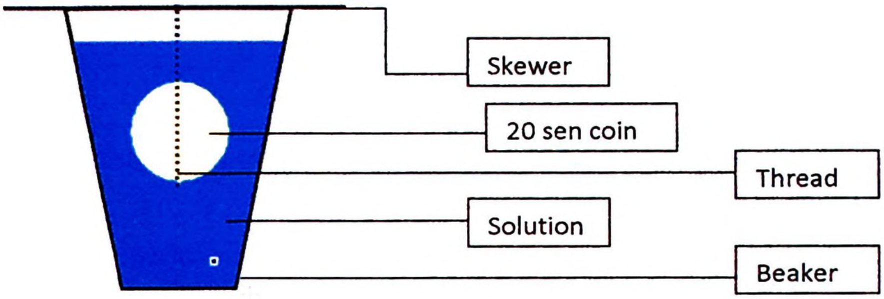

Fig 3.4: The diagram how experiment was set up.

The analysis of coins was completely based on observation under the Leica stereomicroscope. Each coin was observed at 0.11 x 50 magnifications. The length of this study was about 30 days. Only sample A images in all solutions will be documented for daily observation while for sample B and C in all solutions, the images will be taken in day 30 of the experiment. For daily observation, sample A in each solution was untied and was put on a tissue in order to dry the 20 sen coin. Each coin then was observed and image was taken at 4 different sections for both surfaces of coins. A holder was utilized to keep coins steady so that the side images of coins could be taken. The images were recorded between 10 a.m. to 4 p.m. daily. Lastly all the results of coins discoloration in sample A, sample B and sample C were compared.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1: Salinity and pH of solutions

Before experiment was carried out, the salinity and pH of the solutions were measured by using salinity meter and pH meter. The results of salinity and pH measurement for each of the solution prior to experiment were shown in Table 4.1, Table 4.2 and Table 4.3.

Table 4.1: The initial salinity and pH of sea water, river water, well water, bleaching agent (clorox), Pepsi, Root Beer and Orange Mirinda solution obtained from the salinity and pH meter.

| Solutions | pH | Salinity |
|---|---|---|
| Sea water | 7.14 | 30.30 |
| River water | 7.09 | 1.08 |
| Well water | 5.52 | 0.06 |
| Bleaching agent | 11.62 | 57.66 |
| Pepsi | 2.23 | 0.25 |
| Root Beer | 3.07 | 0.08 |
| Orange Mirinda | 2.61 | 0.21 |

Table 4.2: The initial pH of 10 g NaCl, 50 g NaCl,100 g NaCl solution obtained from pH meter

| Solutions | A | B | C |
|---|---|---|---|
| 10 g NaCl | 6.55 | 6.25 | 6.33 |
| 50 g NaCl | 6.10 | 5.93 | 5.78 |
| 100 g NaCl | 5.38 | 5.51 | 5.35 |

Table 4.3: The initial salinity of 10 g NaCl, 50 g NaCl, 100 g NaCl solution salinity meter

| Solutions | A | B | C |
|---|---|---|---|
| 10 g NaCl | 20.12 | 20.50 | 20.08 |
| 50 g NaCl | 94.27 | 95.20 | 96.29 |
| 100 g NaCl | 173.52 | 172.99 | 175.44 |

For the pH measurements, bleaching agent solution had highest basicity (11.62) while Pepsi solution had highest acidity (2.23) compared to the other solutions.

For salinity measurements, 100 g NaCl solutions had highest salinity (sample A = 173.52, sample B = 172.99 and sample C = 175.44) while well water had lowest salinity (0.06) measurement compared to other solutions. The salinity of the solution reflects the amount of sodium chlorides (NaCl) in the solution. The higher salinity of the solution, the higher its NaCl contents in its solution.

For 10 g, 50 g and 100 g NaCl solutions, NaCl was used from same brand (Halagel) with different packages. As the results, all their samples (A, B and C) had different salinity and pH measurements.

## 4.2: Mass of 20 sen coins

The mass of the 20 sen coins were measured by using analytical balance prior to and after the experiment. All new standardize coins did not have similar initial mass measurements (refer to Table 4.4). The highest mass recorded was sample B in 100 g NaCl solution with 4.1977g while the lowest mass was recorded in Root beer solution with 4.1460g

Table 4.4: The initial mass of the 20 sen coins

| Solutions | Sample A (g) | Sample B (g) | Sample C (g) |
|---|---|---|---|
| Sea water | 4.1501 | 4.1693 | 4.1729 |
| River water | 4.1519 | 4.1793 | 4.1539 |
| Well water | 4.1733 | 4.1913 | 4.1798 |
| Bleaching agent | 4.1888 | 4.1958 | 4.1523 |
| Pepsi | 4.1845 | 4.1696 | 4.1570 |
| Root beer | 4.1460 | 4.1607 | 4.1913 |
| Orange Mirinda | 4.1666 | 4.1518 | 4.1649 |
| 10g NaCl | 4.1668 | 4.1645 | 4.1781 |
| 50g NaCl | 4.1923 | 4.1849 | 4.1717 |
| 100g NaCl | 4.1733 | 4.1977 | 4.1751 |

On the last day of the experiment (day 30), the final mass of each utilised coin was measured. The results of all mass of coins were recorded in the Table 5.5. The highest final mass was recorded in sample C in bleaching agent solution (4.1966) while lowest mass was recorded in sample B in Orange Mirinda solution (4.1290).

Table 4.5: The final mass of the 20 sen coins.

| Solutions | Sample A (g) | Sample B (g) | Sample C (g) |
|---|---|---|---|
| Sea water | 4.1459 | 4.1639 | 4.1676 |
| River water | 4.1590 | 4.1791 | 4.1539 |
| Well water | 4.1728 | 4.1908 | 4.1793 |
| Bleaching agent | 4.1891 | 4.1540 | 4.1966 |
| Pepsi | 4.1454 | 4.1519 | 4.1700 |
| Root Beer | 4.1403 | 4.1854 | 4.1511 |
| Orange Mirinda | 4.1407 | 4.1290 | 4.1375 |
| 10g NaCl | 4.1724 | 4.1575 | 4.1699 |
| 50g NaCl | 4.1550 | 4.1747 | 4.1629 |
| 100g NaCl | 4.1809 | 4.1871 | 4.1643 |

In each solution, the graph of the mass changes in sample A, B and C were plotted. All these graph were plotted in order to identify either the pattern of mass changes increase or decrease. The change patterns from initial mass to final mass for the all samples in each solution were shown in Fig 4.1 (seawater), Fig 4.2 (river water), Fig 4.3 (well water), Fig 4.4 (bleaching agent), Fig 4.5 (Pepsi), Fig 4.6 (Root beer), Fig 4.7 (Orange Mirinda), Fig 4.8 (10 g NaCl), Fig 4.9 (50 g NaCl) and 14 (100 g NaCl). X-axis represented the day while Y-axis in all figures represented the mass. The initial mass was taken in day 2 while the final mass was taken in day 30.

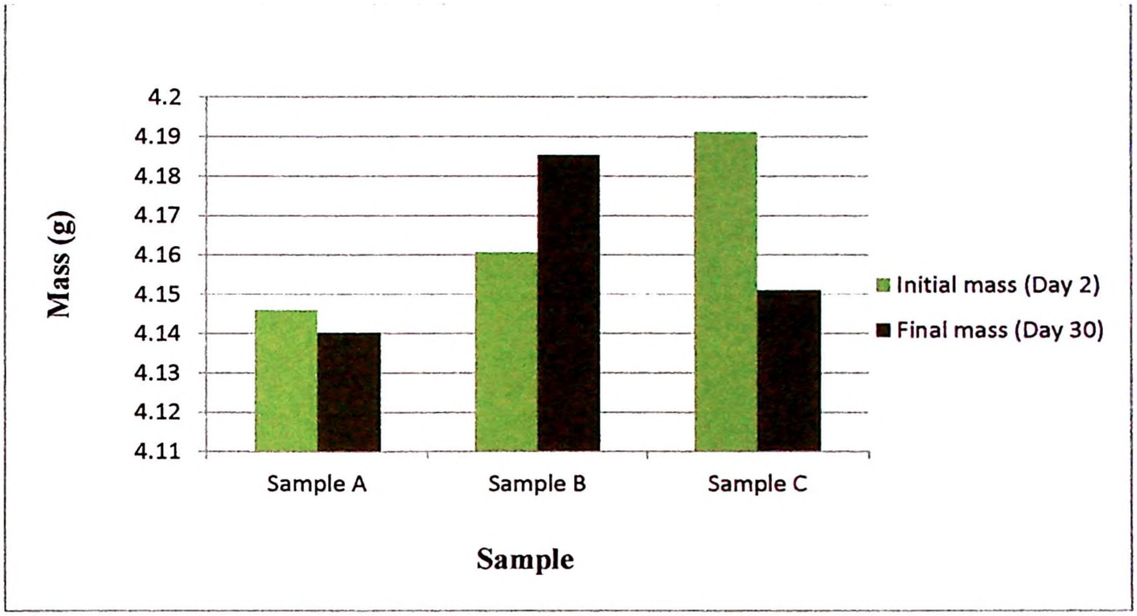

Fig 4.1: The changes of mass of sample A, B and C in seawater solution

Fig 4.1 showed that the pattern of all samples mass from initial experiment to final experiment in seawater solution. All samples show decreases in mass.

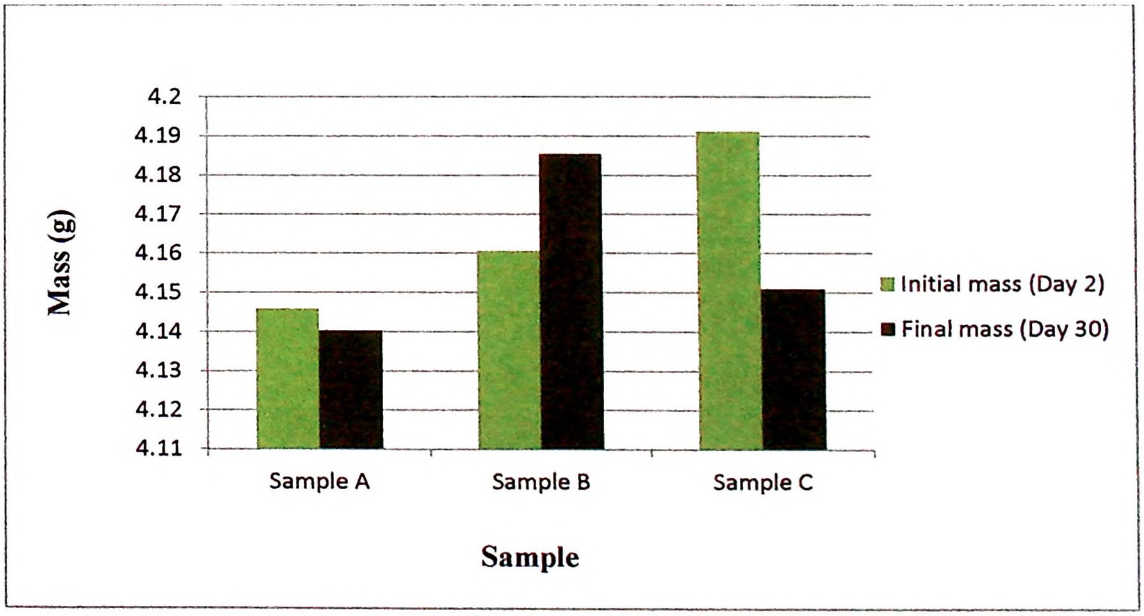

Fig 4.2: The changes of mass of sample A, B and C in river water solution

Fig 4.2 showed that the pattern all samples mass from initial experiment to final experiment in river water solution. The mass in sample A was increased. In sample B, the mass was slightly decreases while in sample C the mass was maintained.

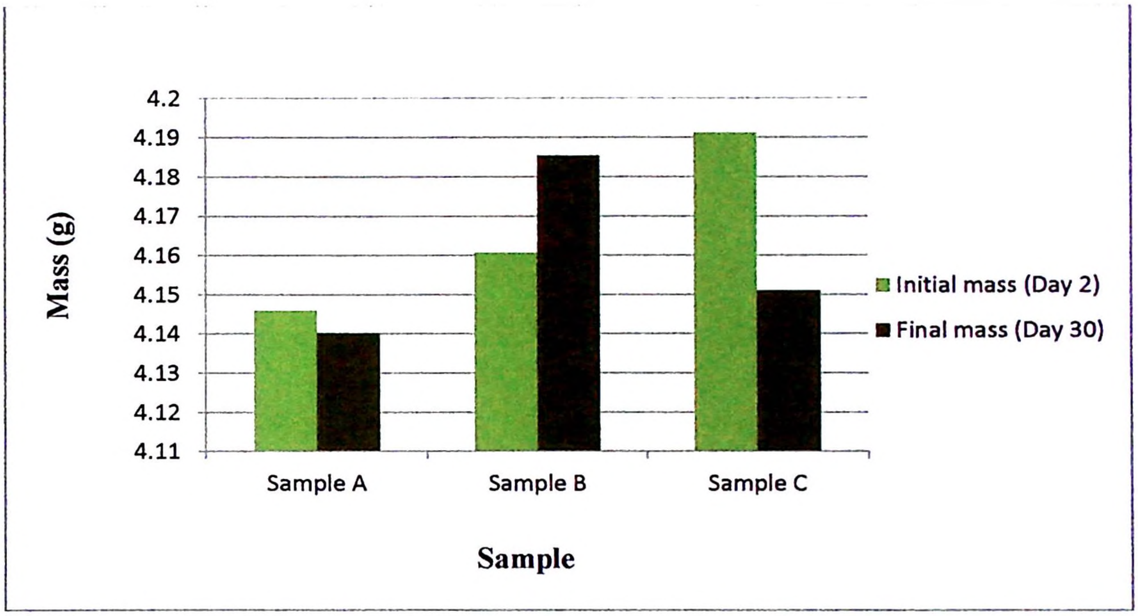

Fig 4.3: The changes of mass of sample A, B and C in well water solution

Fig 4.3 shows that the pattern all samples mass from initial experiment to final experiment in well water solution. All samples show decrease in mass.

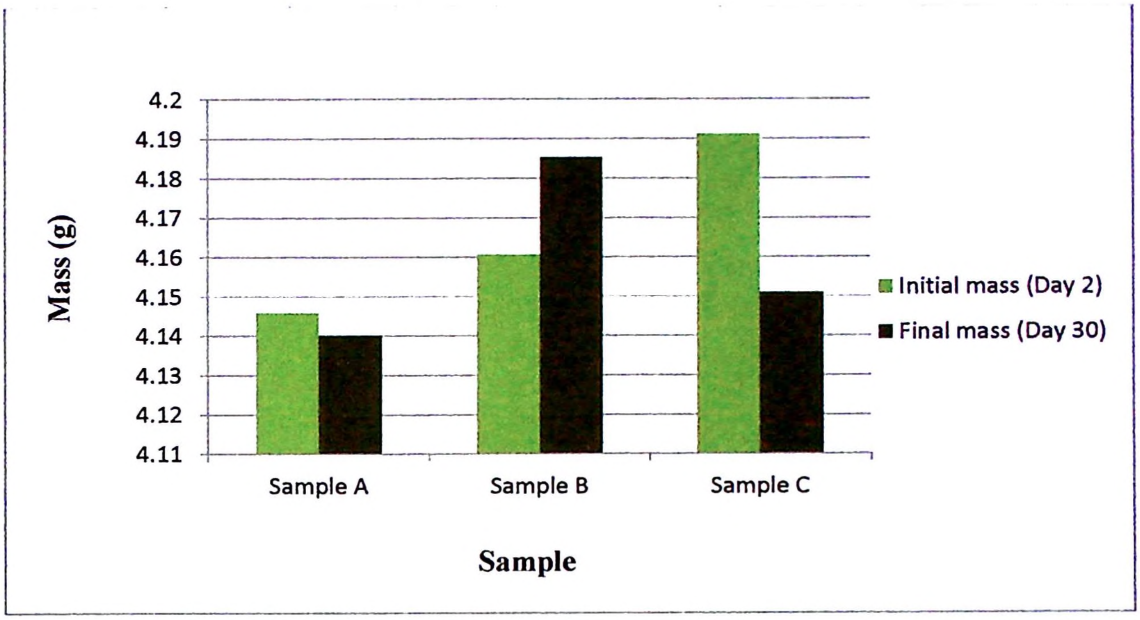

Fig 4.4: The change of mass of sample A, B and C in bleaching agent solution

Fig 4.4 shows that the pattern all samples mass from initial experiment to final experiment in bleaching agent solution. The mass for sample A was slightly increased and sample C was increase while in sample B, the mass was decrease.

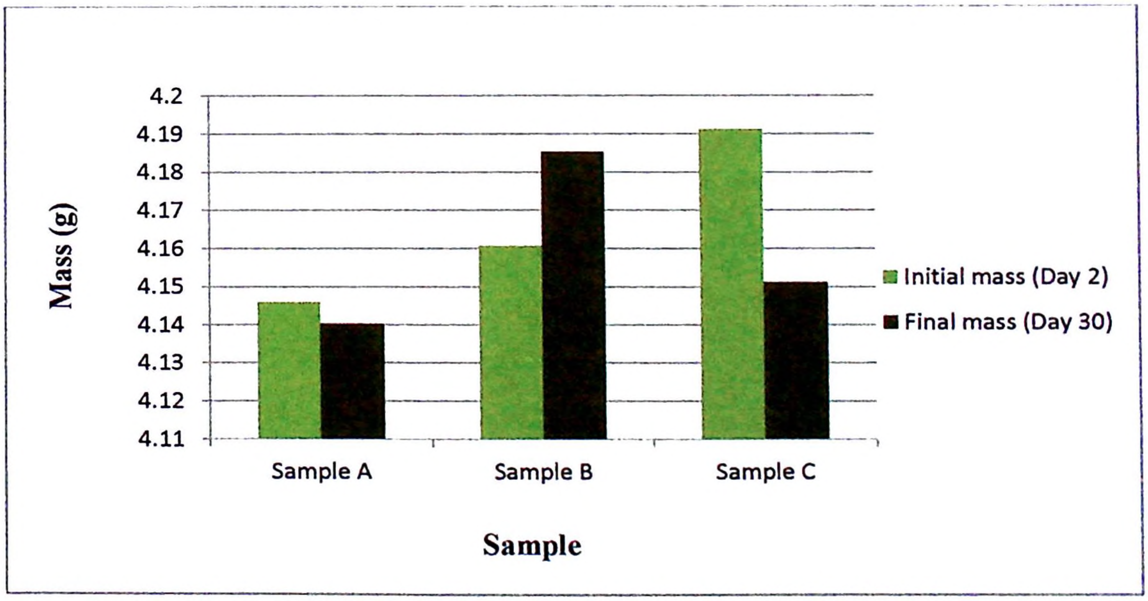

Fig 4.5: The change of mass of sample A, B and C in Pepsi

Fig 4.5 shows that the pattern all samples mass from initial experiment to final experiment in Pepsi solution. Sample A and B show decrease in mass while sample C shows increase in mass.

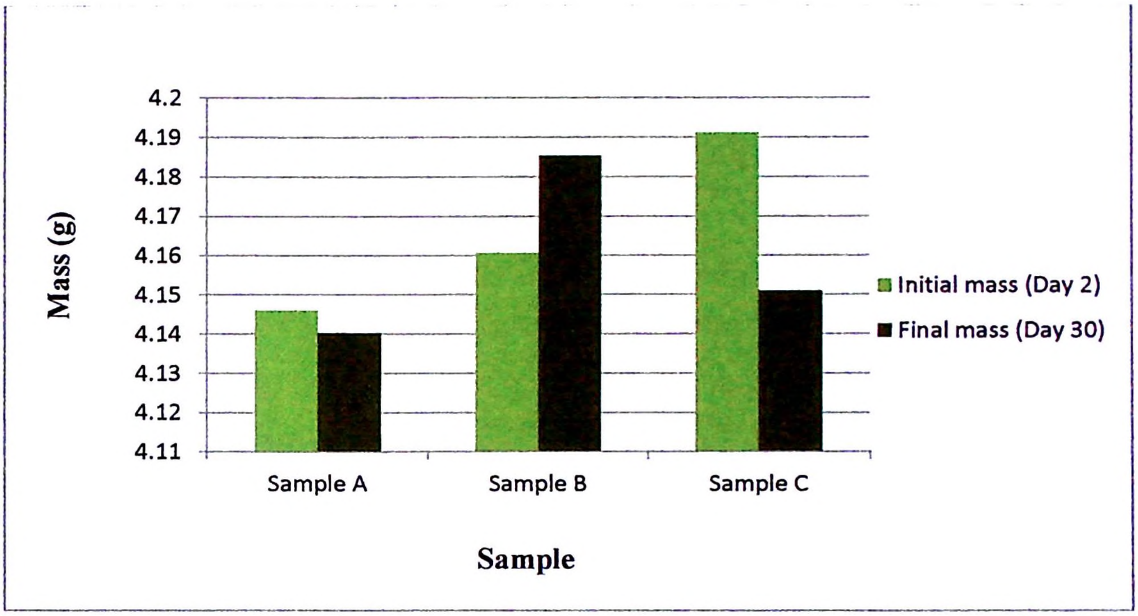

Fig 4.6: The change of mass of sample A, B and C in Root beer

Fig 4.6 shows that the pattern all samples mass from initial experiment to final experiment in Root beer solution. All samples show decrease in mass.

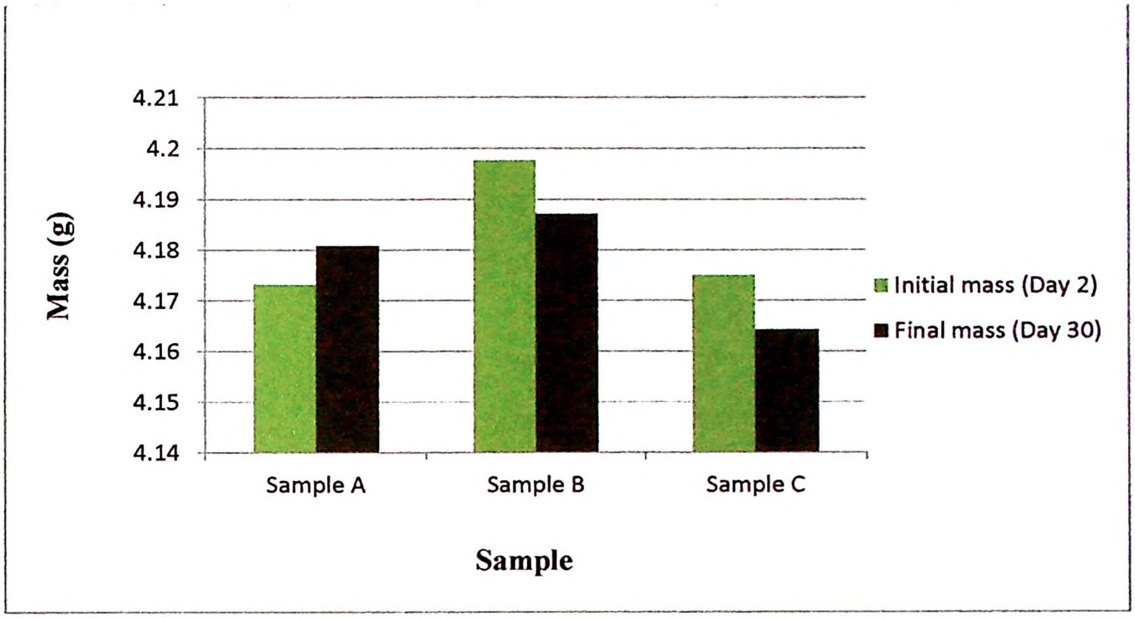

Fig 4.7: The change of mass of sample A, B and C in Orange Mirinda

Fig 4.7 shows that the pattern all samples mass from initial experiment to final experiment in Orange Mirinda solution. All samples show decrease in mass.

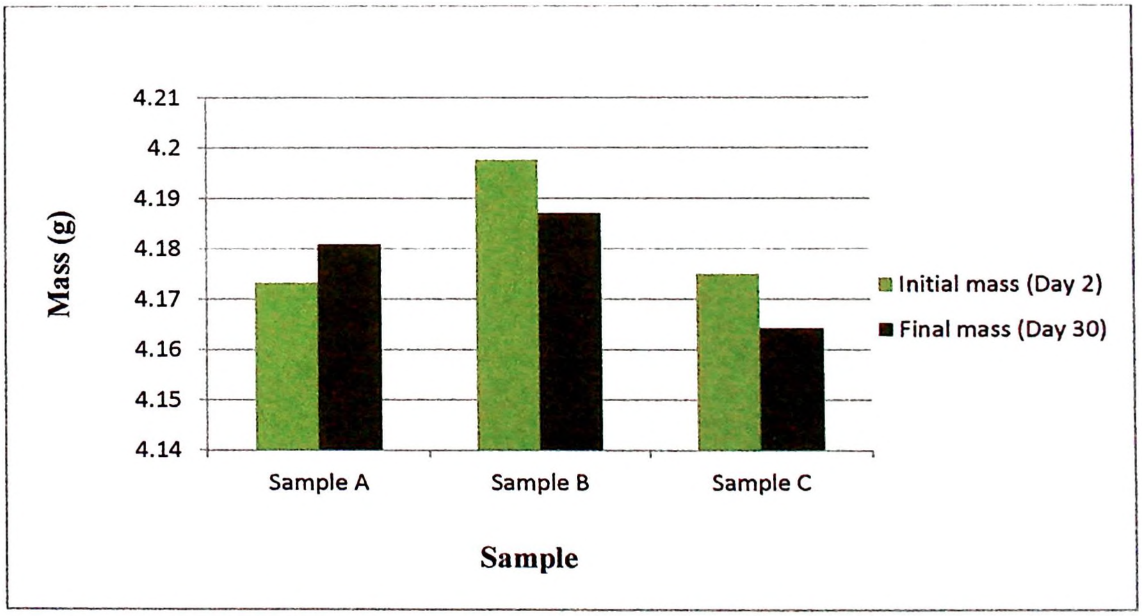

Fig 4.8: The change of mass of sample A, B and C in 10 g NaCl solution