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# Research Activities of Faculty Staff & Postgraduates in Chemical Engineering Department



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# Research Activites of Faculty Staff & Postgraduates in Chemical Engineering Departement

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# **Faculty Staff Researches In Chemical Engineering Department**



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## Experimental Investigation and Thermodynamic Study of Heavy Metal Ions Removal From Industrial Wastewater Using Pomegranate Peel as Natural Adsorbent.

Prof. Dr. Thamer J. Mohammed. Assist. Prof. Dr. Raheek I. Ibrahim. And Aliaa Essam

### ABSTRACT

The contamination of water by toxic heavy metals through the discharge of industrial wastewater is worldwide environmental problem. The environmental impact due to their toxicity has led to the enforcement of stringent standards for the maximum allowable limits of their discharge into open landscape and water bodies. Copper is generally considered to be toxic to ratan at concentration exceeding  $5 \text{ mg/L}$ , imparts color and undesirable taste. The World health organization's guide line for drinking Water based on its staining properties is  $1 \text{ mg/L}$ . Fruit peel of pomegranate is used as natural resin adsorbent to remove copper ions from wastewater. Peels are dried, crushed and washed several times till the water was clear of all coloration and finally dried in an air oven. After drying the adsorbent was sieved to get the desired particle size. The adsorption capacity is tested and thermodynamic analysis of the system is also included in the study as well as break through which indicates the feasibility and economic aspects of adsorption process.

### دراسة عملية وثرموديناميكية لازالة المعادن الثقيلة من المياه الصناعية باستخدام قشور الرمان كمادة طبيعية

أ.د. ثامر جاسم محمد ، أ.م.د. رحيق اسماعيل ابراهيم ، م.م. علياء عصام

#### الخلاصة

ان الملوثات السامة الموجودة في المياه الصناعية تشكل مشكلة بيئية في كل انحاء العالم وتشكل ايونات عنصر النحاس احد العناصر السامة للإنسان اذا زاد التركيز عن  $5 \text{ ملغم/لتر}$  بينما حددت منظمة الصحة العالمية تركيز  $1 \text{ ملغم/لتر}$  كحد اقصى لعنصر النحاس في مياه الشرب. في هذا البحث يتم استخدام قشور الرمان كمادة مازة طبيعية لازالة ايونات النحاس بعد جمع القشور وتجفيفها وطحنها وغسلها عدة مرات ثم يتم تجفيفها في فرن هوائي ثم يجري نخلها للحصول على حجم دقائق مناسب. يتم إجراء الحسابات على سعة الامتزاز وتحليل ثرموديناميكي للنظام الاضافة الى منحنى والذي يشخص الجوانب العلمية والاقتصادية لعملية الامتزاز



## Preparation and Characterization of Activated Carbon From Wheat Kusk and Its Application In Color Removal of Textile Waste water

Assist Prof. Dr. Mohamed I. Mohamed, Assist Prof. Dr. Ana'am A. Sabri, and  
Dr. Eman J. Taha

### ABSTRACT

Among varies industries, textile industry ranks first in usage of dyes for colorization of fiber. As a result, they generate a considerable amount of colored waste water. Among dye removal process, adsorption is proven to be one of the most efficient techniques. The present work aims to investigate the sorption of simulated textile waste water on to wheat husk as that acts as a low cost adsorbent. Batch mode adsorption was performed to investigate the adsorption capacities of this adsorbent by varying initial dye concentration, contact time, adsorbent dose and PH. The equilibrium adsorption data of dye onto wheat husk were analyzed using freundlich and long muir adsorption isotherms. Also the adsorption kinetic data were analyzed using pseudo first order, pseudo second order and Elovich models

### ازالة الالوان من الماء الملوث لمعامل النسيج باستخدام قشور الحنطة

أ.م.د. محمد ابراهيم محمد ، أ.م.د. انعام اكرم صبري ، م.د. ايمان جواد

### الخلاصة

ان قابلية الكربون المنشط على قصر الالوان قد زادت من اهميته في السنوات الاخيره في ازالة الالوان الملوثة للماء والنواتجة من معامل الاصباغ وخصوصا تلك المتعلقة بمصانع انتاج الاقشمة. في هذا البحث يتطلب العمل على انتاج الكربون المنشط من قشور بذرة الحنطة واستخدامه كمادة الممتزة للالوان في تنقية المياه. كما سيتم دراسة خصائص الكربون المنشط الفيزيائية من خلال دراسة الحجم الحبيبي والمساحة السطحية وسعة الامتزاز والكثافة والتركيب المجهرى.



## Catalytic Phenol Oxidation with Phase Change in Periodically Operated Trickle Bed Reactor

Dr .Farah T. Jasim

### ABSTRACT

Periodic operation of fixed bed reactors Industrial fixed bed reactors are usually operated under steady state conditions. However, recent studies have demonstrated that the reactor performance is significantly improved under forced periodic operation conditions both at laboratory and pilot plant scale .The term 'periodic operation' refers to an operation, in which one or more operating parameters liquid flow rate, feed composition or temperatures are periodically varied in time. Since 1989, many studies were dealing with liquid flow, gas flow and composition and reactant feed composition modulation (alpha-methyl styrene , dicyclopentadiene hydrogenation , Oxidation of ethanol and benzyl alcohol) . The enhancement observed in an unsteady state fixed bed reactor operation arises from the alteration of the gas and liquid phases for supply in reactant to the catalyst surface by periodically modifying the conditions of the gas-liquid hydrodynamics (pressure drop, liquid and gas holdup, partial wetting) and mass and heat transfer in the reactor. Only a few works has been dedicated to periodic operation of liquid flow and gas flow and composition applied to the CWAQ of phenol in Trickle bed reactors in the last few years. The present study continued to study further points utilizing the advantages associated with periodic operation in order to meet the demands for process intensification to control on the wetting efficiency. Steady State Operation of TBR for CWAQ with phase change broader range of operating conditions: LHSV , reaction temperature ,Phenol concentration .Periodic operation of TBR for CWAQ with phase change under: liquid flow modulation(phenol feed flow). in broader range of operating conditions of cycle period and cycle split.

## اكسدة الفينول بالعامل المساعد بتغيير الطور في مفاعل الطبقة الوشلة بالتشغيل الدوري المتقطع

م.د. فرح طالب جاسم

### الخلاصة

تعد المخلفات الصناعية مصدرا من مصادر تلوث مياه الانهار اذ ان الفضلات الصناعية والمواد والمخلفات الورقية والفضلات الكيميائية والبتروولية وفضلات الصناعات النسيجية والصناعات المعدنية والتعليب وغيرها ، اصبحت هذه الانهار مصارف لهذه الملوثات الصناعية. ومياه الأنهار في العراق تتعرض بصورة يومية إلى عملية تدمير قد تفوق كل التصورات العالمية. وفي ظل هذا التدهور البيئي تهدف دراستنا لدراسة كفاءة تقنية Periodic operation لمفاعل الطبقة الوشلة لمعالجة المياه الملوثة بالملوثات العضوية "الفينول" التي تطرحها الانشطة الصناعية. دراسة العوامل المؤثرة لمعالجة تلوث المياه بالمادة الفينول بطريقة Catalytic Wet Oxidation في مفاعل الطبقة الوشلة " Trickle bed Reactor " عند طرق تشغيليه مختلفه ، التشغيل المستقر (Steady State Operation) والتشغيل الدوري (Unsteady Periodic Operation) والمتضمن التقطيع الدوري لمعدل جريان السائل ( Liquid Flow Modulation ) لبيان إمكانية زيادة كفاءة العمل و تحسين الانتقائية. تضمنت الدراسة العملية نصب جهاز مختبري واجراء سلسلة من التجارب لدراسة العوامل المؤثره وهي :-معدل جريان السائل وضغط المفاعل و درجة حرارة المفاعل وعوامل التشغيل الدوري وتشتمل على زمن الدورة الكلي (Period time) على نمطين، البطيء (slow mode) والسريع (Fast mode) ونسبة زمن فتح السائل الى زمن الدورة الكلي (Cycle split).





## Absorption of Acidic Gas( $\text{CO}_2$ ) into Aqueous Ammonia Promoted with Ethanolamine

Dr. Farah T. Jasim

### ABSTRACT

Carbon dioxide is the major greenhouse gas in the world that needs to be reduced. There are various technologies used to separate  $\text{CO}_2$  from flue gas. These include chemical solvent methods, physical absorption methods, cryogenic methods, membrane systems, biological fixation, and the  $\text{O}_2/\text{CO}_2$  combustion process. Compared with the chemical plant, power plant has a large flue gas flow, different ingredients, relatively low  $\text{CO}_2$  concentration and other characteristics. So the chemical solvent methods are generally recognized as the most effective technologies at present. This requires that the researchers developed a relatively low-cost, low-energy requirement  $\text{CO}_2$  capture technology. Among the conventional  $\text{CO}_2$  chemical removal processes, the mono-ethanolamine (MEA) process has been comprehensively studied and successfully used in chemical plants for  $\text{CO}_2$  recovery. Some of the problems associated with the use of alkanolamines in absorption include oxidative degradation and high vapor pressure. These contribute to solvent losses, degradation product handling, and other negative effects in the process. Aqueous ammonia ( $\text{NH}_3$ ) solutions are now being proposed as an alternative to aqueous alkanolamines based liquid absorbents for PCC. Aqueous ammonia has been shown to achieve higher  $\text{CO}_2$  loadings (on a molar and mass basis) than sterically free primary alkanolamines such as mono-ethanolamine (MEA). This is mainly due to the  $\text{CO}_2\text{--NH}_3\text{--H}_2\text{O}$  system favoring bicarbonate over carbamate formation, particularly as  $\text{CO}_2$  loading increases. Aqueous ammonia has also been shown to require less heat input for desorption than MEA. This is due to the smaller reaction enthalpy for  $\text{CO}_2$  absorption and higher  $\text{CO}$  partial pressure at elevated temperature compared to MEA. Also, ammonia is resistant to oxidative degradation, which is a major ~~draw~~ when treating oxygen containing gas streams such as those from coal-fired power stations. The other main attractive feature is that in the presence of sulphur and nitrogen oxides in the gas stream, the ammonium salts that form may have commercial value as fertilizers. A major drawback in the use of ammonia is its vapor pressure. Due to its small molecular weight ammonia vapor pressure is high (compared to alkanolamines). To address this it has been proposed that the absorption process take place at lower temperatures to reduce losses via volatilization. A series of tests was conducted in a semi-batch reactor (bubble column) that has been developed in this research.  $\text{CO}_2$  removal efficiencies of aqueous ammonia promoted with ethanolamine have been studied. To study of the absorption rate, mass transfer coefficient and reaction kinetic type and regime.

## امتصاص الغازات الحامضية CO<sub>2</sub> باستخدام محلول الامونيا مع الايثانول امين

م.د.فرح طالب جاسم

### الخلاصة

غاز ثاني أكسيد الكربون هو من الغازات الاحتباس الحراري الرئيسية في العالم التي تحتاج إلى تخفيض . هناك العديد من التقنيات المستخدمة لازالة غاز ثاني اوكسيد الكربون من غازات الاحتراق . وتشمل هذه الطرق المذيبات الكيميائية، وطرق الامتصاص الفيزيائي، وأساليب المبردة وأنظمة الاغشية، التثبيت البيولوجي، وعملية الاحتراق. O<sub>2</sub>/CO<sub>2</sub> مقارنة مع مصنع للمواد الكيميائية، محطة الطاقة لديها تدفق كبير لغازات الاحتراق، والمكونات المختلفة، وتركيز CO<sub>2</sub> منخفضة نسبيا وغيرها من الخصائص . الامتصاص بالمذيبات الكيميائية هي الأكثر فعالية في الوقت الحاضر لازالة الغازات الحامضية وخاصة غاز ثاني اوكسيد الكربون . وهذا يتطلب اجراء دراسات لايجاد افضل انواع المذيبات والتي تكون بكلفة واطنة وكفاءة عالية في الازاله للغازات الحامضية . وجد من خلال الدراسات ان استخدام الامينات ( المونوايثانول امين ) من المذيبات ذات كفاءة عالية لكن لديها ضغط بخري عالي وتتفكك بوجود غاز الاوكسجين مما يؤدي الى استبداله بانواع اخرى ذات مقاومه اعلى لغاز الاوكسجين من بين هذه الانواع الكربونات ومحلول الامونيا من افضل الخيارات وجدت . والعيب الرئيسي في استخدام الأمونيا هو ضغط بخاره . بسبب ضغط بخاره صغيرة الوزن الجزيئي الأمونيا عالية ( مقارنة بالمونوايثانول امين ) ولمعالجة هذا وقد اقترح أن عملية الامتصاص تتم في درجات حرارة منخفضة للحد من الخسائر عن طريق التطاير . في هذا البحث تتم دراسة عملية امتصاص غاز ثاني اوكسيد الكربون باستخدام محلول الامونيا المطور باستخدام مفاعل العمود الفقاعي.

## Experimental Study and Mathematical Modeling of Leaching of Copper From Computer Electronic Waste by Direct Reacting

Dr. Eman J. Taha, Taghreed L. Abdul-Rahm , and Nahla F.

### ABSTRACT

Computer electronic wastes are currently being dumped in landfills which are causing a series environmental harm in the form of toxic gases or hazardous compounds. The extraction from electronic waste is both profitable and environmentally. This study aims to design a commercial process to extract copper from electronic waste. The proposed extraction process has been sub-divided into two stages 1 physical separation 2 metal recoveries. Stage 1 involve s size reeducation to 1 mm, stage 2 involves the dissolution of metals in acid in different operating condition (time, temperature, concentration of acid, weight of sample).

### دراسة عملية مع موديل رياضي في أسترجاع النحاس من مخلفات الحاسبة الألكترونية

م.د ايمن جواد ، م.تغريد لطفي ، م.م. نهلة فاضل

### الخلاصة

تسبب مخلفات الحاسبة الألكترونية المتزايدة الأعداد حالياً مخاطر بيئية جدية بشكل غازات سامة او مواد خطرة بيئياً. ويعتبر أستخلاص المعادن من هذه المخلفات الألكترونية عمل مربح و صديق للبيئة. تهدف هذه الدراسة لتصميم عملية تجارية لاستخلاص النحاس من مخلفات الحاسبة الألكترونية وتقسم الى مرحلتين المرحلة الأولى الفصل الفيزيائي و المرحلة الثانية استرجاع المعدن . تتضمن المرحلة الأولى تقليل الحجم الى قطر 1 ملم و وتتضمن المرحل الثانية انحلال المعادن في الحامض عند ظروف تشغيلية مختلفة (زمن ، درجة حرارة ، تركيز الحامض ، وزن النموذج).



## Improve the Performance of Magnetic Nanoporous MCM-41 for Removal of Pollutants from Wastewater

Assist Pro. Dr. Ghanim M. Alwan , Dr. Talib M. Naieff, Omer S. Mahday

### ABSTRACT

The research is aimed to prepare magnetic nanoporous material MCM-41 and study its Physical characterization in order to improve its magnetic properties for study the operating conditions on the separation efficiency of the pollutants of wastewater by adsorption process. The experimental results are analysed so as to building mathematical model of the process and to determine the optimum operating conditions for the magnetic nanoporous material.

### تحسين أداء التركيب النانوي المسامي المغناطيسي MCM-41 في إزالة الملوثات من المياه الصناعية

أ.م.د. غانم مقبول علوان ، د. طالب محمد نايف، م.م. عمر صباح مهدي

#### الخلاصة

يهدف البحث الى تحضير ا لتركيب النانوي المسامي MCM-41 ودراسة الخصائص الفيزيائية للمادة النانوية المسامية في تحسين الخواص المغناطيسية للتركيب النانوي المسامي MCM-41 وكذلك دراسة الظروف التشغيلية على كفاءة الفصل للملوثات بعملية الامدصاص او التكتيف. يتم تحليل النتائج العملية في بناء موديل رياضي للعملية و تحديد الظروف التشغيلية والتصميمية المثلى للتركيب النانوي المسامي.

## Using Steganography and Genetic Algorithm Along with Cryptography to Produce a less Noise Image

Nahla F. , Nissren N.

### ABSTRACT

The issues of maintaining the confidentiality of information are of the most important topic of concern to researchers in data security .The steganography is the art and the science of hiding information so that it cannot be detected unless the person is a party in it. Now steganography is one of the most prevalent ways to deliver confidential information from the sender to wanted person. The proposed method is to create a way to hide the secret information by integrating steganography with genetic algorithm and encryption to produce an image with less noise and clearly more and at same time hide the required information by encrypts the secret information at the least signifying bit of the original image which hide information so that it becomes detectable difficult. The confidential information is recovered after decoding. Mat lab will be used for programming.

### استخدام النظرية الجينية و أخفاء المعلومات مع التشفير لإنتاج صورة أقل ضوضاء"

م.م. نهلة فاضل ، باحث اقدم . نسرین نجم

### الخلاصة

أن موضوع الحفاظ على سرية المعلومات من أهم المواضيع التي تشغل بال الباحثين في أمنية البيانات ويعتبر أخفاء المعلومات فن وعلم لأخفاء المعلومات بحيث لا يمكن كشفها مالم يكن الشخص طرفا في ذلك زوالن هي من أكثر الطرق أنتشارا في توصيل المعلومات السرية من المرسل الى الشخص المطلوب. البرنامج المقترح هو إنشاء طريقة لأخفاء المعلومات أكثر أمنا و ذلك بدمج طريقة أخفاء المعلومات مع الخوارزمية الجينية وبالتشفير أيضا لتنتج صورة ذات ضوضاء أقل ووضوح أكثر وبنفس الوقت تخفي المعلومات المطلوبة ويتم ذلك بتشفير المعلومات السرية عند البت الأقل أهمية للصورة الأصلية التي تخفي المعلومات بحيث يصبح كشفها صعبا. ويتم أسترجاع المعلومات السرية بعد فك التشفير وسوف يتم أستخدام برنامج المثالاب للبرمجة.



## Recognition Offline Arabic Handwritten Characters Using Neural Network

Safa A. Ahmed

### ABSTRACT

Because of the little attention for recognition Arabic handwritten and because difficulty with the Arabic script because of the position of character and diacritic marks associated to Arabic characters. This paper presents new approach for recognition offline Arabic handwritten characters. This approach involves using pack prorogation neural network algorithm and AHC of Arabic handwritten characters database. In this paper, 500 samples for each Arabic handwritten characters which provided by AHC database are used as training sample for pack prorogation neural network algorithm. This approach was tested using 87 Arabic handwritten characters and work with accuracy 71%.

### تميز احرف اللغة العربية المكتوبة بخط اليد باستخدام الشبكات العصبية

م.م. صفا امين

### الخلاصة

بسبب الاهتمام القليل بتميز اللغة العربية المكتوبة بخط اليد وبسبب صعوبة التعامل مع الحرف العربي بسبب موقعه و التشكيل المرتبط بالحروف العربية. يعرض هذا البحث طريقة جديدة لتمييز الأحرف المكتوبة بخط اليد العربية. ينطوي هذا النهج باستخدام خوارزمية الشبكة العصبية وقاعدة بيانات AHC تحتوي على الحروف العربية المكتوبة بخط اليد في. هذا البحث يستخدم 500 عينة لكل الأحرف المكتوبة بخط اليد العربية التي تقدمها قاعدة بيانات AHC كما لتدريب خوارزمية الشبكة العصبية. تم اختبار هذه الخوارزمية باستخدام 87 حرفا بخط اليد العربية وكان العمل مع دقة 71%.

## Removal of Dyes from Synthetic Wastewater by Agricultural Waste

Dr. Jenan A. Al-Najar

### ABSTRACT

This work aimed to use low cost adsorbent for the removal of such chemical contaminated in wastewater. These adsorbents will be used is waste agricultural like peel beans and wild plants. These adsorbents will be used directly and or subjected to specific chemical treatment as well. Adsorption technique is one of the most important technologies for the treatment of polluted water from dyes, but seeking for the low-cost adsorbent is the target of this study. Batch adsorption experiments will perform by varying adsorbent dose, pH of the metal ion solution and contact time. The adsorbent capacity will be study in this work as well. Also the physical and morphology characteristic of the adsorbent will be studied such as analyzing the internal structure with scanning electronic microscopy (SEM) and the pore size volume using BET. Also the surface functional group by will be investigated by Fourier transformation infrared spectroscopy techniques. The adsorbents will be analyzed to determine its chemical characteristics such as bulk density, moisture content, ash content, pH, iodine number, porosity, pH, yield percentage and surface area.

### أزالة الاصباغ من مياه الصرف الصحي باستخدام المخلفات الزراعية

م.د. جنان النجار

### الخلاصة

يهدف البحث إلى استخدام مواد رخيصة الثمن وهي المخلفات الزراعية كمادة ممدصة لغرض إزالة الملوثات الكيميائية من مياه الصرف الصحي. هذه المواد تستخدم مباشرة لغرض معالجة المياه. وكذلك يتم استخدامها بعد معاملتها مع مواد كيميائية. يتم دراسة قابلية هذه المواد لازالة الملوثات الاصباغ باستخدام تقنية الامتزاز الوجداني Batch adsorption. يتم دراسة تأثير عدد من المتغيرات مثل تركيز الملوثات، حامضية المحلول، زمنه وسرعة الامتزاز. كذلك يتم دراسة وتحليل المادة الممتزة من حيث تحليل التركيب الداخلي لهذه المواد، مساميتها، مساحه السطحية وكذلك دراسة التركيب الكينيائي لها وسعتها الامتزازية لمعرفة كفاءتها لعملية الامتزاز.

## Effect of Acetic Acid on Electrochemical Behavior of Sealed AA2319 T3 Anodized in Phosphoric Acid Electrolytes

Dr. Khalid H. Rashid

### ABSTRACT

The present study investigates the effect of acetic acid on corrosion behavior of hydrothermally sealed anodized AA2319. Anodizing treatment is performing in phosphoric acid electrolyte with or without addition of acetic acid. Hydrothermal sealing is carrying out in boiling water for each anodized specimen. A potentiostatic polarization technique is performing to assess corrosion behavior and anodic current reduction of the anodic films. The open circuit potential of the unsealed and sealed anodic films is examining using open circuit potential measurement to assess corrosion behavior of the anodic films. The corrosion potential of the sealed anodic films is examining using polarization technique to assess sealing quality and corrosion resistance of the anodic films.

تأثير حامض الخليك على السلوك الكهروكيميائي لأنودة وختم مسامات سبيكة المنيوم 2319 في محاليل  
حامض الفوسفوريك الأليكترووليتية

د. خالد حامد رشيد

### الخلاصة

في هذا البحث سيتم دراسة تأثير حامض الخليك على سلوك التآكل لسبيكة الألمنيوم AA2319 المختومة مساميتها باستخدام الماء المغلي. سيتم إجراء عملية الأنودة في المحلول الأليكترووليتي لحامض الفوسفوريك بوجود وبدون وجود إضافة حامض الخليك. سيتم إنجاز عملية الختم بطريقة الماء المغلي لكل نموذج مأنود. سيتم استخدام تقنية الاستقطاب للجهد الساكن لتعيين سلوك واختزال التيار الأنودي لطبقات الأكسدة. وسيتم إجراء فحص جهد الدائرة المفتوحة لطبقات الأكسدة المختومة والغير مختومة باستخدام قياس جهد الدائرة المفتوحة لتعيين سلوك التآكل لطبقات الأكسدة. جهد التآكل لطبقات الأكسدة المختومة سيتم فحصها باستخدام تقنية الاستقطاب لتعيين نوعية الختم ومقاومة التآكل لطبقات الأكسدة.

## Nanosilicate Extraction from Rice Husk Ash as Green Corrosion Inhibitor for Low Carbon Steel

Dr. Shatha A. Sameh , Dr. Najat H. Saleh . Basheer A. Abdul-Hussein

### ABSTRACT

Nano-Silica was extracted from rice husk ash (RHA) used to produce green corrosion inhibitor for low carbon steel. Different concentrations of this inhibitor are preparation to evaluate the efficiency of correction rate before and after use nano-silica by applied weight loss and polarization technique. The surface morphology and microstructure of carbon steel with and without inhibitor are investigated by AFM (Atomic Force microscope) and optical microscope or SEM.

استخدام مثبطات تأكل صديقة للبيئة (نانوسليكا) المستخلصة من قشور الرز لحماية الفولاذ الواطيء الكربون

د. شذى احمد سامح ، د. نجاة جمعة صالح ، بشير احمد عبد الحسين

### الخلاصة

يتم في هذا البحث استخدام مادة (النانو سليكا) التي تم استخلاصها من قشور الرز لغرض انتاج مثبط تأكل اخضر (صديق للبيئة) يستخدم لحماية معدن الصلب الكربوني والذي له استخدامات متعددة في الصناعة. يتم تحضير تراكيز مختلفة من هذا المثبط لغرض تحديد افضل كفاءة لتقليل معدل التآكل للمعدن عن طريق تجارب الفقدان بالوزن وتقنية المجهد الساكن ( Potentiostat ). يتم دراسة البنية المجهرية للطبقة المتكونة على سطح المعدن باستخدام اجهزة ميكروسكوب القوى الذرية (AFM) والمجهر الإلكتروني الماسح (SEM) قبل وبعد عملية استخدام المثبط.

## Nucleation and Non-Isothermal Kinetics Model of PBT/MWCNT Composite Nanofibers System

S. R. Sultan, Amer A. Abdul-rahman, Ayad D. Jaafar

### ABSTRACT

In this research, the composite nanofibers of Poly(butylene terephthalate) (PBT)/multiwalled-carbon nanotubes (MWCNTs) will be prepared by electrospinning technique in the form of a random fibers web. After that, the characterization of samples for their chemical and physical properties using different analytical techniques will be carried out. Moreover, the nucleation and non-isothermal crystallization kinetics model of PBT- MWCNTs nano composites will be developed by differential scanning calorimetry (DSC).

### نمذجة حركية التفاعل لنظام PBT/MWCNT مركبة الياف النانو

م.د. سعد رحيم سلطان، م.د. عامر عزيز عبد الجبار، اياد داري جعفر

### الخلاصة

في هذا البحث سيتم تحضير مركبة الياف البولي بيوتلين ترفثاليت المدعمة بنانابيب كربونية نانوية باستخدام تقنية الغزل الكهربائي. بعد ذلك سيتم توصيف الخواص الكيميائية والفيزيائية للنماذج المحضرة باستخدام تقنيات التحليل المختلفة. علاوة على ذلك سيتم تطوير نموذج حركية التفاعل والتبلور عند درجات حرارة مختلفة





# Summaries of M.Sc. Students Researches



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**Research Title: A Comparative Study of Coagulation-Flocculation and Electro Coagulation in the Treatment of Produced Water**

**Supervisor: Prof. Dr. Thamer J. Mohammed**

**Student Name: Esraa Radih Abbas**

**Produced Oil Field Water (Definition and Characteristic )**

Petroleum is a major source of energy and revenue for many countries today, and its production has been described as one of the most important industrial activities in the twenty-first century, Oliveira EP, Santelli RE, Cassella RJ, et al. (2005). Iraq's energy sector is heavily based upon oil, with approximately 94% of its energy needs met with petroleum. Since late 1850s when Edwin Drake drilled the first oil well, demand for petroleum has continued to rise. It's estimated that world daily petroleum consumption would increase from 85 million barrels in 2006 to 106.6 million barrels by 2030, [www.eia.doe.gov/oiaf/ieo/index.html](http://www.eia.doe.gov/oiaf/ieo/index.html) (2009). Despite its significance, petroleum is produced with large volumes of waste, with wastewater accounting for more than 80% of liquid waste, Azetsu-Scott K, Yeats P, Wohlgeschaffen G, et al. (2007). and as high as 95% in ageing oilfields, Kaur G, Mandal AK, Nihlani MC, et al. (2009). Generally, the oil/water volume ratio is 1:3, Fakhru'l-Razi A, Pendashteh A, Abdullah LC, et al. (2007). In North America, the ratio is approaching 10:1, but in Iraq is >1:5 (Huda 2013) therefore there is a lot of water produced in Iraq reported that for every 1 billion barrel of oil, 7 bbl. of water is produced. During the process of lifting oil or gas from underground formations, trapped water is brought to the surface along with oil or gas this water is known as produced water. Produced water has a complex composition, but its constituents can be broadly classified into organic and inorganic compounds, Hayes T and Arthur D (2004). It contains dissolved and dispersed oils, grease, heavy metals, radionuclides, treating chemicals, formation solids, salts, dissolved gases, scale products, waxes, microorganism and dissolved oxygen. Sirivedhin T, McCue J, Dallbauman L et al.

Generally the physical and chemical properties of produced water significantly depend on the geographic location of the oil or gas field geological contact materials of the water in the past, and the type of the products . Globally, 250 million barrels of water are produced daily from both oil and gas fields, and more than 40% of this is discharged into the environment Daniel Arthur J, Langhus BG, Patel C. et al .(2005). Generally, most of the produced water is reused and rejected into the underground for enhancing oil recovery after certain treatment yet large amounts of produced water are discharged directly into the environment (Guyinget al.2007) .Oilfields are responsible for more than 60% of daily produced water generated worldwide .The rate of oil field produced water production is expected to increase as oilfield ages (Fig. 1). Other factors have been reported to affect the quantity of produced water generated in an oilfield . Generally, produced water is composed of dissolved and dispersed oil components, dissolved formation minerals, production chemicals, dissolved gases (including CO<sub>2</sub> and H<sub>2</sub>S) and produced solids There is a wide variation in the level of its organic and inorganic composition due to geological formation, lifetime of the reservoir and the type of hydrocarbon produced.

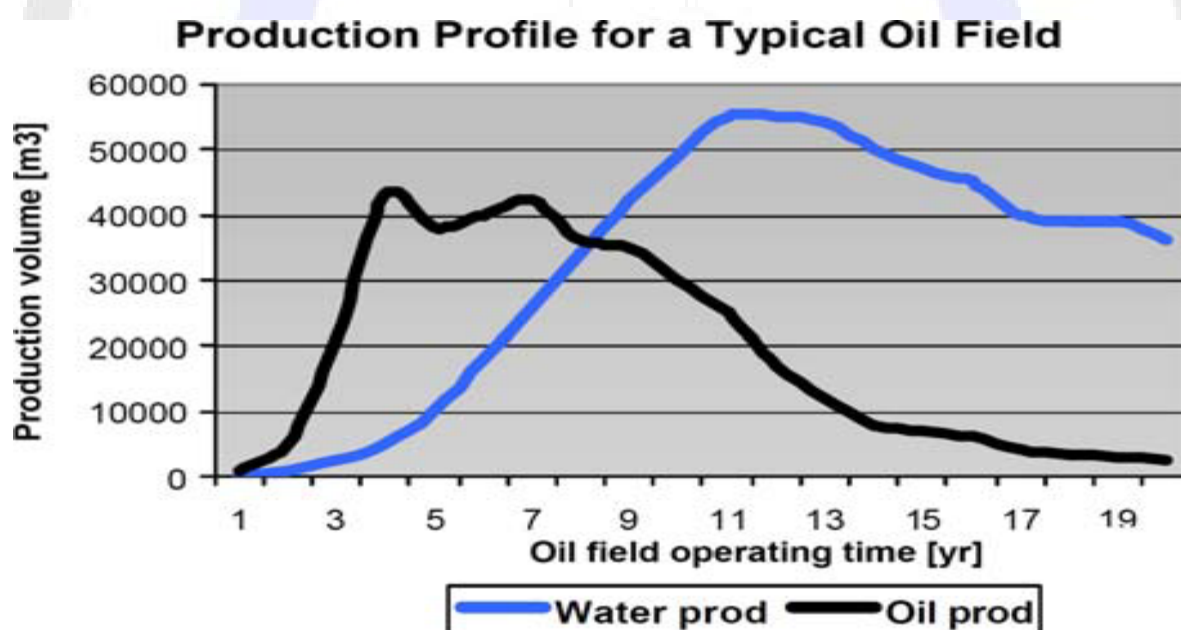


Figure (1) Typical production profile for an oilfield

Currently, oil and gas operators treat produced water via one or more of the following options :-



**Membrane filtration technology:-** There are different types membrane separation processes, including :-

- a. Microfiltration/ultrafiltration
- b. Polymeric/ceramic membranes
- c. Reverse osmosis and Nano filtration

These membrane are microspores films with specific pore ratings, which selectively separate a fluid from its components. treatment of waste water or produced water by these membrane were studied by numerous researchers such as ,xu and drewes ,(2006),Madaeni SS,(1999), Judd S and Jefferson B,(2003).

**Thermal technologies:-**Thermal separation process was the technology of choice for water desalination before the development of membrane technology and it employed in regions where the cost of energy is relatively cheap.**The major types thermal technologies are;** MSF, MED, VCD,Hamed OA,(2004), Colorado,(2009),GWI ,(2006), Ettouney HM, El-Dessouky HT, Gowin PJ, et al.

**Biological aerated filters:-**BAF can remove oil, ammonia, suspended solids, nitrogen, chemical oxygen demand (COD), biological oxygen demand (BOD), heavy metals, iron, soluble organics, trace organics and hydrogen sulphide from produced water, Colorado,( 2009), EPA. Onsite (1980), Su D, Wang J, Liu K, et al,(2007), Ball HL,(1994).

**Hydrocyclones:-** use physical method based on the density of the solids to be separated. They are used in combination with other technologies as a pre-treatment process, Svarovsky L,(1992).

**Gas flotation:-**This process uses fine gas bubbles to separate suspended particles that are not easily separated by Sedimentation, Cassidy AL,(1993).

**Evaporation:-** Evaporation ponds are typically economical and have been employed for the treatment of produced water onsite and offsite, Cassidy AL,(1993).

**Adsorption** :- It has been used to remove manganese, iron, total organic carbon (TOC), BTEX, oil and more than 80% of heavy metals present in produced water, Colorado, ( 2009)

**Media filtration**:- Filtration technology is extensively used for the removal of oil and grease and TOC from produced water, Colorado,( 2009).

**Ion exchange technology**:-It is especially useful in the removal of monovalent and divalent ions and metals by resins from produced water , McGraw-Hill,(1999).

**Chemical oxidation**:- Chemical oxidation is an established and reliable technology for the removal of colour, odour, COD, BOD, organics and some inorganic compounds from produced water, Barratt PA, Xiong F, Baumgartl A, et al.(1997).

**Electrodialysis/electrodialysis reversal** :- These processes involve separation of dissolved ions from water through ion exchange membranes, Colorado, (2009).

**Freeze thaw evaporation**:-FTEw process employs freezing, thawing and conventional evaporation for produced water management,Barratt PA, Xiong F, Baumgartl A, et al,(1999).

**Dewvaporation: AltelaRainSM process** :-Dewvaporation is a desalination technology. A prototype system based on dewvaporation process, AltelaRainSM, was developed by Altela Inc. and is already applied in full-scale commercial treatment of produced water, AltelaRainTM,(2007).

**Macro-porous polymer extraction technology**:- Macro-porous polymer extraction (MPPE) is one of the best available technologies and best environmental practices for produced water management on offshore oil and gas platforms,Akzo Nobel MPP Systems,(2004).

## Materials and methods

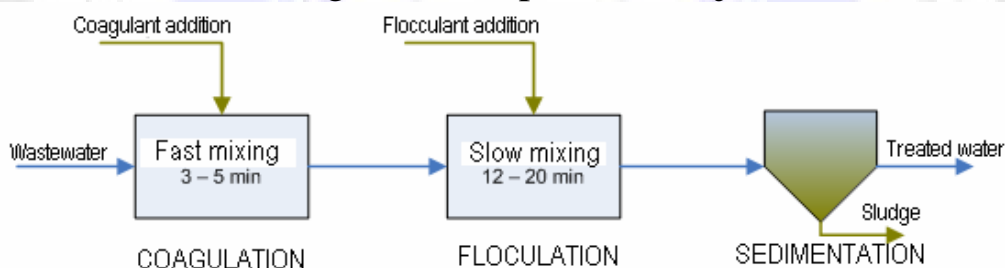
The present work will be investigate the evaluation possibility of treatment produced water by applied two methods are :-

**Coagulation and flocculation** :This process can be carried out by jar-test method as shown in figure:-



**Figure (2)Coagulation and flocculation process**

Coagulation is the process of making the particle less stable by neutralizing its charge, thus encouraging initial aggregation of colloidal and finely divided suspended matter. Particles no longer repel each other and can be brought together (NSF 1999), (EM2001).When oil particles suspended in water, the charge on organic and inorganic colloids is typically negative, because of electrostatic forces the negative colloid charge attracts positive ions, and figure illustrates how coagulants reduce the electric charges on the colloidal surfaces, allowing colloidal particles to join (EM 2001).



**Fig Coagulation– flocculation flowchart system**

## Coagulants and flocculants :-

Name	Comments
Alum	Widely used
Sodium aluminate	Used with alum; provide alkalinity and pH control
Aluminum Chloride	Used in blends with organic polymers
Polyaluminum Chloride (PACl)	Several formulations based on Al strength, $[OH^-]/[Al_2]$ , and anions and cations added
Polyaluminum Sulfate	Produced on-site
Ferric Chloride	Widely used
Ferric Sulfate	Widely used
Ferric Chlorosulfate	Used
Polyiron Chloride	Produced on-site
Cationic Organic Polymers	Wide variety of formulations with different charge densities and molecular weights; Poly (DADMAC) <sup>+</sup> and Epi/DMA <sup>+</sup> types are common

Zuxin et al, 2010 used Aluminium Sulphate, Ferric chloride, Polyaluminium Chloride (PAC) and Polyferric Sulfate (PFS) in coagulation- flocculation process and found Polyaluminium Chloride (PAC) proved most effective on the removal efficiency of COD and Turbidity, comparing the four coagulants employed. Chenget al, 2009 used Diatomite as core material to enhance the flocculation efficiency which composed of diatomite and PAC, used to treat oilfield produced water. The results showed that diatomite could improve the flocculation efficiency and the removal rate of turbidity and suspended solid could reach over 88%. Natural and synthetic coagulant aids are termed “polyelectrolytes” and have characteristics of both polymers and electrolyte (Culp and Culp, 1971). The present work will be study the treatment possibility of removal efficiency of some pollutants from produced water by addition of some chemical or natural coagulants through coagulation –flocculation

## Electrocoagulation:-

Electrocoagulation is a complex process, with many synergistic mechanisms operating to remove water pollutants (metals, anions, organic compounds, etc.) (Bebeșelea et al., 2006; Noubactep and Schöner, 2010). The main advantage of this treatment is the onsite production of disinfection agents in the same electrochemical cell (Canizares et al., 2005; Canizares et al., 2006; Ruiz, 2005; Secula et al., 2011). The electrocoagulation is a process which removes simultaneously heavy metal ions, solids in suspension, organic emulsions and many others water pollutants, using electric energy and sacrificial metallic plates (electrodes) instead expensive chemical reagents (Canizares et al., 2005; PISOI et al., 2011; Zaharia, 2005). The “sacrificial” anodes corrodes and discharge in the solution active precursor coagulant (usually iron or aluminum cations)

(Adhoum and Monser, 2004). As a result of their dissolution, the anodes are disappearing during the treatment, reaching a time when their replacement is necessary. In the electrocoagulation process it is important to use soluble anodes made of aluminum, iron or other material, and cathodes made of the same material, or steel (Bebeșelea et al., 2006; Mameri et al., 1998; Teodosiu, 2001; Vik et al., 1984). By applying to the electrocoagulation cell a voltage bigger than the theoretical voltage for water electrolyses, the metallic ions are generated in aqueous solution in a quantity depending on the electric current passing across the cell (Holt et al., 2002; Holt et al., 2005; Mollah et al., 2001). The electrocoagulation process can be described as follows: at the anode, the dissolved metallic ions species destabilize the colloids; besides that, this contributes further to their precipitation and at the cathode, the obtained hydrogen bubbles (resulted as a product of water electrolyses) capture the dispersed particles that are then separated by flotation (Bebeșelea et al., 2006; Miron et al., 2010).

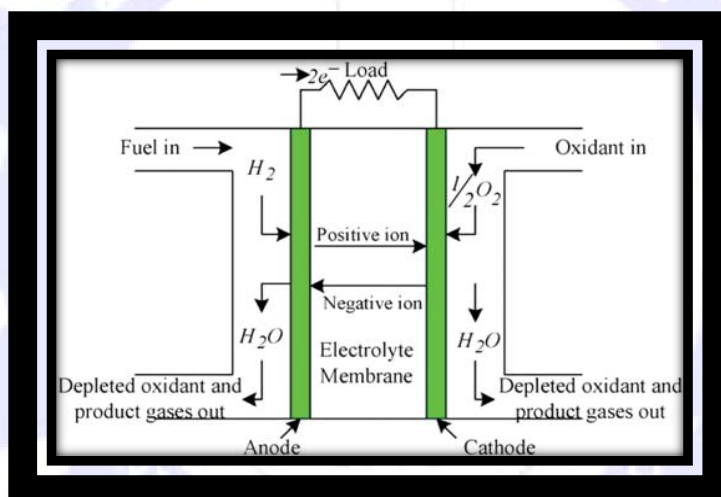


Figure (3) electrocoagulation process

### Comparison Between Two Methods

The comparison between the two methods to reach the most efficient method to remove contaminants. In order to point out some common aspects for both studied processes, the basic theory of chemical coagulation and electro coagulation will be briefly discussed. Both types of coagulation are based on the same principle: the addition of metallic ions (usually  $\text{Fe}^{3+}$ ,  $\text{Al}^{3+}$ ) into the treated water in order to destabilize the electrical charge of the colloidal particles from water, leading to the formation of aggregates bigger than the initial colloids, which determines the sedimentation and





water purification (Canizares et al., 2006; Canizares et al., 2007; Guibal and Roussy, 2007; Holt et al., 2002;). The difference between these two processes consists in the way metal ions are added. In case of chemical coagulation, the reagents ( $\text{FeCl}_3$ ,  $\text{Al}_2(\text{SO}_4)_3$ , etc) are directly added (Riera-Torres et al., 2010), while in case of electrocoagulation, the metallic cation is supplied by an electricity stream generated by the oxidation of the metallic electrode, producing the corresponding metal ions. In the same time with anodic material dissolution, takes place the electrolysis of water (involving some electrochemical processes) which also can improve the quality of treated water (Emamjomeh and Sivakumar, 2009).

### **Application of Produced Water Treatment**

Avoid production of water onto the surface – Using polymer gels that block water contributing fissures or fractures or Down hole Water Separators which separate water from oil or gas streams down hole and reject it into suitable formations. This option eliminates waste water and is one of the more elegant solutions, but is not always possible.

1. Inject produced water – Inject the produced water into the same formation or another suitable formation; involves transportation of produced water from the producing to the injection site. Treatment of the injectate to reduce fouling and scaling agents and bacteria might be necessary. While waste water is generated in this option, the waste is emplaced back underground.
2. Discharge produced water – Treat the produced water to meet onshore or offshore discharge regulations. In some cases the treatment of produced water might not be necessary.
3. Reuse in oil and gas operations – Treat the produced water to meet the quality required to use it for drilling, stimulation, and work over operations.
4. Consume in beneficial use – In some cases, significant treatment of produced water is required to meet the quality required for beneficial uses such as irrigation, rangeland restoration, cattle and animal consumption, and drinking water for private use or in public water systems.

## Objectives

There are different objective for treatment of produced oil filed water, such as :-

- De-oiling – Removal of free and dispersed oil and grease present in produced water.
- Soluble organics removal – Removal of dissolved organics.
- Disinfection – Removal of bacteria, microorganisms, algae, etc.
- Suspended solids removal – Removal of suspended particles, sand, turbidity, etc.
- Dissolved gas removal – Removal of light hydrocarbon gases, carbon dioxide, hydrogen sulfide, etc.
- Desalination or demineralization – Removal of dissolved salts, sulfates, nitrates, contaminants, scaling agents, etc.
- Softening – Removal of excess water hardness.
- Sodium Adsorption Ratio (SAR) adjustment – Addition of calcium or magnesium ions into the produced water to adjust sodicity levels prior to irrigation.
- Miscellaneous – Naturally occurring radioactive materials (NORM) removal.
- The present work will be study and select a case of oil well in Iraq and treatment of produced water to removal some as recycle pollutants which depend on where it is used. by applied two technology, chemical treatment (coagulation-flocculation),electro coagulation and comparative between them ,to find higher removal efficiency and low cost.

### Chart of planning thesis work

TASK \ Month	1	2	3	4	5	6	7	8	9	10	11	12
INTRODUCTION												
LITERATURE SURVEY												
EXPERIMENTAL WORK												
RESULTS AND DISCUSSION												
CONCLUSIONS ANDRECOMMENDATIONS												



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## Research Title: **Thermal Pyrolysis of Waste activated Sludge**

**Supervisor: Dr. Riyadh S. AlMukhtar**

**Student Name: Ruaa Omar Taha**

### **Introduction**

Sewage sludge is produced in tremendous amounts when municipal and industrial wastewater effluents are treated by biological processes. Sewage sludge is an inevitable major byproduct of wastewater treatment, and its disposal leads to a great problem. Besides, the cost of sludge treatment takes almost 50% of the capital and operating cost of a wastewater treatment facility. Pyrolysis of sewage sludge to produce bio-oil is under study as a useful way to valorize this waste. Sewage sludge is the waste produced in the wastewater treatment plants. Its composition may change due to the origin and to the non-standardized treatments in the wastewater treatment plants. The organic and inorganic matter composition, and the volatile and ash content of these sewage sludge samples were different. The influence of these parameters on the pyrolysis product distribution and on some characteristics of these products will be study.

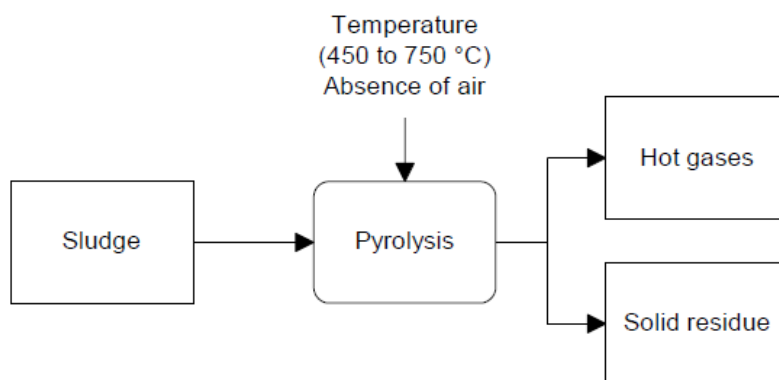
### **Proposal of the Study**

This study investigates the pyrolysis characteristics of sludge from wastewater treatment plants and focuses on the pyrolysis kinetics, heating values, elemental composition of residue, and volatile organic compounds (VOCs) of exhaust gas.

### **Review of the literature**

Sewage sludge is the waste generated when the water is purified in the wastewater treatment plants. It consists of a complex heterogeneous mixture of organic (undigested organics, such as, cellulose, lipids and dead bacteria and microbe) and inorganic materials. The composition and characteristics of sewage sludge depend on several factors like the origin of the wastewater, the purification treatment of the wastewater, the stabilization treatment of the sewage sludge, the time and storage conditions of the sewage sludge or the coagulant agents used. Moreover, the treatments in the wastewater treatment plants are not standardized(1). Pyrolysis is a thermal process treatment in

absence of oxygen. Waste is not burnt, but brought to a temperature of 300 to 900 °C. The process produces two kinds of residues: solids containing mineral matter and carbon, and hot gases. The process is presented in figure.



As the products of the process have a calorific value, pyrolysis is considered as a pre-treatment, requiring further valorisation of the solids and gases. Analyses of the composition of the gaseous product of the pyrolysis of sludge have shown that generally H<sub>2</sub>, CO, CO<sub>2</sub> and hydrocarbons are the main compounds found in the gas. The proportions however depend of the sludge type. CO is the dominant compound, with hydrocarbons representing in some cases an important part of the gas. Composition of the gas also depends on the temperature of the pyrolysis, as described in the table below [Werther and Ogada, 1999]. The composition of gases implies their treatment and use on site. They can also be cracked, as it facilitates their further use.

### Methods and Procedure

The fixed-bed pyrolysis experiments were performed in a vertically and externally heated tubular reactor (5 cm i.d. and 60 cm long), constructed from glass and heated by high-frequency generator (i.e., induction-heating) as reported previously. For all experiments, the sludge sample mass and sweep gas (i.e., N<sub>2</sub>) flow rate (controlled by a mass flow controller) were fixed at about 10 g and 1000 cm<sup>3</sup>/min (at room temperature), respectively. The experimental conditions in the pyrolysis system were as follows: pyrolysis temperature of 200-350 °C, and holding time (at the specified pyrolysis temperature) of 10-30 min. The resulting liquid products after pyrolysis were cooled to room temperature, and then taken from holding crucible and condensable collectors in order to weigh the masses of residual solid and liquid tar, respectively. The yields of the resulting products were thus calculated based on the mass of the sample fed, and then used for further characterization.





## Sampling

Samples of sewage sludge were supplied from municipal wastewater treatment plant of Alboethaa. These sample were dried in the treatment plant , proximate and analyses were made to these samples following standardized procedures.

## Data Collection

Oil analysis pyrolytic oils obtained well mixed and homogenized prior to analysis being made. The viscosity and caloric value of pyrolytic oils were determined according to some physical properties of pyrolytic oils were determined by using the following standard methods; ASTM D445 and ASTM D240. Elemental analysis (C, H, and N) of oils was determined with an elemental analyzer) The Sulphur amount in pyrolytic oils was determined using Ultraviolet Fluorescence according to ASTM D5453. The solid products from pyrolysis contain char, ash and unchanged biomass material. The pyrolysis conditions determine the chemical composition of the solid products. The char can be used in the preparation of active carbon when its pore structure and surface area are appropriate.

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## **Research Title: Mass and Heat Transfer Analysis of Water Desalination Using Membrane Distillation**

**Supervisors: Dr. Qusay F. Alsalhy  
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**Student Name: Fatima A. Hashim**

### **Introduction**

Membrane distillation is a process that utilizes differences in vapor pressure to permeate water through a macro-porous membrane and reject other non-volatile constituents present in the influent water [1,2].

Membrane Distillation (MD) is a hybrid thermal-membrane process that can use low grade waste heat to generate a vapor pressure difference across a hydrophobic membrane to produce a high quality distillate from concentrated brines. The MD process presents several benefits compared to Reverse Osmosis (RO) including: superior product water quality; ability to treat high salinity brines, and potentially lower capital & operating costs. These unique features of the MD process make it an ideal technical solution to desalinate brines from thermal desalination plants to increase fresh water production. The driving force for the MD processes is quite different from other membrane processes, being the vapor pressure difference across the membrane rather than an applied absolute pressure difference, a concentration gradient or an electrical potential gradient, which drives mass transfer through a membrane [1,3].

Membrane distillation was introduced in the late 1960s [4,5]. However, it was not commercialized at that time for desalination purposes. There were two major factors hindering its development [6]: (1) Membranes with adequate characteristics and at reasonable cost were not available; and (2) the economics of the process were not favorable compared to reverse osmosis (RO) [7]. The comparative economics were based on typical data from those membranes and systems which were far from optimal and the finding that the temperature polarization coefficient was low (estimated by Schofield et al. [8] to be 0.32). Hence, for this system, when the temperature difference between the bulk temperature of the hot and cold channels was 10 °C, the actual temperature difference across the membrane was only 3.2 °C. In the 1980s, with the availability of new membranes, more research focused on membrane distillation and

many novel MD modules were designed based on improved understanding of the mass and heat transfer principles of MD [9,10]. Furthermore, new applications formembrane distillation [11,12] were considered in environmental protection and wastewater treatment. According to the Terminology for Membrane Distillation [13], the MD processshould have the following characteristics:

- The membrane should be porous;
- The membrane should not be wetted by process liquids;
- No capillary condensation should take place inside the pores of the membranes;
- Only vapor should be transported through the pores of the membrane;
- The membrane must not alter the vapor equilibrium of the different components in theprocess liquids;
- At least one side of the membrane should be in direct contact with the process liquid; and
- For each component, the driving force of the membrane operation is a partial pressure gradientin the vapor phase.

According to previous research [14], there are two major factors hindering the application of membrane distillation: One is suitable membranes for MD and the other is energy efficiency.

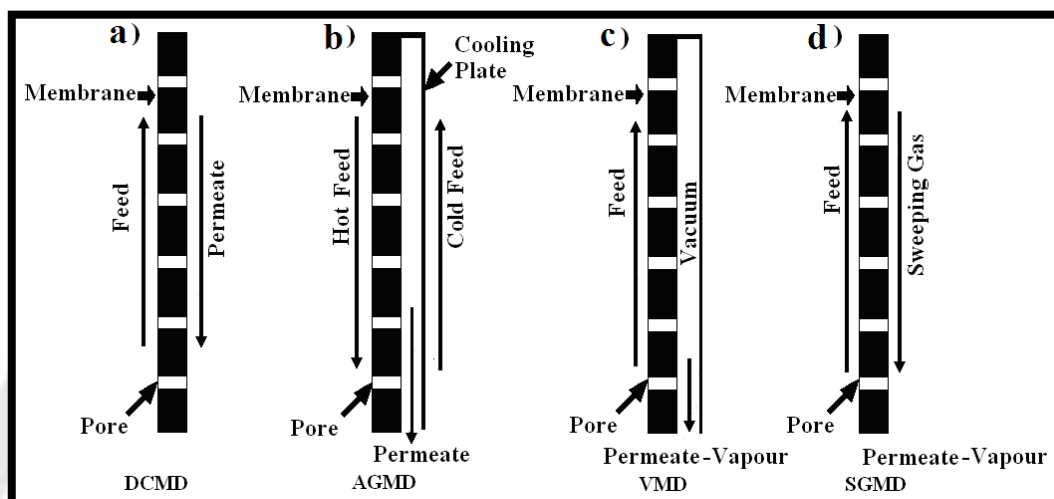
Figure 1 illustrates four configurations of the MD system, which differ based on the nature of the cold side processing of the permeate [6,14]:

**Direct Contact Membrane Distillation (DCMD)**, in which the membrane is in direct contact with liquid phases. This is the simplest configuration capable of producing reasonably high flux. It is best suited for applications such as desalination and concentration of aqueous solutions (e.g., juice concentrates) [1].

**Air Gap Membrane Distillation (AGMD)**, in which an air gap is interposed between the membrane and a condensation surface. The configuration has the highest energy efficiency, but the flux obtained is generally low. The air gap configuration can be widely employed for most membrane distillation applications [15], particularly where energy availability is low.

**Vacuum Membrane Distillation (VMD)**, in which the permeate side is vapor or air under reduced pressure, and if needed, permeate is condensed in a separate device. This configuration is useful when volatiles are being removed from an aqueous solution [16].

**Sweep Gas Membrane Distillation (SGMD)**, in which stripping gas is used as a carrier for the produced vapor. It is used when volatiles are removed from an aqueous solution [17].

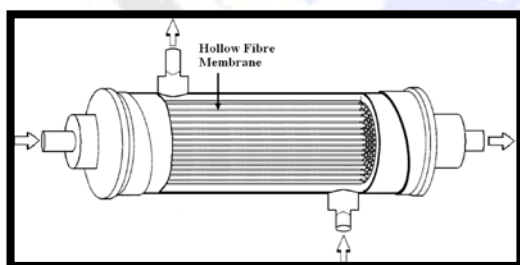


**Figure 1.**Membrane distillation configurations: (a) (DCMD); (b) (AGMD); (c) (VMD);(d) (SGMD).

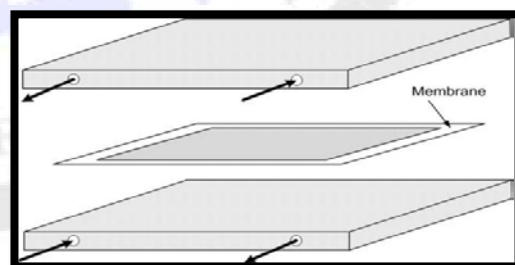
There are two major MD module configurations [2], which are the tubular module and the plate and frame module.

**Figure 2a** shows a schematic diagram of a hollow fiber tubular module, in which hollow fiber membranes are glued into a housing. This configuration can have a very high packing density ( $3000 \text{ m}^2/\text{m}^3$ )[18].

**Figure 2b** shows the structure of the plate and frame module. This module is suitable for flat sheet membranes and can be used for DCMD, AGMD, VMD, and SGMD. In this configuration, the packing density is about  $100\text{--}400 \text{ m}^2/\text{m}^3$ [18].



**a**



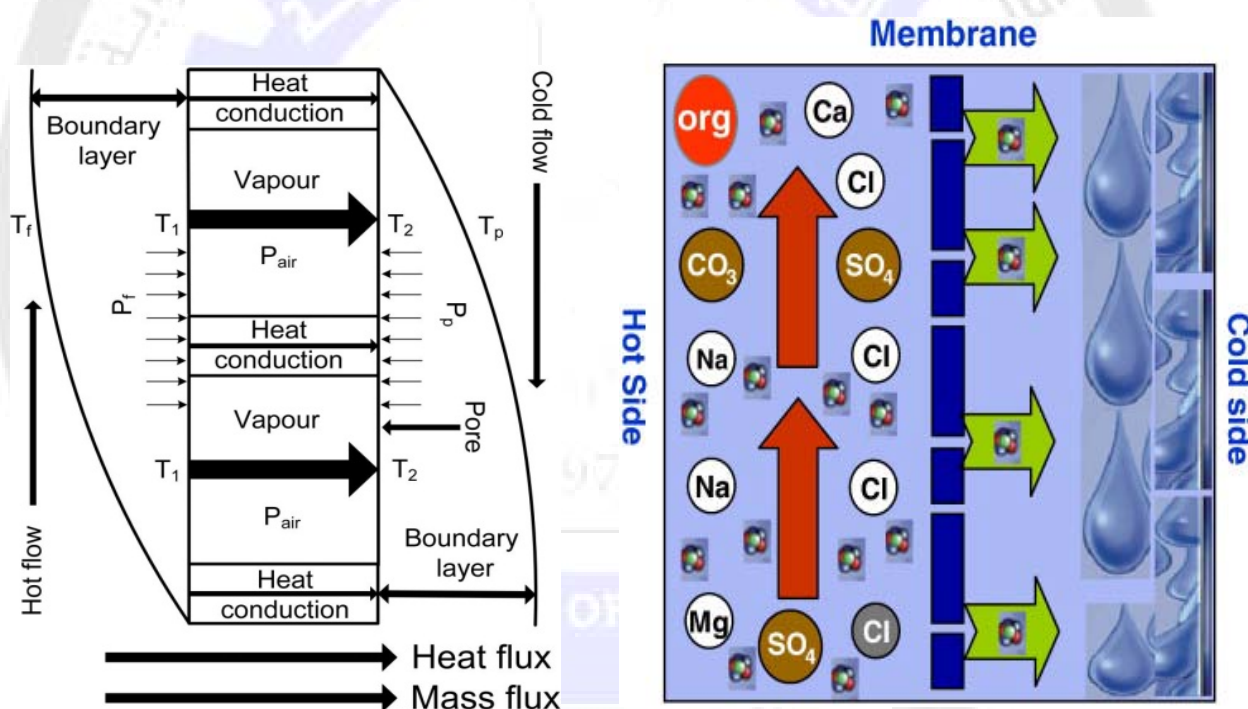
**b**

**Figure 2.**Membrane distillation (MD) Modules: (a) Tubular module for hollow fiber; (b) Plate and frame module for flat sheet membrane.



### Heat Transfer and Mass Transfer Phenomena in MD

In MD processes, heat and mass transfers are coupled together in the same direction from the hot side to the cold side [19]. Figure 3 illustrates these processes in DCMD, which is typical for MD configurations. The feed temperature,  $T_F$ , drops across the feed side boundary layer to  $T_1$  at the membrane surface. Some water evaporates and is transported through the membrane. Simultaneously, heat is conducted through the membrane to the cold (permeate) side. The cold flow temperature  $T_P$  increases across the permeate boundary layer to  $T_2$  at the membrane surface on the cold side as water vapor condenses into the fresh water stream and gains heat from the feed side. The driving force is, therefore, the vapor pressure difference between  $T_1$  and  $T_2$ , which is less than the vapor pressure difference between  $T_F$  and  $T_P$ . This phenomenon is called temperature polarization. The temperature polarization coefficient is defined by Schofield *et al.* [8] as follows:  $TPC = (T_1 - T_2) / (T_F - T_P)$



**Figure 3.**DCMD heat transfer and mass transfer through membrane.

## Heat Transfer

Heat transfer from the feed side to the permeate side involves two steps [2]: First, the heat transfers from the hot side to the cold side across the membrane as sensible heat and latent heat, so as to form the temperature difference between boundary layer and bulk flow; second, the heat transfers from the bulk flow of the feed to the boundary layer via heat convection, due to the temperature difference arising from the first step. In the first step, as shown in Figure 3, the sensible heat is conducted through the membrane to the cold side, and the latent heat is carried by the water vapor, which is evaporated at the interface between the hot stream and membrane pores and is condensed at the interface between the pores and cold stream for DCMD [20].

According to the two heat transfer processes, the heat balance of the feed stream can be described by [19] with the following Equations:

$$Q_1 = \frac{k}{\delta}(T_1 - T_2) + \lambda N$$

where

$$k = \varepsilon k_G + (1 - \varepsilon)k_S$$

$$Q_2 = h(T_F - T_1)$$

$$Q_1 = Q_2$$

At steady state

where  $Q_1$  or  $Q_2$  are the total heat flux from the hot side to the cold side,  $k$  is the thermal conductivity of the membrane,  $\delta$  is the membrane thickness,  $\varepsilon$  is the membrane porosity,  $h$  is the convective heat transfer coefficient on the hot side,  $N$  is the permeate flux, and  $\lambda$  is the enthalpy change of vaporization.

The calculation of the thermal conductivity assuming parallel heat flow through air and membrane material, and hence this approach to estimating thermal conductivity is appropriate for these membranes.

The sensible heat loss,  $(k/\delta)(T_1 - T_2)$  is the sensible heat loss through the membrane and  $\lambda N$  is the total enthalpy carried by the permeate. In AGMD, an air gap is interposed between the membrane and the cooling plate, and the percentage of sensible heat loss is less than that in DCMD, but the stagnant air gap also increases the resistance to the mass transfer. Instead of the stagnant air gap, as tripping gas is used in SGMD, which boosts the mass transfer and provides good resistance to sensible heat transfer, but there is more energy consumption from the blower and/or condenser if the permeate is the product. In VMD, the sensible heat loss can even be neglected, if a very low vacuum is employed in the permeate chamber, but it would not be as competitive as



DCMD and AGMD if the thermal energy cannot be recovered from the external condenser.

### Mass Transfer

Mass transfer in the DCMD process includes three steps: firstly the hot feed vaporizes from the liquid/gas interface, secondly the vapor is driven by the vapor pressure difference and crosses from the hot interface to the cold interface through the pores, and thirdly the vapor condenses into the cold side stream. Therefore, there are two major factors controlling the mass transfer: one is the vapor pressure difference, and the other is the permeability of the membrane.

If the fluid dynamics conditions on both sides of the membrane could be considered good, mass transfer through the membrane may be the limiting step for mass transfer in MD. The influence of the physical properties on membrane permeability includes:

- (1) The effective area for mass transfer is less than the total membrane area because the membrane is not 100% porous;
- (2) For most practical membranes, the membrane pores do not go straight through the membrane and the path for vapor transport is greater than the thickness of the membrane; and
- (3) The inside walls of the pores increase the resistance to diffusion by decreasing the momentum of the vapor molecules.

The mass transport mechanism in the membrane pores is governed by three basic mechanisms known as Knudsen-diffusion ( $K$ ), Poiseuille-flow ( $P$ ) and Molecular-diffusion ( $M$ ) or a combination between these known as the transition mechanism [2]. The Knudsen number ( $Kn$ ) is used to indicate the dominant mass transfer mechanism in the pores:

$$Kn = l/d$$

where  $d$  is the mean pore size of the membrane; and  $l$  is the mean free path of the molecules defined by Kuhn and Forsterling and Albert and Silbeyas:

$$l = \frac{k_B T}{\pi ((\sigma_w + \sigma_a)/2)^2 P_{pore}} \frac{1}{\sqrt{1 + (m M_w / m M_a)}}$$

where  $k_B$  is the Boltzmann constant ( $1.381 \times 10^{-23}$  J/K),  $\sigma_w$  and  $\sigma_a$  the collision diameters for water vapor ( $2.641 \times 10^{-10}$  m) and air ( $3.711 \times 10^{-10}$  m),  $T$  is the mean temperature in the pores, and  $M_w$  and  $M_a$  are the molecular weights of water and air. At a typical membrane temperature of 60 °C, the mean free path of the water vapor in the membrane pores is 0.11 μm. The pore sizes of the membranes used for membrane

distillation are in the range of 0.2 to 1.0  $\mu\text{m}$ , so  $Kn$  will be in the range of 0.5 to 0.1. Table 2 shows the dominating mass transfer mechanism based on the  $Kn$  [21] for different configurations. There are also two other popular mass transfer models for membrane distillation, which are Schofield's model and the dusty-gas model for DCMD. In the "Dusty-Gas" model, the porous membrane is assumed to be an array of dust particles held stationary in space, and the dust particles in terms of the classical kinetic theory of gases are supposed to be giant molecules in the interactions between gas and surface. Based on this model, a general flux equation for a gas that permeates through a porous media in the Knudsen-viscous transition region can be described as:

**Table 2.** Dominating mass transfer mechanism in different MD configurations.

Configurations	Component in pores	Vapor Pressure difference across pores	Driving force	Mass transfer mechanism ( $0.01 < Kn < 1$ )
DCMD	Vapor-air mixture	$\Delta P = 0$	Partial vapor pressure difference	M-K transition
AGMD	Vapor-air mixture	$\Delta P = 0$	Partial vapor pressure difference	M-K transition
SGMD	Vapor-air mixture	$\Delta P = 0$	Partial vapor pressure difference	M-K transition
VMD	Vapor	$\Delta P \neq 0$	Partial vapor pressure difference	P-K transition

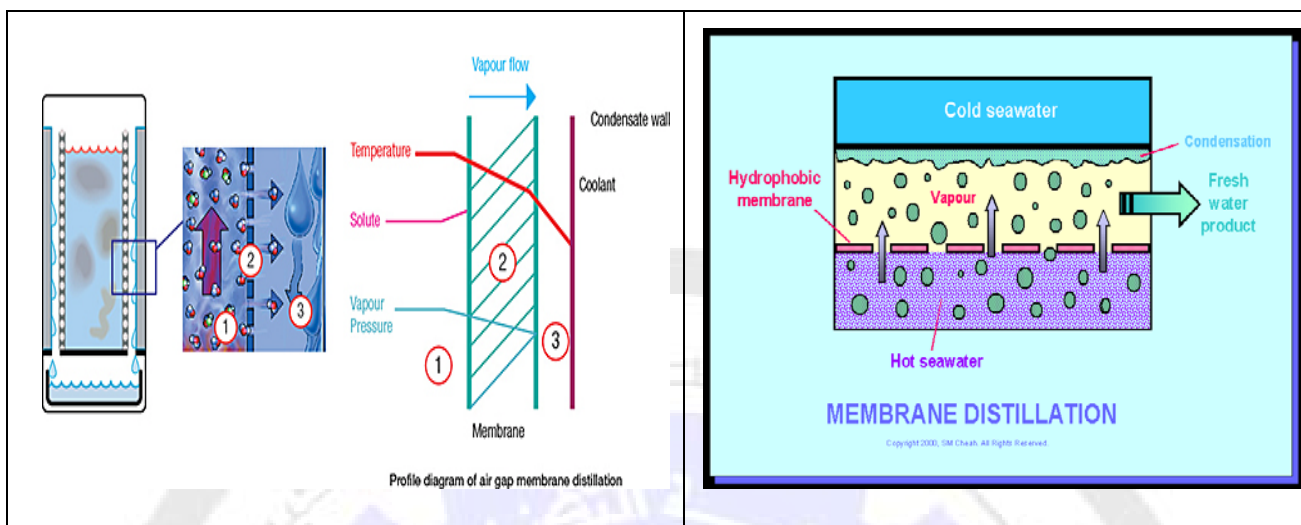
$$N = -\frac{M}{RT} \left( K_o \bar{v} + \frac{B_o P_{pore}}{\mu} \right) \frac{(P_{T1} - P_{T2})}{b}$$

where

$$K_o = \frac{d\epsilon}{3\tau} \text{ and } B_o = \frac{d^2\epsilon}{32\tau}$$

It can be concluded that the flux for MD can be increased by increasing pore sizes and porosity and by reducing the tortuosity and thickness of the membrane. However, according to heat transfer equation reducing the thickness of the membrane also increases the sensible heat loss from the hot side to the cold side, which leads to a reduction of water flux due to decreased interfacial temperature differences (vapor pressure difference). Therefore, there is an optimum membrane thickness for membrane distillation efficiency.

To minimize the sensible heat loss, the heat transfer coefficient ( $k/\delta$ ) of the membrane can be reduced by increasing the membrane porosity. This will also reduce the sensible heat transfer as according to heat transfer equation the average thermal conductivity of the membrane will be reduced since the thermal conductivity of the air is in general one order of magnitude less than that of the membrane materials.



### Objectives of the Study

The main objectives of the present study include the following:

- Construct a MD system and test its performance for water desalination at high salt concentration.
- Investigate the influence of operating conditions such as feed temperature, feed concentration, feed flow rate on permeation flux for hollow fiber membrane.
- Determine the factors which have significant effect on permeate flux and detected the optimum operating conditions by using Numerical technique and analyzed the data of experimental design.
- Compare between the theoretical and experimental results obtained in the present work and that reported in the literature.

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## Research Title: **Prediction of the Behavior for Polymer Blends Using Thermodynamic Model**

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Student Name: **Mohamad Sherbaz Kreash**

### Introduction and Theoretical Framework

Polymeric materials find growing applications in various fields of everyday life because they offer a wide range of application relevant properties. Blending of polymers is a technological way for providing materials with full set of desired specific properties at the lowest price, e.g. a combination of strength and toughness, strength and solvent resistance, etc. Blending also benefits the manufacturer by offering improved processability, product uniformity, quick formulation changes, plant flexibility and high productivity.

Polymer blends have received much attention since blending is a simple, effective approach to develop new materials exhibiting combinations of properties that cannot be obtained by individual polymers. Miscibility between two components is governed by the thermodynamics represented by the Gibbs free energy of mixing ( $\Delta G_{\text{mix}} = \Delta H_{\text{mix}} - T\Delta S_{\text{mix}}$ ). The mixtures are miscible when the value of  $\Delta G_{\text{mix}}$  is negative, i.e., low value of  $\Delta H_{\text{mix}}$  and high value of  $\Delta S_{\text{mix}}$ . Immiscibility is a rule in polymer blends because both the  $\Delta H_{\text{mix}}$  and the  $\Delta S_{\text{mix}}$  are unfavorable. The  $\Delta S_{\text{mix}}$  is unfavorable because there are few molecules of large molecular weight per unit volume. The  $\Delta H_{\text{mix}}$  is also unfavorable because the van der Waals dispersion force is always positive. However, when the specific interactions such as hydrogen bonding, dipole-dipole interaction, or ionic interaction are established, the miscibility between two polymer mixtures can be achieved [1]. If two polymers are mixed, the most frequent result is a system that exhibits a complete phase separation due to the repulsive interaction between the components (i.e. the chemical incompatibility between the polymers). Complete miscibility in a mixture of two polymers requires that the following condition is fulfilled:

$$\Delta G_m = \Delta H_m - T\Delta S_m < 0 \quad (1)$$

where  $\Delta G_m$ ,  $\Delta H_m$ , and  $\Delta S_m$  are the Gibb's free energy, the enthalpy and entropy of mixing at temperature  $T$ , respectively. The most important characteristic of a polymer blend of two (or more) polymers is the phase behavior. Polymer blends (like low molecular weight solvents) can exhibit miscibility or phase separation and various levels of mixing in between the extremes (e.g., partial miscibility). For a stable one-phase system, criteria for phase stability of binary mixtures of composition  $\phi$  at fixed temperature  $T$  and pressure  $p$  are:

$$\Delta G_m < 0 \quad , \quad \left( \frac{\partial^2 \Delta G_m}{\partial \phi^2} \right)_{p,T} > 0 \quad (2)$$

Miscible polymer blend is a polymer blend which is homogeneous down to the molecular level and associated with the negative value of the free energy of mixing and the domain size is comparable to the dimensions of the macromolecular statistical segment. The value of  $T\Delta S_m$  is always positive since there is an increase in the entropy on mixing. Therefore, the sign of  $\Delta G_m$  always depends on the value of the enthalpy of mixing  $\Delta H_m$ . The polymer pairs mix to form a single phase only if the entropic contribution to free energy exceeds the enthalpic contribution, i.e.,

$$\Delta H_m < T\Delta S_m \quad (3)$$

For most polymer blends the miscibility increases with increasing the pressure. The effect depends on the magnitude of the heat of mixing  $\Delta H_m$ . For  $\Delta H_m < 0$  the miscibility is enhanced by compression, whereas for those with  $\Delta H_m > 0$  it is reduced.

For lowmolecularweightmaterials, increasing temperature generally leads to increasing miscibility as the  $T\Delta S_m$  term increases, thus driving  $\Delta G_m$  to more negative values. For higher molecular weight components, the  $T\Delta S_m$  term is small and other factors (such as non-combinatorial entropy contributions and temperature dependant  $\Delta H_m$  values) can dominate and lead to the reverse behavior, namely, decreasing miscibility with increasing temperature [2].

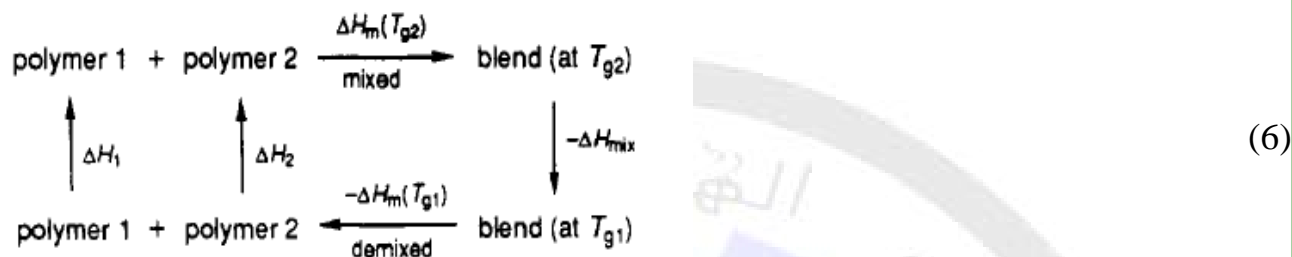
Consider two polymers having glass transition temperatures  $T_{g1}$  and  $T_{g2}$  and respective molar enthalpies  $H_1$  and  $H_2$ . The molar enthalpy of a mixture of the two polymers is:

$$H_{mix} = x_1 H_1 + x_2 H_2 + \Delta H_m \quad (4)$$



$$\Delta H_{\text{mix}} = x_1 \Delta H_1 + x_2 \Delta H_2 + \Delta H_m(T_{g2}) - \Delta H_m(T_{g1}) \quad (5)$$

Where  $x_i$  represents the mole fraction of polymer  $i$  in the blend and  $\Delta H_m$  is the excess enthalpy of mixing.



The thermodynamic cycle for the mixing process is represented by Eq5, where  $\Delta H_1$ ,  $\Delta H_2$ , and  $\Delta H_{\text{mix}}$  are the changes of enthalpies when the temperature is increased from  $T_{g1}$  to  $T_{g2}$  at constant pressure for polymer 1, polymer 2, and their blend, respectively.  $\Delta H_m(T_{g1})$  and  $\Delta H_m(T_{g2})$  are the excess enthalpies of mixing at  $T_{g1}$  and  $T_{g2}$ . Solving Eq5 for  $\Delta H_{\text{mix}}$  yields The enthalpy changes corresponding to heating the individual components and the mixture from  $T_{g1}$  to  $T_{g2}$  are [3]:

$$\begin{aligned} \Delta H_1 &= \int_{T_{g1}}^{T_{g2}} c_{p1}^1 dT \\ \Delta H_2 &= \int_{T_{g1}}^{T_{g2}} c_{p2}^g dT \end{aligned} \quad (7)$$

Knowledge of the glass transition temperatures ( $T_g$ s) as function of composition reflects miscibility (or lack of it) and is decisive for virtually all properties of polymer-based materials. Immiscible polymers (not an infrequent case) clearly demonstrate two  $T_g$  values for the respective pure components that are independent of composition. The glass transition temperature ( $T_g$ ) reflects the molecular rearrangement rate in supercooled liquid and thus is one of the most important factors among the many transitions and relaxations in polymers. Measurement of  $T_g$  is one of the easiest determinations of whether they are miscible or immiscible in polymer mixtures. A single  $T_g$  between individual two polymers appears for miscible blends whereas two  $T_{gs}$  are shown for immiscible blends. When  $T_g$  of miscible polymer blends shows the linear

relationship against the polymer composition, the value of  $T_g$  is adequately expressed by the widely used Fox equation.

$$\frac{1}{T_g} = \frac{w_1}{T_{g1}} + \frac{w_2}{T_{g2}} \quad (8)$$

where  $w_1$  and  $w_2$  are the weight fractions of components 1 and 2 with  $T_{g1}$  and  $T_{g2}$ , respectively. This equation is also used to predict the  $T_g$  of copolymers. The change in the glass transition temperature produced by blending polymer 1 and the polymer 2 can be described by equation 9 which provides a configurational entropy theory for the glass transitions of binary polymer blends. From this model, we can predict  $T_g$  for the polymer blends with various compositions.

$$\ln\left(\frac{T_{g12}}{T_{g1}}\right) = \beta \left(1 - \gamma_{spe} \ln\left(\frac{z-1}{e}\right)\right) \left(\frac{\phi_1}{r_1} \ln \phi_1 + \frac{\phi_2}{r_2} \ln \phi_2\right) + \phi_2 \ln\left(\frac{T_{g2}}{T_{g1}}\right)$$

where  $T_{g1}$  and  $T_{g12}$  are the  $T_{gs}$  of the pure polymer 1 and of the blend of polymer 1 and polymer 2, respectively.  $\phi_1$  and  $\phi_2$  are the volume fractions of components 1 and 2, respectively.  $z$  is the lattice coordination number.  $\gamma_{spe}$  is a proportionality constant representing the specific interaction such as hydrogen bonding, dipole-dipole interaction, or ionic interaction between two polymers, and  $\beta$  are the gas constant, the molecular weight of the repeat unit, and the isobaric specific heat of polymer 1, respectively [4]. A schematic phase diagram is shown in Figure 1. There are three regions of different degree of miscibility: 1. The single-phase miscible region between the two binodals, 2. The four fragmented metastable regions between binodals and spinodals, and 3. The two-phase separated regions of immiscibility, bordered by the spinodals. The diagram also shows two critical solution temperatures, the lower, LCST (at higher temperature), and the upper, UCST (at lower temperature).

$$\beta = zR/(M_{1u}\Delta C_{pp}). R, M_{1u}, \text{ and } \Delta C_{pp}$$

The phase diagram with two critical points is a rule for mixtures of low molar mass components, whereas the polymer blends usually show either LCST (most) or UCST [5].

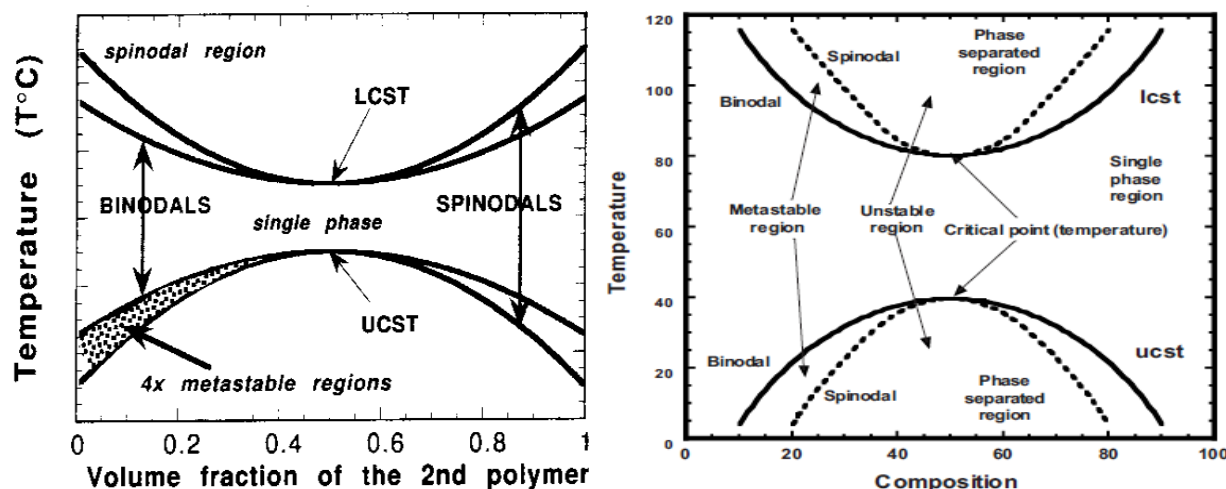


Figure 1 Phase diagram for liquid mixtures with the upper and the lower critical solution temperature, UCST and LCST, respectively.

The binodals (Figure 1) separate miscible (one-phase) and metastable region, the spinodals separate metastable and two-phase region. The thermodynamic conditions for phase separations are given by:

$$\text{Binodal: } \left( \frac{\partial \Delta G_m}{\partial \phi} \right)_{p,T} = 0 \quad (10)$$

$$\text{Spinodal: } \left( \frac{\partial^2 \Delta G_m}{\partial \phi^2} \right)_{p,T} = 0 \quad (11)$$

$$\text{Critical point: } \left( \frac{\partial^3 \Delta G_m}{\partial \phi^3} \right)_{p,T} = 0 \quad (12)$$

The experimental phase diagrams are often not symmetrical, unless the molecular weights of the components are similar, and in the case of large differences in molecular weights, they can be highly non-symmetric. With phase separation, the binodal defines the composition of the component 1 rich phase and component 2 rich phase (Figure 2). The tie line noting temperature  $T_2$  between the binodal points can be employed to determine the relative amounts of each phase. The tie line is illustrated in Fig. 3. The volume fraction of component 1 rich phase,  $\phi_{1r}$ , and component 2 rich phase,  $\phi_{2r}$ , can

be determined from the expression, with  $\phi$  representing the overall composition of the component noted in Fig. 3:

$$\frac{\phi_{1r}}{\phi_{2r}} = \frac{\phi_b - \phi}{\phi - \phi_a} \quad (13)$$

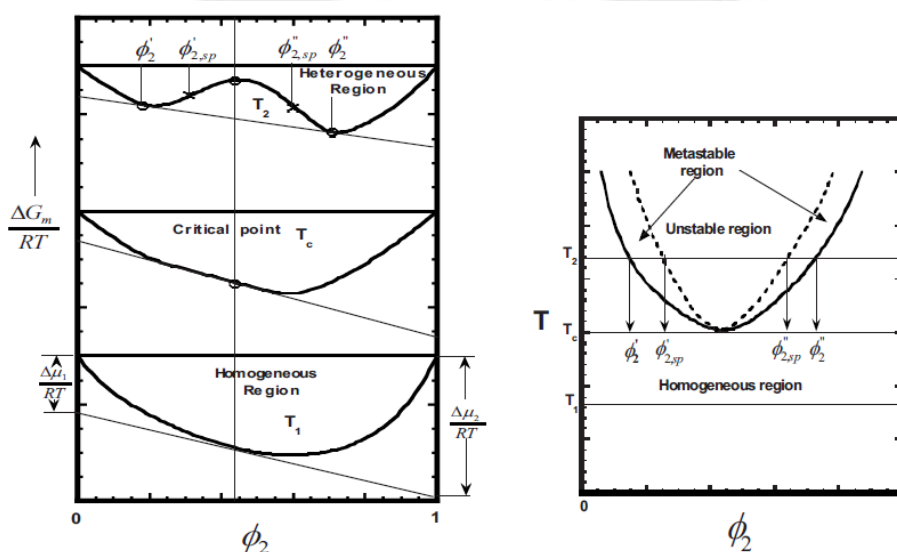


Figure 2: Free energy of mixing versus volume fraction generalized behavior for various positions on the phase diagram

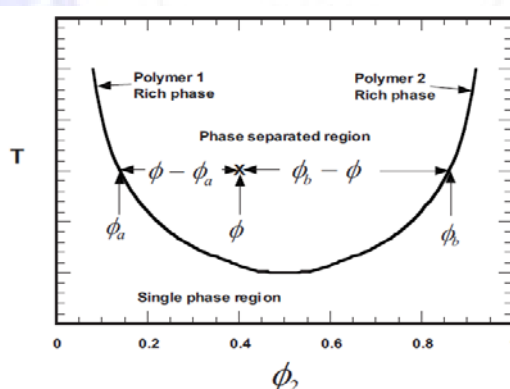


Figure 3: Tie-line calculation of phase compositions

Highly miscible polymers exhibit single phase behavior over the entire temperature-volume fraction space available for experimental verification. If *ucst* or *lcst* behavior

exists, it cannot be determined. At low temperatures, the *ucst* cannot be determined due to the glassy state restricting molecular motion (phase separation); and at higher temperatures, polymer degradation occurs before phase separation can be observed. With highly immiscible polymer blends, the phase diagram is virtually all in the two phase region with the binodal curves virtually overlapping the y axis at 0 and 1.0 volume fraction. The phase separation takes place when a single-phase system suffers a change of either composition, temperature or pressure that forces it to enter either the metastable or the spinodal region. When the system enters from single-phase region into the metastable region, the phase separation occurs by the mechanism resembling crystallization – slow nucleation followed by growth of the phase separated domains. By contrast, when the system is forced to jump from a single-phase into the spinodal region of immiscibility the phases separate spontaneously by a mechanism called spinodal decomposition [6].

Starting point for most of the theoretical interpretations of polymer solutions and blends is the Flory-Huggins lattice theory. It is basically an extension of the concept of regular solutions on polymer solutions. Thus the model restrictions are no change of volume during mixing (incompressible model), the entropy of mixing is entirely given by the number of rearrangements during mixing (combinatorial entropy) and the enthalpy of mixing is caused by interactions of different segments after the dissolution of interactions of the same type of segments. It is a mean-field model, i.e. only average interactions are taken into consideration. The main problem was to find an expression for the entropy of mixing because it was found experimentally that polymer solutions show significant deviations from values expected for ideal solutions. Assuming a rigid cubic lattice model, this problem was independently solved for polymer solutions by Huggins and Flory [3].

The lattice theory for the enthalpy of mixing in polymer solutions, developed by Flory and Huggins, can be formally applied to polymer mixtures, which provides a rough estimation of the miscibility of the polymers. Assuming random mixing of two polymers and  $\Delta V_m = 0$  yields the well-known expression for the combinatorial entropy of mixing  $\Delta S_m$  of the Flory-Huggins theory:

$$\Delta S_m = -R \left[ \frac{\phi_1}{r_1} \ln \phi_1 + \frac{\phi_2}{r_2} \ln \phi_2 \right] \quad (14)$$



where  $\phi_i$  is the volume fraction of the component  $i$  and  $r_i$  is the number of polymer segments,  $R$  is the gas constant. It can be seen that the entropy of mixing decreases with increasing molar mass ( $r_i$  is proportional to the degree of polymerization) and vanishes for infinite molar masses. Applying the concept of regular solutions and assuming all pair interactions in the framework of a mean-field theory yields for the enthalpy of mixing  $\Delta H_m$  :

$$\Delta H_m = RT\chi\phi_1\phi_2 \quad (15)$$

For binary systems the Flory-Huggins equation can be expressed in the following form:

$$\Delta G_m = RT \left[ \frac{\phi_1}{r_1} \ln \phi_1 + \frac{\phi_2}{r_2} \ln \phi_2 + \chi\phi_1\phi_2 \right] \quad (16)$$

where  $\chi$  is the so called Flory-Huggins binary interaction parameter.  $R$  is the universal gas constant, and  $T$  is the absolute temperature. The first two terms of the right hand side in Equation 16 are related to the entropy of mixing and the third term is originally assigned to the enthalpy of mixing. For polymers having infinite molar mass (i.e.  $r_i$  is infinite) the entropic contribution is very small and the miscibility or immiscibility of the system mainly depends on the value of the enthalpy of mixing (Equation 15). Miscibility can only be achieved when  $\chi$  is negative. The term 'parameter' is widely used to describe  $\chi$  but it is definitively better characterized by the term 'function', because  $\chi$  depends on such quantities as temperature, concentration, pressure, molar mass, molar mass distribution and even on model parameters as the coordination number of the lattice and segment length. For polymers, the miscibility can only be achieved when  $\chi < \chi_{cr}$ . The  $\chi$  parameter at the critical point  $\chi_{cr}$  can be obtained from the definition of the critical point (Figure 1) and Equation 16 as follows:

$$\chi_{cr} = \frac{1}{2} \left( \frac{1}{\sqrt{r_1}} + \frac{1}{\sqrt{r_2}} \right)^2 \quad (17)$$

where  $r_i$  is the number of polymer segments (which is proportional to the degree of polymerization). It should be mentioned that the Equations 16 and 17 are based on the

assumption that  $\chi$  is not a function of composition,  $\chi_{cr}$  is only a function of the molar masses [7].

### Statement of the Problem

The factors affecting the miscibility of polymer blends will be examined experimentally and predicted thermodynamically. The miscibility and dynamics of phase separation will be investigated experimentally for different polymer blends concentrations to determine both the binodal and the spinodal curves. The relationship between the binodal curve and the phase transition, such as melting and glass transitions, will be studied to discuss the compatibility of blend system including solid component. The glass transition temperature will be experimentally determined and predicted thermodynamically to establish polymer miscibility.

### Purpose of the Study

- The miscibility of the blends through glass transition temperature  $T_g$  analysis by DSC will be evaluated.  $T_g$  will be correlated with a measure of the intermolecular interactions, such as the Flory-Huggins interaction parameter,  $\chi$ .
- The effect of blend ratios on the mechanical properties and the probability to creating compatible system for the polymer blend will be studied.
- Methods of polymer blends preparation, and the best methods for detecting miscibility will be studied.
- The thermodynamic relationships will be applied to determine the free energy of mixing, heat of mixing, the binodal and spinodal curves, the critical points and thus the phase behavior.
- Phase behavior and phase separation kinetics of polymer solutions will be investigated experimentally.
- The miscibility and dynamics of phase separation will be investigated in solutions of different polymer concentrations to determine both the binodal and the spinodal

## Review of the Literature

The kinetics of phase separation in “polymer + solvent” systems is of continuing interest. The phase separation in polymer solutions can be induced by changes in the temperature, the solvent (concentration or composition) or the pressure. Binder *et al* [8-9] studied the kinetics of spinodal decomposition of polystyrene solutions in cyclohexane induced by a temperature jump into the unstable region. Phase separation process was monitored by time- and angle-resolved light scattering at ambient pressures. Berghmans *et al* [10] recently carried out a numerical study of temperature-induced phase separation kinetics of polymer solutions subjected to a linear spatial temperature gradient. Their results showed that anisotropic structures and morphologies can be induced by a gradient temperature jump. In addition to temperature quench, phase separation can also be induced by exposing the solution to a non solvent vapor as antisolvent. Binder *et al* [11] reported the kinetics of phase separation in a polymer solution (polysulfone in N-methyl-2-pyrrolidinone) film induced by a nonsolvent vapor, water. The data were analyzed based on Cahn-Hilliard linear theory in the initial stages of phase separation. Much attention has been paid to the phase behavior of polymers in compressed fluids at high pressures [12-14]. However, these have mostly focused on the liquid-liquid (L-L) phase boundary, with limited data on the solid-fluid (S-F) boundary. For crystallizable polymer-solvents systems, it is possible to observe the S-F boundary as well as L-L phase boundary in a phase diagram.

## Question and/or Hypotheses

- It is reasonable to believe that the changes of thermal enthalpy are caused by the occurrence of phase separation during annealing. Therefore, the phenomenon is indicative of the occurrence of phase separation.
- The changes of thermal properties of blends composed of polymer can provide information about the occurrence of phase separation, and thermal analysis can be used to determine the phase boundary of such blends.
- The specific interactions such as hydrogen bonding, dipole-dipole interaction, or ionic interaction between two polymers reduce the overall entropy

## Method and Procedures

The binary blends will be made by mixing solutions (approximately 3% w/w) of each polymer in 98% formic acid. The solutions will be stirred for 2h at ambient temperature. The films for DSC and FTIR measurements will be prepared by casting the polymer

solutions into shallow soda-glass dishes and allowing the solvent to evaporate slowly. The thin films will be dried at 60 °C and placed under vacuum at 70-80°C for at least 3 days to constant weight. Blend compositions will be 80/20, 60/40, 50/50, 40/60 and 20/80 by weight.

### Sampling

#### Differential Scanning Calorimetry (DSC)

DSC measurements will be performed on a DuPont 910 DSC Differential Scanning Calorimeter equipped with a Thermal Analysis Data System (TA-2000). The samples will be first heated from room temperature to 250°C and maintained for 2 minutes, and then the samples will be quenched cooled to 0 °C to prevent crystallization before thermograms will be taken. The scanning rate was 10 °C /min. In the isothermal crystallization experiments blends samples of 9-11mg will be used. Starting at room temperature, the samples will be rapidly heated to melting temperature to remove any previous crystallinity. The samples will be held for 6h at a certain crystallization temperature ( $T_C = 50, 100$  and  $150^\circ\text{C}$ ), and then will be heated to 250°C at a rate of 10 °C /min under dry nitrogen atmosphere.

#### Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR spectra will be collected on dry thin film polymer blend samples using a UNICAM (Mattson 5000) spectrophotometer by sandwiching the film samples between two KBr disks. All of the films will be sufficiently thin to be within a range where the Beer-Lambert law is obeyed. Films will be annealed at 50, 100, and 150°C for 6h, then 32 scans will be made for each  $T_C$  at a resolution of  $8\text{cm}^{-1}$ .

### Instrumentation

The most common method to establish polymer miscibility is Differential Scanning Calorimetry (DSC), with which determination of the glass transition temperature ( $T_g$ ) IR spectroscopy has proved to be an excellent tool to study the hydrogen-bonding behavior in polymer blends. If the blend is immiscible, the absorption spectrum of the blend will be the sum of those for the components. If the blend is miscible because of the specific interactions, then differences will be noted in the spectrum of the blend relative to the sum of those for the components. The FTIR investigation of a miscible blend will not only reveal the presence of such an interaction, but will provide information on which groups are involved



### Data collection and Analysis

Several approaches based on kinetic or thermodynamic features of the glass transition phenomenon will be proposed to provide a theoretic foundation for the equations currently used to predict the compositional dependence of the  $T_g$  of blends of miscible polymers. Information on the experimental details and any special procedures used for preparation of the mixtures (temperature of mixing, type of solvent, drying processes, etc) can be found in the original references [1-7]. The experimental data analyzed will be obtained using conventional DSC and FTIR.

### Limitation and Delimitation

- The most important factor leading to miscibility in low molecular weight materials is the combinatorial entropy contribution which is very large compared to high molecular weight polymers. This contribution is the reason that solvent-solvent mixtures offer a much broader range of miscibility than polymer-solvent combinations. The range of miscible combinations involving polymer-polymer mixtures is even much smaller.
- The Flory-Huggins approach is not directly capable of predicting lcst behavior unless a temperature dependent  $\chi_{12}$  value exhibiting increasing values (negative to positive) with increasing temperature is employed.
- The Flory-Huggins lattice model theory is an incompressible model that does not allow for the compressibility effects on the system thermodynamics.
- For high molecular weight polymers,  $\Delta S_m$  is negligibly small and the sign of  $\Delta G_m$ , is dominated by  $\Delta H_m$ . In general,  $\Delta H_m$  is negative only if there are specific associative interactions between the two polymers. Therefore, the formation of miscible polymer blends depends on the occurrence of exothermic interactions such as hydrogen bonding, dipole-dipole interactions, acid-base interactions, or transition metal complexation.
- The thermodynamic functions, entropy, enthalpy, and volume, are continuous at  $T_g$ , but the first derivatives of these functions undergo discontinuities at  $T_g$ . In principle, any of these thermodynamic functions could be used to derive the relation for the compositional variation of  $T_g$ , but, in practice, the dependence of these variables on composition is not usually known. As a result, approximations of the thermodynamic functions are usually used.
- The value of  $\chi_{12}$  for any polymer blend is usually small and representative of the overall interaction of two different polymer molecules



- Many polymer pairs are not only immiscible but also incompatible, Compatibility arises from thermodynamic interaction between the blend constituents, which is a function of their physical and chemical structure

### Significance of the Study

- Blending of friendly environmental polymers with synthetic polymers has proven to be a suitable tool to produce novel materials with combined characteristics in having both improved application properties and low cost advantages in material performance.

- Polymer blend represents a very important field in processing of new materials, which has better properties in comparison with the neat polymers. They are significant also from ecological and economical viewpoint.

- The relationship between the binodal curve and the phase transitions, such as melting and glass transitions, become important to discuss the compatibility of binary blend system including solid component.

- Considerable interest in the study of polymer blends because of their importance in academic and technical aspects. Particularly, much attention has been paid to miscibility and phase behavior in polymer blends

- Glass transition temperature  $T_g$  values are useful indeed for a variety of purposes. Particularly needed are  $T_g$  values as a function of composition for binary polymer blends; they tell us whether the blends are miscible, semimiscible (called compatible) or not miscible at all.

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**Research Title:** Oxidative Desulfurization of Diesel Fuel using Functionalized Multi-walled Carbon Nanotubes (CNTS)

**Supervisors:** Dr. Neran K. Ibrahim  
Dr. Adaweya Juma

**Student Name:** Marwa Abdelkareem

### Introduction

Sulfur compounds are the most notorious and undesirable petroleum contaminants and a large portion of these compounds can be transferred to diesel oil during refining process. In general, sulfur occurs as hydrogen sulfide, organic sulfides and disulfides, benzothiophene, dibenzothiophene, and their alkylated derivatives. Upon diesel combustion, sulfur compounds are converted to sulfur oxides ( $\text{SO}_x$ ) that contribute to acid rain and environmental pollution (Fabio et al., 2011). In order to reduce the sulfur contents in diesel fuels, the environmental regulation agencies have introduced an allowable limit of 10ppm with the ultimate goal of further reducing  $\text{SO}_x$  gases emissions. As a result of the aforementioned environmental regulations, there have been several reports successfully reducing the organic sulfur contents in diesel fuels to less than 10ppm. For instance, of the various desulfurization techniques, hydrodesulfurization (HDS), oxidative desulfurization, biodesulfurization, and adsorptive desulfurization are being investigated for their ability to produce clean fuels. One of the current industrial methods for removal of sulfur from fuels is HDS, for reducing of organic-sulfur in gasoline, diesel, and other intermediate distillates where various catalysts are used. HDS process removes many organosulfur compounds and their derivatives from transportation fuels; however, this method has certain limitations and is less effective at the removal of sterically hindered dibenzothiophene derivatives such as 4,6-dimethyldibenzothiophene, which are most prominent in diesel fuels. Some suggestions such as the use of more active catalysts, longer residence times, and higher temperatures and pressures have been reported for improving the effectiveness of HDS for producing low sulfur product (Babich and Moulijn, 2003). Therefore, to meet the demands of producing ultraclean fuels with lower than 15ppm of organosulfur compounds via HDS will increase both monetary investment and operational costs.

Consequently, it is imperative that advanced technologies be developed for desulfurization at ambient temperature and pressure. Currently, the most common HDS alternative method used to achieve ultraclean fuels is oxidative desulfurization (ODS). Hydrogen peroxide is the most common oxidant for ODS process, because it is cheap, environmentally friendly, and commercially available. Another advantage of  $H_2O_2$  is that it can be joined with various types of catalysts to oxidize sulfur compounds effectively. Recently, the application of carbon nanotubes (CNTS) as sorbent/catalyst has attracted a great deal of attention of the catalysis community due to their unique textural property and chemical features. The CNTS with the higher degree of graphitization had higher catalytic activity for DBT oxidation since its higher electric conductivity benefited the transfer of electrons involved in the oxidation–reduction reaction.

### Statement of the Problem

The present research work based on the combination of different techniques to remove sulfur contents i.e. an oxidative desulfurization catalyzed by CNTs and solvent extraction of sulfones from diesel to achieve low sulfur product. Oxidative method does not need high temperature and pressure. It carries out in the absence of hydrogen gas thus requiring significantly less capital to install a unit. The oxidative desulfurization and adsorption methods have great potential and found favorable for the removal of stubborn refractory sulfur compounds from diesel.

The catalytic oxidative desulphurization followed by extraction method is proposed for the desulfurization of commercial diesel containing about 500ppm, wt. sulfur.

We believe that functionalized multi walled CNTS as adsorbent/catalyst, will find useful applications in petroleum industry because of their operational simplicity, high efficiency, and high capacity. Experiments will be designed to optimize the parameters for the adsorptive desulfurization process.

### Chemicals

1.  $H_2O_2$  (45% wt), (AR, Analytically pure reagent)
2. Formic Acid (AR)
3. Acetonitrile
4. Hydrochloric Acid
5. Sodium Hydroxide
6. Sulfuric Acid
7. Nitric Acid
8. Promoted Activated Carbon
9. Carbon nanotubes (CNTS)
10. Commercial Diesel (500ppm,wt. sulfur)





### Equipments

1. 100 ml three-necked reaction flask
2. Condenser
3. Mechanical stirrer
4. Thermometer
5. Beaker
6. Heater

### Instrumentation

1. X-Ray Fluorescence Sulfur Analyzer
2. BET Surface Area Analyzer
3. GC mass Spectroscopy
4. Field Emission Scanning Electron Microscope (FESEM)
5. Energy Dispersive X-Ray Spectroscopy (EDX)
6. Fourier Transform Infrared Spectroscopy (FTIR)
7. Scanning Electron Microscopy (SEM)

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**Research Title: Dynamic Study of Acid Gas Absorption Using Promoted Absorbent in Bubble Column Reactor**

**Supervisor: Dr. Safa Al-Naimi**

**Student Name: Ahmed N. Kokaz**

**Carbon Dioxide Capture**

Removal of acidic gases, e.g., carbon dioxide ( $\text{CO}_2$ ), is an important industrial operation. Carbon dioxide is produced in large quantities by many important industries such as fossil-fuel-fired power plants, steel production, chemical and petrochemical manufacturing, cement production, and natural gas purification. The reasons for the  $\text{CO}_2$  removal are traditionally technical and economical concerns. Carbon dioxide present in natural gas will reduce the heating value of the gas and as an acid component it has the potential to cause corrosion in pipes and process equipment and also, according to Astarita et al. (1983),  $\text{CO}_2$  causes catalyst poisoning in ammonia synthesis. Natural gas pipe lines usually permit from 1 to 2 mol %  $\text{CO}_2$  and sometimes as high as 5 mol % (Buckingham, 1964). In the past decades,  $\text{CO}_2$  removal from flue gas streams started as a potentially economic source of  $\text{CO}_2$ , mainly for enhanced oil recovery (EOR) operations. Moreover,  $\text{CO}_2$  was also produced for other industrial applications such as carbonation of brine, welding as an inert gas, food and beverage carbonation, dry ice, urea production, and soda ash industry (Rao and Rubin, 2002; Suda et al., 1997). However, environmental concerns, such as the global climate change, are now focused as one of the most important and challenging environmental issues facing the world community, and have motivated intensive research on  $\text{CO}_2$  capture and sequestration. Carbon dioxide as one of the greenhouse gases (GHG) is currently responsible for over 60% of the enhanced greenhouse effect, methane ( $\text{CH}_4$ ) contributes 20%, and the remaining 20% is caused by nitrous oxide ( $\text{N}_2\text{O}$ ), a number of industrial gases, and ozone. Scientific evidence now strongly suggests that increased levels of GHG may lead to higher temperature, and cause climate change on a global scale. Various climate models estimate that the global average temperature may rise by

$\sim 1.4 - 5.8$  °C by the year 2100 (Williams, 2002). In general, technologies to separate  $\text{CO}_2$  from gas streams are based on absorption, adsorption, membranes or other physical, chemical and biological separation methods. currently exist for separation and capture of  $\text{CO}_2$  from gas streams as given by Rao and Rubin (2002).

Such systems have been used in the chemical industry and in the production of technical gases for industrial and laboratory use (Desideri and Corbelli, 1998). In principle, various methods could be used for the removal of  $\text{CO}_2$ . According to Shaw and Hughes (2001), several process-related factors affect the selection of the appropriate method such as  $\text{CO}_2$  concentration in the feed stream, nature of other contaminants present in the feed stream (e.g.,  $\text{H}_2\text{S}$  and water in natural gas), pressure and temperature at which the feed stream is available, product considerations, and other considerations such as geographical location which can be a significant consideration when treating natural gas, as gas wells can be remote. Figure 1 shows the general guidelines for selection of the  $\text{CO}_2$  removal processes based on these considerations. It can be seen from this figure that absorption in a liquid is the most common process used in the industry for  $\text{CO}_2$  removal today. For economic reasons, the absorbents must have a low solvent cost, a high net cyclic capacity and high reaction/absorption rate for  $\text{CO}_2$  and must be an energy saving solvent.

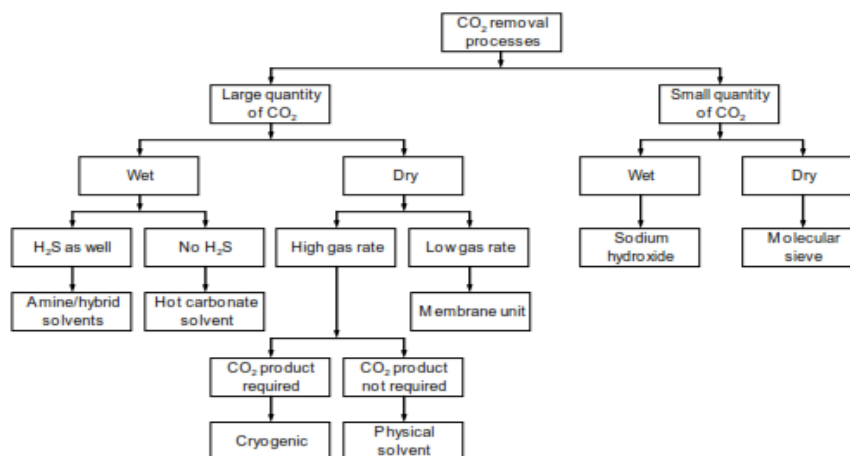


Figure 1. Process selection chart for the  $\text{CO}_2$  removal processes (Shaw and Hughes, 2001).



Absorption is a separation process in which soluble components of a gaseous mixture dissolve in an absorption liquid. There are two main types of absorption processes; one based on physical solubility (physical absorption), and the other based on chemical reactions between solute and solvent (chemical absorption). Both processes have advantages and disadvantages. The chemical absorption provides higher absorption rates and higher absorption capacity but its regeneration process normally requires more energy consumption. The regeneration process for physical absorption is easier and less energy demanding but the solvent capacity strongly depends on partial pressure. Generally the physical absorption is favorable at high partial pressures above 5 – 10 atm (Kohl and Nielsen, 1997) whereas the chemical absorption is favored at lower partial pressure. The chemical absorption is, therefore, more suitable for the CO<sub>2</sub> removal process from exhaust gases where the gas is typically at atmospheric pressure and containing 3 – 4 mol % CO<sub>2</sub> for natural gas (Poplsteinova, 2004), 10 – 14 mol % CO<sub>2</sub> for coal-fired power plant, and 20 – 30 mol % CO<sub>2</sub> in process gasses in the iron and steel-making industry.

#### **Solvent Based CO<sub>2</sub> Capture Processes.**

Industrially, solvent-based CO<sub>2</sub> capture processes have been operated for many years. Separation of CO<sub>2</sub> by using reactive solvents is considered as the most cost effective and operationally mature technology available for low pressure, post-combustion flue gas. (Alkanol)amines which are of industrial importance are monoethanolamine (MEA), diethanolamine (DEA), diisopropanolamine (DIPA), N-methyldiethanolamine (MDEA), diglycolamine (DGA) and their mixtures (with or without “activators” such as piperazine) (Astarita et al. 1983 ).

Some of the problems associated with the use of alkanolamines in absorption include oxidative degradation and high vapour pressure . These contribute to solvent losses, degradation product handling, and other negative effects in the process. Potassium carbonate (K<sub>2</sub>CO<sub>3</sub>) is an alternative solvent that may potentially overcome some of the issues associated with amine solvents. The major benefit is the ability to run the absorption process at high temperatures resulting in a more efficient and economical regeneration process. Potassium carbonate is also associated with lower toxicity and better resistance to degradation than commonly seen with amine solvents at high temperatures and in the presence of oxygen and other minor flue gas components such as SO<sub>x</sub> and NO<sub>x</sub> [Supap et al 2005 , Bello et al ,2005, strazisar et al., 2003, Kohl and Riesenfelid , 1985].



The use of potassium carbonate as an absorption solvent has emerged since the early 20th century [Kohl and Riesenfeld, 1985]. In the 1950's, Benson and field established the Benfield process which employed hot potassium carbonate as a CO<sub>2</sub> absorption solvent. This process was run at high partial pressures of CO<sub>2</sub> and temperatures with a purpose to enhance the mass transfer and thus, reduce the gas purification costs [Bensonfeld, 1956 and 1954, Tosh et al, 1959]. During 1970's, this process was further developed by adding

a small amount of a rate promoter, DEA which significantly reduced the capital and operating costs of the process and generated higher treated gas purity [Kohl and Riesenfeld, 1985].

Researchers found that carbon dioxide capture systems employing hot carbonate solvents require less heat integration between the absorber and the regenerator as heats of absorptions are 37% that of amine systems [Simioni et al 1988, Bensonfeld, 1956]. With regeneration energy constituting almost half of the total capture cost [Rao and Rubin, 2002], it is obvious that a significant reduction in this energy demand can increase the overall efficiency of the plant.

The major challenge associated with potassium carbonate is its low rate of reaction resulting in poor mass transfer performance. Previous studies indicate that the transfer of carbon dioxide into potassium carbonate solvents at a room temperature approximately equals that of physical solvents such as water, indicating negligible rate enhancement due to chemical reaction [Astara and savage, 1981, shen et al, 2010]. At 45 °C, the rate enhancement due to the reaction becomes apparent leading to a substantial increase in the mass transfer rate when compared to physical solvents. However, the mass transfer rate is still far below that of amine solvents such as MEA, DEA and piperazine, even at a temperature as high as a typical absorber operating temperature of 120 °C [Astara and savage, 1981, shen et al, 2010].

One approach to improving solvent performance is to blend potassium carbonate with promoters. Factors that are considered in screening a promoter include:

- Promoters should possess a high CO<sub>2</sub> absorption rate
- They should be economically affordable for mass production
- They should have a low vapour pressure to suppress the loss of promoter through evaporation
- They should be environmentally benign, non-corrosive and resistant to degradation by solvent exposure to high temperature, oxygen, gas impurities such as SO<sub>x</sub> and NO<sub>x</sub>
- They should be a lewis base that cannot be too strong or too weak.

A recent study by Cullinane and Rochelle, 2004 suggests that when such a promoter is used, potassium carbonate solvent is an energy efficient CO<sub>2</sub> absorbent and acquires



several advantages over amine solvents such as MEA. Bishnoi et al 2000, determined through experimental kinetic studies that carbonate systems when promoted by piperazine (PZ) have rate constants which surpass that of amine solvents. Past studies on a number rate promoters typically used in carbonate systems are summarized in Table1 .

**Table 2-5** Most commonly used rate promoters for carbonate solvent systems.

Table 1	Promoter concentration	K <sub>2</sub> CO <sub>3</sub> concentration	Temperature range	P <sub>CO2</sub> (kPa)
Diethanolamine (DEA)	1 - 3wt%	30 wt%	100 °C	N/A*
	2 M	1 M	18 °C	100
Triethanolamine (TEA)	1 - 3wt%	30 wt%	100 °C	N/A*
Monoethanolamine (MEA)	1 - 3wt%	30 wt%	100 °C	N/A*
	2 M	1 M	18 °C	100
Piperazine (PZ)	0.45- 3.6 M	0 - 3.1 M	25 - 110 °C	0 - 48
Diisopropanolamine (DIPA)	0.6 M	2 M	90 °C	30
2-amino-2-methyl-1-propanol (AMP)	unknown			
Boric acid, B(OH) <sub>3</sub>	1 - 5 wt%	30 wt%	50 - 80 °C	unknown

\*Note that Results for DEA, TEA and MEA presented in this table were obtained from desorption experiments and thus, partial pressure of CO<sub>2</sub> is not relevant.

Usually primary or secondary amines are used as rate promoters while tertiary amines (where the zwitterions can no longer deprotonate) do not show a significant rate increasing effect. The use of boric acid in carbonate solvents is attractive as it is economically affordable, readily available for mass production and not expected to interact with gas impurities such as SO<sub>x</sub> and NO<sub>x</sub>. Amino acids have been used as promoters in carbonate solutions while amino acid salts (AAS) were used for the selective removal of H<sub>2</sub>S or CO<sub>2</sub> from a variety of gas streams; however this process called the alkazid process, formerly licenced by BASF is no longer competitive and was replaced by alkanolamine based solvents. It generally used a solution of the salt of a strong inorganic base and a weak organic nonvolatile amino acid . Some researcher found that amino acid salt solutions have better resistance to degradation, especially in the removal of acid gases from oxygen-rich gas streams like flue gases. He reported that the ionic nature of the solutions make their volatility negligible and increases the surface tension. Other researchers indicated that the reactivity and CO<sub>2</sub> absorption capacity of amino acid salts are comparable to aqueous alkanolamines of related classes. Amino acids have the added advantage that many of them are naturally occurring and thus have no environmental or toxicity issue. The salts resulting from



amino acids will have a pKa favourable for carbon dioxide absorption, and, by using a solvent solution in salt form, the ionic nature of the absorbent will reduce solvent vaporization losses since it will have lower vapour pressure. Several studies have investigated the reactions of amino acids or amino acid salts with CO<sub>2</sub>. However, they only investigated the amino acid salts of a strong inorganic base (either potassium or sodium hydroxide) and reported that amino acid salts from inorganic bases form carbonate precipitates at higher CO<sub>2</sub> loadings. Recently, some researcher investigated the CO<sub>2</sub> absorption potential of a new absorbent class made by combining an amine and an amino acid to form an amine amino acid salt (AAAS). They found that an AAAS can have improved CO<sub>2</sub> absorption potential compared to an AAS. Also it found

that AAAS does not form precipitate upon loading with CO<sub>2</sub> like many AAS, which precipitate at high loadings [shen, et al ,2013].

### Chemical and Physical Fundamentals

Processes to capture CO<sub>2</sub> based on absorption are distinguished depending on whether the solvent either reacts chemically with the sorbate (CO<sub>2</sub>) to form chemical compounds from which the CO<sub>2</sub> is subsequently recovered, or is chemically inert and absorbs the sorbate without a chemical reaction. These distinct processes are termed chemical and physical absorption respectively. Chemical absorption for CO<sub>2</sub> capture is based on the exothermic reaction of a sorbent with the CO<sub>2</sub> present in a gas stream, preferably at low temperature. The reaction is then reversed in a so-called stripping, or regeneration, process at higher temperature. Chemical absorption is particularly suitable for CO<sub>2</sub> capture at low partial pressure, with amine or carbonate solutions being the predominant solvents.

### Carbonate-based absorption

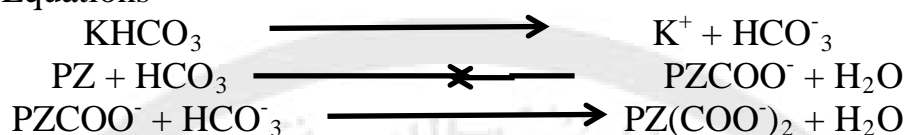
Generable aqueous carbonate solutions have been proposed for CO<sub>2</sub> capture by chemical absorption. A potassium carbonate (K<sub>2</sub>CO<sub>3</sub>) absorption system is based on the following two-stage reaction:



These reactions have the advantage of lower desorption energy requirements compared to a mine-based systems (0.9 – 1.6 MJ per kg-CO<sub>2</sub> vs. 2.0 MJ per kg-CO<sub>2</sub> for MEA) balanced by the disadvantage of lower rates of reaction at the low CO<sub>2</sub> pressures

typical for flue gases. However, the rate of absorption and solvent absorption capacity can be increased by adding piperazine to the reaction. Piperazine is a cyclohexane ring

with two opposing carbon atoms replaced by amine functional groups ( Figure2 ). The piperazine (PZ) enhanced reaction scheme can be simplified as follows, following the reactions in Equations



### Amine-Based Absorption

Amines are organic compounds derived from ammonia ( $\text{NH}_3$ ) in which one or more of the hydrogen atoms are replaced by organic components or substituents. Depending on the number of substituents these compounds are termed primary, secondary, or tertiary amines. The simplest primary amine is methylamine ( $\text{CH}_3\text{NH}_2$  or  $\text{CH}_5\text{N}$ ), with one hydrogen replaced by a methane ( $\text{CH}_3$ ) group. To simplify the nomenclature, the organic group is commonly replaced by R, giving  $\text{R}_1\text{-NH}_2$ ,  $\text{R}_1\text{R}_2\text{-NH}$ , and  $\text{R}_1\text{R}_2\text{R}_3\text{-N}$  for primary, secondary, and tertiary amines respectively.

The most commonly used amine for  $\text{CO}_2$  capture is ethanolamine (or monoethanolamine [MEA]), a primary amine with  $\text{R} = \text{CH}_2\text{CH}_2\text{OH}$ . In an aqueous solution, MEA acts as a weak base, which can neutralize an acidic molecule such as  $\text{CO}_2$ . In this reaction, a weakly bonded compound called a carbonate is formed Figure (2):



the heat of absorption for  $\text{CO}_2$  in MEA being 2.0 MJ per kg-  $\text{CO}_2$ . Two other reactions also occur that result in  $\text{CO}_2$  dissolution, base-catalyzed hydration of  $\text{CO}_2$ :



and the formation of carbonic acid:



However, compared to the rate of the reaction for MEA, the other two reactions make a minimal contribution to the overall  $\text{CO}_2$  absorption rate.

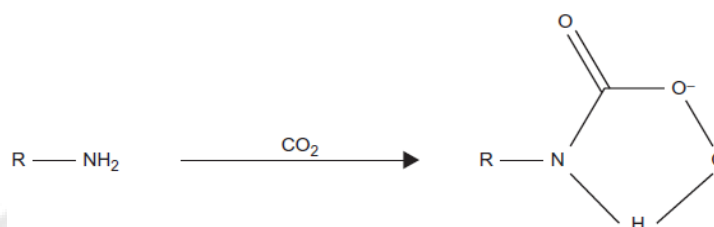
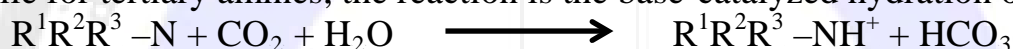


Figure 2 amine functional groups

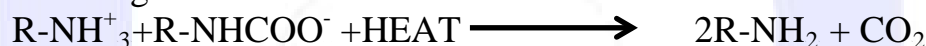
For a secondary amine, the equivalent carbonation reaction would be:



While for tertiary amines, the reaction is the base-catalyzed hydration of  $CO_2$  :



The carbonate ion nitrogen – carbon bond is easily broken down by the application of heat, leading to the reverse reaction in which the original solvent is regenerated. For example, for MEA regeneration:



The application of these reactions to the removal of  $CO_2$  from flue gases

### Amine Amino Acid -Based Absorption

They are used in salt form and the ionic nature of the solvents make them practically non-volatile<sup>(1)</sup>. Recently, Aronu et al.(2010a) investigated the  $CO_2$  absorption potential of a new absorbent class made by combining an amine and an amino acid to form an amine amino acid salt (AAAS). They found that an AAAS can have improved  $CO_2$  absorption potential compared to an AAS. Aronu et al.(2009) also found that AAAS does not form precipitate upon loading with  $CO_2$  like many AAS, which precipitate at high loadings (Aronu et al., 2009; Hook, 1997; Majchrowicz et al., 2009). Further, Aronu et al.(2010b) conducted a pilot plant test on one aqueous AAAS and found a potential for reduced energy consumption as it needs half the stripping steam requirement of MEA. It is therefore of interest to further develop the understanding of the fundamentals of the reaction mechanisms of AAAS solvent systems. This will be useful for improvements on the efficiency of any process using this solvent, since the design or simulation of acid gas treating processes require in for motion including

mass-transfer ,reaction kinetics, physiochemical properties and vapor–liquid equilibrium. In the study of

kinetics of CO<sub>2</sub> reacting with amines and amino acid salt systems, the zwitterion mechanism by Caplow(1968) and the Termolecular mechanism by Crooks and Donnellan(1989) are commonly used to interpret the experimental data. It has ,however ,been shown that both reaction mechanisms give identical results (Aronuetal.,2011a; Hartonoetal.,2009; Knuutila,2009). The Termolecular mechanism appears to be more attractive due to its simplicity as it has one parameter less than the zwitterion expression. In the present study, the CO<sub>2</sub> absorption performances of the potassium salts of common amino acids were assessed using Bubble columns reactor experiments. Suggested amino acids were categorized into four groups: linear amino acids alanine, and sterically hindered amino acids (alanine (ALA), serine (SER),and cyclic amino acids (proline (PRO), and arginine (ARG)). The molecular structures and CAS number of these amino acids and reference amines (monoethanolamine, piperazine) are shown in Table 2.

Table 2

of suggested amino acids and amines		
	Monoethanolamine (MEA), 141-43-3	Piperazine (PE), 110-83-0
	Glycine (Gly), 56-40-6	Proline (PRO), 106-95-7
	L-Alanine (ALA), 107-06-6	α-Aminobutyric acid (L-ABA), 106-13-7
	D-Alanine (D-ALA), 107-06-6	α-Aminobutyric acid (D-ABA), 107-06-6
	L-Serine (SER), 107-06-6	Serine (SER), 107-06-6
	L-Proline (PRO), 106-95-7	Proline (PRO), 106-95-7
	L-Arginine (ARG), 107-06-6	Arginine (ARG), 107-06-6
	L-Asparagine (ASN), 107-06-6	Asparagine (ASN), 107-06-6
	L-Glutamine (GLN), 107-06-6	Glutamine (GLN), 107-06-6

## Materials and Methods

The present work will be investigate the study experimental and modeling carbon dioxide capture with promoted potassium carbonate by amine amino acids using :-  
Experimental Apparatus Experiments of absorption of carbon dioxide from gaseous mixture (10% carbon dioxide - air) have been carried out by aqueous solution of

promoted potassium carbonate. These have been performed in a bubble column (7.5 cm inside diameter and 100 cm height, glass cylindrical column) over a wide range of gas flow rate homogeneous flow regime, Schematic diagram of experimental set up was

shown in Figure (2). Perforated plate sparger was used as gas distributor (porous disc) and placed between the column and distributor chamber which having a drain at the bottom and gas inlet at the side. Gas (carbon dioxide - air) flow rate was measured by using two calibrated rotameters. In all experiments the volume of liquid has been constant and equal to (1.5 liter, 30 cm height above the sparger). The temperature was measured each 1 minute until the end of the absorption run, the temperature remain constant. All experiments were perforated at ambient temperature and atmospheric pressure.

### Scope of the Work

This work was focused on development and characterization of new absorbents for  $\text{CO}_2$  capture. The work includes selection of new absorbents whose absorption rates and loading capacities, the ratio between moles of  $\text{CO}_2$  absorbed and moles of  $\text{CO}_2$ -free absorbent used, that were higher than those of other amine or amine mixtures. Develop a 2D mathematical model to described the behavior of chemical absorption of carbon dioxide in promoted potassium carbonate I bubble column reactor.

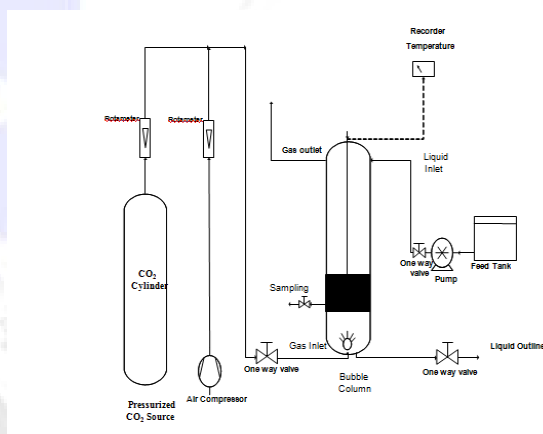


Figure (2). Schematic diagram of experimental apparatus.





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**Research Title:** **Synthesis and Characterization of Mesoporous Silica for Drug Delivery**

**Supervisors:** **Dr. Issam K. Salih.**  
**Dr. Talib M. Albayati.**

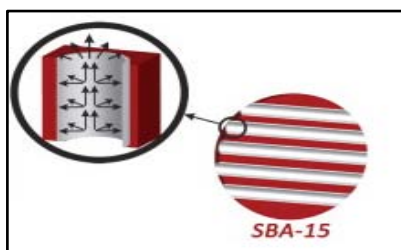
**Student Name:** **Haneen F. Alazzawi.**

### Background

At present, the most common ways of delivering drugs to humans are oral administration and injection. However, these methods have lower efficiency for some therapies. Some therapeutic agents are unstable or poorly soluble drugs; therefore, new delivery systems are currently required. The concentrations of drugs to be delivered can be considerably increased by using nanomaterial which acts as drug delivery vehicles that controlled and enhanced the efficacy of the drugs by improving the adsorption capacity and release properties of the drugs [1].

### Scientific Context for Mesoporous Silica

Recently, silica-based mesoporous materials are applied in biomedicine as biomarkers, enzyme supporters and biosensors [2]. The mesopores silica materials are tunable since the pore size can be preserved at the optimum narrow size distribution according to the size of the active agent. Therefore, these materials are ideal matrices for certain applications such as drug immobilization and controlled release. Fig. 1 shows a schematic illustration of controlled release of a molecule from the pores of the nanoporous oxide *SBA-15*.



### Fig. 1: Controlled release of pharmaceutical compound from SBA-15

**Aims:** preparation and characterization of different mesoporous materials such as MCM-41, MCM-48 and SBA-15, In order to evaluate their activities as carrier for controlled drug delivery.

#### Objectives and Experimental Program

1. Mesoporous oxides, comprising *MCM*- and *SBA*- types, will be prepared and characterized using established methods.
2. The characterizations of mesoporous materials will be studied in details such as XRD, SEM, TEM, EDAX, BET surface area and FT-IR.
3. A range of pharmaceutical compounds will be positioned within the pores, by means of adsorption from solution.
4. The adsorption isotherm will performed at equilibrium conditions according Langmuir, Frenlich and Timken isotherms.
5. The pseudo-first-order kinetic and the pseudo-second-order kinetic will investigate to study the kinetics of the adsorption process.
6. The time-dependent release of the pharmaceutical compounds from the mesoporous oxides will be studied by means of desorption from solution.

**Methodology:** The proposed project has been designed for a period of 12 months, and can be systematically performed by four parts as follow:

**Part (1):** Revision of scientific background and literature survey (1 month).

**Part (2):** Experimental work is consisting of three subdivided parts as follow:

**2.1: Preparation and Characterization (2 months):** A variety of mesoporous materials such as; MCM-41, MCM-48 and SBA-15 will be prepared by using established methods. All prepared materials will be extensively characterized by using different techniques such as XRD, SEM, TEM, EDAX, BET surface area and FT-IR in order to confirm their properties.



**2.2: Adsorption experiments (2 months):** A range of pharmaceutical compounds, initially *antibiotics*, will be loaded into the pores of nanoporous oxide by the adsorption process from the solution.

**2.3: Time-Dependent Release or desorption experiment (2 months):** The drug release experiments will be performed by means of desorption from solution.

**Part 3:** The result analysis and calculation steps (2 months).

**Part 4:** Thesis writing (3 months).

**Instrumentations:** The properties of the produced drug delivery will be analyzed according to the American Standard Test Method (ASTM) so as to measure the amount or concentration of drugs by the following instrumentations.

1. UV spectrophotometer.
2. HPLS method

### Dissemination

Hopefully the successful outcomes of this project will be sufficient scientific merit to warrant a number of publications in high-impact journals. Dissemination will also occur through publications in other peer-reviewed scientific journals and via posters and presentations at conferences.

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## **Research Title: Preparation Of Nano-Silica Catalyst From Rice Husk For Cracking Applications**

**Supervisors: Dr. Najat J. Saleh  
Dr. Bashir Y. Sherhan**

**Student Name: Zainab Mohammed Sapar**

### **Introduction and Theoretical Framework**

The most suitable cracking process has a high degree of flexibility and can be utilized for the improvement of the petroleum product generation efficiency via carefully adjusting its operating parameters, especially in the term of the catalyst – which plays a significant role in quantitatively and qualitatively controlling the cracking process and generation of more acceptable yield. Generally, the process by which a catalyst affects a reaction speeds up or slows down, is called catalysis, and a catalyst can be either hetero-geneous or homo-geneous with bio-catalysts (enzymatic) are often seen as a separate group. A catalyst is defined as any substance “organic, synthetic, or metal” that works to accelerate a chemical reaction by reducing its activation energy ( $E_a$ ) without affecting in any way the possibilities for this reaction within a chemical system.

### **Statement of the Problem**

Adding the catalyst diminishes decomposition temperature and promotes decomposition speed, hence makes a chemical process more efficient and reduces pollution by saving energy while minimizing unnecessary products and by-products. Therefore, the kind of catalyst is utilized to realize a maximum conversion of the feedstock by increasing the rate of reaction. Nanosilica  $\text{SiO}_2$  has found various applications as filler in rubber and plastics, nanocomposites, absorbent, drying powder, substrate for catalysts and anticorrosion agent. Various methods have been reported for preparing nanosilica in the literatures, such as plasma synthesis, chemical vapor deposition, sol-gel processing, micro-emulsion processing, combustion synthesis, and hydro- thermal technique. Meanwhile, a series of methods have investigated for recovering amorphous silica from rice husk and rice husk ash. The production of





reactive nanoscale silica from RH is a simple process compared to other conventional production techniques such as vapor phase reaction with such a large availability of an inexpensive waste raw material, it becomes economical method with high purification percent, high surface area, high reactivity, and amorphous in form this economic method, as applied to waste material, also provides many benefits to the local agro-industry. The sol-gel processing technique for the synthesis of silica nanoparticles has been widely used since pore volume and pore size can be controlled at the chemical solution stage, sol-gel-derived nano-silica has many unusual properties such as an adjustable refractive index, a high porosity, a low thermal conductivity, and a low dielectric constant. Silica ( $\text{SiO}_2$ ) is a ceramic material that is currently gaining prominence among the inorganic porous materials most widely used as catalyst supports. Its importance is due primarily to the physicochemical properties that only an inorganic covalent structure can exhibit, such as high mechanical strength, high physical and thermal stability, high porosity, large specific surface area, and pore sizes ranging from micro pores to mesopores. A catalyst support is a material that constitutes the greater part of a catalyst and that serves as a base, support or binder of the active constituent (metal), but which alone has little or no activity in terms of their action in question. The function of a mechanical support is to serve as a base or structure for the catalyst component, which is the metal that acts as a catalytic promoting agent. In addition to this function, other desirable effects of a catalytic support are to increase the area exposed to the active agent, there by augmenting the catalytic activity of an agent with low surface area; increase the stability of the catalyst; keep the crystals of the active material apart to prevent them from sintering and thus losing their activity; and to chemically complex the support with the active mass, resulting in higher activity per unit surface area. The use of nanosilica as a catalyst support in different chemical processes is widely reported in the literature. Zeolites are microporous crystalline aluminosilicates. Faujasite (FAU) is one of the most important industrial zeolites. More than 80% of chemical industries use catalytic technologies and 95% of these catalysts are of the zeolite-Y type, since it is widely used in hydrocarbon cracking reactions in the petroleum industry. Zeolites of type Y have a similar three-dimensional structure to faujasite, where the unit cell is cubic with a very large dimension ( $a_0$ ) of approximately 24.7 Angstroms, and it contains 192 total  $\text{SiO}_4$  and  $\text{AlO}_4$  tetrahedra. The following apparatuses were used to prepare NaY zeolite forms, and the below Table shows the reagents utilized in the experimental work.

Table Showing reagents used to prepare the NaY and NH<sub>4</sub>Y zeolite forms

Material Name	Batch Composition Formula	Manufacturer	Function
Anhydrous sodium aluminate	50.9 wt% Al <sub>2</sub> O <sub>3</sub> + 31.2 wt% Na <sub>2</sub> O + 17.9 wt% H <sub>2</sub> O	Sigma-Aldrich	Alumina source for NaY zeolite synthesis
Ludox AS-40 colloidal silica	40 wt% suspension in water	Sigma-Aldrich	Silica source for NaY zeolite synthesis
Sodium hydroxide	99 wt% NaOH	Merck	Mineraliser source for NaY zeolite synthesis
De-ionized water	About 100% H <sub>2</sub> O	University of Manchester	Solvent source for NaY zeolite synthesis

An acceptable laboratory method will be utilized to synthesize Na-Y zeolite, which can be synthesized by hydrothermal process using an alumina source and a mineralizer, as well as an amorphous silicate phase from RH will be employed as silica source in zeolite synthesis rather than Ludox in the above Table in order to achieve zeolite Y catalyst formation via utilizing abundance agricultural wastes (i.e. Rice husk materials) and then testing its activity, selectivity and stability in hydrocarbon cracking reactions.

### Purpose of the Study

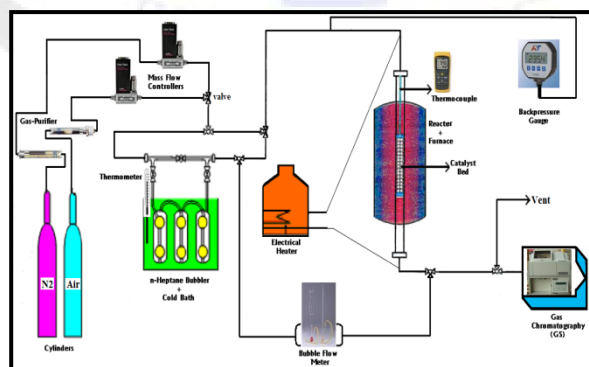
- Synthesis of catalyst from the local raw materials (Iraqi rice husk, as a source of silica) with satisfactory morphology.
- Analysis of the synthesized catalyst by means of the most common characterization techniques (i.e. XRD, ESEM, EDX, ICP and BET) to investigate their properties and establish the correlations between the achieved results from these characterizations. Analysis of both the kinetic and the thermodynamic parameters using TG and DSC analyses respectively can also be studied.
- Modifications of synthesized catalyst using the available treatment techniques such as cation exchange phenomenon, chemical treatment, and successive combinations of leaching treatment (desilication and /or dealumination) to discovery the impact of these modification techniques on the performance of synthesized catalysts during the cracking process.

d. The final aim of the present study was catalytic cracking of short chain hydrocarbon such as n-hexane ( $nC_6$ ) over the synthesized/modified catalysts. A cracking rig will be constructed for this work, as well to assess the deactivation/selectivity and kinetic/mechanism tests. In the first test, the catalytic activity and the catalytic selectivity together with the coke deposited on the prepared catalysts will be studied. While in the second test, the effects of both the kinetic parameters and the cracking mechanism on the  $nC_6$  cracking conversion will be investigated.

### Methods and Procedures (Description of Cracking System)

A custom reactor rig has been designed as revealed in the below Figure, and will be constructed and commissioned to carry out the cracking experiments. In addition to the mass flow controller and readout device, several valves will be employed for further controlling the flow of gases through the piping system. The flow of each gas will typically be checked by using both the bubble flow meter and a timer.

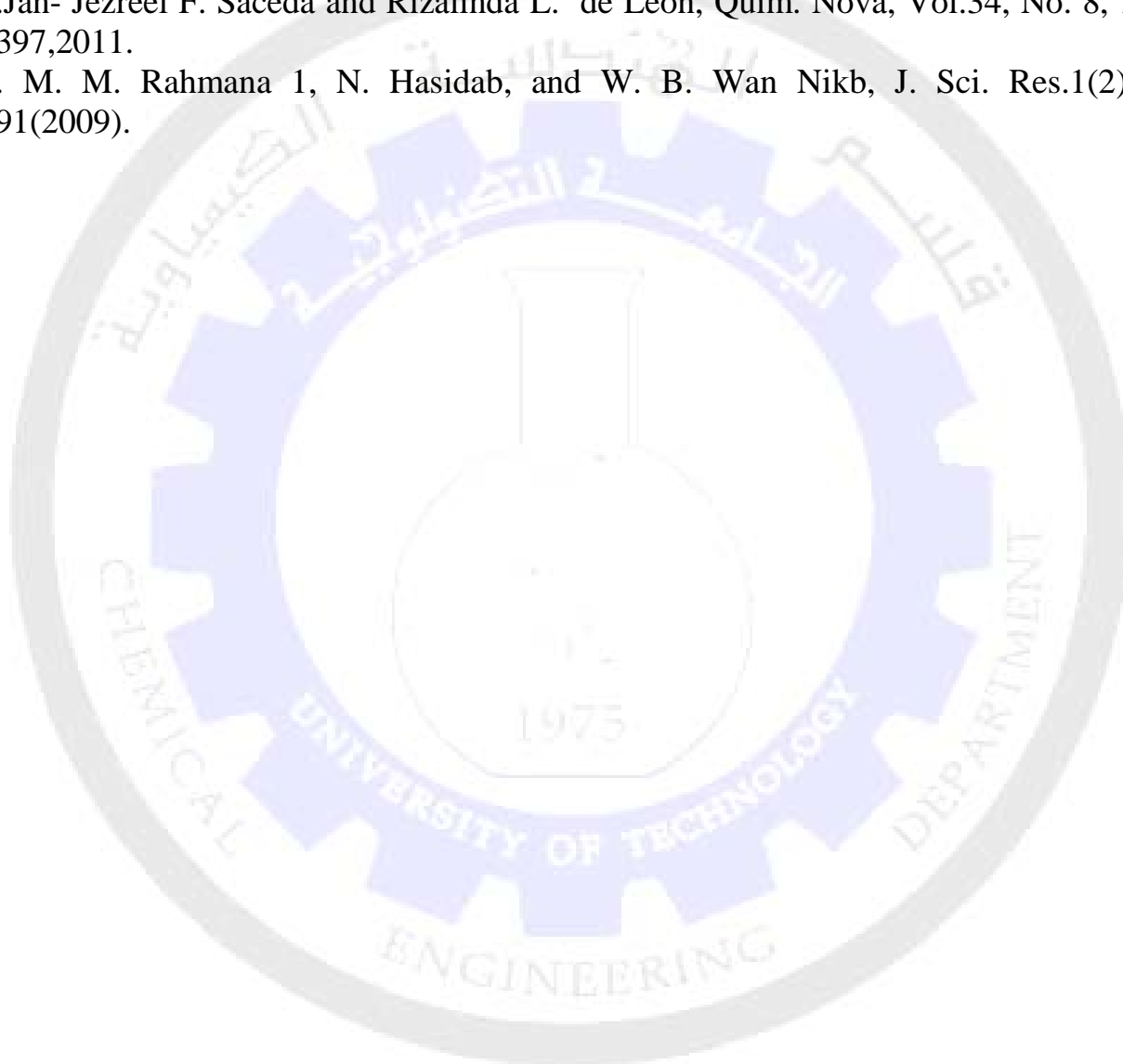
Three connected bubblers will be half filled with 99 wt% liquid n-hexane. So as to keep the contact time constant throughout the reaction, the bubblers will be placed in a cold bath surrounded by ice and thus the temperature will set at  $\approx 0^\circ\text{C}$ . An  $N_2$ -gas cylinder will be used to provide an oxygen-free nitrogen stream that will be passed through a gas purifier prior to carrying out the  $nC_6$  molecules from the bubblers into the cracking zone. The purifier will be utilized to clean the carrier gas from any possible contaminants. Stainless steel tubes with I.D. of about (1/8 in) will be connected between the bubblers and the GC and will be wrapped with heating wire supplied by a DC voltage, and then covered by aluminum foil to maintain the temperature at  $110^\circ\text{C}$  and thereby avoiding the condensation of feed or product vapors. The cracking reaction in a gas phase will be performed inside a fixed-bed plug-flow tubular reactor and the outlet from the reactor will be continuously transferred to the GC via a two-way valve in order to analyze the gaseous products immediately. The GC will also be calibrated before beginning any cracking experiment.





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**Research Title: Applying Modern optimization Techniques in Prediction of Reaction Kinetics of Iraqi Refinery's**

**Supervisor: Dr. Zaidoon M. Shakor**

**Student Name: Anfal Hayder**

**Introduction**

Petroleum Refinery includes several physical, thermal and catalytic processes such as in table below.

Physical	Chemical	
	Thermal	Catalytic
Distillation Solvent extraction Propane deasphalting Solvent dewaxing Blending	Visbreaking Delayed coking Flexicoking	Hydrotreating Catalytic reforming Catalytic cracking Hydrocracking Catalytic dewaxing Alkylation Polymerization Isomerization

Catalytic hydrotreating is a hydrogenation process used to remove about 90% of contaminants such as nitrogen, sulfur, oxygen, and metals from liquid petroleum fractions. If these contaminants are not removed from the petroleum fractions they can have detrimental effects on equipment, catalysts, and the quality of the finished product. Hydrotreating processes differ depending upon the feedstock available and



catalysts used. Typically, hydrotreating is done prior to processes such as catalytic reforming so that the catalyst is not contaminated by untreated feedstock. Hydrotreating is also used prior to catalytic cracking to reduce sulfur and improve product yields, and to upgrade middle-distillate petroleum fractions into finished kerosene, diesel fuel, and heating fuel oils. In addition, hydrotreating converts olefins and aromatics to saturated compounds. Figure (1) shows the trickle bed reactor used for hydrotreating process.

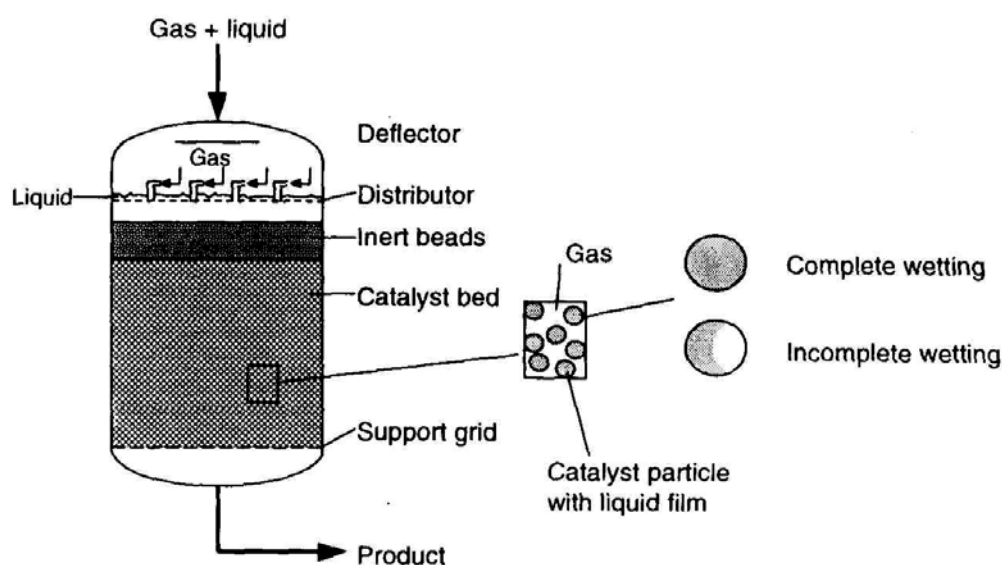


Figure (1) Hydrotreating: trickle-bed reactor

### Aim of Study

Parameter estimation is one of nine phases in modelling, which is the most challenging task that is used to estimate the parameter values for chemical and biological system that is non-linear. There is no general solution for determining the nonlinearity of the dynamic model. Experimental measurement is expensive, hard and time consuming. Hence, the aim for this research is to implement Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) to obtain optimum kinetic parameters for heavy naphtha hydrotreating.

## Objectives

The reaction kinetic in modern Iraqi refineries are not known will. This study is became to identify the hydrotreating reaction kinetics throw the steps.

## Plan For Research Activities

1. Collect a data that describe the hydrotreating process.
2. Modeling hydrotreating trickle bed reactors in one dimensional model TO describe the process.
3. Applying modern optimization techniques such as Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) to describe the reaction kinetic by lest square optimization.
4. Applying computational fluid dynamics CFD to simulate the hydrotreating trickle bed reactor in three dimension.

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## Web site

[http://cns.mak.ac.ug/sites/default/files/docs/5\\_Oil\\_Refinery\\_Processes.ppt](http://cns.mak.ac.ug/sites/default/files/docs/5_Oil_Refinery_Processes.ppt)

**Research Title: Bioremediation of Wastewater by Algae**

**Supervisor: Dr. Nahidh W. M. Kasser**

**Student Name: Farah Ali Mohammed**

### Introduction

Pollution interacts naturally with biological systems. It is currently uncontrolled, seeping into any biological entity within the range of exposure. The most problematic contaminants include heavy metals, pesticides and other organic compounds which can be toxic to wildlife and humans in small concentration. There are existing methods for remediation, but they are expensive or ineffective.[1] However, an extensive body of research has found that a wide variety of commonly discarded waste including eggshells, bones, peat,[2] fungi, seaweed, yeast and carrot peels [3] can efficiently remove toxic heavy metal ions from contaminated water. Ions from metals like mercury can react in the environment to form harmful compounds like methyl mercury, a compound known to be toxic in humans. Bioremediation is a waste management technique that involves the use of organisms to remove or neutralize pollutants and Microorganisms used to perform the function of bioremediation are known as bioremediators. This process involved in the removal of hydrocarbons and heavy metals include biosorption (adsorption and absorption), degradation and storage, which are affected by various environmental factors, particularly, co-contamination [4].

### Statement of the Problem

The main objective of the present study is to effectively utilize di-oiled algal biomass (DAB) as an adsorbent. Chlorinated cyclic hydrocarbons and heavy metals will be used as a sorbate for evaluating the potential of DAB as a biosorbent. The DAB was characterized by Scanning electron Microscope (SEM), Fourier Transform Infrared (FTIR), particle size, pore volume and pore diameter to understand the biosorption



mechanism. The equilibrium studies were carried out by variation in different parameters, i.e., pH, temperature, biosorbent dosage, contact time, agitation speed and pollutants concentration. Artificial neural network (ANN) model will be tested to validate the

experimental removal efficiency with theoretically predicted values. Adsorption capacity of DAB will be studied in fixed bed column and in batch studies. The probable mechanism for biosorption in this study is chemisorptions via surface active charges on the DAB cellular wall at initial stage which will be followed by physical sorption by occupying the pores of DAB. The Main objective of the present study is to evaluate the effects of different physicochemical parameters like pH, agitation speed, temperature, pollutants-biosorbent contact time, DAB concentration and initial pollutants concentration with the performance as will be predicted through different kinetic models including pseudo-first and second order kinetics and intra particle diffusion. Analysed the whole data set using artificial neural network (ANN) to validate the experimental as well as predicted values generated which should be agree well with each other. Changes in enthalpy ( $\Delta H^0$ ), entropy ( $\Delta S^0$ ), Gibbs free energy ( $\Delta G^0$ ) as well as the equilibrium constant (Kc) for different pollutants biosorption over DAB will be calculated using van't Hoff equation .

### Modeling Artificial Neural Network (ANN)

Modeling is important to identify the complex input-output relationship and to develop a model to predict the output of dependent variables from the given set of independent variables. ANN will be used to evaluate the performance of various parameters for hydrocarbons and metal adsorption using mean square error and regression. The present study will use Neural Network Toolbox of MATLAB R2013a software.

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### Research Discussed of M.Sc.

No	Research M.Sc.	Student Name	Supervisors
1	Applications of Numerical Methods in, Galvanic Corrosion of Coupled Metals	بسمة محمد كاظم	أ.م.د. جمال مانع علي
2	Sea Water Desalination by Membrane Distillation	سمراء رفعت خليل	أ.م.د. قصي فاضل م.د. صلاح سلمان
3	Effect of particle and floc size on water treatment by physico-chemical process	مهند ابراهيم فرحان	أ.د. ثامر جاسم محمد
4	Phase equilibria for extraction of phenolic pollutants from industrial wastewater using liquid membrane technique	انور جاسم محسن	م.د. خالد فرهود
5	Optimization of the Factors Affecting the Production of Nanosilica From Iraqi Sand and Its Industrial Application	علي داود سلمان جاسم	أ.م.د. نجاة جمعة صالح م.د. رحيق اسماعيل ابراهيم
6	Performance enhancement in unsteady state operated trickle bed reactor of organic compound	غيداء ضياء الدين نجيب	أ.د. صفاء الدين عبدالله م.د. فرح طالب جاسم
7	Computer aided design and optimization of a petrochemical complex	هدى عامر عبد القادر	أ.د. صفاء الدين عبدالله أ.م.د. زيدون محسن شكور
8	Treatment and Reclaiming of Iraqi Oil Field Produced Water by Flotation Column and Membrane Technology	هدى كاظم حسن زامل	أ.د. ثامر جاسم محمد أ.م.د. قصي فاضل
9	Study the Corrosion Behavior of Carbon Steel in Presence of CO <sub>2</sub> Gas in Oil Pipelines	نضال أحمد شاكر	أ.م.د. شذى أحمد م.د. شروق طالب
10	Application of Lab View and Genetic Algorithm for Controlling of A plate Heat Exchanger.	ايمن فوزي زوين حمد	أ.م.د. زيدون محسن شكور
11	Advanced Oxidative Desulfurization of Fuel Oils	جعفر مازن جعفر حسين	أ.د. نيران خليل ابراهيم م.د. ولاء عبد الهادي
12	The Effect of LSM Corrosion Protection on Al and Al Alloys	هبة خميس اسماعيل	أ.م.د. شذى أحمد
13	Hydrodynamics and Kinetic Study in an Ebulated-Bed Reactor for the (Heavy Oil) H-oil Unit	هالة حسين حسن عباس	أ.م.د. محمد فاضل د. شاكر محمود
14	Numerical Solution to Hydrodynamic Characteristics of Mixing of Multiphase Flow System	زين العابدين علي قاسم حسين	أ.د. ثامر جاسم محمد أ.د. جلال محمد جليل
15	The Use of Advanced-Non Conventional-Technologies to Improve the Properties of Heavy and High Sulfur Crude	علياء محمد عواد محمد	أ.د. نيران خليل ابراهيم
16	Effect of Overheating on the Corrosion of Steam Boilers Pipes	زينب ضياء محمد عباس	أ.م.د. شذى احمد سامح أ.م.د. عبد الخالق فوزي حمود
17	Purification of Ethanol Produce by Almosl State Company for Sugar Production Using Carbon Nano Filter	احمد طلال صادق عيسى	أ.م.د. محمد ابراهيم أ.م.د. عدنان عبد الجبار





### Current Research of M.Sc.

No	Research M.Sc.	Student Name	Supervisors
1	Study of Fluidizing System Behavior Using Nano- Particles	سارة طلال حسين سلمان	أ.م.د. جمال مائع علي
2	Optimization Study for the Preparation of Nano Silica Using Sol –Gel Process and Its Application in Rubber Reinforcement	علي هيثم سليم داود	أ.د. نجاة جمعة صالح أ.م.د. أنعام أكرم
3	Experimental Study and Simulation of Advanced Oxidation Processes for Wastewater Treatment	لمياء عدنان عبد الرضا	أ.م.د. محمد فاضل أ.م.د. غانم مقبول
4	Entrapment of Phase Change Material Using Cellulose Acetate Butyrate (CAB) as Coating Polymer	علا سعد محمد ندا	أ.م.د. ناهض وديع ميخائيل
5	Dynamic Study of Acid Gas Absorption using Promoted Absorbent in Bubble Column Reactor	احمد نوري كوكز حسون	أ.د. صفاء الدين عبدالله
6	Modeling and Simulation of Inverse Three Phase Fluidized Bed Characteristics Using MATLAB	نسمة بلاسم احمد عبد	أ.م.د. زيدون محسن شكور م.د. عامر عزيز
7	Removal of Pollutants from Aqueous Solution by Functionalized Mesoporous Material	داليا باسل عبد رجب	أ.م.د. أنعام أكرم أ.م.د. طالب محمد نايف
8	Preparation and characterization of nanocatalyst for desulfurization of (Vacuum Gas Oil) VGO	محمد احمد شهاب احمد	أ.م.د. محمد أبراهيم أ.م.د. عدنان عبد الجبار
9	Experimental Study For Removal Harmful Organics From Refinery Wastewater Using Solar Photocatalytic Reactor	اريج فالح كاظم عبيس	أ.م.د. محمد فاضل عبد علي أ.م.د. عروبة نافع عبد الله
10	Regeneration of Used Lubricating oil by Extraction Method	غسان روكان دهام حميد	أ.م.د. عدنان عبد الجبار م.د. عادل شريف حمادي



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