Development of Kapok Based Plumbum and Cadmium Detection From Taste Sensor Technology

by

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ABSTRACT

To many people, heavy metal pollution is a problem associated with areas of intensive industry. However, roadways and automobiles now are considered to be one of the largest sources of heavy metals. Zinc, copper, **cadmium** and **lead** are three of the most common heavy metals released from road travel. **Lead** concentrations, however, consistently have been decreasing since leaded gasoline was discontinued. In modern societies, environmental pollution by bacteria, organic chemicals and heavy metal ions is becoming more and more severe. Lead is a toxic heavy metal element, associated with various adverse health effects. Lead ions (Pb2+) easily accumulate in the environment and produces toxic effects in plants and animals, even at low concentrations, since Pb2+ is not biodegradable. It is therefore crucial and of great importance to develop a method for the rapid and sensitive determination of lead as well as for cadmium. Based on the taste sensor technology, the occurrence of heavy metals can be detected and quantified. These are made possible through application of some potential heavy metal detection material such as Kapok, castor seed hull and others as taste sensor electrodes that will 'taste' if heavy metal occurs. The types of heavy metal detected will be largely depends on what type of material used. In this research project, Kapok were incorporated as a sensing material into a modified carbon paste electrode to detect lead as a model heavy metal pollutant. Furthermore, we found that Kapok presents some good response in terms of detecting lead after tested in anodic stripping voltammetry analysis. This means that Kapok have great potential as a heavy metal detection material if it is further developed. Hence, after detecting these heavy metals, we will then prevent people from using solutions for example water; when it was detected to contain above safe level of heavy metals in it.

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1.0 INTRODUCTION

1.1 Background Study

This project is designed basically to detect heavy metals in chemical. In this project, a heavy metal sensor in form of carbon paste electrode will be developed. The main idea of any sensing system is to detect particular ions using several kinds of materials such as kapok, castor seed hull and others; and converts the information of those heavy metal ions substances into electric signal. [1]

This research will focus on developing a chemical sensor by applying Kapok and suftactants such as Sodium dodecyl sulfate (SDS) and Cetyl trimethylammonium bromide (CTAB) as sensing materials, incorporated into carbon paste electrode to detect lead as a model heavy metal pollutant.

1.2 Problem Statement

Heavy metal pollution is a quickly growing problem for our oceans, lakes, and rivers. Right now it may not be the biggest pollution problem, but just waiting for it to go away or to solve it is not going to help. We need to be aware of the problems heavy metal creates, so we all, in our own little ways, can contribute to the solutions. Heavy metal pollution is a threat to human health, animals, plants, and the planet itself, and is mainly caused by industrialization and its consequences. While some of the metal pollutants come from fertilizers and sewage, the biggest source of heavy metal pollution definitely is industrialization. Clean water is our step into a clean future. We need to inform people about how heavy metal pollution gets into our environment so they can be more aware of the threats of these pollutants.

By considering the above matter as our basis, we need to develop a sensing material that used to detect heavy metal ions especially in clean water. In the biological mechanism, taste signals are transduced by nerves in the brain into electric signals. [1]

Similar mechanism takes place in this heavy metal sensor. The electric signals are generated as potentiometric variations. This step is achieved by the potentiostat statistical software which interprets the sensor data into graph patterns. By considering two of the most threatening heavy metals which are lead and cadmium, a heavy metal sensor will be developed, by first concentrating on developing the Kapok based carbon electrode paste sensor.

1.3 Objective

The main objectives of this Final Year Project were:

1) To study the appropriate detecting material that could detect lead as model heavy metal pollutant
2) To design a carbon paste electrode as a medium for heavy metal extraction
3) To modify the carbon paste electrode by adding Kapok with cationic surfactant (SDS and CTAB) into the mixture
4) To develop a sensitive electrochemical method for the determination of lead content in a solution

The project will be divided into several steps which will be further discussed. In order to achieve the objective, the project will be completed based on the planned schedule and within the time frame. The scope of study will include identifying various types of transducer and how it can be incorporated into the whole sensor component.

2.0 LITERATURE REVIEW

2.1 Taste Sensor Technology

2.1.1 Taste

Taste (or, more formally, gustation) is a form of direct chemoreception and is one of the traditional five senses. It refers to the ability to detect the flavor of substances such as food and poisons. In humans and many other vertebrate animals the sense of taste partners with the less direct sense of smell, in the brain's perception of flavor. Classical taste sensations include sweet, salty, sour, and bitter. More recently, psychophysicists and neuroscientists have suggested other taste categories (umami and fatty acid taste most prominently.) [3]

Taste is a sensory function of the central nervous system. The receptor cells for taste in humans are found on the surface of the tongue, along the soft palate, and in the epithelium of the pharynx and epiglottis. [3]

2.1.2 Bitterness

The bitter taste is perceived by many to be unpleasant, sharp, or disagreeable. Common bitter foods and beverages include coffee, unsweetened chocolate, bitter melon, beer, uncured olives, citrus peel, many plants in the Brassicaceae family, dandelion greens and escarole. The bitterest substance known is the synthetic chemical denatonium, discovered in 1958. [3]

2.1.3 Saltiness

Saltiness is a taste produced primarily by the presence of sodium ions. They can pass directly through ion channels in the tongue, generating an action potential. Calcium ($Ca2+$) ions can also easily activate the taste, but potassium and magnesium ions do not do so nearly as effectively, instead activating the bitter taste. [3]

2.1.4 Sourness

Sourness is the taste that detects acidity. The mechanism for detecting sour taste is similar to that which detects salt taste. Hydrogen ion channels detect the concentration of hydronium ions ($H3O+$ ions) that are formed from acids and water. [3]

2.1.5 Sweetness

Sweetness is produced by the presence of sugars, some proteins and a few other substances. Sweetness is often connected to aldehydes and ketones, which contain a carbonyl group. Sweetness is detected by a variety of G protein coupled receptors coupled to the G protein gustducin found on the taste buds. [3]

2.1.6 Umami

Umami is the name for the taste sensation produced by compounds such as glutamate, and is commonly found in fermented and aged foods. In English, it is sometimes described as "meaty" or "savoury". The word is from the Japanese word which literally mean "delicious flavour." [3]

2.2 Sensor

A sensor is a device which measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. For example, a mercury thermometer converts the measured temperature into expansion and contraction of a liquid which can be read on a calibrated glass tube. [4]

A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes. Sensors that measure very small changes must have very high sensitivities. [4]

2.3 Electronic Tongue

Nowadays, taste sensor technology is widely known by the current development of Electronic Tongue (E-Tounge). **E-Tounge** is an analytical instrument comprising of an array of non-specific, low selective chemical sensors with partial specificity (cross-sensitivity) to different components in solution, and an appropriate method of pattern recognition and/or multivariate calibration for the data processing. [5]

Of primary importance is the stability of sensor behavior and enhanced cross-sensitivity, which is understood as reproducible response of a sensor to as many species in solution as possible. If properly configured and trained (calibrated), the electronic tongue is capable to determine quantitative composition (the content on multiple components) and to recognize (distinguish, classify, identify) complex liquids of different nature. A unique feature is the possibility to maintain a correlation between the output of the electronic tongue and human perception. [5]

2.4 Taste Sensor Experimental Set-up

Figure 2.2 (a) shows the experimental set-up for the measurement of tastes of five basic taste substances, i.e., NaCl for saltiness, HCl for sourness, quinine-HCl for bitterness, sucrose for sweetness and monosodium glutamate (MSG) for umami. As shown in Figure 2.2 (b), the membrane electrode device was fabricated by mounting a cross-linked and phosphorylated PVA membrane over a cavity on a perspex block. The cavity was filled with a 100mM KCl solution through a narrow hole, and a Ag/AgCl electrode was inserted into the cavity. The reference electrode device was constructed of an Ag/AgCl electrode enclosed in a glass tube filled with 100mM KCl and 1% agar. The two electrode terminals were connected to a digital multimeter for measuring the potential across the polymer membrane. [10]

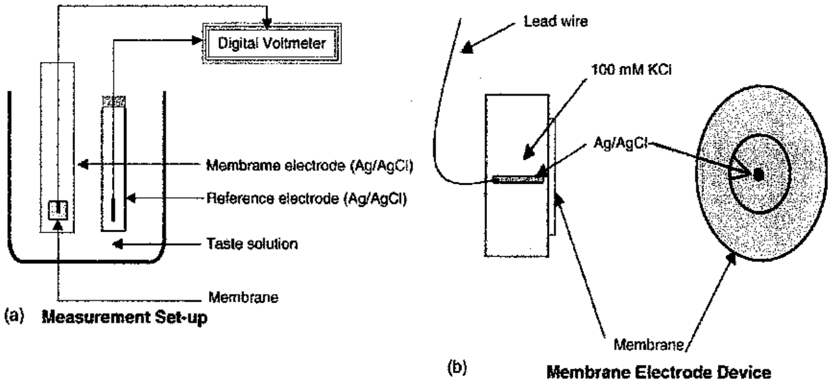


Figure 1: (a) Experimental set-up for measurement; (b) Membrane electrode device used in the set-up

2.4.1 Modification

Based on objective of study, there is possibility to modify this *Basudham Adhikari*'s method to other chemicals or materials for example this case to change it to be Kapok to detect heavy metals, specifically lead. This is because the concept and procedure is the same and it's highly applicable; same methodology that makes the membrane is able to detect five basic tastes.

2.5 Heavy Metal Pollution

Heavy-metals (HM) are highly toxic to both plants and animals and have well-documented neurotoxic (lead, mercury), haematotoxic (lead) and nephrotoxic (lead, cadmium, mercury) effects on humans. It is also known that organometallic complexes such as methyl mercury can be even more toxic than the simple metallic form, primarily due to their high affinity for -SH donors, thus facilitating their accumulation in tissues. Unlike carbon-based contaminants that can be completely degraded to form relatively harmless products, metal ions can be transformed in only a limited number of ways by biological or chemical remediation processes. In recent years the presence of mercury species in natural waters, soil and seafood has been recognized as an issue of major food safety concern. [2]

The current repertoire of standard techniques for trace heavy-metal analysis includes Atomic Absorption Spectrometry (AAS) and Inductively Coupled Plasma-Mass Spectrometry (ICPMS). However, these methods require expensive equipment, which cannot be used in the field, and also produce gaseous effluents that are difficult to treat and dispose of. Moreover, virtually all of the methods involve complicated and time-consuming sample treatment and preconcentration steps that can be carried out only by trained professionals. This prohibits screening for heavy metals at various stages of food production and hinders the objective of preventing heavy metal contamination as early as possible in the production chain. Electrochemical methods are seen as complementary to the aforementioned techniques, and are especially attractive because they allow the possibility of creating inexpensive and portable instrumentation. [2]

2.6 Kapok as a potential detecting material

Kapok (Ceiba pentandra) is a tropical tree of the order Malvales and the family Malvaceae (previously separated in the family Bombacaceae), native to Mexico, Central America and the Caribbean, northern South America, and (as the variety C. pentandra var. guineensis) to tropical west Africa. The word is also used for the fibre obtained from its seed pods. The tree is also known as the Java cotton, Java kapok, or ceiba. It is a sacred symbol in Maya mythology. [7]

Figure 2: Kapok

The tree grows to 60-70 m (200-230 ft) tall and has a very substantial trunk up to 3 m (10 ft) in diameter with buttresses. The trunk and many of the larger branches are densely crowded with very large, robust simple thorns. The leaves are compound of 5 to 9 leaflets, each up to 20 cm (8 in) and palm like. Adult trees produce several hundred 15 cm (6 in) seed pods. The pods contain seeds surrounded by a fluffy, yellowish fiber that is a mix of lignin and cellulose. [7]

The fibre is light, very buoyant, resilient, highly flammable and resistant to water. The process of harvesting and separating the fibre is labour-intensive and manual. It is difficult to spin but is used as an alternative to down as filling in mattresses, pillows, upholstery, teddy bears, zafus and for insulation. In Southeast Asian countries kapok has larger seed pods and the fibre which is highly flammable is used as a fuel in fire pistons, in Thailand called taban fai. The commercial tree is most heavily cultivated in Asia, notably in Java (hence its nicknames), Philippines, and Malaysia, but also in South America. This tree is the official national tree of Puerto Rico. [7]

Kapok's Material Safety & Data Sheet (MSDS) is attached in APPENDICES.

2.7 Lead Nitrate

Lead (II) nitrate is an inorganic compound with the chemical formula Pb(NO3)2. It commonly occurs as a colourless crystal or white powder and, unlike most other lead(II) salts, is soluble in water. [9]

Figure 3: Lead Nitrate

Known since the Middle Ages by the name plumb dulcis, the production of lead(II) nitrate from either metallic lead or lead oxide in nitric acid was small-scale, for direct use in making other lead compounds. In the 19th century lead(II) nitrate began to be produced commercially in Europe and the United States. Historically, the main use was as a raw material in the production of pigments for lead paints, but such paints have been superseded by less toxic paints based on titanium dioxide. Other industrial uses included heat stabilisation in nylon and polyesters, and in coatings of photothermographic paper. Since around the year 2000, lead(II) nitrate has begun to be used in gold cyanidation. [9]

Lead(II) nitrate is toxic, an oxidising agent, and is categorised as probably carcinogenic to humans by the International Agency for Research on Cancer. Consequently, it must be handled and stored with the appropriate safety precautions to prevent inhalation, ingestion and skin contact. Due to its hazardous nature, the limited applications of lead(II) nitrate are under constant scrutiny. [9]

Lead Nitrate's Material Safety & Data Sheet (MSDS) is attached in APPENDICES.

2.8 Cadmium Nitrate

Cadmium nitrate is a white crystalline solid that absorbs moisture from air and becomes watery, i.e. it is deliquescent. Deliquescent materials are substances (mostly salts) that have a strong affinity for moisture and will absorb relatively large amounts of water from the atmosphere if exposed to it, forming a liquid solution. Deliquescent salts include calcium chloride, magnesium chloride, zinc chloride, potassium carbonate, potassium phosphate carnallite, ferric ammonium citrate, potassium hydroxide and sodium hydroxide. Due to their very high affinity for water, these substances are often used as desiccants, which is also an application for concentrated sulfuric and phosphoric acids. These compounds are used in the chemical industry to remove the water produced by chemical reactions, to increase the yields. In everyday life people are most likely to come across deliquescence when they spill some instant coffee. This turns from a dry powder to sticky liquid when exposed to air for a few hours. [11]

It is sometimes used to provide a solution containing cadmium ions. It is used to give reddish-yellow luster to glass and porcelain, in photographic emulsion, and as laboratory reagent. [11]

Cadmium Nitrate's Material Safety & Data Sheet (MSDS) is attached in APPENDICES.

2.9 General Purpose Electrochemical System (GPES) Software

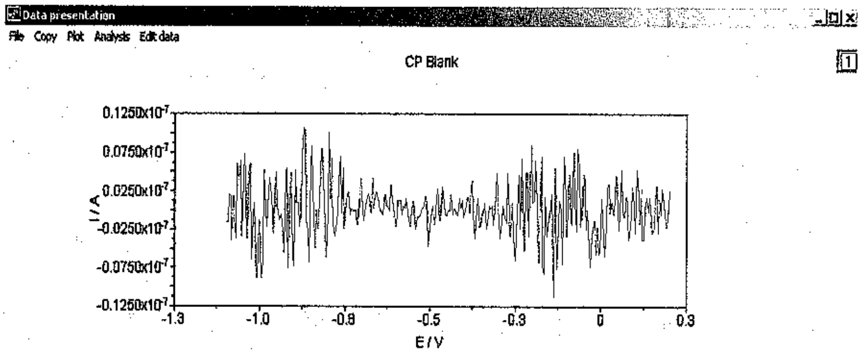


Figure 4: Screenshot of GPES Software

Autolab and the General Purpose Electrochemical System software (GPES) provide a fully computer controlled electrochemical measurement system. It can be used for different purposes, i.e.:

- general electrochemical research
- polarographic analysis in conjunction with a dropping or static mercury drop electrode
- voltammetric analysis with solid electrodes, such as glassy carbon or rotating disk electrodes
- research of electrochemical processes like plating, deposition and etching
- electrochemical corrosion measurements
- electrochemical detection in Flow Injection Analysis (FIA) and High Performance Liquid Chromatography (HPLC). [12]

The instrument is controlled by a personal computer equipped with an IBM/PC or AT I/O expansion bus. All the Autolab configurations are supported by GPES:

- μAutolab or μAutolab Type II, the compact version of a standard Autolab with potentiostat
- Autolab with potentiostat/galvanostat PGSTAT10/12/20/30/100 and other, optional, modules.

The GPES combines the measurement of data and its subsequent analysis. [12]

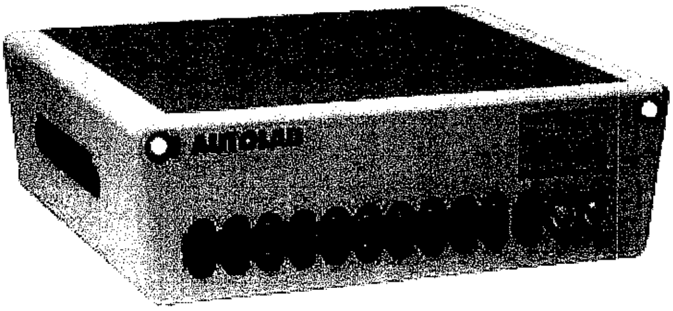


Figure 5: GPES Hardware

3.0 METHODOLOGY

3.1 Methodology Approach

In this research, the methodology/research approach will be as below:

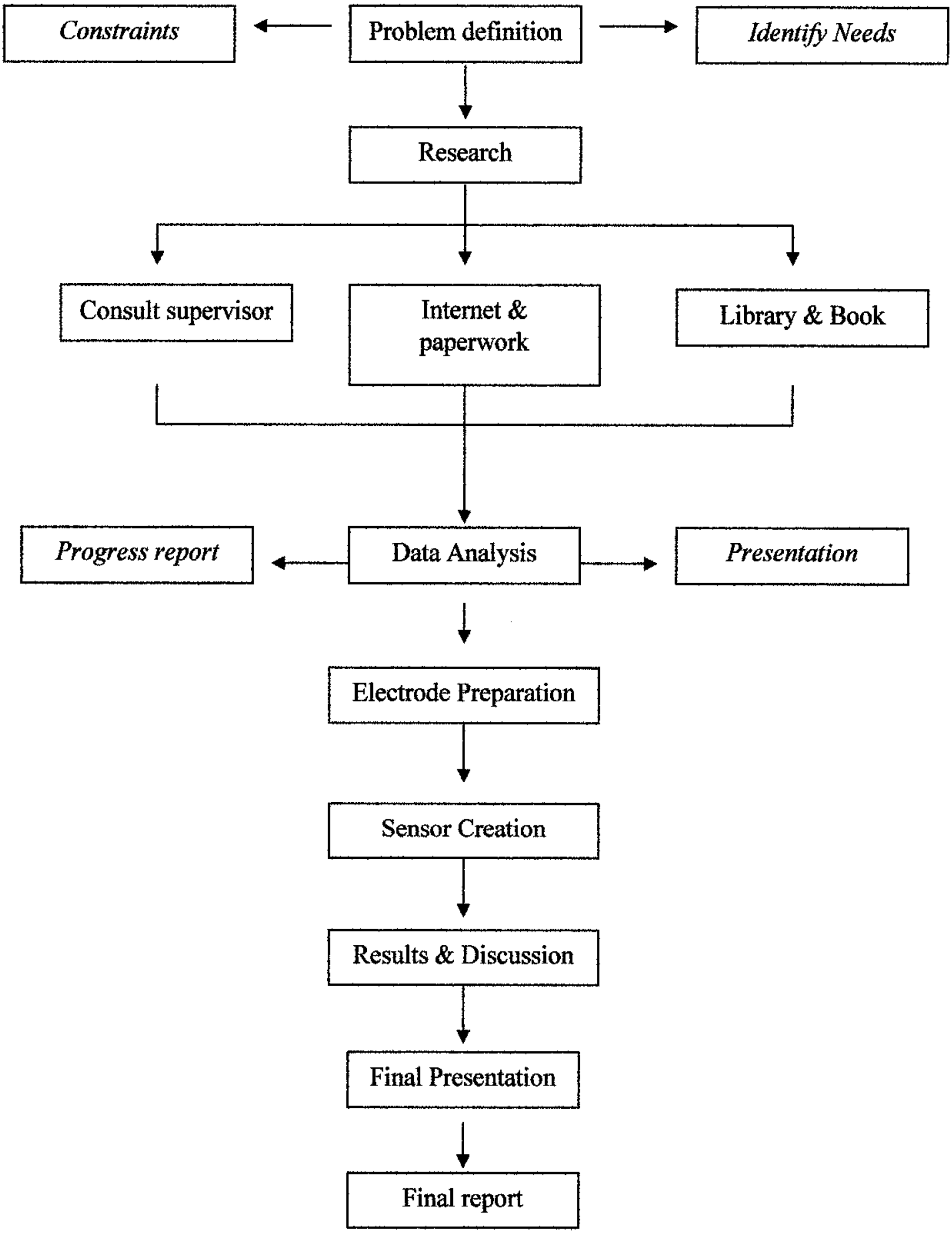


Figure 6: Flowchart of Plan and Schematic Flow Process

3.2 Project Activity

Here are some activities included:

1. Detailed research on taste sensor technology.
2. Research on heavy metal pollution.
3. Research study on General Purpose Electrochemical System (GPES) Software.
4. Study on how to prepare the electrode.
5. Comparison on modified electrode.
6. Study to optimize obtained results.
7. Submission of report and presentation.

3.2.1 Kapok Preparation

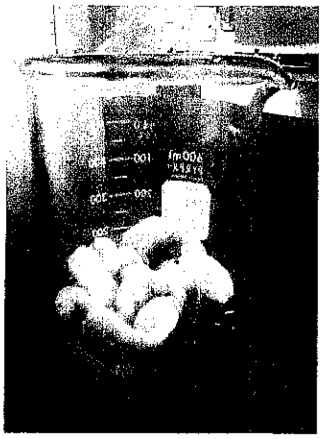


Figure 7: Kapok Treated with NaOH

The equipments and chemicals were prepared. First, prepared 10 ml of the Sodium dodecyl sulfate (SDS) and Cetyl trimethylammonium bromide (CTAB) surfactants was dissolved separately in 500 ml deionized water. Next, Kapok with treated 1% Natrium Hydroxyde, NaOH solvent kapok was added into the solution. That means we have prepared 1% NaOH solution and then soak the Kapok in it. The Kapok was fully treated with NaOH after two hours of stirring. After that, the contents were mixed thoroughly in a shaker for 2 hour. The mixture was then centrifuged and kapok was washed out about 5 times with deionized water to remove superficially surfactant on the surface. It was then dried in an oven before it can be further processed. [13]

3.2.2 Carbon Paste Electrode Preparation

The carbon electrode was prepared as follows. 1.0 g graphite powder and 0.5 mL paraffin oil was mixed in an agate mortar and ground. [13]

Figure 8: Blended Kapok, graphite powder and paraffin oil in a mortar

The homogeneous paste was then packed into a cavity (3 mm diameter) at the end of a Teflon tube. Redundant paste was mechanically removed with a filter paper. The surface was smoothed against weighing paper. The electrical contact was provided by a copper wire connected to the paste in the inner hole of the tube. Preparation of modified electrode was accomplished by adding different ratios of surfactant modified Kapok in carbon electrodes; 1:1, 1:3, 1:5. [13]

Figure 9: Kapok, graphite and paraffin oil is mixed at 1:1, 1:3 and 1:5 ratios (modified carbon paste)

Figure 10: Prepared paste is inserted to the electrode body (electrode preparation)

Figure 11: The electrode is tested using anodic stripping voltammetry (ASV)

3.2.3 Taste Sensing Unit

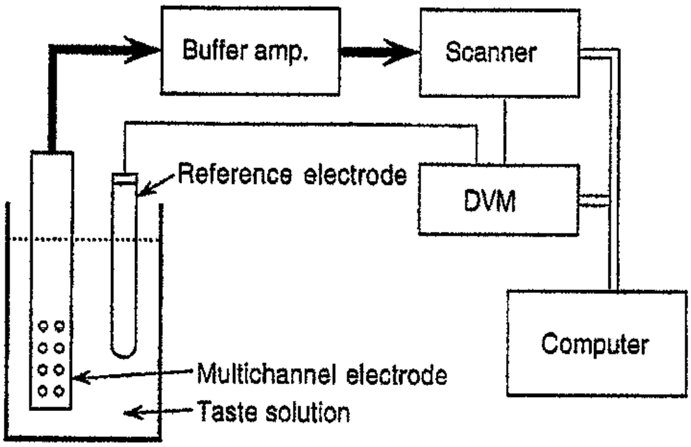


Figure 12: Experimental set-up for Taste Sensing

Modification

From the K. Hayashi paper, Fig 12 shows how a unit of test sensing system is set up. The basics are actually four components; a working electrode, a testing solution, a scanner (or analyzing hardware) and a computer to generate the results. Based on this system, we need to implement a slight modification as we will not use the electrode to detect taste. Instead, as in Figure 3.3 above, we will just make changes so that the applied Kapok-modified carbon paste electrode to be analyzed to detect lead which will show that it is potential to become a heavy metal detection material. [6]

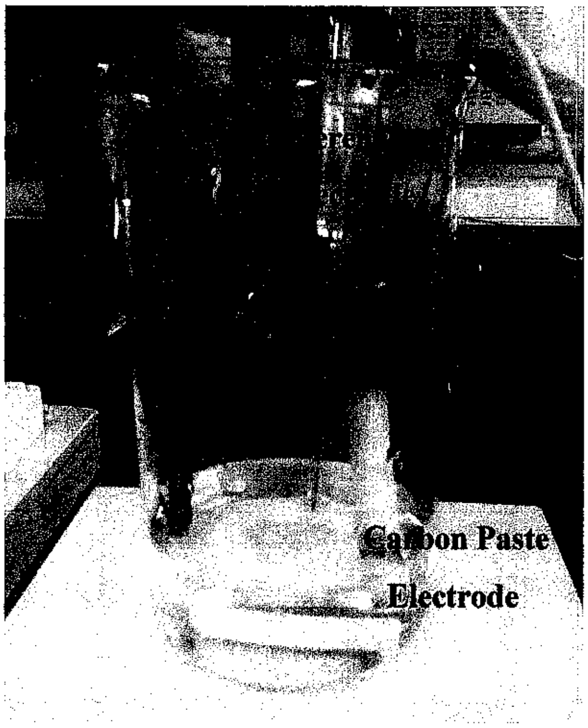


Figure 13: Beaker with all three electrodes including magnetic bar

From Fig 13, we can see that the carbon paste electrode, which will vary accordingly to the carbon paste that we are analyzing. The second one is the graphite electrode. Next is the reference electrode, which has a potential that is accurately known, constant and completely insensitive to the composition of the analyte solution. In addition, this electrode should be rugged and easy to assemble and should maintain a constant potential while passing minimal currents. [17]. The second and third electrode will be fixed and unchanged throughout the experiment.

3.3 Experimental Analysis

After at least 12 hours after the carbon paste electrode was prepared, the carbon pasted electrode was then finally ready for the analysis. [16]

3.3.1 Experimental set-up

Before this experiment can be started, we have completed these procedures with the guidance of the lab technician:

a) Installing and connecting the instrument (Autolab-USB)
b) Installing the GPES software
c) Configuring and testing the Autolab instrument [12]

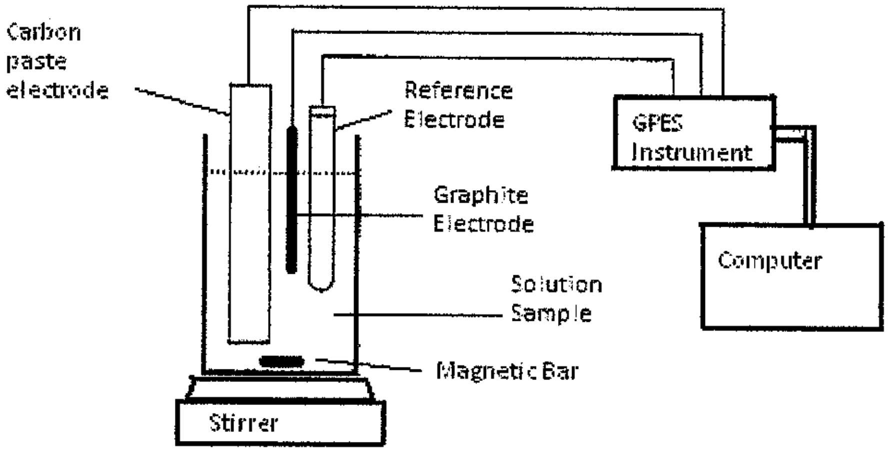


Figure 14: Simple Graphical Set-up of Experiment

3.4 Project Tools

In this project, there are several things/equipments that need to be used throughout this whole project:

a) General Purpose Electrochemical system version 4.9, Eco Chemie B.V., Ultrecht, The Netherlands.
b) Kapok
c) Electrochemical cell, AgCl/KCl Metrohom reference and Pt/ Graphite bar auxiliary electrodes
d) Graphite powder (average particle size would be analyzed through particle size analyzer)
e) Paraffin oil or nujol
f) Sodium dodecyl sulfate (SDS), Cetyl trimethylammonium bromide (CTAB),
g) NaH_2PO_4/Na_2HPO_4,
h) Small volume cell mm or 3.0 mm flat tipped modified carbon electrode
i) Polishing kit
j) A magnetic stirrer and a small bar inside the cell
k) 50 ml and 100 ml volumetric flasks

3.4 Gantt Chart / Milestone

Attached.

4.0 RESULTS AND DISCUSSIONS

4.1 Electrochemical Process from Taste Sensor Technology

This will be the point where we will really prove the applicability of Taste Sensor Technology into Electrochemical detection of heavy metals; in this particular case to be lead. The main idea of any taste sensing system is to detect particular ions using several kinds of materials and converts the information of those taste ions substances into electric signal. [1] The idea almost the same with Electrochemical detection where it sends the chemical signals into electric signal. So basically we will just modify the system by changing the membrane developed to detect taste with modified carbon paste electrode and change the sample solution to be lead solution instead of taste solution. This project is designed basically to detect heavy metals in chemical. In this project, a heavy metal sensor in form of carbon paste electrode will be developed.

4.2 Analytical Method

Anodic Stripping Voltammetry (ASV) is the most sensitive, convenient, and cost effective analytical method for heavy metal detection. ASV used to detect ions such as Pb, Cd, and etc in low levels, even in ppb.

ASV functions in two steps:

- preconcentration of a metal phase onto a solid electrode surface at negative potentials
- selective oxidation of each metal species during an anodic potential sweep

4.2.1 Response of Bare Carbon Paste Electrode

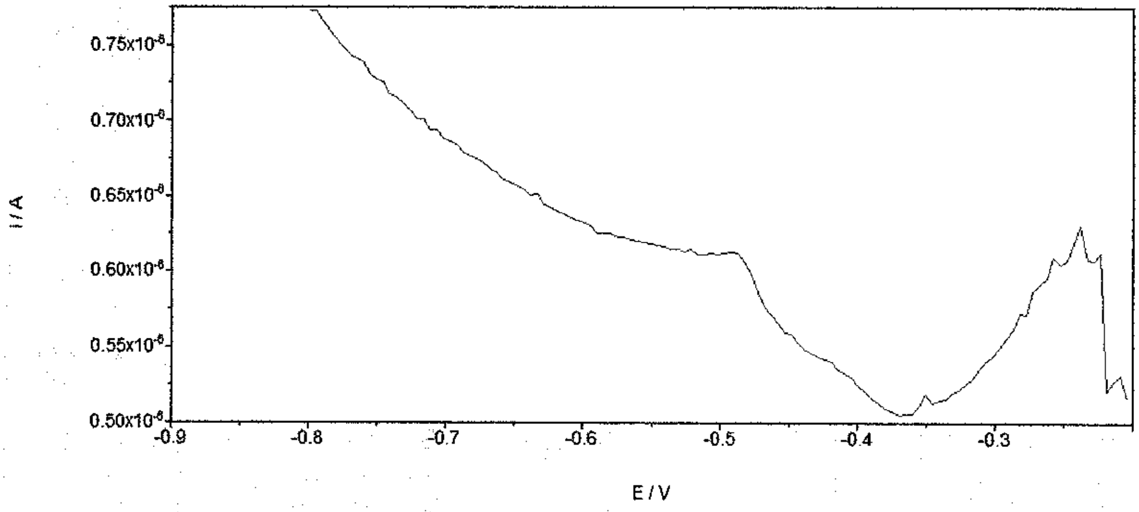


Figure 15: Response of Bare CPE with 10ml Pb2+ Solution

Figure 15 shows the response of the bare carbon paste electrode towards the adsorption of the Pb2+ inside a 10mL Pb solution (electrolyte). The starting background current was of 0.5 x 10-4 A showed that the potential was not sufficient to cause the discharge of Pb2+. The measured background current was due to several causes, such as the resistance of the cell, the discharge of residual oxygen, the capacitive current and the electronic noise of the electrical current. The graph showed the first peak at -0.5V are possibly the detection of Pb2+ ion started here. Because of the discharge potential, the point at which the curve peaked could be where the Pb2+ ions discharged themselves to the electrode. At faster response, the diffusion layer becomes poorer and a spontaneous flow of other Pb2+ ions was established from the bulk solution as shown in Figure 15. Second peak shows at potential of -0.2V after sharp drop at potential around -0.5V to -0.35V. Descending part of the peak shows that the concentration of Pb2+ into the layer of solution close to the electrode is practically small because the diffusion layer has become dramatically impoverished of Pb2+. The current decreases because the potential scanning velocity is so high that the electro active compound is not able to reach the electrode much earlier. At these values of potential, all Pb2+ ions arriving at the electrode are reduced immediately and their concentration in the diffusion layer is very slow

4.2.2 Response of Carbon Paste Electrode with Modified Kapok

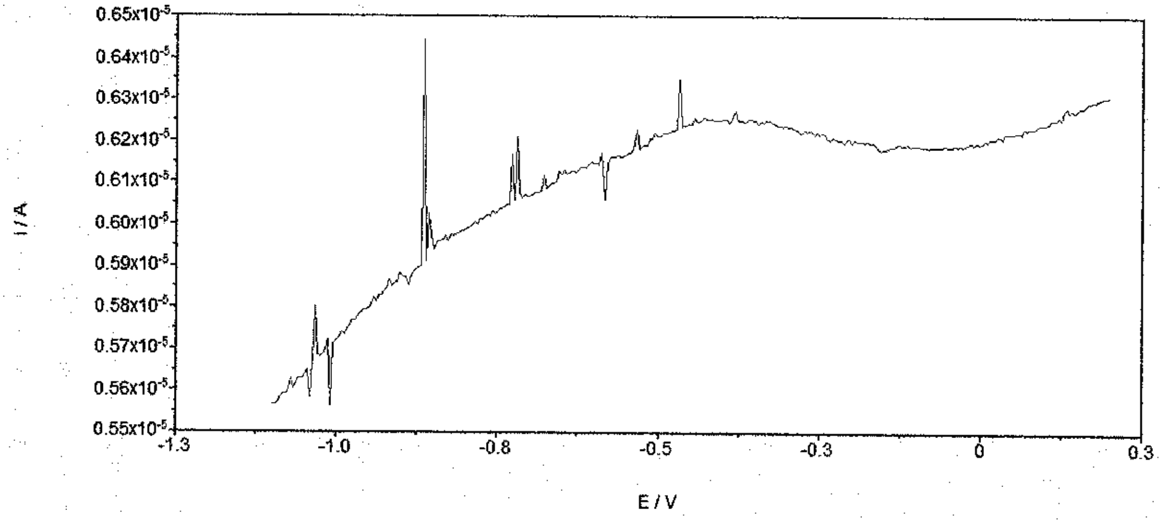


Figure 16: CP with NaoH .017 kapok with 10 mMKCl 10 ml Pb

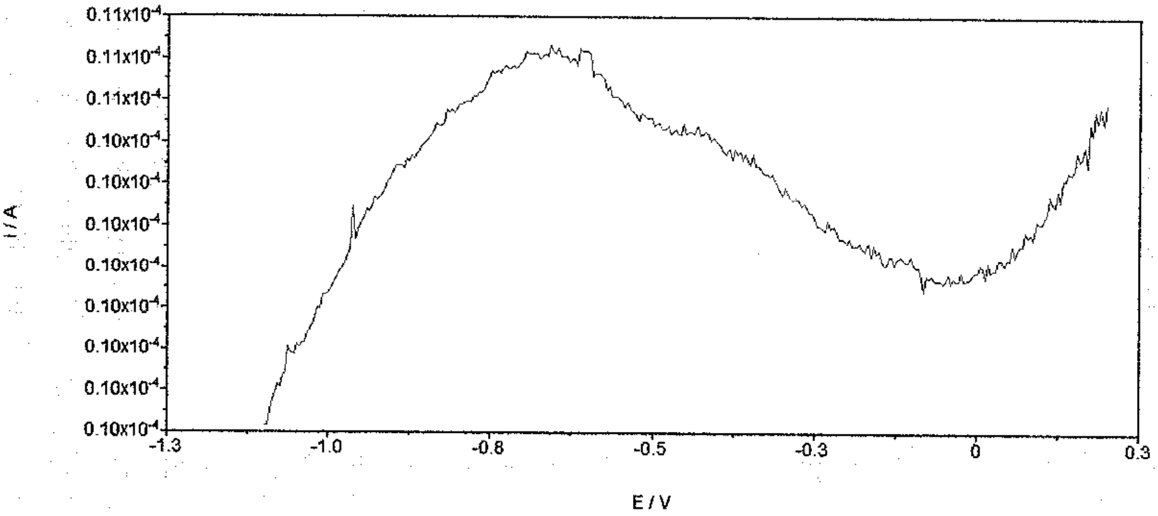


Figure 17: CP with NaoH .017 kapok with 10 mMKCl 20 ml Pb

Figure 16 and 17 shows the responses of the modified carbon paste electrode with the NaOH-Kapok towards the adsorption of the Pb2+. The difference between both graph is that the amount of lead solution that we are testing. The first with only 10mL and the second with 20mL of lead solution. By observing the bell-shape of the graph, these are the type of responses that we are looking for. We can see that for both amount of Pb2+ solution, it started well by increasing smoothly towards the peak and decreasing smoothly. The end respond which makes the different between them is largely because the amount of Pb2+ solution is high enough that it could not decrease the detection of Pb2+ ions. The other possible reason might be on the experimental error. From these results, it really shows that Kapok treated with NaOH has a very attractive potential to be developed to be a heavy metal detection material because from the experiments, they did showed some very good results.

4.2.3 Response of Carbon Paste Electrode with Modified Kapok-SDS

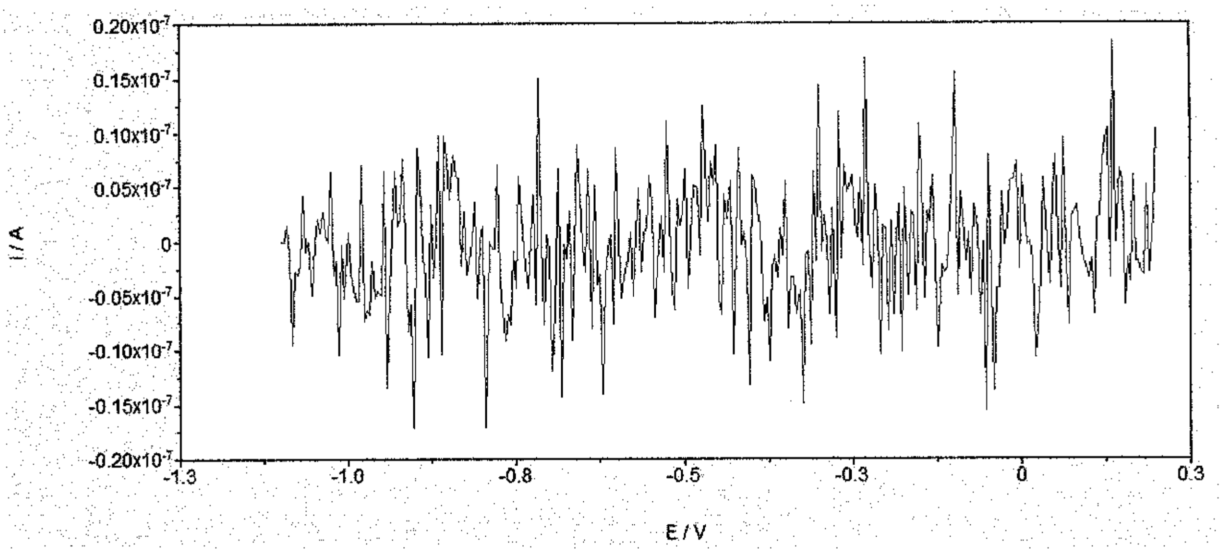


Figure 18: SDS modified Kapok with 10 mMHCl 10 ml Pb

Figure 18 show the responses of the modified carbon paste electrode with the SDS-Kapok towards the adsorption of the Pb2+. From the the graph obtained, we can see that the response fluctuating very quickly and sharply along the way from the start until the end of the analysis. This shows that the SDS-Kapok modified carbon paste electrode is not a good detector of ion Pb2+.

4.2.4 Response of Bare Carbon Paste Electrode to Cadmium Solution

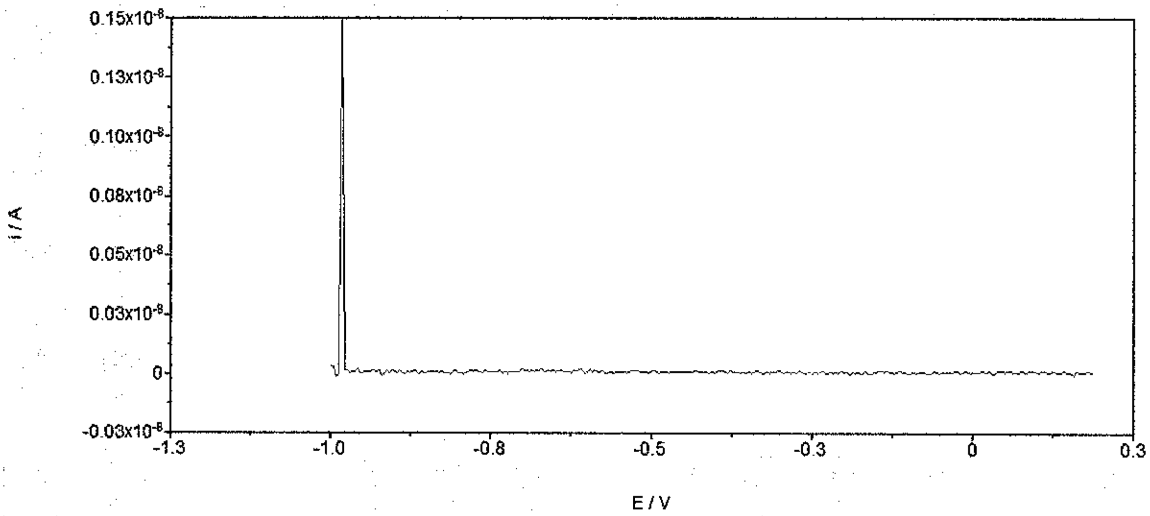


Figure 19: CP with 10mM HCl & 10 ml Cd

Figure 19 show the responses of the simple carbon paste electrode towards the adsorption of the Cd2+. From the above figure, we could see the response is very quick and short. It went to the peak very quick at the early stage of the analysis and went down right away after touching the maximum line. After that, it respond with just straight-behavior line until the end. From these result we can interpret it as no observable detection of Cd2+ which means that these carbon paste electrode is yet to be a suitable and dependable detector of Cd2+ ions.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A simple and effective Kapok-modified carbon paste electrode, CPE was constructed for the sensitive determination of Pb2+. Compared with the unmodified CPE, the Kapok-modified CPE significantly enhances the stripping peak current of Pb2+ due to the large cation-exchange capacity and strong adsorptive ability of Kapok. Based on this, a sensitive and convenient electrochemical method was developed for the determination of Pb++. For Cadmium, a further study and optimization needed to be done in order to develop it as a better heavy metal detector.

As a conclusion, Kapok has great potential to be incorporated into the design of a portable, robust, inexpensive and green heavy metal detection apparatus.

5.2 Recommendations

For improvement of this research work, some recommendations need to be considered.

- Use of membrane to increase selectivity
- Detection of other heavy metals such as phenol, mercury, silver, tin and etc.
- Avoid all sources of contaminants during conducting the experiment since it will give an effect to the analysis results.
- It is highly recommended that the analysis equipment must be calibrated before performing the analysis.
- Improvement to the result can be achieved by adding surfactant/ ionic liquid
- Integrate the project with EE department for assistance in creating the sensor

REFERENCES

1. Kiyoshi Toko from **Taste Sensor**, Sensor and Actuators Journal B64 205-215.

2. http://www.biocop.org/content_pdf/WP9_Brochure_Final.pdf

3. http://en.wikipedia.org/wiki/Taste

4. http://en.wikipedia.org/wiki/Sensor

5. http://www.electronictongue.com/what02.html

6. K. Hayashi from **Electric Characteristics of Lipid-modified Monolayer Membranes for Taste Sensor**, Sensors and Actuators B23 (1995) 55-61

7. http://en.wikipedia.org/wiki/Kapok

8. http://www.sciencelab.com/msds.php?msdsId=9927682

9. http://en.wikipedia.org/wiki/Lead_nitrate

10. Basudam Adhikari from **Polyvinyl Alcohol: A Taste Sensing Material**, Sensors and Actuators B114 (2006) 747-755

11. http://en.wikipedia.org/wiki/Cadmium_nitrate

12. General **Purpose Electrochemical System (GPES) Manual Book**

13. **Electrochemical determination of lead(II) using a montmorillonite calcium-modified carbon paste electrode,** Dong Sun1;2, Chidan Wan

14. **Beneficial role of surfactants in electrochemistry and in the modification of electrodes** R. Vittal a,*, H. Gomathi b, Kang-Jin Kim

15. **Modification of montmorillonite with cationic surfactant and application in electrochemical determination of 4-chlorophenol,** Hongyu Yanga,b, Xiaojiang

16. **Studies on adsorption of cetyltrimethylammonium bromide at carbon paste electrode and the enhancement effect in thyroxine reduction by voltammetry and electrochemical impedance spectroscopy,** Chengguo Hu, Xueping Dang, Shengshui Hu

17. **Analytical Chemistry 8th**, Skoog

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	▨	▨													
2	Research on taste sensor and electronic tongue		▨	▨	▨											
3	- Submission of Preliminary Report - Detailed research on taste and related chemicals				▨	▨										
4	- Detailed research on taste and related chemicals - Research on sensing system					▨	▨	▨								
5	Prepare for progress report							▨								
6	Submission of Progress Report									▨						
7	- Research *Minicom* Communications Program (software) - Research membrane creation procedure/methodology - Seminar 2									▨	▨	▨	▨	▨		
8	Prepare for Interim report												▨	▨	▨	
9	Submission of Interim Report Final Draft														▨	
10	Oral Presentation															▨

☐ Suggested Process

Figure 1.2: Gantt chart / Milestones for the project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10		11	12	13	14
1	- Start create membrane creation - Formalize collaboration with UniMAP - Prepare for progress report 1	▨	▨													
2	- Submission progress report 1 - Comparison on membrane cultivation process and performance on different thickness.	▨	▨	▨	▨											
3	- Prepare for Progress report 2 - Testing on membrane durability - Start sensor development					▨	▨									
4	- Submission of progress report 2									▨						
5	- Project work continue - Attend the seminar - Preparation for poster exhibition												▨			
6	- Poster exhibition - Prepare for dissertation (softcopy)															
7	- Prepare for dissertation - Submission of dissertation (soft bound)												▨	▨	▨	
8	Oral presentation														▨	
9	Submission of Project Dissertation (hard bound)															▨

☐ Suggested Process

Figure 1.3: Gantt chart / Milestones for the project

PENDICES

Material Safety Data Sheet – Kapok's MSDS [8]

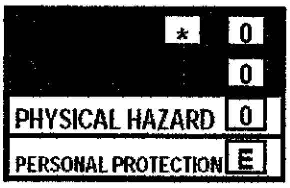
Section 1: Chemical Product & Properties

ıpearance : White or color coated woven mat on face with water-based paint with amber re.
lor : Low to no odor
ysical State : Solid
I @ 25 ° C : Not applicable
ıpor Pressure : Not applicable
ıpor Density (Air = 1): Not applicable
iling Point : Not applicable
ıpor Pressure (mm Hg): Not applicable
eezing Point : Not applicable
aporation Rate (BuAc = 1): Not applicable
elting Point : > 800 °C/1470 °F
rcent Volatile : 0
ftening Point : Not determined
rticle Size : Not applicable
lubility (H2O) : Insoluble
olecular Weight : Not applicable
scosity : Not applicable
lk Density : Not determined
ecific Gravity (H20 = 1): Variable (approximately 2.6 – 3.0)

FORMATION FOR HANDLING AND IDENTIFICATION OF CHEMICAL HAZARDS

PA Ratings:	
ealth:	0
e:	0
activity:	0

HIMS Ratings:	
Health:	*0
Fire:	0
Reactivity:	0



0 = Minimal Hazard
1 = Slight Hazard
2 = Moderate Hazard
3 = Serious Hazard
4 = Severe Hazard

rsonal Protection: Use eye protection. Use gloves and NIOSH/MSHA-approved respiratory protection en required.

espirable crystalline silica can cause lung disease and/or cancer.

MERGENCY OVERVIEW

is product is not expected to produce any unusual hazards during normal use. Exposure to high dust els may irritate the skin, eyes, nose, throat, or upper respiratory tract.

OTENTIAL HEALTH EFFECTS:

e components of ceiling panels and tiles are bound in a cementitious matrix. When panels are cut or mmed, especially with power tools, the resulting dust may cause transitory mechanical irritation to n, eyes or respiratory tract. Breathing large amounts of dust or fibers from this product may lead to ronic health

fects. Formaldehyde gas, which can cause severe eye and respiratory irritation, may be released under nditions of high heat and humidity. Inhalation of formaldehyde may result in discomfort such as usea, headache, or weakness; upper respiratory tract (nose and throat) irritation marked by mild rning sensation, sore and dry throats, and thirst; and temporary lung irritation effects with cough, comfort, difficulty in breathing, and shortness of breath. In a few rare instances, respiratory tract nsitization (asthma) has been reported in individuals exposed to formaldehyde. Skin or respiratory posure to formaldehyde may cause skin or respiratory sensitization (allergy).

CUTE:

es : Direct contact of dust with eyes can cause mechanical irritation.

in : Mechanical action of fiber glass wool and/or continuous glass filaments can cause itchiness. Skin irritation may occur with prolonged and repeated contact.

halation : Dust inhalation can cause nose, throat and respiratory tract irritation.

gestion : If ingested, it may cause temporary irritation to the gastrointestinal tract, especially the omach.

HRONIC:

es : No known effects

in : No known effects

halation : Prolonged and repeated exposure to respirable fiber glass wool may result in lung disease and/or lung cancer

gestion : No known effects

Section 3: First Aid Measures

RGET ORGANS : Skin, eyes, respiratory system,

imary Routes of Entry : Physical contact (skin, eyes). Inhalation (upper respiratory tract)

RST AID PROCEDURES

es : Do not rub or scratch your eyes. Dust particles may scratch the eye. Flush eyes with large amounts of water for 15 minutes. If irritation persists, contact a medical professional.

in : Wash gently with soap and warm water to remove dust. Wash hands before eating or using the restroom.

halation : Remove to fresh air. Drink water to clear throat, and blow nose to remove dust.

gestion : This product is not intended to be ingested or eaten. If this product is ingested, irritation of the gastrointestinal (GI) tract may occur, and should be treated symptomatically. Rinse mouth with water to remove fibers, and drink plenty of water to help reduce the irritation. No chronic effects are expected following ingestion.

EDICAL CONDITIONS WHICH MAY BE AGGRAVATED: Pre-existing chronic skin, eye, spiratory (e.g., bronchitis, emphysema, and asthma), disease or conditions.

ɪtes to Physician: This product is a mechanical irritant, and is not expected to produce any chronic alth effects from acute exposures. Treatment should be directed toward removing the source of itation with symptomatic treatment as necessary.

Section 4: Fire Fighting Measures

ash Point (Method Used) : Not applicable
per and lower flammable limits in air : Not applicable
toignition temperature : Not determined
ımmability classification : Not determined
ırning rate : Not determined
ızardous combustion products : Formaldehyde, nitrogen oxides, amines, oxides of carbon,
v
molecular weight hydrocarbons, hydrogen chloride, phosgene and acetic acid.
operties that initiate/contribute to fire : Not applicable

TINGUISHING MEDIA : Carbon dioxide (CO2), water, water fog, foam, dry mical.
ECIAL FIRE FIGHTING PROCEDURES : No special procedures are expected to be cessary for this product. Normal fire fighting procedures should be followed to avoid inhalation of smoke and gases.
IUSUAL FIRE AND EXPLOSION HAZARDS : None
ECIAL FIRE FIGHTING PROTECTIVE UIPMENT : Use self-contained breathing apparatus in a sustained fire and full protective fire fighting gear.

Section 5: Accidental Release Measures

ONTAINMENT	: Not necessary. Treat as inert material.
LEAN UP	: Pick up large pieces. Use gloves to avoid skin irritation. Vacuum dust, preferable with an industrial vacuum cleaner with high efficiency air filter. If sweeping is necessary, use dust suppressant such as water. Do not dry sweep dust accumulation or use compressed air for clean up. These procedures will help minimize potential exposures.
SPOSAL	: Dispose in sanitary landfill in accordance with local, state and federal quirements.

Material Safety Data Sheet – Lead Nitrate's MSDS[8]

Section 1: Physical and Chemical Properties

ysical state and appearance: Solid. (Translucent crystals.)

lor : Odorless.

ste : Not available.

olecular Weight : 331.2 g/mole

lor : White. Colorless.

I (1% soln/water) : Not available.

iling Point : Not available.

elting Point : 470°C (878°F) - decomposes

itical Temperature : Not available.

ecific Gravity : 4.53 (Water = 1)

por Pressure : Not applicable.

por Density : Not available.

latility : Not available.

lor Threshold : Not available.

ater/Oil Dist. Coeff. : Not available.

icity (in Water) : Not available.

spersion Properties : See solubility in water, methanol.

lubility:

sily soluble in cold water, hot water.

luble in methanol.

lubility in water: 1 g/2 ml cold water; 1 g/0.75 ml boiling water; 37.65 g/100 ml water @ 0 deg. C;
.5 g/100
water @ 20 deg. C; 127 g/100 ml water at 100 deg. C.

lubility in absolute alcohol: 1 g/2500 ml

lubility in Methanol: 1 g/75 ml

oluble in concentrate nitric acid.

Section 2: Hazards Identification

tential Acute Health Effects:

ry hazardous in case of ingestion. Hazardous in case of skin contact (irritant), of eye contact (irritant),

alation. Slightly hazardous in case of skin contact (permeator). Prolonged exposure may result in skin
rns
d ulcerations. Over-exposure by inhalation may cause respiratory irritation.

tential Chronic Health Effects:

RCINOGENIC EFFECTS: Classified A3 (Proven for animal.) by ACGIH, 2B (Possible for human.)
by IARC.
JTAGENIC EFFECTS : Mutagenic for mammalian somatic cells.
RATOGENIC EFFECTS : Not available.
VELOPMENTAL TOXICITY : Classified Reproductive system/toxin/female, Reproductive
stem/toxin/male
[SUSPECTED].
e substance may be toxic to blood, kidneys, the reproductive system, peripheral nervous system,
tral
rvous system (CNS).
peated or prolonged exposure to the substance can produce target organs damage.

Section 3: First Aid Measures

e Contact:

eck for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of
ter for at
st 15 minutes. Cold water may be used. Get medical attention.

in Contact:

case of contact, immediately flush skin with plenty of water. Cover the irritated skin with an
ollient. Remove

ntaminated clothing and shoes. Cold water may be used.Wash clothing before reuse. Thoroughly clean oes fore reuse. Get medical attention.

rious Skin Contact:

ash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek mediate ɔdical attention.

halation:

inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give ygen. Get ɔdical attention.

rious Inhalation:

acuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or ıistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to- ›uth ıuscitation. WARNING: It may be hazardous to the person providing aid to give mouth-to-mouth ıuscitation ıen the inhaled material is toxic, infectious or corrosive. Seek medical attention.

gestion:

› NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth an conscious person. If large quantities of this material are swallowed, call a physician immediately. osen tight ›thing such as a collar, tie, belt or waistband.

rious Ingestion: Not available.

Section 4: Fire and Explosion Data

ammability of the Product: Non-flammable.

ıto-Ignition Temperature: Not applicable.

ash Points: Not applicable.

ammable Limits: Not applicable.

'oducts of Combustion: Not available.

re Hazards in Presence of Various Substances: combustible materials, organic materials

ɩplosion Hazards in Presence of Various Substances:

sks of explosion of the product in presence of mechanical impact: Not available.

sks of explosion of the product in presence of static discharge: Not available.

ıghtly explosive in presence of heat, of combustible materials, of organic materials.

re Fighting Media and Instructions: Not applicable.

ıecial Remarks on Fire Hazards:

ill accelerate burning when involved in a fire.

ay ignite combustibles (wood, paper, oil, clothing, etc.).

ad nitrate reacts with brilliant sparks when projected on red-hot carbon.

ıngerous fire risk in contact with organic materials.

hen heated to decomposition it emits very toxic fumes of lead and nitrogen oxides.

ıecial Remarks on Explosion Hazards:

ay react explosively with hydrocarbons (fuels).

any metal oxo-compounds (nitrates, oxides, and particularly sulfates) and sulfides are reduced

ɔlently or

plosively in heating with aluminum powder to a suitably high temperature.

ay explode when in presence of organic or easily oxidizable compounds.

ay form explosive compound with ammonium thiocyanate, potassium acetate, or lead hypophosphite.

Section 5: Accidental Release Measures

ıall **Spill:** Use appropriate tools to put the spilled solid in a convenient waste disposal container.

ırge **Spill:**

ıidizing material.

ɔp leak if without risk. Avoid contact with a combustible material (wood, paper, oil, clothing...). Keep
bstance
mp using water spray. Do not touch spilled material. Prevent entry into sewers, basements or confined
ːas;
ɛe if needed. Call for assistance on disposal. Be careful that the product is not present at a
ncentration level
ove TLV. Check TLV on the MSDS and with local authorities.

Section 6: Handling and Storage

ecautions:

ːep away from heat. Keep away from sources of ignition. Keep away from combustible material.. Do
t
ʒest. Do not breathe dust. Wear suitable protective clothing. If ingested, seek medical advice
mediately and
ow the container or the label. Avoid contact with skin and eyes. Keep away from incompatibles such

mbustible materials, organic materials.

orage:

ːep container tightly closed. Keep container in a cool, well-ventilated area. Separate from acids,
ːalies,
lucing agents and combustibles. See NFPA 43A, Code for the Storage of Liquid and Solid Oxidizers.

Material Safety Data Sheet – Cadmium Nitrate's MSDS[8]

Section 1: Physical and Chemical Properties

ysical state and appearance : Solid. (Crystals solid.)
dor : Not available.
ste : Not available.
olecular Weight : 236.43 g/mole
lor : White.
I (1% soln/water) : Not available.
iling Point : Decomposes.
elting Point : 59.5°C (139.1°F)
itical Temperature : Not available.
ecific Gravity : Not available.
por Pressure : Not applicable.
por Density : Not available.
latility : Not available.
lor Threshold : Not available.
ater/Oil Dist. Coeff. : Not available.
nicity (in Water) : Not available.
spersion Properties : See solubility in water.
lubility : Easily soluble in cold water.

Section 2: Hazards Identification

tential Acute Health Effects:

tremely hazardous in case of ingestion. Very hazardous in case of inhalation. Hazardous in case of in ntact (irritant), of eye contact (irritant). Prolonged exposure may result in skin burns and ulcerations. er-exposure by inhalation may cause respiratory irritation. Severe over-exposure can result in death.

tential Chronic Health Effects:

tremely hazardous in case of ingestion.

zardous in case of skin contact (irritant), of eye contact (irritant), of inhalation.

RCINOGENIC EFFECTS: Classified A2 (Suspected for human.) by ACGIH, 2 (Reasonably icipated.) by P.

JTAGENIC EFFECTS: Not available.

RATOGENIC EFFECTS: Not available.

VELOPMENTAL TOXICITY: Not available.

e substance is toxic to blood, kidneys, lungs.

Section 3: First Aid Measures

e Contact:

eck for and remove any contact lenses. Immediately flush eyes with running water for at least 15 nutes, eping eyelids open. Cold water may be used. Do not use an eye ointment. Seek medical attention.

in Contact:

ter contact with skin, wash immediately with plenty of water. Gently and thoroughly wash the ntaminated skin th running water and non-abrasive soap. Be particularly careful to clean folds, crevices, creases and oin. ld water may be used. Cover the irritated skin with an emollient. If irritation persists, seek medical ention.

rious Skin Contact:

ash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek mediate edical attention.

halation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

rious Inhalation:

acuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or aistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-outh suscitation. Seek medical attention.

gestion:

o not induce vomiting. Examine the lips and mouth to ascertain whether the tissues are damaged, a ssible dication that the toxic material was ingested; the absence of such signs, however, is not conclusive. oosen ght clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-outh suscitation. Seek immediate medical attention.

erious Ingestion: Not available.

Section 4: Fire and Explosion Data

lammability of the Product : Non-flammable.
uto-Ignition Temperature : Not applicable.
lash Points : Not applicable.
lammable Limits : Not applicable.
roducts of Combustion : Not available.
ire Hazards in Presence of Various Substances: Not applicable.
xplosion Hazards in Presence of Various Substances:
isks of explosion of the product in presence of mechanical impact: Not available.
isks of explosion of the product in presence of static discharge: Not available.
ire Fighting Media and Instructions : Not applicable.
pecial Remarks on Fire Hazards : Not available.
pecial Remarks on Explosion Hazards: Not available.

Section 5: Accidental Release Measures

nall Spill: Use appropriate tools to put the spilled solid in a convenient waste disposal container.

rge Spill:

idizing material.

op leak if without risk. Avoid contact with a combustible material (wood, paper, oil, clothing...). Keep

bstance

mp using water spray. Do not touch spilled material. Prevent entry into sewers, basements or confined

as;

e if needed. Call for assistance on disposal. Be careful that the product is not present at a

ncentration level

ove TLV. Check TLV on the MSDS and with local authorities.

Section 6: Handling and Storage

ecautions:

ep locked up Keep away from heat. Keep away from sources of ignition. Keep away from

mbustible

terial Do not ingest. Do not breathe dust. Wear suitable protective clothing In case of insufficient

ntilation,

ar suitable respiratory equipment If ingested, seek medical advice immediately and show the

ntainer or the

el. Avoid contact with skin and eyes Keep away from incompatibles such as reducing agents,

nbustible

terials, organic materials.

rage:

ep container tightly closed. Keep in a cool, well-ventilated place. Highly toxic or infectious materials

uld be

red in a separate locked safety storage cabinet or room.