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## التنمية العمرانية المستدامة في مركز الكرخ التاريخي

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### مستخلص البحث :

تعد المشاكل التي تواجه المراكز التاريخية في المدن من اكثر المواضيع تطرقا" للبحث على مدى زمني طويل ومنذ منتصف القرن العشرين ، وقد توجهت الادبيات الخاصة بالتطوير العمراني لدراستها ، فضلا عن قيام عدد كبير من مشاريع التطوير للمراكز التاريخية في العديد من مدن العالم ، وقد ظهرت من تطبيق هذه المشاريع امور مستحدثة مضافة للمشاكل الحضرية الأصلية لها بسبب تعامل هذه المشاريع مع البنى الفيزيائية العمرانية والتخطيط لها مع اهمال الجوانب الاجتماعية والاقتصادية والتي تمثل اساسا" في التنمية المستدامة . وفي ضوء ذلك تحددت مشكلة البحث في عدم وضوح المعرفة حول امكانيات التنمية المستدامة في حل المشاكل الحضرية للمراكز التاريخية بشكل عام ومركز بغداد التاريخي في الكرخ بشكل خاص . وبالتالي تحدد هدف البحث في ايضاح كيفية توظيف معطيات التنمية على مستوى الاستدامة الحضرية بجميع مستوياتها البيئية والاجتماعية والاقتصادية لإيضاح مشاكل التطوير العمراني للمراكز التاريخية بشكل عام ومركز بغداد في الكرخ بشكل خاص، وبالتالي معرفة الامكانيات التي بموجبها يمكن وضع مشاريع التنمية المستدامة لهذا المركز التاريخي المهم وتحقيق ديمومة الحياة والارتقاء بها فيه .

**التنمية ، الاستدامة ، التنمية المستدامة ، التطوير العمراني ، المراكز التاريخية .**

### **The sustainable urban development in Al\_Kharkh historic center**

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### **ABSTRACT**

**T**he problems of urban historic centers are considered some of the subjects which are widely dealt with in urban studies since the middle of the 20th century. literature of urban development have raised it , beside the fact that large number of urban development projects of the historical centers in many cities of the world ,and emerged from the application of these new problems projects added their original urban problems , because these projects have dealt with the physical structures with the neglect of the social and economic sides, which are the base in sustainable development

Research problem was elaborated as : The unclearly of knowledge of the potentials of the sustainable development in solving the urban problems of historic centers in general, and In Baghdad historic center of Karkh in particular. So the objective of the research becomes: clarifying how to elaborate the outputs of sustainable urban development with all its aspects.

**Development , Sustainable , The Sustainable Development , Urban Development , Historic centers .**



## المقدمة :

تواجه المراكز التاريخية للمدن الكثير من التغيرات التي تصيب هيكلها العمراني وتركيبها الاجتماعي وبنيتها الاقتصادية والتي تحدث نتيجة لضغوطات التطور العمراني المعاصر ومتطلباته . وهذه التغيرات قد لا تتدمج مع بنيتها التاريخية شكلا ومضمونا، فهذا (التطور) قد يتطلب إزالة أجزاء كثيرة من نسيجها الحضري ودخول وظائف جديدة تجارية أو صناعية أو خدمية لم تكن موجودة أصلا مما يؤدي إلى الازدياد في تدهورها وبالتالي قد يضر ذلك بمعالمها وبنيتها ، ويؤثر على حياة قاطنيها، فيتحول المركز الى بيئة غير صالحة للسكن ، فتبدأ ظاهرة هجرة السكان الأصليين من هذه المناطق إلى الأطراف والضواحي الحديثة حيث تتوافر البيئة الأكثر ملائمة لمتطلباتهم . وكنيجة لذلك تتحول المراكز التاريخية إلى مأوى للجماعات ذات الدخل المنخفض والمهاجرين والباحثين عن السكن الرخيص والعمل مما يساهم في تدهور المراكز التاريخية .

وقد ظهرت العديد من برامج التطوير العمراني و التجديد الحضري لإنقاذ ما تبقى من النسيج الحضري لهذه المراكز وإعادة الحياة لها ، الا ان غالبية هذه المخططات والمشاريع التطويرية تعنى بالبنى الفيزيائية فقط هاملة " بنية المدينة الاجتماعية والاقتصادية والتي تمثل اساسا في التنمية المستدامة، وهذا قد يمثل حلا" تخطيطيا" للبنية الفيزيائية للمدينة او المركز التاريخي ولكنه لا يمثل حلا" لواقع الحياة في هذه المناطق واهليتها للسكن والعمل معا .

وفيما يخص مدينة بغداد فقد مرت بمراحل تنموية سريعة بدءا" من نشوء المدينة المدورة عام(762م) ونشوء الكرخ والرصافة كمراكز غدت تاريخية في الوقت الحاضر واستمر عموم المركز التاريخي الى الان يواجه موجات من التغيرات والتحولات على مستوى بنيته الحضرية تماشيا مع تطور الزمن ومتطلبات العصر وهذه التحولات بالتأكيد غيرت معالم الشخصية الحضرية والاجتماعية للمركز التاريخي ، وقد اعدت الكثير من الدراسات التخطيطية التنموية من قبل امانة العاصمة لإنقاذ ما تبقى من النسيج التراثي لمركز مدينة بغداد والحد من تدهوره ، من هذه الدراسات التخطيطية حظي مركز الكرخ التاريخي منها بدراسة واحدة اقترحت في الثمانينات.

## 1: التنمية :

ان كلمة تنمية حسب ما ورد في معجم اللغة العربية المعاصر هي مصدر مأخوذ من الفعل (نمى) ومفعوله (نموا) ، ونمى الشيء اي جعله ناميا ، ومعناه الانتقال من حالة الى حالة افضل ، ومصطلح التنمية مشابه لمصطلح التطوير Development حيث يمثل الاخير اضافة جديدة لما موجود لتحسينه . (عمر،2008،ص57) ، ويعد مفهوم التنمية من اهم المفاهيم العالمية اذ تمثل التنمية عملية تغيير من واقع الى واقع افضل منه على جميع المستويات ، ولهذا فالتنمية لها جوانب عديدة منها الاقتصادية والاجتماعية والسياسية والبيئية وغيرها (عارف،2008،ص2) ، فمفهوم التنمية يتوجه نحو احداث تغييرات جذرية في حياة المجتمع تجعله يتحول من واقعه الى واقع افضل منه بهدف تحسين نوعية الحياة لكل افراده ، بمعنى اكساب المجتمع القدرة على التطوير الذاتي لواقعه وهي بذلك تتوجه نحو اعادة تنظيم واعادة توجيه كامل النظام الاجتماعي والاقتصادي والبيئي بالاتجاه الافضل (النعيمي ،2002،ص247).

## 2: انواع التنمية :

للتنمية لها فروع عديدة حيث تطور مفهوم التنمية مع مرور الزمن ليرتبط بالعديد من الحقول المعرفية ليتضمن اجراء تغييرات جذرية شاملة ومتكاملة تشمل كل جوانب الحياة في المجتمع وفي الدولة والهيكل على جميع مستوياتها : ( الاجتماعية - الاقتصادية - الثقافية .. الخ ) فأصبح هنالك التنمية الاقتصادية والتي تسعى الى رفع مستوى الدخل القومي، بمعنى زيادة قدرة المجتمع على الاستجابة للحاجات الأساسية والحاجات المتزايدة لأعضائه، بالصورة التي تكفل زيادة درجات إشباع تلك الحاجات، عن طريق الترشيح المستمر لاستغلال الموارد الاقتصادية المتاحة، وحسن توزيع عائد ذلك الاستغلال.(العظم ،2009،ص1) ودخلت الى مجال السياسة في الستينيات من القرن الماضي والذي يهتم بتطوير البلدان الغير الأوربية تجاه الديمقراطية فوصفت التنمية إنها عملية تغيير اجتماعي متعدد الجوانب غايته الوصول الى مستوى الدول الصناعية.(عارف،2008،ص14) وارتبطت بالبيئة فالتنمية البيئية هي التي تسعى للحفاظ على البيئة وترشيح استهلاك مواردها بصورة سليمة . وهنالك التنمية الثقافية التي تسعى لرفع مستوى الثقافة في المجتمع وترقية الإنسان، (النعيمي،2002،ص247) ، وهنالك التنمية الاجتماعية وهي عملية تغير اجتماعي مقصود ومخطط له تلحق بالبناء الاجتماعي ووظائفه وتسعى لإقامة بناء اجتماعي جديد و تهدف الى تطوير التفاعلات المجتمعية بين جميع

اطراف المجتمع ، الفرد ، الجماعة ، المؤسسات الاجتماعية المختلفة ، المنظمات الاهلية، ورفع مستوى الحياة الاجتماعية من حيث الصحة والتعليم والمستوى المعاشي والخدمات بشتى أنواعها. (سعد، 2004، ص13) ، وهناك ايضا التنمية البشرية وهي مرتبطة بالتنمية الاجتماعية حيث تهتم بدعم قدرات الفرد والعمل على تحسين اوضاعه في المجتمع من خلال رفع مستوى التعليم، وتحسين نوعية حياة الإنسان السياسية والاقتصادية والاجتماعية ( الامم المتحدة ، 2005 ، ص16)

و كتعريف اجرائي للتنمية واهدافها يمكن التوصل الى انها عملية اصلاحية تطويرية تعتمد على التغيير في البنى الارتكازية الاساسية الاقتصادية والاجتماعية والبيئية من مستوى وضعها الاصلي الى مستوى افضل . وهي عملية ديناميكية وليست ثابتة وذات اتجاهات متعددة وليست باتجاه واحد . وهي تهدف الى التغيير الذي يشمل جميع المستويات المذكورة . وان عملية التغيير تعد انجاز في زمنها بحكم متطلبات العصر وقد تنسى مستقبلا في حكم متطلبات المستقبل ، ولهذا لابد لهذا التغيير ان يتصف بالمرونة الكافية لمواكبة هذه المتطلبات وهذا يتطلب ان يكون التغيير المنشود مستمرا دائما" ومتاغما مع متطلبات العصر ، بمعنى ان تكون التنمية حاملة لصفة الديمومة اي انها (مستدامة) لضمان ديمومة التغيير .

### 3: الاستدامة :

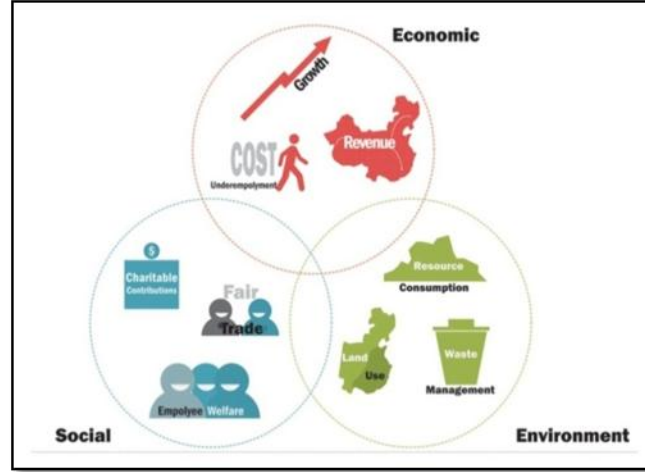
ان مفهوم الاستدامة حسب ما ورد في المعجم المفصل في علوم اللغة يعني الاستمرار والتجدد ( البعلبي ، 1998 ، ص934 ) . وان كلمة الاستدامة تعود الى اصول لاتينية مشتقة من كلمة ( Sustainer ) ( وهي بمعنى Support from below , To hold up ) اي بمعنى الاسناد من الاسفل للارتفاع ، وهي ايضا بمعنى الاستمرارية ، واطالة البقاء ، والمد بأسباب الحياة ، ودعم موارد البيئة ( Senosiain, 2003, p3) . ان مفهوم الاستدامة مفهوم ليس بالجديد حيث ظهر بشكل واضح ضمن التوجهات التنموية المختلفة خلال النصف الثاني من القرن العشرين ، واخذ يفرض نفسه بقوة في مطلع القرن الواحد والعشرين ، ومفهومها لا يعني فقط الاقتصاد في استغلال الموارد ضمن الحدود المسموح بها بل ان مفهومها يتعدى ذلك ليشمل الاستغلال الامثل لها . ( خروقة 2006 ، ص6 )

وضعت من قبل المنظرين والمنظمات عدة تعريفات لمفهوم الاستدامة منها تعريف (Phillip Sutton) حيث يقول بأن الاستدامة تتجسد بالحفاظ على الشيء وأمداده بأسباب الحياة والديمومة وليست حول تكامل القضايا البيئية والاجتماعية والاقتصادية او تحسين نوعية الحياة فقط " ( Sutton, 2000, p9) وهذا يعني ان فكر الاستدامة لا يتجسد بالحفاظ فحسب وانما يتجسد بالحفاظ والاستمرارية وتحسين نوعية الحياة البشرية . اما ( Harwood ) يقول بأن الاستدامة هي النظام الذي يمكن ان يتطور الى ما لانهاية نحو اكبر فائدة للإنسان ويعمل على زيادة الكفاءة في زيادة الموارد والعمل على ديمومتها وتحقيق التوازن مع البيئة . وهذا ايضا ورد في تعريف الاتحاد الدولي لحماية الطبيعة والموارد الطبيعية للاستدامة فهي " تحسين لنوعية الحياة البشرية ضمن الامكانيات المتاحة في النظام الايكولوجي " ( IUCN\UNEP\WWF, 1980, p2 ) . اما روبرت جلمان (Robert Gelman) فعرف الاستدامة من منظور بسيط ذاكرة انها تشير الى مفهوم قديم وبسيط جدا ممثلا بالقاعدة الذهبية هي " زرعوا فأكلنا ونزرع فيأكلون " ( Gelman, 1990, p10) . وهنا قد يبدو لدى البعض ان الاستدامة تمثل توجهها نوستالجيا للماضي واسلوب الحياة البسيطة ، الا ان ( Jacobs ) اكد العكس تماما حيث تمثل الاستدامة دعوته لتبني اسلوب جديد للتفكير والتعامل بشكل اكثر مسؤوليه تجاه البيئة المحيطة وهذا لا يعني ان هنالك اسلوبا محددا لتحقيق ذلك فالاستدامة تعني التعامل بوعي مع البيئة والموارد الطبيعية وليس مجرد معادله او صفة جاهزة للبقاء ( Jacobs, 1999, p61)

اذا" الاستدامة هي صفة يجب ان تكون متلازمة مع التنمية لضمان ديمومتها فهي ظاهرة تنموية مستمرة متجددة تسعى الى بناء الحياة في الوقت الحاضر وضمان استمرارها مستقبلا دون اهمال لمعطيات الماضي و من خلال التعريفات السابقة لها نستنتج انها تقوم على اساس مبدأ التوازن في توزيع الموارد .

ولها ثلاثة ابعاد اساسية متداخلة فيما بينها وتشمل البعد البيئي والذي يهتم بتحقيق التوازن البيئي والحفاظ على البيئة سواء كانت بيئة طبيعية ام مشيدة ، والبعد الاجتماعي والذي يضمن تحسين واقع المجتمع وضمان حقه من الموارد المتاحة ، والبعد الاقتصادي الذي يهتم بتحقيق التطور الاقتصادي وزيادة الانتاجية وتحقيق كفاءة الأداء الاقتصادي . وهذه الابعاد متداخلة ومتكاملة كما يمكن

ان نستنتج بديهيا ولتحقيق تكامل هذه الابعاد الاساسية ظهر ما يسمى بال (Triple Bottom Line) (الشكل 1) واستخدام هذا المصطلح لأول مرة "جون ايلكنجتون (John Elkington) ، وهو اقتصادي متخصص بالبيئة حيث اكد بأنه لا يمكن تحقيق استدامة بيئية او اجتماعية او اقتصادية بشكل منفصل ، بل لابد من اخذ الابعاد الثلاثة بنظر الاعتبار في وقت واحد لتحسين نوعية البيئة والنمو الاقتصادي مع تحقيق العدالة الاجتماعية (Elkington,1999,p75) .



الشكل 1 يوضح الابعاد الاساسية للاستدامة المتداخلة  
فيما بينها - المصدر (موسوعة ويكيبيديا)

#### 4: التنمية المستدامة :

ان التنمية المستدامة بمعناها الشامل هي التنمية التي تهتم ببيئة الانسان حيث ان الاستدامة لا يمكن ان تتحقق بدون خطط تنمية واستراتيجيات تمكنها من تحقيق مبادئها الاساسية ، وهناك العديد من التعريفات الخاصة بالتنمية المستدامة ، بعضها يتصف بالشمولية وبعضها تعرف من منظور محدد ومن هذه التعريفات :

- من منظور التركيز على الجانب المادي : جاء تعريفها في قاموس ( Webster ) بأنها تلك التنمية التي تستخدم الموارد الطبيعية دون ان تسمح باستنزافها او تدميرها جزئيا (Webster,2010,p63) .

- ومن منظور التركيز على الجانب الاجتماعي: فالتنمية المستدامة هي التنمية التي تسعى لنقل المجتمع من الأوضاع القائمة إلى أوضاع أكثر تقدماً لتحقيق أهداف محددة تسعى أساساً لرفع مستوى معيشة المجتمع ككل من جوانبه كافة اقتصاديا واجتماعيا وعمرانياً وذلك في إطار الموارد المتاحة .

- من منظور التركيز على الجانب الاقتصادي تعرف بأنها عملية الحصول على الحد الأقصى من منافع التنمية الاقتصادية بشرط المحافظة على الموارد الطبيعية ونوعيتها (Steel,1997, p43). وهناك تعريفات اقتصادية اخرى ركزت على مبدأ ان استخدام الموارد اليوم يجب ان لا يقلل من الدخل الحقيقي في المستقبل ، ويقف وراء هذا المبدأ الفكرة التي تؤكد بان القرارات الحالية ينبغي ان لا تضر بإمكانيات المحافظة على مستويات المعيشة في المستقبل او تحسينها بالشكل الذي لا يؤثر على البيئة المحلية ( اديب،2002،ص16) ، وهذا ما طرحه وليم رولكر هاوس W.Ruchelshaus حيث عرف التنمية المستدامة بأنها العملية التي تقرر بضرورة تحقيق نمو اقتصادي يتلاءم والقدرات البيئية ، وذلك من منطلق ان التنمية الاقتصادية والمحافظة على البيئة ، هي عمليات متكاملة وليست متناقضة (Church ,1998,p3) .

-وهي من منظور التركيز على الجانب البيئي يشترك التعريف الذي وضعه وليم رولكر مع الجانب الاقتصادي في تعريف التنمية المستدامة من منظور التركيز على الجانب البيئي ، كما انها تعرف بأنها الاستثمار الامثل للبيئة والاستفادة من الموارد والامكانات المتاحة سواء أكانت بشرية ام مادية ام طبيعية بشكل فعال ومتوازن اقتصادياً وبيئياً وعمرانياً واجتماعياً لتحقيق العدالة للسكان ودون اهدار مكتسبات الاجيال اللاحقة ( الداغستاني،2009،ص 75) .

- وتعرف من منظور التركيز على الجوانب التكنولوجية بأنها استخدام التكنولوجيا الجديدة لإنقاذ الموارد الطبيعية بهدف الحد من التلوث وتحقيق استقرار المناخ واستيعاب النمو في عدد السكان (عبد اللطيف، 1993، ص8) .

ان استعراض هذه التعريفات المتعددة للتنمية المستدامة يمكننا من تحليل المحاور التي تتوجه اليها التنمية المستدامة وهي البيئية والاجتماعية والاقتصادية ، فيوضح ان الانسان هو محور التنمية المستدامة الاساسي حيث تتضمن تنمية بشرية تؤدي الى تحسين المستوى الصحي والتعليم والرفاه الاجتماعي وتحسين المستوى الاقتصادي بمعنى ان التنمية حتى تكون مستدامة يجب ان تعتمد مبدأ التوازن بين محاور الاستدامة البيئية والاجتماعية والاقتصادية .

### **5: اهداف التنمية المستدامة :**

- تسعى فكرة التنمية المستدامة الى توجيه السياسات التنموية المستقبلية الفاعلة بحيث تعمل على تحقيق مجموعه من الاهداف التي تم وضعها بالاعتماد على نظرية التوازن المذكورة انفا" (Estes, 2009, p10)
- 1- تسعى التنمية المستدامة الى تكامل السياسات البيئية والاجتماعية والاقتصادية .
  - 2- تعمل التنمية المستدامة على المحافظة على المصادر الطبيعية واستمرار تزويدها للأجيال القادمة عن طريق الاستخدام الفعال للطاقة الغير المتجددة واعادة تشغيل وتطوير تقنيات بديله غير مؤذية للبيئة مع الحفاظ على التنوع البيولوجي .
  - 3- تعمل على رفع مستوى المعيشة وتحقيق الاحتياجات الاساسية للسكان .
  - 4- رفع معدلات النمو الاقتصادي .
  - 5- الحفاظ على البيئة والموارد الطبيعية لتلبية احتياجات الاجيال الحالية واللاحقة .
  - 6- تحقيق العدالة الاجتماعية والحد من سياسات التنمية التي تزيد حجم الفجوة بين طبقات المجتمع الغنية والفقيرة .
- وبهذا تشكل الابعاد الرئيسية للتنمية المستدامة المتمثلة بالابعاد الاقتصادية والبيئية والاجتماعية بتكاملها اهدافا اساسية للتنمية المستدامة للوصول الى حاله التوازن الطويل المدى من خلال الحفاظ على الموارد البشرية وحماية البيئة لتجنب التدهور البيئي وتحقيق التنمية الاجتماعية والاقتصادية وايفاء متطلبات البشر .

### **6: مؤشرات التنمية المستدامة :**

يعتمد تصنيف مؤشرات التنمية المستدامة على ابعادها . وعلى هذا الاساس فمؤشرات التنمية المستدامة هي المؤشرات الاقتصادية والاجتماعية والبيئية . الغرض منها معرفة كيفية عمل التنمية المستدامة وعن طريق هذه المؤشرات نتمكن من تحديد اتجاهات حل المشكلات في حالة وجودها ، وتعرف بأنها معايير تقييم لتحقيق التنمية المستدامة في المجتمع اذ يمكن استخدامها لمراقبة ظروف وميول التنمية وتحديد مدى التقدم وتقييم تأثير السياسات التنموية وتحسين المشاركة بما يخص قضايا الاستدامة (ديب، 2009، ص53).

تمكن مؤشرات التنمية المستدامة المجتمع من معرفة الاحتياجات الاساسية من اجل مواجهة المشاكل قبل ان يصبح لها تأثيرا سلبيا ، فضلاً عن ان هذه المؤشرات توضح نقاط الضعف في العلاقة بين النواحي الاقتصادية والبيئية والاجتماعية . وبذلك فان هذه المؤشرات تختلف عن مؤشرات التنمية التقليدية التي تعمل على قياس التغيرات في مجال من مجالات التنمية. وبصورة عامة فان هذه المؤشرات تهدف الى تحقيق اهداف اجتماعية واقتصادية وبيئية فضلاً عن اهداف ادارية ( الداغستاني، 2009، ص89).

### **7: انواع مؤشرات التنمية المستدامة :**

تقسم مؤشرات التنمية المستدامة الى ثلاثة انواع اعتمادا على ابعاد التنمية المستدامة وهي المؤشرات الاقتصادية والاجتماعية والبيئية ، وهذه المؤشرات يجب الاعتماد عليها عند تطبيق مفاهيم وسبل التنمية المستدامة وهذه المؤشرات حددتها هيئة الامم المتحدة للتنمية المستدامة :



- 1- المؤشرات الاجتماعية : وتتكون من مجموعه من المعايير او المؤشرات الثانوية حسب ما حددتها هيئة الامم المتحدة للتنمية المستدامة وهي ( Abid,2003,p3) : تحقيق العدالة الاجتماعية والتعليم والسكن والصحة العامة والامن ومعدل النمو السكاني وغيرها .
  - 2- المؤشرات البيئية : ويتكون البعد البيئي من المؤشرات الاتية ( الزبيدي ، 2006،ص31) : الغلاف الجوي ، المياه العذبة وحماية الموارد الطبيعية وغيرها .
  - 3- المؤشرات الاقتصادية : وتتكون من مجموعه من المعايير او المؤشرات الثانوية ( الامم المتحدة، 2001،ص20،21،22): البنية الاقتصادية ، انماط الانتاج والاستهلاك ، الحد من تفاوت الدخل وغيرها من المؤشرات .
- ان معايير هذه المؤشرات انفة الذكر جاءت حسب تقرير هيئة الامم المتحدة عام 2001 (تطبيق مؤشرات التنمية المستدامة في بلدان الاسكوا) والتي طرحت موضوع مؤشرات التنمية المستدامة وأكدت انها مؤشرات مرنة يمكن تغييرها وتطويرها حسب الحاجة فهي اذا ليست حديه التطبيق الا انها تصنف الى تصنيفاتها (ابعادها) الأساسية البيئية والاجتماعية والاقتصادية وما يندرج من معايير تحت قائمه كل من هذه الابعاد القابلة للتغير بمرونة اعتمادا على نوع وطبيعة تطبيقها .

### 8: المراكز التاريخية ، تعريفها والمشاكل التي تواجهها :

ان موضوع المراكز التاريخية من المواضيع الواسعة وطرح مفهومها من قبل العديد من المنظرين والباحثين ، وحسب ما عرفتھا منظمة (الايكوس ICOMOS ) فهي تمثل محتوى الخصائص التاريخية للمدن المتمثلة بمجموعة من العناصر المادية والروحية التي تكون الصورة والشكل العمراني الذي يتكون من شبكة الشوارع ومن تقسيم المناطق العمرانية ، وما يربطها من علاقات كالمناطق الخضراء المحيطة بها وشكل المباني ونظامها الانشائي وكذلك المواد المستعملة وتفصيلها . (ICOMOS,1987) .

وتواجه المراكز التاريخية مجموعة من التغيرات عبر الزمن التي تصيب هيكلها العمراني وتؤثر عليه ، ولهذا ظهر ما يسمى بالتجديد العمراني لمعالجة هذه التغيرات. تتضمن عملية التجديد العمراني بشكل عام اربعة مناهج او اساليب مختلفة تمثل السياسات الرئيسية للتجديد العمراني وهي (اعادة التطوير واعادة التأهيل والحفاظ والاملاء الحضري) وبسبب تعامل هذه السياسات مع البنية الفيزيائية للمركز التاريخي بغض النظر عن البنية الاجتماعية والاقتصادية ظهرت هنالك مشاكل عديدة في المراكز التاريخية .

اذ" فالمشاكل التي تواجه المراكز التاريخية تتضمن مشاكل التغير عبر الزمن والتي تمثل اساس المشاكل العمرانية . هذا بالإضافة الى التغيرات التي تواجه المراكز التاريخية بسبب مشاريع التطوير العمراني وهي :

- **التغير على مستوى الوظيفة :** حيث يأتي نمو المركز التاريخي متوكبا مع النمو الطبيعي للكتلة العمرانية لها، وملبيا للاحتياجات الوظيفية والإدارية للمجتمع البشري، ومع التطور في النظم السياسية والإدارية للدول تظهر غالبا مشكلة مسايرة نمو مركز المدينة لهذا التطور، أيضا من تغير في شكل وهياكل النظم الإدارية حيث تظهر وظائف ومؤسسات وهياكل إدارية جديدة (وزارات ومراكز بحثية ومجالس محلية وغيرها) التي تختلف عن الواقع الإداري والتنظيمي للفترة السابقة لعمليات التطوير .
- **تغير على مستوى اداء الحركة والمواصلات :** فمع ظهور وظائف جديدة لمركز المدينة ومع النمو الطبيعي للسكان ومواكبة تلبية احتياجاتهم، يحدث نمو طبيعي في الكتلة العمرانية سواء للمدينة ككل أو المركز على وجه الخصوص، ومع ظهور السيارة كوسيلة رئيسية للحركة إضافة إلى وسائل المواصلات المختلفة وما تتبعها من خدمات أساسية لها من محطات أو ساحات الوقوف و انتظار إلى جانب المكون الرئيس وهو الطريق، أصبح النسيج العمراني للمركز التقليدي أو التاريخي للمدينة غير قادر على استيعاب هذا النمط من الحركة والمواصلات.
- **النمو الترفيهي والتجاري:** فمع التطور الاقتصادي وتطور أساليب التعامل وحركة البيع والشراء، وتحول شكل السوق التجاري إلى نمط المراكز التجارية مروراً بالطرق التجارية التقليدية، هذا بالإضافة إلى ظهور تطور هائل في الوسائل الترفيهية، والتي لم يتمكن المركز التقليدي من مسايرتها.

- **هجرة السكان الاصليين:** والمتمثل بتغير التركيبة السكانية بسبب هجرة السكان الاصليين حيث تواجه المراكز التقليدية والمدن القديمة تحديات متنوعة أثرت في توازن الحياة الاجتماعية والاقتصادية للسكان و هجرة السكان الأصليين بحثاً عن الراحة ونمط معيشي جديد نتيجة لتراجع مستوى الخدمات والبنية التحتية للمدينة القديمة يشكل أحد أسباب التدهور للمدينة القديمة. وهذه بشكل عام هي اهم التغيرات التي تخلق المشاكل العمرانية بين ما هو قائم واداءه العمراني والمعماري ، وبين الحاجة البشرية والوظيفية المطلوبة والفعاليات البشرية ، فتنشأ المشاكل المتعددة .

لقد تم النظر الى العديد من المراكز التاريخية من منظور التطوير العمراني وكما سبق ذكره وفق الاساليب المذكورة سابقا ولكن هذه الاساليب رغم اهدافها الجيدة الا انها تراعي الجانب العمراني الفيزيائي من دون النظر الى الجانب المكمل له على مستوى ظهور المشكلة وهو الجانب الانساني البشري ، وعليه ومن هذا المنطلق وبالعرب مع مفهوم التنمية المستدامة الذي تم بحثه سابقا سوف يتم تقصي معنى التنمية المستدامة في المجال العمراني مع النظر الى مشاكل التطوير العمراني في المراكز التاريخية .

### 9: التنمية المستدامة في المجال العمراني :

ظهرت فكرة التنمية العمرانية المستدامة في عدة مؤتمرات عالمية منها مؤتمر قمة الارض في ريودي جانيرو عام 1992 ، و في مؤتمر الهابيتات2 Habitat2 في إسطنبول عام 1996 ، كما ظهر مفهوم التنمية العمرانية المستدامة خلال مؤتمر جوهانسبرك عام 2002 (الامم المتحدة ، 2001 ص76) . وغيرها من المؤتمرات . وخلال المؤتمرات السابقة طرحت عدة تعريفات لمفهوم التنمية العمرانية المستدامة مفادها يتضمن (تحسين نوعية الحياة في المدينة ، على المستوى العمراني فضلا عن المستوى البيئي ، والثقافي ، والسياسي ، والمؤسسي ، والاجتماعي ، والاقتصادي ، ضمن حدود الموارد المتاحة دون ترك اعباء للأجيال القادمة نتيجة استنزاف الموارد الرئيسية) . وعلى هذا الاساس فإن مفهوم التنمية العمرانية المستدامة يجب ان يقوم على مبدأ التوازن بين المواد والطاقة ، وكذلك المدخلات والمخرجات المالية التي تلعب دورا مهما في جميع القرارات المستقبلية للتنمية في المناطق العمرانية . (ديب 2009 ، ص52) . هذا بمعنى ان التنمية العمرانية المستدامة ينبغي لها ان تسير باتجاهين حيث يتعلق الاول بتحسين الاوضاع المعيشية في المدن بيئيا واجتماعيا واقتصاديا من خلال دراسة ما يتعلق بالفقر وتدهور البيئة الحضرية في المدن والاقاليم حيث يلاحظ الافتقار في الموارد الرئيسية مثل الاراضي، توفر المياه الصحية، الصرف الصحي وغيرها ، وتشمل كذلك تلوث الهواء، النقص في المناطق المفتوحة والخضراء، ادارة غير كفوة في مجال المخلفات الصلبة، تدهور حالة السكن، مشكلات النقل، الخدمات الاجتماعية. اما الاتجاه الثاني فيسير نحو تحقيق الاستدامة في عملية التنمية اذ تختلف المشكلات من حيث النوع عما سبقها فهنا يتعلق الامر بكيفية العمل على جعل عملية التنمية للمدن ذات مدى طويل ومن ثم يركز في الاهتمام بالإدارة والموارد الطبيعية وتحسين قدرات التخطيط من اجل استدامة مستقبلية للمناطق العمرانية. (Hildebrand,1999,p145). وبالتأكيد فإن كلا الاتجاهين يعتمدان حسب الحالة و المستوى الذي تعيشه المدينة. ففي الدول النامية يتم التركيز (على سبيل المثال) في المشكلات الناتجة عن تلوث الهواء وتقليل الملوثات الناتجة، في حين في الدول المتقدمة يركز في تقليل متطلبات استخدام الطاقة الناضبة والحاجة الى استعمال وسائل جديدة وهكذا .

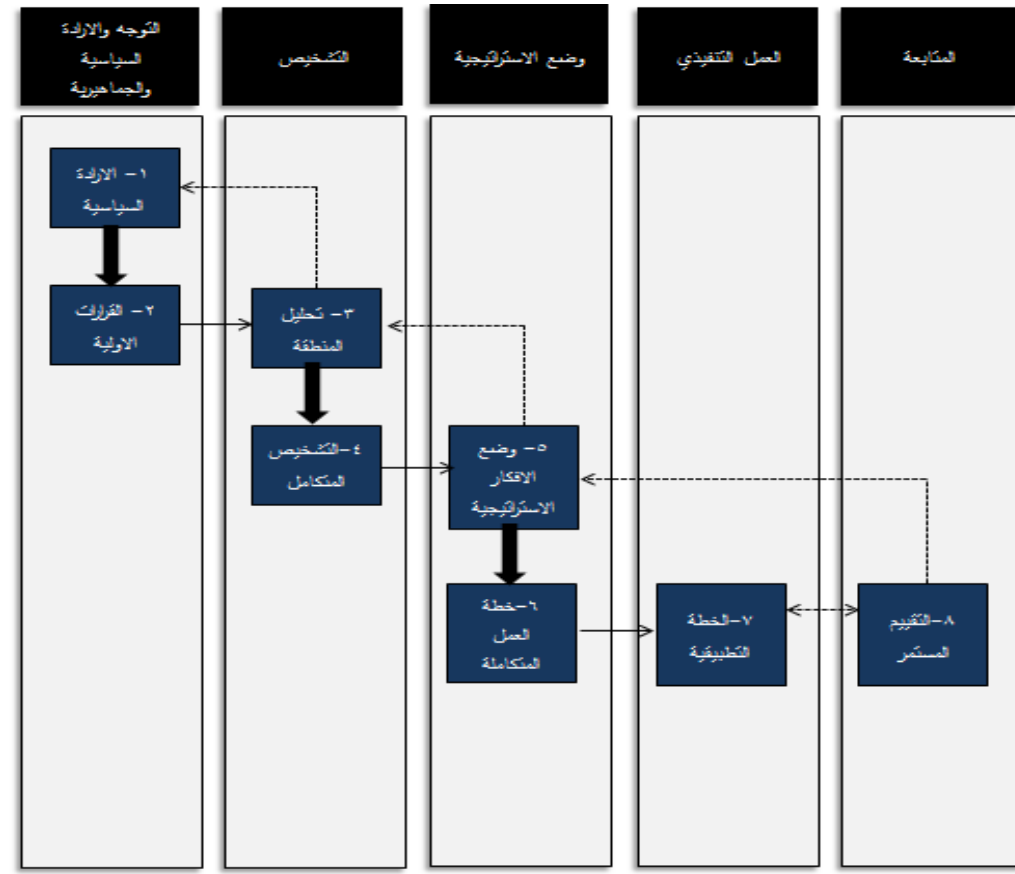
### 10: مبادئ تحقيق التنمية العمرانية المستدامة:

- بشكل عام هنالك عدة مبادئ لتحقيق تنمية عمرانية مستدامة في المراكز الحضرية وهي كما يلي (Hildebrand,1999,p137):
- 1- تحقيق مبدأ الاكتفاء الذاتي من خلال استغلال العمالة والطاقة ، فلا يجب ان تكون المدينة مستهلكة اكثر من كونها منتجة .
  - 2- تحقيق الاستقلالية المحلية من خلال تعزيز قدرة الافراد والمجتمعات على تشكيل وتكوين بيئتهم عن طريق احتياجاتهم وطموحاتهم لتحقيق الانتماء والإحساس بالمكان وايضاً القدرة في ادارة بيئتهم المحلية ،(ريحان، 2009، ص126).
  - 3- ان تكون المدينة عادلة تتوزع فيها العدالة الاجتماعية وتوفر الخدمات بشكل متساوي كما يشترك الجميع فيها بالحكومة ، اضافته الى كونها مدينة مبتكرة تتجاوز والتغيرات بسرعة موسعة الافاق والتجارب (Rogers,1997,p60) .
  - 4- إمكانية تطبيق تنوع الاستعمالات الارض من خلال تعديل أولويات استعمالات الأراضي لتشكيل مدن متضامنة ذات استعمالات حيوية متنوعة.

- 5- إمكانية الوصول للخدمات: Access To Services & Facilities حيث ان التدرج الهرمي لمراكز الخدمات على مختلف مستويات تشكيل المدينة من المستوى المحلي الى مستوى مركز المدينة مع توافر درجة عالية من امكانية الوصول وسهولة الحركة يساعد على زيادة حرية الاختيار وتحقيق الاكتفاء الذاتي على المستوى المحلي .
- 6- إمكانية الوصول للمناطق المفتوحة الخضراء مثل الحدائق والمناطق الطبيعية، بالإضافة الى استخدام أسس التدرج الهرمي في توزيع الفراغات المفتوحة والمناطق الخضراء بالمدينة ابتداءً من التجمع السكني والمحلة السكنية الى المستوى الأكبر مع تدعيم مشاريع الزراعة المحلية والمشاريع العمرانية الخضراء.
- 7- تحقيق التوافق والانسجام التام مع الطبيعة والبيئة واحترامها وتأكيدها بحيث يتم تحقيق بيئة خالية من التلوث والضوضاء والازدحام والجرائم وتحديد البيئات الحضرية الملوثة والمتدهورة والاستعمالات الملوثة أيضاً مالم تتلاءم مع المعايير القياسية للبيئة.
- 8- وضوحية صورة المدينة عن طريق استخدام التدرج الهرمي في تركيب المدينة وتوزيع الخدمات والمناطق المفتوحة والفراغات وتميز الاحياء بتمركز الاستعمالات.
- تطبق المبادئ انفة الذكر على البيئات الحضرية لتحقيق تنمية عمرانية مستدامة سواء على مستوى المدن الجديدة او المراكز التاريخية و يتضح من خلال هذه المبادئ انها تعتمد على ابعاد التنمية المستدامة الاساسية البيئية والاجتماعية والاقتصادية ، وهنا يتحول المستوى البيئي الى مستوى البيئة الحضرية الفيزيائية للمدينة فضلا عن البيئة الطبيعية .
- ما سبق يوفر قاعدة معرفية نظرية حول مفهوم التنمية العمرانية المستدامة واسس تطبيقها على مستوى البيئة الحضرية بشكل عام ، وفيما يخص البحث فإنه يعنى بالاستفادة من معطيات التنمية المستدامة في حل المشاكل التي تواجه المراكز التاريخية ، وعلى هذا الاساس ينتقل البحث لدراسة نموذج من المنهجيات المطروحة عالمياً للتعرف على الية تفعيل التنمية المستدامة في المراكز التاريخية .

### **11: منهجية ريهابيميد لإعادة تأهيل العمارة التقليدية:**

- وضعت (ريهابيميد) منهجا" يهدف الى تنظيم عملية التنمية واعادة تأهيل الاحياء التقليدية والمتمثلة بالمراكز التاريخية وركزت على المراكز التاريخية ضمن المدن الشرق اوسطية ، وبينت هذه المنهجية ان عملية التنمية العمرانية يجب ان تتوجه الى الحفاظ على الطابع الحضري للمنطقة وحماية التراث الموجود وأصالته وبما يتضمنه من تركيز على الإنسان بقدر ما يتم التركيز فيه على المباني ذات القيمة التراثية ، وبذلك فالعملية يجب ان تتضمن تحقيق توازن بين الجوانب الاجتماعية والاقتصادية والبيئية بمستوياتها العمرانية والطبيعية .
- ووضعت (ريهابيميد) خمسة مبادئ اساسية تضمن نجاح عملية اعادة تأهيل المراكز التاريخية وهي كالآتي (RehabiMed,2005,p9):
- التكامل : والمقصود به فهم طبيعة المركز التاريخي وخصوصياته والتعامل معه بشكل متكامل مع المدينة ككل وليس كأجزاء متفرقة .
  - الشمولية : ويعني ان تشمل عملية التنمية كافة الجوانب الاجتماعية والاقتصادية والبيئية بشكل متوازن .
  - المشاركة والتنسيق : من خلال تنسيق سياق محدد من العمل وتنظيمه بالشكل الذي يسمح لكافة الاطراف المعنية بالمشاركة في عملية التنمية (الخبراء ، الجهات الحكومية ، سكان المنطقة انفسهم وما الى ذلك) حيث ان هذه العملية تضمن استدامة عملية التنمية كما ذكر في موضوع المشاركة الاجتماعية .
  - المرونة: بحيث تكون ذات مدى طويل الامد يتقبل التقييم المستمر لسير العملية وان تكون قابله للتغيير والتحويل تبعاً للمتغيرات الاجتماعية والاقتصادية والتي لا يمكن التنبؤ بها منذ بداية وضع الخطة التنموية .
  - القابلية على التكيف ، والمقصود به ان تكون الحلول الموضوعية للتنمية قابله للتكيف والتطبيق على المراكز التاريخية ضمن الشرق الاوسط مع وضع بعض الخصوصيات لكل مركز .
- وقد وضعت (ريهابيميد) خمسة مراحل منهجية لتحقيق التنمية المستدامة في المراكز التاريخية في الشرق الاوسط وتتضمن (الشكل 2):



**الشكل 2** يوضح المراحل المنهجية لتحقيق التنمية في المراكز التاريخية حسب منهجية ريهابيميد ، المصدر (الباحث بالاعتماد على (RehabiMed,2005)

- 1- **التوجه والارادة السياسية والجماعية:** حيث تبدأ العملية بالإرادة السياسية والوعي والدعم الاجتماعي لعملية التنمية (الخطوة 1) ومن خلالها يتم اخذ القرارات الأولية لتنظيمها (الخطوة 2).
- 2- **التشخيص:** حيث يتم عمل تحليل عميق ومفصل للمركز التاريخي (الخطوة 3)، ووضع برنامج تشخيصي يتم التعامل فيه مع المنطقة وقيمها التاريخية والتوجه السياسي واحتياجات ومتطلبات السكان وغيرها من الأمور التي اكتشفت بمرحلة التحليل (وقد يتطلب إعادة التوجيه السياسي) وبذلك يتم عمل تشخيص متكامل (الخطوة 4) .
- 3- **وضع الاستراتيجية:** حيث يتم وضع أفكار استراتيجية لعملية التنمية وإعادة التأهيل (الخطوة 5) تأخذ بنظر الاعتبار جميع إمكانات المنطقة ومشاكلها المستخلصة من المرحلة الثانية (ومن خلالها سيتم تقييمها إذا كانت مستوفية أو يعاد النظر فيها)، ثم يتم وضع خطة عمل متكاملة لعملية التنمية (الخطوة 6) يتم فيها تفصيل الأعمال الواجب تنفيذها للوصول للهدف.
- 4- **العمل،** في هذه المرحلة يتم تنفيذ خطة العمل (الخطوة 7) شاملة بذلك الإجراءات العمرانية (أعمال التخطيط العمراني ومشاريع معينه لإعادة تأهيل المباني ذات القيمة التاريخية وأعمال الفضاءات العامة وغيرها) والإجراءات الاجتماعية (والتي تتعامل مع السكان المقيمين والمستخدمين) وأيضا الإجراءات الاقتصادية والبيئية المكاملة.
- 5- **المتابعة:** وتشمل مرحلة التقييم المستمر (الخطوة 8) لجميع أعمال التنفيذ، حيث تتداخل مع كل الفترات وخصوصا فترة التنفيذ وحتى بعد الانتهاء من العمل، حيث انه ، وبملاحظة أي خلل في تطبيق الأهداف ، يتم العودة إلى مرحلة التفكير الاستراتيجي أو حتى إلى مرحلة التشخيص.



مما سبق ، ومن خلال تحليل نموذج من المنهجيات المطروحة للتنمية المستدامة للمراكز التاريخية يمكننا ان نتوصل الى استنتاج مفردات الاطار النظري التي يتعامل معها كل جانب من جوانب التنمية العمرانية المستدامة في المراكز التاريخية وكما يلي (الجدول 1) :

#### 1- المستوى البيئي : و يقسم الى قسمين اساسيين :

أ- **البيئة العمرانية** والذي يقسم الى مستويين ثانويين حيث **المستوى الاول**: هو المستوى الحضري الذي يتعامل مع النسيج الحضري للمنطقة و الارتفاعات البنائية في المنطقة والحالة الإنشائية للمباني . فضلا عن حركة المرور من خلال تحليل وتقييم شبكة الطرق والحركة داخل المراكز التاريخية وتطويرها وتحديد أماكن حركة المركبات لساكني ومستخدمي المنطقة وحركة السابلة وأيضا الحركة العامة والخاصة وكذلك تطوير الوصول وتكامل المنطقة مع المناطق المجاورة . اما **المستوى الثاني** : المستوى الوظيفي حيث يتعامل مع مكونات المنطقة المتمثلة باستعمالات الارض القائمة فيها. فضلا المكونات التراثية التي تمتلكها المنطقة .

ب- **البيئة الطبيعية والاساسية**: حيث يتعامل مع موارد البيئة الطبيعية وحالة البيئة الاساسية في المنطقة (الانهار – المساحات الخضراء – الهواء – البنية التحتية – توفر الماء الصافي – المجاري ,, الخ) ودرجة توفرها في المنطقة فضلا عن دراسة مصادر تدهورها

2- **المستوى الاجتماعي** : حيث يتعامل مع الوضع الاجتماعي للسكان و التركيبة السكانية ودرجة الانسجام الاجتماعي فيها فضلا عن المستوى الاقتصادي للسكان المتمثل بمستويات البطالة والفقر والحالة الاقتصادية لهم ، وكذلك المستوى الثقافي للسكان ومدى قدرتهم على المشاركة في عملية التنمية .

3- **المستوى الاقتصادي** : الذي يتعامل مع الوضع الاقتصادي للمركز التاريخي على مستوى انواع المهن السائدة ودرجة الفاعلية الاقتصادية في المنطقة ونسبة الاستعمالات التجارية بالنسبة لبقية استعمالات المنطقة . ويتعامل هذا المستوى مع الاطار المؤسسي من خلال إنشاء هيكل إداري متكامل يدير عملية التنمية وما تتطلب من تشريعات وقوانين بالإضافة إلى التنفيذ والإشراف والتقييم المستمر وإعادة التفكير وبما يتلاءم مع المتغيرات والأهداف . فضلا عن مصادر التمويل وتحديد الكلف التخمينية وإيجاد سبل تمويلها .

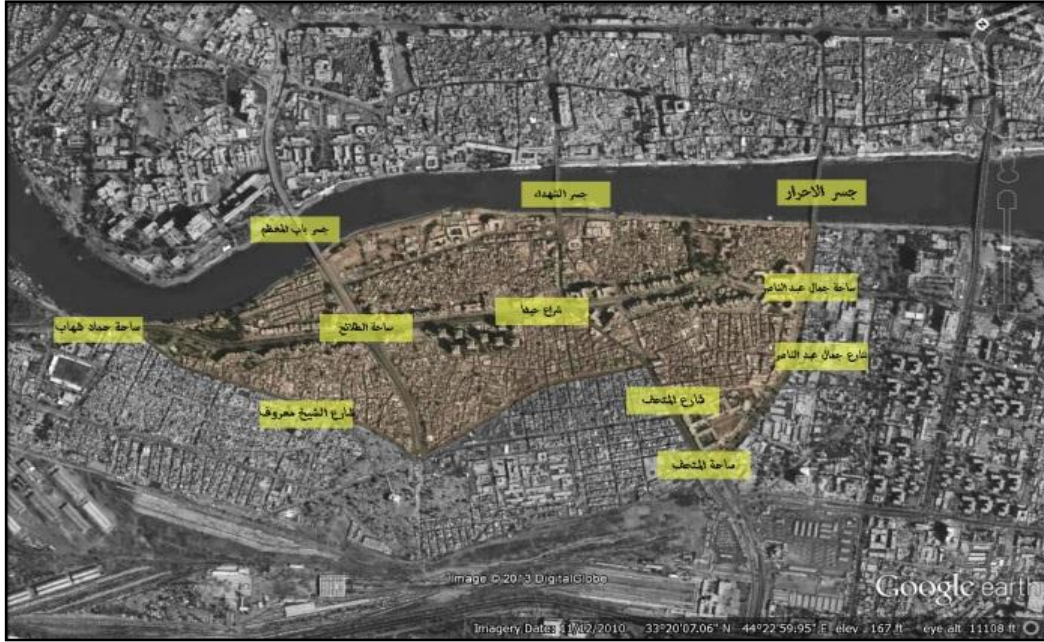
### الجدول 1 مفردات الاطار النظري - الباحث

التنمية العمرانية المستدامة في المراكز التاريخية					
بيئيا			اقتصاديا	اجتماعيا	
وظيفيا	حماية الهياكل التراثية		البيئة العمرانية	ترقية المستوى الاقتصادي للسكان	الاستمرارية الاجتماعية
	تنمية استعمالات الارض				
	الحفاظ على المعالم`			تنمية الوظائف التجارية	التوافق والانسجام الاجتماعي
حضريا	تنمية انظمة المرور			تعزيز الوظيفة السياحية	القضاء على الفقر
	تناسقية خط السماء				
	تنمية البنية التحتية			ترقية مستوى البيئة الفيزياوية للعقارات	الحد من البطالة
		الارتقاء بمستوى التعليم			
		الحد الهجرة السكانية (الحراك السكاني)			
		بناء قدرات ابناء المجتمع			
ملوثات الهواء والمياه		البيئة الطبيعية	تعزيز المشاركة الاجتماعية		

ومن اجل تطبيق هذه المؤشرات بشكل عملي اختار البحث منطقة الكرخ كجزء مهم من مركز مدينة بغداد التاريخي لكونه لم يحظى بدراسة تطويره لتنميته عدا الدراسة المقترحة في الثمانينات من قبل مكتب الالوسي للاستشارات الفنية عام 1982 وكانت اهدافها الحفاظ على النسيج القديم الى جانب التطويرات الحديثة المتمثلة بمباني شارع حيفا العالية . كما تهدف الى التكامل مع مشروع شارع حيفا المنجز وبين الاجزاء المجاورة له من النسيج القديم ، الا انه لم ينفذ بشكل متكامل .

### 12: منطقة الكرخ التاريخية :

تقع منطقة الدراسة (الكرخ التاريخية) ضمن قضاء الكرخ وعلى الشاطئ الغربي لنهر دجلة ويحدها من شمال شاطئ النهر ، ما بين شارع جمال عبد الناصر وساحة حماد شهاب ، يحدها من الجنوب شارع جمال عبد الناصر ومن الغرب شارع الشيخ معروف الكرخي ويمثل نهر دجلة حافة شرقية للمنطقة ، وترتبط المنطقة بالرصافة بواسطة ثلاثة جسور (الاحرار والشهداء وباب المعظم) (الشكل 3)



الشكل 3 منطقة الدراسة (الكرخ)

وقد مرت الكرخ التاريخية عبر الزمن بمجموعة من المراحل أثرت على بنيتها الحضرية و يمكن حصر المراحل التحول التي مرت بها الكرخ الى مرحلتين اساسيتين هما المرحلة التاريخية والمرحلة المعاصرة :

- المرحلة التاريخية تمتد في الفترة ما قبل تأسيس بغداد المدورة وحتى فتره الاحتلال العثماني وخلال هذه المرحلة كانت الكرخ عبارة عن قرى ومستوطنات (مستقرات) منتشرة ضمن طسوج بادوريا وهذه المنطقة تحتوي على ثلاثة عقد طبيعية اساسية تمثل العامل المهم في تأسيس بنيه المنطقة ، اول هذه العقد تتمثل بنهر دجلة والعقدتين الثانيتين هما نهري الصراة والرفيل الذي تكونت عندها بقية القرى انفة الذكر بانتشارها الخطي فاصبح نهري الصراة والرفيل يمثلان المحاور الاساسية التي اسست بنية المنطقة .

#### (الشكل 4)

- في نهاية المرحلة التاريخية انحسرت قرى الكرخ باتجاه نهر دجله ضمن الشريط الذي تقع عنده منطقة الكرخ التاريخية اليوم مما يؤشر قدم المنطقة . وظهرت في نهاية المرحلة العباسية معالم مهمة لاتزال باقية الى اليوم وهي جامع وتربة الشيخ معروف الكرخي ومسجد المنطقة ومرقد زمرد خاتون ومسجد القمرية .

- خلال المرحلة المعاصرة مرت الكرخ بموجة مهمة من التغيرات اوصلتها الى ماهي عليه اليوم وهي :

- نشوء سور الكرخ : حدد شكل النسيج الحضري للمركز التاريخي (الشكل 5) .

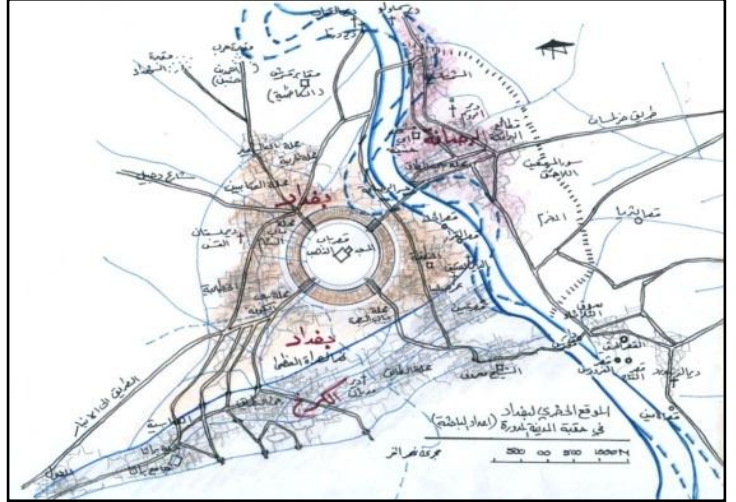
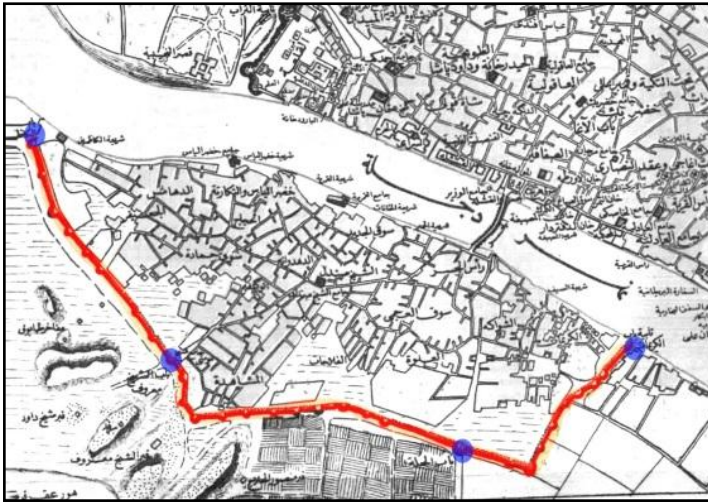
- تهدم السور وبدايات التوسع العمراني .

- ظهور المحاور الحركية الجديدة خلال فتره الاحتلال البريطاني (شارع الشيخ معروف ، شارع جمال عبد الناصر ، بدايات شارع حيفا (الشكل 6) .

- ظهور مفردة الساحات (ساحة الملك فيصل ، تمثال مود )

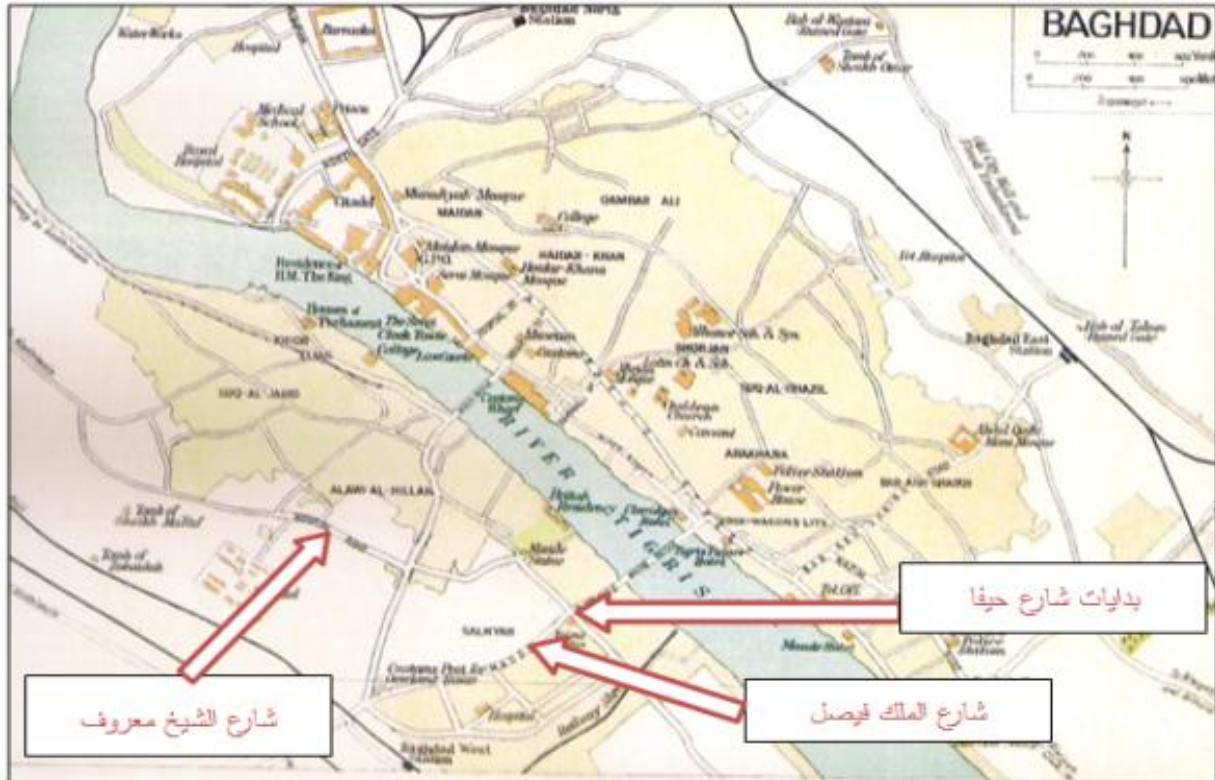
- في مرحلة الخمسينات توسعت المحاور الحركية وارتبطت الكرخ بالمناطق المجاورة (جنوبا مع كراة مريم ، وغربا مع منطقة المنصور ) .

- عام 1956 ، 1958 ، 1973 وضعت المخططات الاساسية لمدينة بغداد ( مينوريو ، دوكسيادس ، بول سيرفس ) حددت فيه منطقة الكرخ كمطقة للأعمال المركزية.



الشكل 5 بغداد كما رسمها فيليكس جونسون تظهر من خلالها اسوار وبوابات الكرخ واهم معالمها في تلك الفترة ،المصدر (سوسة،1952) ايضاح الباحث

الشكل 4 بنية الموقع الحضري لبغداد في حقبة المدينة المدورة ونشؤ الكرخ ،المصدر (روزوقي،2008)



الشكل 6 خارطه محلات بغداد الماخوذة من دليل كوك عام 1934 يظهر من خلالها حدود محلات الكرخ وتكون الشوارع ضمن المحلات وظهور عقد الحركة ، المصدر (بيبري،2009،ص48)



### 13: مشروع تطوير شارع حيفا :

تعود بدايات فكرة شارع حيفا الى منتصف الستينات وفي عام 1973 تم إنشاء مجلس تطوير شارع حيفا من قبل أمانة بغداد وتم وضع عدة دراسات تخطيطية لإنشاء منطقة مركزية تجارية، ركزت على إعادة تطوير الطرق وعلى توسيع الشارع وبطول 200م ويعرض 50م على حساب النسيج التراثي، وفي عام 1980 تم إعطاء اهتمام كبير إلى تطوير الإسكان العمودي المتمثل بالعمارات السكنية العالية وما ترافقه من أبنية تجارية وخدمية . وبذلك قامت أمانة بغداد بتكليف عدة مكاتب استشارية عالمية لوضع التصاميم المعمارية لأجزاء المشروع، وتتسيق هذه العملية من خلال فريق إدارة المشروع والمتمثل (بمكتب الدراسات الفنية/ العراق بالمشاركة مع وراينيكه كونسلت/ إيرلندا) من خلال المناقشات وجلسات الحوار التصميمية . يمتد مشروع تطوير شارع حيفا من ساحة الملك فيصل الاول الى التقاء الشارع بكورنيش العطفية ، وهو مكون من جزئين ، جزء انشئ حديثا " وجزء قديم ، بالنسبة للجزء الحديث فيقع بين ساحه حماد شهاب وتقاطع النصر (تقاطع الشارع المؤدي الى جسر الشهداء مع شارع حيفا) وهو باتجاهين وخمس مسارات حركة في كل اتجاه ، وتبعد واجهات الابنية في هذا الجزء عن الشارع بمقدار (36م) وتتباين هذه المسافة على طول الشارع حيث تزيد او تنقص حسب قرب الابنية او بعدها ولذلك يبدو الشارع عريضا في مواضع وضيقا في اخرى وقد استغلت المنطقة المحصورة بين الابنية والشارع لتوفير ممرات الحركة للسابلة والمشاة ومداخل الابنية والعمارات السكنية .

اما الجزء القديم من شارع حيفا فيقع بين تقاطع النصر وساحة الملك فيصل الاول (وتعود بداياته الى المرحلة السابقة من تطور الكرخ كما اشرنا) وتم توسيعه كجزء من متطلبات تطوير الشارع واستبدلت الابنية القديمة الواقعة ضمن منطقة الشواكه والتي تم هدمها (عدا الدور التراثية التي تم الحفاظ عليها ) بأبنية حيفا الجديدة .

تم تقسيم المشروع (والبالغ مساحته 349 هكتار) إلى ثماني أجزاء تترتب بشكل شريطي على طول جانبي شارع حيفا تتخللها بعض التقاطعات والطرق أبرزها ساحة الطلائع حيث خصص ستة أجزاء منها للاستعمال السكني بمساحة (228.7 هكتار) مقسمة إلى 2096 شقة (75% منها بثلاث غرف نوم والباقي بغرفتين)، وخصصت المساحة المتبقية للاستعمال التجاري والثقافي والإداري، وتتراوح ارتفاع الأبنية ما بين خمسة إلى تسعة طوابق مع استثناء الجزء الثامن والذي يرتفع لغاية خمسة عشر طابقا. (الشكل 7)



الشكل 7 مخطط تقسيم منطقة شارع حيفا ، المصدر ( الالوسي ومشاركوه، 1982)

### 14: مشروع تطوير الكرخ :

اعد مشروع تطوير الكرخ من قبل مكتب الالوسي للاستشارات الفنية عام 1982 وكانت اهدافه التكامل مع مشروع شارع حيفا المنجز وبين الاجزاء المجاورة له من النسيج القديم الا انه لم ينفذ بشكل متكامل (الشكل 8).

### 1- على مستوى البيئة المبنية :

#### أ- المستوى الحضري :

يركز مشروع تطوير الكرخ على دمج القطاعات التقليدية مع مشروع شارع حيفا المنجز وذلك من خلال تقسيم النسيج على اساس نظام المحلة ووفق ما تم على اساسه تقسيم مشروع حيفا الى سبعة مناطق وخلق منطقة تجارية ضمن كل قسم (مركز المحلة) وهذا ما يعزز دمج القطاعات التقليدية مع المستحدثة .

يعد مشروع شارع حيفا نقطة بداية التحولات البنوية في منطقة الكرخ على مستوى محاور الحركة و خط السماء للمنطقة ، فعلى مستوى المحاور الحركية اصبح شارع حيفا يشكل محورا خطيا اساسيا قسم النسيج الى قسمين اساسيين واصبحت مباني شارع حيفا تعمل كعازل بنيوي للمناطق التقليدية عن بعضها .

ب- المستوى الوظيفي : من خلال ملاحظة مخطط استعمالات الارض المقترح نجد ان مشروع تنمية الكرخ ساهم وبشكل فعال في استحداث استعمالات جديدة للارض تتمثل بالاستعمالات التجارية والصناعية والادارية والثقافية بعد ان كانت مقتصرة على الاستعمال السكني بالدرجة الاولى والتجاري على نطاق محدود.

### 2- على المستوى الاقتصادي نجد ان مشروع تطوير الكرخ ساهم وبشكل فعال في توسيع الاستعمال التجاري في المنطقة من

خلال خلق منطقة تجارية محدده وتم تأسيس المنطقة التجارية بالكرخ على محور النشاطات التجارية التقليدية بالكرخ

### 3- المستوى الاجتماعي : حيث ان المقترح التنموي لم يتطرق الى الجوانب الاجتماعية ماعدا تحديد عدد السكان المتوقع اقامتهم عند اكتمال تنفيذ المشروع .



الشكل 8 استراتيجية التصميم الاساسي المقترحة ضمن مشروع

تنمية الكرخ (1982).

### 15: متغيرات المنطقة بعد ثمانينات القرن العشرين :

1- يعد شارع حيفا المتغير الاكبر الذي حصل في المنطقة منذ هدم الاسوار التاريخية فقد مثل اختلافاً على مستوى الارتفاع ، الطراز المعماري ، العلاقات الخطية المستقيمة .

2- هنالك تناقض حاد على مستوى ارتفاعات الابنية في المنطقة فهو يتراوح بين طابق او طابقين الى (15) طابق .(الشكل 9)



الشكل 9 مخطط ارتفاعات الارض - الباحث

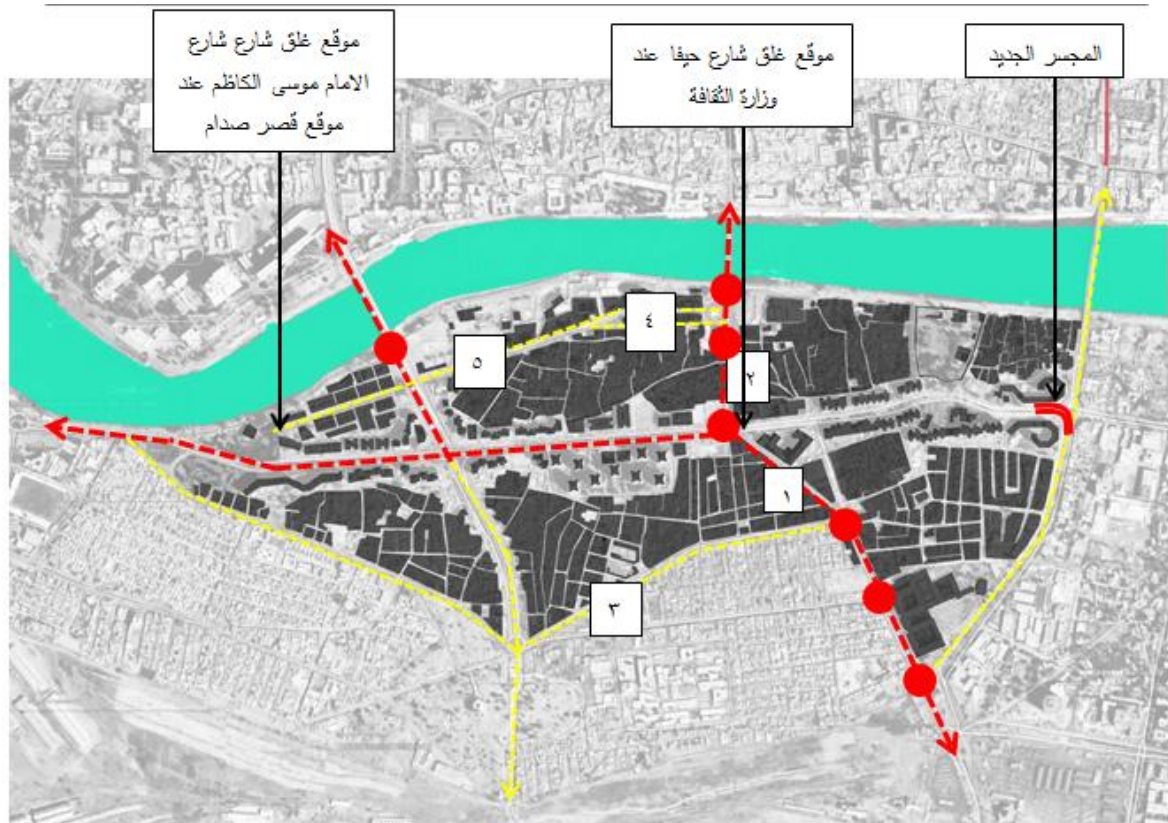
3- اقيم عام 2013 جسر مرتفع عن الارض (جسر الصالحية ) الذي اثر بتوقيعه بهذا الشكل على المشهد الحضري للمنطقة بشكل عام ومعالج ساحة الملك فيصل بشكل خاص . فضلا عن كونه لا يخدم الغاية المرجوة منه بتقليل الازدحام لأنه ينقل حركه السير من شارع جمال عبد الناصر ( شارع النقليات) الى المنطقة المغلقة من شارع حيفا .(الشكل 10)

4- بعد عام (2003) وبسبب سوء الاوضاع الامنية والاجراءات الامنية الحالية دخلت الى المنطقة متغيرات جديدة ساهمت في تفاقم المشاكل الحضرية للنسيج العمراني منها غلق شارع حيفا عند موقع وزارة الثقافة بواسطة الكتل الكونكريتية وتم استغلال الجزء المتبقي من الشارع كمواقف للسيارات تخدم موظفي الوزارة ، هذا ادى الى جعل مسار الحركة الرئيسية للمركبات ينعطف عند موقع الغلق باتجاه العلاوي ما ادى الى حصول اختناق مروري عند نقطة التقاطع المذكورة وفي شارع العلاوي باتجاه المتحف .فضلا عن تركيز مشاكل الازدحام المروري عند عقد الانتقال الى الجسور الرابطة مع الرصافة وخاصة عند جسري الشهداء وباب المعظم ( الشكل 11) .





الشكل 10 المجسر الجديد الذي ينقل من شارع جمال عبد الناصر الى شارع



الشكل 11 يوضح مسار حركة السيارات الحالي ونقاط الاكتضاض ، المصدر الباحث

5- دخلت الى المنطقة مع شارع حيفا عدد من الوظائف التي تعد مركزية للمدينة وليست جزءا من المحيط الداخل للشارع مثل الوزارات مما زاد من ازدحام السير في الشارع الذي كان اساسا قد استخدم للمرور ، وهذه الابنية زادت من تداخل الوظائف العامة

مع السكن والتي كانت قد بدأت مع عدد من الوظائف مثل دائرة التقاعد ناهيك عن وزارتي العدل والبلديات في اول الشارع ، ثم بناية المتحف العراقي ودائرة الآثار التي تقع على محيط الموقع .

6- اقيم في التوسعات مشروع سكني في منطقة سوق حمادة محدد السعة وتمثل ببناء سكني منخفض الارتفاع كما تم ذكره ، ولم يكن هذا المشروع في اطار خطة تطويرية شاملة بل بأمر من رئيس النظام السابق بتطوير محدد لمحلة التكاثره بعد زيارته لهم ورغم ان المشروع كان محدد لنفس سكان المنطقة لكنه كان محدود السعة ومتجزئا عن الخدمات العامة والبنى الحضرية المحيطة به . (الشكل 12)

وبهذا فأن واقع حال المنطقة يتمثل في تناقض عمراني كبير وتداخل الوظائف المركزية للمنطقة بذاتها ، وهذا التداخل والتناقض على مستوى البيئة المبنية له تأثير كبير على مستوى التركيبة الاجتماعية والاقتصادية للمنطقة ، ومن اجل التعرف على طبيعة التغيرات البيئية والاجتماعية والاقتصادية بشكل دقيق سيتم اختيار عينات من المنطقة ودراستها بشكل تفصيلي اعتمادا على الملاحظة الشخصية

للباحث واستمارة الاستبانة والاسئلة الشخصية الموجهة لسكان المنطقة



الشكل 12 نمط السكن الحديث ضمن محلة التكاثره (محلة سوق حمادة) ، تصوير الباحث

### 16: العينات المختارة من موقع الدراسة :

تم انتخاب ست عينات بصورة عشوائية ضمن المحلات الاربعة التي تتكون منها منطقة الدراسة (216,210,212,218) وقد روعي عند اختيار كل عينة ارتباطها مع شارع حيفا وطبيعة علاقتها معه من جهة، ومع جهة النهر (بالنسبة للمحلات 218 و 212) ومع شارع الشيخ معروف ومدى تأثرها بالاستعمالات الصناعية للشارع (بالنسبة للمحلات 216 ، 210) . فيما عدا العينة المختارة ضمن محلة التكاثره .

وسيتم دراسة مكونات هذه العينات على المستويات الآتية :

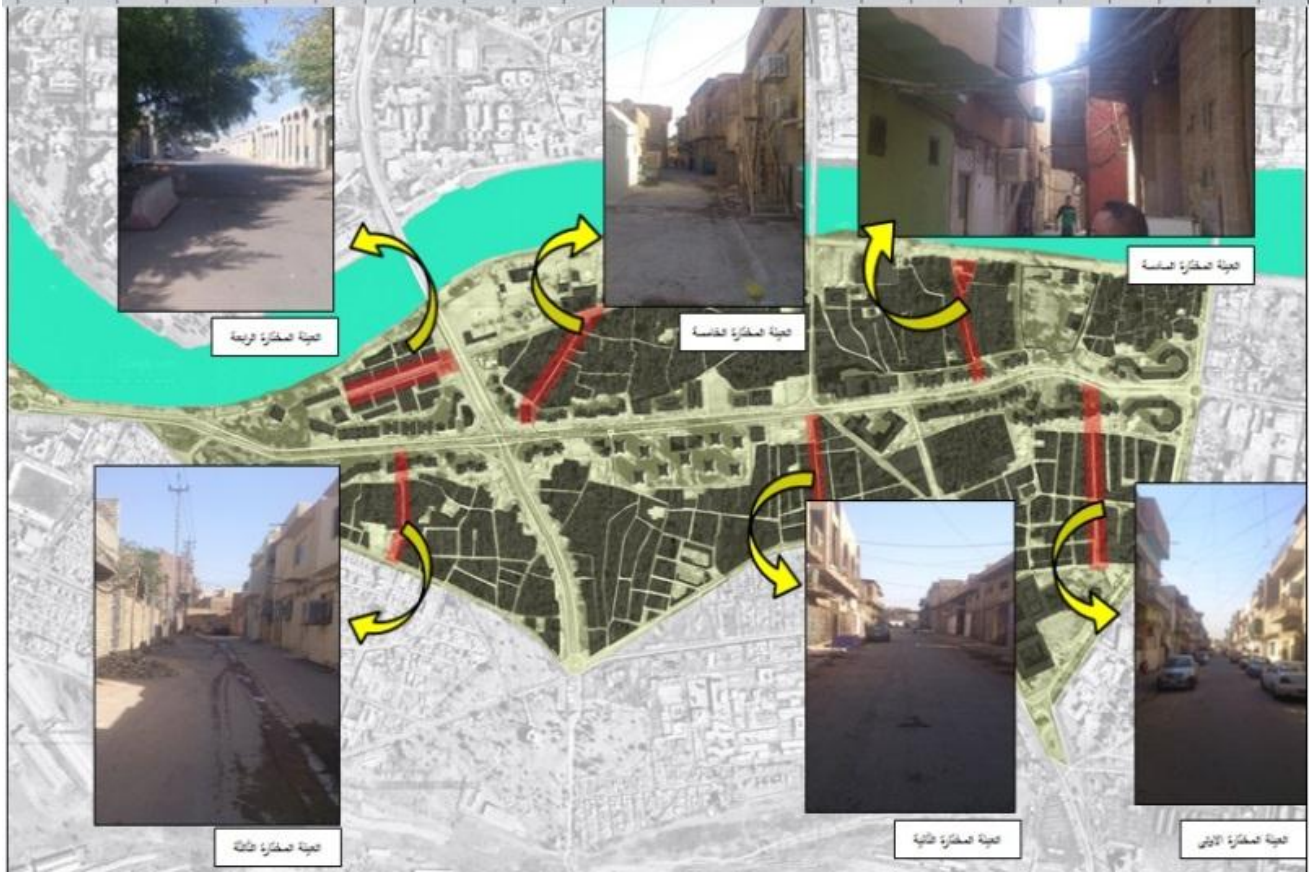
- البيئة العمرانية ( المكونات الوظيفية ، الحالة الانشائية ، ارتفاعات الابنية ) ضمن كل عينة . من خلال الاعتماد على المسح الميداني والملاحظة الشخصية

وسيتم الاعتماد على نتائج الاستبانة لتحليل :

- المستوى الاجتماعي لسكان ومستخدمي هذه العينات . من خلال تحليل طبيعة العلاقات الاجتماعية بين سكان ومستخدمي الجزء التقليدي لكل عينة ، وبين سكان عمارات شارع حيفا ، وطبيعة العلاقة بين سكان ومستخدمي الجزء التقليدي وعمارات شارع حيفا لكل عينة .

- المستوى الاقتصادي من خلال دراسة طبيعة الاختلاف في المستوى الاقتصادي بين سكان المنطقة التقليدية وسكان العمارات السكنية للمنطقة. (الشكل 13)





الشكل 13 العينات المختارة ضمن منطقة الدراسة

### 17: تحليل الواقع العمراني للعينات المنتخبة

بعد تحليل البيئة العمرانية للعينات المنتخبة من منطقة الدراسة على مستوى استعمالات الارض والحالة الانشائية وارتفاعات الابنية نستنتج ما يلي :

- يلاحظ ان هنالك تداخل على مستوى استعمالات الارض بالنسبة للينة الاولى والينة الثانية والسادسة ونلاحظ في الينة الثانية يظهر تداخل الاستعمالات بقوة خاصة كونها قريبة جدا من المنطقة الصناعية ، فالمنطقة سكنية بالدرجة الاولى الا انه نجد ان هنالك استعمالات تجارية بشكل محلات تجارية وصناعية بشكل ورش للنجارة ضمن المنطقة واستغلال الطوابق العليا كمساكن في بعض الاحيان ، وهذا التداخل الحاد في استعمالات الارض احد اهم العوامل المؤثرة على الطابع العام للمنطقة كونه سكني بالدرجة الاولى فضلا عن تأثيره على نمط المباني السائد في المنطقة.
- لا يوجد هنالك عزل واضح بين المنطقة السكنية ومعالم المنطقة الثقافية والدينية ، فبالنسبة للينة الاولى انها تؤدي الى موقع المتحف العراقي والزقاق حاليا مغلق بواسطة الكتل الكونكريتية . وكذلك بالنسبة للينة الخامسة نلاحظ اندماج موقع جامع عطا مع المحلة السكنية مما يفقده قيمته التراثية.

- تمثل العمارات السكنية لشارع حيفا عازلا بصريا وماديا بين المنطقة التقليدية وشارع حيفا ، حيث تعمل المساحات مخصصه كمواقف السيارات و عن الأسيجة العازلة بين الزقاق والمواقف فضلا عن عمارات شارع حيفا نفسها على عزل المنطقة التقليدية عن شارع حيفا بصريا وماديا" .

- تتعرض الانماط البنائية للمساكن التقليدية ضمن العينات الى اعمال مختلفة من ، بسبب قدم الهياكل الانشائية لها ، واعمال التحوير تتم من خلال اضافته بعض التغييرات على الواجهة (صبغ ، تغيير مادة الانتهاء البنائية ، تغيير اطارات الفتحات الخارجية واضافه كتائب وغيرها) بسبب قدم هياكلها فضلا عن بناء اكثر من طابقين كما لاحظنا في العينة الاولى. واعمال التحوير لا تلائم النمط الاصلي لهذه المباني وانما تحور وفقا" للأنماط البنائية الحديثة (السائدة حاليا) مما يؤثر سلبا" على النمط البنائي السائد .

- نلاحظ ضمن جميع العينات ان هنالك تناقضا" حادا" في خط سماء المنطقة فهو يتدرج من طابق او طابقين واحيانا ثلاث الى تسعة طوابق.

ولغرض الحصول على معلومات ادق عن واقع حال المنطقة بيئيا" و اجتماعيا" واقتصاديا" ، تم اعداد استمارة الاستبانة لواقع الحال واستمارة الاستبانة موجهه الى مستخدمي المنطقة (الساكنين فيها والعاملين ) لغرض الحصول على معلومات دقيقه حول واقع الحال للمنطقة والاستناد عليها (بالإضافة الى المعلومات المستخلصة مما سبق على مستوى البيئة المبنية) في وضع التوصيات الاساسية لتنمية المنطقة .

### 18: الاستبانة لواقع الحال :

تم اعداد استمارة الاستبانة بالاستناد على المحاور الاساسية الثلاثة للتنمية العمرانية المستدامة (البيئية والاجتماعية والاقتصادية) وعلى هذا الاساس فان استمارة الاستبانة تضمنت ثلاثة محاور رئيسية :

1- المحور الاجتماعي : والغرض منه الحصول على المعلومات التي تخص الحالة الاجتماعية مثل العمر والتحصيل الدراسي والمشاكل الاجتماعية التي يواجهها السكان . الغرض من هذا المحور هو التوصل الى تحديد نقاط الضعف والقوه في البنية التحتية الاجتماعية في المنطقة من اجل التعرف على الكيفية التي يتم من خلالها صياغة برامج التوعية والبرامج التدريبية من اجل تعزيز اشراك المجتمع القائم في عملية التنمية لمنطقتهم . ونظم بشكل عشره أسئلة وكما يلي :

- تضمنت الاسئلة من 1-5 معلومات اساسية عن المستبين (عمره ، جنسه ، حالته الاجتماعية، عدد افراد الاسرة ، تحصيله الدراسي) الغرض منها لتقييم مستوى الاجابة على اساس نظرة المستبين وخبرته . - السؤال السادس فالغرض منه تحديد درجة البطالة ومدى كفاءة الايدي العاملة لسكاني المنطقة . السؤال السابع الغرض منه معرفه درجة التناغم والانسجام بين سكان المنطقة . السؤال الثامن والتاسع الغرض منهما معرفه درجة التغير في البنية الاجتماعية للمنطقة خاصة بعد مشروع التنمية . ويتعلق السؤال العاشر بمعرفه تطلعات السكان نحو نوع السكن المفضل وهذا السؤال يرتبط بسابقه (8و9) لغرض معرفه درجة التغير في البنية الاجتماعية لسكاني المنطقة .

2- المحور البيئي : والغرض منه الحصول على المعلومات التي تخص البيئة المبنية والطبيعية، ويقسم هذا المحور الى اربعة محاور ثانويه :

أ- يتضمن أسئلة يستخلص منها معلومات حول الاستعمال السكني والحالة السكنية للساكين ، وهو مرتبط مع المحور الاجتماعي الغرض منه معرفه مدى فاعليه السكن والحالة الإنشائية للمساكن و مدى توجه الساكنين الى السكن في عمارة او مسكن ارضي . وهذا المحور يتكون من اربعة أسئلة يتعلق الاول والثاني بمعرفه مساحة الوحدة السكنية للسكان من اجل المقارنة بينها وبين عدد افراد الاسرة للمستبين ومعرفه مدى راحه المسكن وفاعليته الوظيفية ، ويتعلق السؤال الثالث بمعرفه مدى فاعليه السكن انشائيا في حين يتطلع السؤال الرابع لمعرفه مدى نظرة وتوجه الساكنين حول نوعيه السكن لشارع حيفا (بالنسبة لسكان عمارات حيفا انفسهم وبالنسبة لساكين المناطق التقليدية ) .

ب- أسئلة يستخلص منها معلومات حول نظرة الساكنين والمستعملين للحالة العمرانية ومدى قابليتها على تلبية حاجاتهم الحالية والنقص الذي تعاني منه المنطقة على مستوى استعمالات الارض . وهذا المحور يتكون من خمسة أسئلة ، يتعلق الاول والثاني والثالث بمعرفه انطباعات الساكنين حول حالة المنطقة التي يعيشون بها والى اي درجه تلبية احتياجاتهم ويأتي السؤال الرابع

لاستطلاع اراء ونظرة السكان حول النقص الذي تعاني منه المنطقة ، اما السؤال الخامس فهو يستطلع نظره السكان حول تفضيل الطابع التقليدي او التغيير الجذري للمنطقة بعد تطويرها .

ج- أسئلة يستخلص منها معلومات حول حركة المرور والنقل في المنطقة لغرض معرفه نظرة الساكنين والمستعملين حول حالة النقل والمرور في المنطقة كواقع حال ومدى تطلعاتهم نحو النظام الامثل لحل ازمة النقل في المنطقة . ويتكون هذا المحور من خمسة اسئلة يتعلق السؤال الاول بمعرفة نوع الوسيلة التي يذهب بها سكان الى مناطق عملهم ، والسؤال الثاني والثالث والرابع الغرض منه استطلاع اراء الساكنين حول شبكة النقل العام ودرجة ادائها ومدى ادراكهم للحلول الانسب لحل مسألة المرور ، اما السؤال الخامس فالغرض منه استطلاع اراء الناس حول فصل حركة السابلة عن حركة المركبات .

د- أسئلة يستخلص منها معلومات حول حالة البيئة الطبيعية وخدمات البنية التحتية في المنطقة ، الغرض منها معرفه نظرة المستعملين حول حاله مصادر البيئة الطبيعية والفضاءات المفتوحة واهم مسببات التلوث البيئي . يتكون هذا المحور من ثمانية اسئلة ، يختص السؤال الاول والثاني بمعرفة انطباعات السكان حول الفضاءات المفتوحة في المنطقة ودرجة توفرها واهميتها بالنسبة لحياتهم ، اما الاسئلة الاخرى فالغرض منها معرفه مسببات تلوث بيئة المنطقة .

3- المحور الاقتصادي : يحوي على أسئلة الغرض منها معرفة طبيعة ملكية السكن او المحل التجاري او الورشة ومستويات الايجار في المنطقة وطبيعة المهن الرائجة من اجل الحصول على بيانات تسخر مع البيانات المستخلصة من الحالة الإنشائية والحالة الاجتماعية لتحليل العلاقة بين ملكية المساكن او المحلات وحالتها الإنشائية والمستوى الاقتصادي للساكنين والمستخدمين . ويتكون هذا المحور من مجموعتين من الاسئلة ، المجموعة الاولى مخصصة للساكنين والمجموعة الثانية مخصصة لأصحاب المحلات التجارية او الورش .

المجموعة الاولى تتكون من اربعة اسئلة يتعلق السؤال الاول بالحصول على معلومات حول طبيعة المهن السائدة في المنطقة ، اما السؤال الثاني فهو لبيان طبيعة ملكية السكن ومقدار الايجارات ، ويأتي السؤال الثالث لمعرفة اسس تحديد مستويات الايجار في المنطقة . اما السؤال الرابع فهو لمعرفة فيما اذا يتم اجراء صيانه دورية للدار اولاً . اما المجموعة الثانية فتتكون من ثلاثة اسئلة ، يتعلق السؤال الاول بطبيعة ملكية المحل التجاري ، اما السؤال الثاني فالغرض منه التعرف على طبيعة الحالة الإنشائية للمحلات التجارية ، ويأتي السؤال الثالث لمعرفة سرعه تبادل السلع التجارية .

4- محور الاسئلة المتفرقة : وهذا المحور الهدف منه معرفة مدى رغبة واندفاع المستخدمين للمنطقة الى الاشتراك في عملية التنمية وما هو نوع المشاركة المستعدين لتقديمها . ويتكون هذا المحور من خمسة اسئلة ، يتعلق السؤال الاول بمعرفة نظرة المجتمع حول اهمية المشاركة المجتمعية ، ويأتي السؤال الثاني والثالث لمعرفة فيما اذا كان للسكان الاستعداد لتقديم هذه المشاركة والكيفية التي يقدمون بها هذه المشاركة ، ثم يأتي السؤال الرابع لمعرفة توجه الساكنين الى البقاء في المنطقة او مغادرتها بعد تطويرها ويأتي السؤال الخامس لمعرفة ما هو توجه الساكنين الى الكيفية التي يتم بها التطوير .

وقد تم توزيع (130) استمارة على سكان المنطقة بشكل عشوائي ضمن العينات المنتخبة لموقع الدراسة، وتم اهمال (20) استمارة والاعتماد على النتائج التحليلية لـ(110) استمارة

ومن خلال تحليل نتائج استمارة الاستبانة تبين ما يلي :

### 1- على مستوى البيئة الحضرية :

- ان قدم المباني وضعف خدمات البنية التحتية وعدم وجود صيانه مستمره للمباني احد اهم العوامل التي تجعل من المنطقة السكنية غير مريحة للساكنين .

- هنالك نقص في الاستعمالات الصحية والتعليمية والثقافية والترفيهية بالمنطقة لا تلبي سوى المتطلبات السكنية كما " وليس نوعا" كما ان المنطقة التجارية تعد غير كافية بالنسبة لحجم السكن في المنطقة وهذا ما يفسر تحول الاستعمالات.

- هنالك نقص في الاستعمالات الصحية والتعليمية والثقافية والترفيهية بالمنطقة لا تلبي سوى المتطلبات السكنية كما " وليس نوعا" كما ان المنطقة التجارية تعد غير كافية بالنسبة لحجم السكن في المنطقة وهذا ما يفسر تحول الاستعمالات.

### 2- على مستوى البيئة الطبيعية:

- تقتقر المنطقة ويشكل حاد الى الفضاءات المفتوحة والمتنفسات خاصة وكونها منطقة سكنية بالدرجة الاولى.

- يمثل انتشار المولدات الكبيرة والاعتماد عليها في توليد الطاقة الكهربائية عاملا ملوثا للبيئة من خلال الأدخنة المسببة للتلوث الهوائي .

### 3- المستوى الاقتصادي :

- تشكل المهن التجارية الاستعمالات الأكثر رواجاً في المنطقة تأتي بعدها المهن الصناعية .  
- هنالك علاقة كبيرة بين المستوى الاقتصادي للسكان وتغير نمط المباني ضمن المنطقة حيث نلاحظ ان غالبية السكان الذين يسكنون المنطقة (وخاصة التقليدية منها ) من ذوي الدخل المحدود وهم يقومون بإجراء صيانه دورية للوحدة السكنية الخاصة بهم ، وهذه الاجراءات تكون على مستوى (صبغ الواجهات ، تعديل الهياكل المنشئية وغيرها) وكونهم ذوي الدخل المحدود فهم ينشئون المواد الرخيصة مما يؤثر سلباً على الطراز التقليدي للدار وقد يتغير كلياً ، وهذا ما يفسر ظهور العديد من الدور التقليدية المحورة بشكل لا يتناسب مع نمطها الاصلي.

### 4- المستوى الاجتماعي :

- على مستوى العلاقات الاجتماعية فقد كان يميل (سابقاً) الى الاستقرار الاجتماعي، ويمكن ان يعزى هذا الاستقرار في الوضع الاجتماعي الى طبيعة النظام الاجتماعي السائد من خلال اعتماد (المحلة) كتكوين سكني اجتماعي مسيطر عليه.  
- في الوقت الحاضر وبعد الاحداث الأخيرة حدث هنالك اختلاط بين السكان الاصليين للمنطقة وغير الاصليين فضلاً عن ضعف سيطرة المحلة كتكوين اجتماعي مسيطر عليه مما يفسر حدوث خلافات اجتماعية بين ابناء المحلة نفسها.  
- ان العلاقات الاجتماعية بين سكان العمارات السكنية اقل قوة مما هو عليه في الازقة التقليدية بشكل عام ، وتكون هذه العلاقات ضعيفة جداً بين قسم وآخر ضمن المشروع .  
- ان سكان العمارات خليط من طبقات اجتماعية متفاوتة في مستوياتها ، وهذا من اكثر العوامل التي تساعد على ضعف العلاقات خاصة في الوقت الحالي بعد ان تفاوتت مستويات العوائل الساكنة في العمارات ثقافياً واقتصادياً واجتماعياً، فضلاً عن عوامل اخرى تتعلق بالطبيعة التصميمية للعمارات السكنية لشارع حيفا .  
- ان العلاقات الاجتماعية بين سكان العمارات السكنية والمحلات التقليدية في الوقت الحاضر يكاد يكون معدوماً او محدوداً جداً .  
- هنالك قصور ثقافي حول اهمية الدور الذي يلعبه المجتمع في التنمية لذا نلاحظ ان هنالك اجابات غير قليلة تفيد ان مشاركته غير مهمه في عملية التطوير ، وكذلك نجد ان استعدادات الساكنين في الاشتراك في العملية التنموية لا يتعدى حدود تقديم المعلومات الضرورية حول المشاكل التي تعاني منها المنطقة فقط .  
- العلاقة المبنية على العزل الحاد بين العمارات السكنية والمناطق التقليدية التي خلفها، بواسطه ترك مساحات متروكة ومسيجه بسياجات حديدية او كونكريتيه وهذه المساحات تستعمل كمواقف للسيارات وهذا ما يمنع او يحدد الاختلاط بين السكان .  
- الفرق في المستوى الاجتماعي والثقافي والاقتصادي بين سكان المناطق التقليديه والعمارات السكنية .

## 19: الاستنتاجات والتوصيات النهائية :

- تمثل التنمية المستدامة عملية اصلاح وتطوير هدفها التغير من مستوى الى مستوى اخر بيئياً واجتماعياً واقتصادياً وبشكل يضمن التوازن بين هذه المستويات وهذا التغير يجب ان يتصف بالديمومة مستقبلاً وهي شرط من شروط استدامة التنمية .  
- ان ابعاد التنمية المستدامة ثلاثة رئيسية : البيئية والاجتماعية والاقتصادية وما يندرج من معايير تحت قائمة هذه الابعاد يجب ان يتصف بالمرونة وحسب المجال التي تطبق فيه التنمية . ففي المجال الحضري يصبح البعد البيئي معنياً بالبيئة الطبيعية والبيئة المبنية من خلال تحقيق افضل استعمالات للأرض ومراعاة الاختيار الجيد والدقيق لها ولمواقعها والسيطره على تطویرها ، هذا بالإضافة الى حماية البيئة الطبيعية وتحسين الانشطة السكنية والترفيهية . ويعمل المستوى الاجتماعي على تحسين احوال المجتمع الاقتصادية من خلال محاربة الفقر وتوفير فرص العمل وتحسين المستوى الثقافي لهم والعمل على اشراكهم في العملية التنموية من خلال بناء قدراتهم ليكونوا قادرين على تنميه مدينتهم . ويصبح المستوى الاقتصادي معنياً بتحسين الانشطه الاقتصاديه في المدينة والعمل على ديمومتها .

- تواجه المراكز التاريخية في المدن المعاصرة جملة من المشاكل نتجت عن تغير انماط الحياة وانماط التخطيط ووظائف الحياة واستعمالات الارض والمواصلات ، وقد توجهت لدراستها ووضع مخطط التطوير لها جهات مهنية تخطيطية ومعمارية منذ زمن طويل ، ورغم الاهتمام الكبير لأحياء هذه المراكز الا ان التركيز كان على المستوى الفيزيائي.
- مر مركز بغداد التاريخي في الكرخ بمراحل تاريخية متعددة امكنا ان نرى فيها انه يمثل الجزء الوحيد من مدينة بغداد الذي كان مسكونا قبل بناء المدينة المدورة ولا يزال يمثل منطقة سكنية حاليا" .
- نمت منطقة الكرخ اثناء حياة المدينة المدورة لتمثل محلة تجارية منافسه لها وانحسرت باتجاه النهر عبر السنين ثم سورت وبقيت مكتضه داخل الاسوار حتى هدمت الاسوار وكان فيها خمس عشر محلة سكنية ، لكنها اليوم مكونه اداريا" من اربع محلات (218,216,210,212) .
- ظهر المتحف العراقي كأحد اهم الوظائف الثقافية على حافة المنطقة بينما ظهرت ساحة الملك فيصل مع معالم تمثال الملك فيصل فيها كما ظهرت فيها بعض الوظائف الاخرى مثل دائرة التقاعد العامة مما ادى الى ظهور مشكلات التداخل الوظيفي في الاستعمالات فضلا عما سبق من مشاكل المواصلات .
- يعد شارع حيفا اول واهم مشروع تطوير حضري جرى في المنطقة ومنذ ثمانينات القرن العشرين ورغم اقتراح مشروع تطوير الكرخ الا انه لم ينفذ مما ابقى تأثير اقامة شارع حيفا الاكثر تأثرا" .
- قطع الشارع المنطقة بمحور طولي موازي للنهر هاملا" المحاور التاريخية التي كانت قائمة في المنطقة مما اوجد تقاطعات شبكية مع الجسور الرابطة مع الضفة الاخرى وتم تقسيم النسيج التراثي الى اربعة اجزاء (محلات) بوضوح ، لكن التقسيم الطولي هو الغالب بسبب محورية الشارع وعرضه وشريطية الابنية التي اقيمت فيه وطرأها العمراني المختلف كليا" عن المنطقة المحيطة والتي لا تحمل في طياتها ايا" من لمحات النسيج او انماطه التكوينية او الفضائية . فأصبح شارع حيفا يمثل (حافة) بين جزئين رئيسيين مما حول المنطقة من نسيج واحد الى منطقتين منفصلتين بمحور اختراق لها.
- رغم ان الوظيفة الرئيسية للتطوير في شارع حيفا سكنية الطابع الا انها لم يمكنها ان تخدم سكان المنطقة بل انت الى المنطقة بشرائح اجتماعية مختلفة عن السكان ثقافيا" واقتصاديا" مما افرز مشكلات اجتماعية بين سكان المنطقة . -ان توقيع الاستعمالات الادارية ضمن المنطقة (وزاره الثقافة، وديوان الرقابة المالية) ادى الى ادخال وظيفة مركزية للمدينة لقلب المنطقة وتحول الشارع من شارع خاص بالمنطقة الى شارع عام قاطع بالحركة وساهم وجود الوظائف الثقافية وخاصة المتحف العراقي في جعل المنطقة اكثر سحبا" لسكان العاصمة ككل والزائرين للمنطقة .
- هنالك تداخل وظيفي وتحول في استعمالات الارض خاصة ضمن المنطقة السكنية التقليدية فالكثير من الازقة التقليدية تحولت الى استعمالات تجارية وصناعية .
- يقترح البحث تعزيز الفعالية السكنية في المنطقة للحفاظ على الطابع السكاني لها وخلق مناخ جذاب للعيش في هذه الاحياء التقليدية من خلال تعديل الاطار القانوني - اعداد تعليمات موحدة تحتوي على ارشادات للترميم - تأسيس لجان متخصصة تقوم بتوثيق الدور السكنية ضمن سجل خاص - توفير الضمان القانوني الذي يشجع مالكي او مستأجري الدور السكنية الحفاظ عليها وتحديثها وفق الضوابط.
- يقترح البحث تطبيق سياسة الحفاظ على الرموز الدينية من خلال الحفاظ على وظائفها الدينية واعادة تطوير الاجزاء المتهترئة منها من خلال : وضع اطار قانوني يسمح بالحفاظ عليها - اجراء استبانات بشكل دوري على السكان يسمح لهم بابداء ارائهم حول حالة هذه الرموز وما يواجهها من مشاكل .
- يتم تعزيز الاهمية الثقافية للمتحف العراقي من خلال الحفاظ عليه واعادة استعماله والعمل على فصله عن المنطقة التجارية الموجود ضمنها من خلال احاطته بمساحة خضراء خاصة . اما بالنسبة لسينما الارضروملي فيجرى اعادة تاهيلها كسينما وتحويل المساحة الفارغة التي تقع جانبها الى مساحه خاصه بها تستغل كمواقف للسيارات خاصة بالسينما .
- يقترح البحث ضرورة توسيع الاستعمال الثقافي في المنطقة لاجل الترويج للهوية الثقافية الحضارية للمنطقة ، يقترح البحث تحويل شارع الشيخ معروف الممتد من ساحة الشيخ معروف الى ساحة العلوي الى استعمالات ثقافية تراثية بعد ترحيل الاستعمالات الصناعية في ضمن الشارع.



- يجب اعادة توقييع الوظائف العامة (الوزارات ) الى مواقع خارج المنطقة من اجل التقليل من الحركة القاطعة للمنطقة ويمكن تطوير منطقة او مناطق تجمع مركزية (ساحات) بحيث تتحول الى مناطق تجمع للسكان مما يسهم في تطوير التواصل الاجتماعي .
- على مستوى الخدمات التجارية يقترح تحويل الجزء الممتد بين ساحة حماد شهاب الى ساحه الشيخ معروف وباتجاه ساحة الطلائع حتى بداية جسر الشهداء كأستعمال تجاري ليساهم مع المنطقة التجارية حول شارع الاردن والعلاوي في تعزيز اقتصاد المنطقة .
- على مستوى الخدمات التعليمية والصحية يقترح تحويل جزء من النسيج الحضري لكل محلة سكنية من المحلات الاربعه (210,218,216,212) الى مجمع يحتوي روضه و مدرسة ابتدائية ومتوسطه واعدادية لكلا الجنسين ، ومستوصف صحي .
- وخلق محور رابط مع مستشفى الكرامه من خلال استغلال شارع (6) بعد ترحيل الاستعمالات الصناعيه منه
- يقترح تحويل المنطقة المحيطة بالسفاره البريطانية وتحويل المنطقة المحيطة بقصر صدام الى منتزهات عامة . فضلا عن تعزيز المسطحات الخضراء والمنتزهات ضمن الضفة النهرية . وضمن الشارع الثقافي المستحدث ( شارع الشيخ معروف ) .
- استغلال الضفة النهرية الممتدة من ساحة الشهداء الى جسر الاحرار كأستعمال سياحي تجاري من خلال اقامة فنادق صغيره ضمن الضفة النهرية واقامة منتجعات ترفيهية ومطاعم وكافيتريات ومقاهي.
- يتم تخصيص ازقة المنطقة ضمن المناطق التقليدية كممرات للسابله فقط والعمل على اعادة تبليطها وتشجيرها مع مراعاة التاكيد على المحاور النافذة الى جهة النهر وباتجاه المسار الثقافي المقترح ضمن شارع الشيخ معروف وخلق جسرات ضمن شارع حيفا لعبور السابله الى المنطقة النهرية والمسار الثقافي وبالعكس .وعملية انشاء جسرات العبور يعمل على ربط جزئي المنطقة المفصول بسبب اختراق شارع حيفا له .
- يقترح البحث التفكير بتغيير صيغة السير في شارع حيفا (تدرجيا") نحو جعله شارعا" خاصا" بالسابله . وتحويل الحركة الرئيسية للسيارات من خلال استحداث شوارع خارج اطار شارع الشيخ معروف.
- التشجيع على اعادة احياء الوسائل التقليدية للتهوية والاناره ، والعمل على ادخال المعايير الفنية الصديقة للبيئة مثل اللوحات الشمسية لتوليد الكهرباء وتسخين الماء فضلا عن تشجيع استعمال المواد التقليدية المحلية الملائمة للطبيعة البيئية للمنطقة.
- تشجيع تحسين الفضاءات العامة من خلال تشجيع زرع الاشجار في المناطق العامة والترويج للنظافة العامة ويؤسس لذلك لجان متخصصة ، ويمكن ان يتم ذلك مقابل حوافز مالية لمن يقوم بذلك من السكان
- منح القروض المالية لاصحاب العقارات والمستاجرين من خلال المصارف الحكومية لاعاده تاهيل مساكنهم التقليدية فضلا عن القروض المالية المقترحة لتطوير البيئة الطبيعية يعمل على رفع المستوى الاقتصادي للسكان .
- تعزيز الاستعمال التجاري في المنطقة وتوسيعه من خلال استحداث منطقة تجارية جديده تسهم في توفير فرص عمل اضافية للسكان خاصة وان غالبيتهم من ذوي الدخل المحدود .
- ان استراتيجية التنمية السياحية المقترحه ضمن الضفة النهرية والتنمية الثقافية ضمن جزء من شارع الشيخ معروف عامل مهم يساعد في رفع قيمة استعمال الارض في المنطقة وتوفير فرص عمل جديده للسكان ، كما ان هذا الاجراء المقترح يسهم في جذب السياحة التي تعد عامل مكمل لتحقيق اقتصاد مستدام للمنطقة من خلال استغلال ايراداتها كقروض تمنح للأغراض المذكورة انفا".
- ان تحقيق التنمية الاجتماعية في منطقة الدراسة تتحقق من خلال مرحلتين متعاقبتين التوعية : من خلال القيام بحملات توعية اجتماعية لدرء الفكره الخاطئة حول كون المراكز التاريخية بيئات متخلفة
- تعزيز المشاركة الاجتماعية من خلال عمل مسوحات مشتركة بين فرق المسح الميداني والمواطنين انفسهم للتعرف اكثر من خلال مستخدمي المنطقة حول المشاكل التي تعاني منها المنطقة .

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### ملحق رقم 1 : استمارة الاستبانة لواقع الحال :

#### بسم الله الرحمن الرحيم

جامعة بغداد كلية الهندسة

قسم الهندسة المعمارية

#### استمارة الاستبانة

ان الاسئلة الواردة في هذه الاستمارة هي لاجراض البحث الميداني الخاصة برسالة الماجستير الموسومة (التنمية المستدامة ومشاكل التطوير العمراني لمركز الكرخ التاريخي ) مقدمة لجامعة بغداد ، كلية الهندسة ، قسم الهندسة المعمارية لنيل درجة الماجستير في علوم الهندسة المعمارية وسأكون شاكراً لتعاونكم معي في الاجابة الدقيقة على اسئلة هذه الاستمارة دون ذكر الاسم.

#### 1- استمارة الحالة الاجتماعية

- عمر المستبين : (من 20-24 ) ( ) (من 25-29 ) ( ) (من 30-34 ) ( ) (من 35-39 ) ( ) (من 40-44 ) ( ) (من 45 فما فوق ) ( ) .
- جنس المستبين : (ذكر) ( ) (انثى) ( )
- الحالة الاجتماعية : (اعزب) ( ) (متزوج) ( ) (مطلق) ( ) (ارمل) ( )
- عدد افراد الاسرة : .....
- ما هو تحصيلك الدراسي : (امي) ( ) ( يقرأ ويكتب ) ( ) (ابتدائي) ( ) ( متوسط ) ( ) ( اعدادي ) ( ) ( جامعي ) ( )
- هل انت عاطل عن العمل ؟ (نعم) ( ) (كلا) ( )
- اذا كان الجواب (نعم) .. ماهي طبيعة عملك ؟ (اعمال حرة) ( ) (تعمل بأختصاصك) ( )
- هل تواجه مشاكل اجتماعية ضمن الحي الذي تسكن فيه ؟ (نعم) ( ) (كلا) ( )
- اذا كان الجواب (نعم) .. ماهي طبيعة المشكلات التي تحدث (مشاجرات) ( ) (سراقات) ( ) (مشاكل تتعلق بالعادات والتقاليد ووجود انحرافات خلقية) ( ) (اخرى) ( )
- هل انت من السكان الاصليين في المنطقة ؟ (نعم) ( ) (كلا) ( )
- اذا كان الجواب نعم منذ متى وانت تسكن المنطقة ؟ .....

- ماهو سبب اختيارك لمنزلك الحالي ؟ (لانة مسقط رأسك) ( ) (لانة قريب من موقع العمل الخاص بك) ( ) (قلة الايجار) ( )  
(العلاقات الاجتماعية وقربك من الال والاصدقاء) ( ) (اخرى) ( ) .  
- ماهو نوع البيت المثالي للذي تفضل السكن به : (بيت ارضي) ( ) (شقة) ( ) (اخرى انكرها رجاء)

## 2-استمارة الحالة البيئية :

### أ- معلومات حول الاستعمال السكني ، والحالة السكنية للمستبين:

- ماهي مساحة وحدتك السكنية ؟ (اقل من 80م<sup>2</sup>) ( ) (80-100م<sup>2</sup>) ( ) (101-150م<sup>2</sup>) ( ) (151-200م<sup>2</sup>) ( ) (اكثر من 200م<sup>2</sup>) ( )  
- هل تعتقد ان سكنك مريح بالنسبة لك ؟ (نعم) ( ) (كلا) ( )  
- ماهو تقييمك للحالة الانشائية لمسكنك ؟ (جيدة انشائيا وعلى مستوى الانهاءات) ( ) (جيدة انشائيا وسيئه على مستوى الانهاءات) ( ) (سيئه انشائيا وعلى مستوى الانهاءات) ( )  
- اذا كان الجواب (كلا) فما هو السبب برأيك؟ (الحالة العمرانية رديئة) ( ) (المنطقة قديمة) ( ) (التصميم العشوائي) ( )  
اخرى (تذكر رجاء) .....

- ماهو رأيك بالحالة السكنية لسكان عمارات شارع حيفا ؟ .....  
ب- معلومات حول الحالة العمرانية واستعمالات الارض في المنطقة .

- ماهي انطباعاتك حول المنطقة التي تسكنها ؟ (رديئة) ( ) (متوسطة) ( ) (جيدة) ( ) (جيدة جدا) ( ) (ممتازة) ( )  
- هل تعتقد ان المنطقة التي تسكنها قادرة على تلبية متطلباتك الحالية ؟ (سكنيا فقط) ( ) (تجاريا فقط) ( ) (صناعيا فقط) ( )  
( ) (تعليميا فقط) ( ) (صحيا فقط) ( ) (دينيا فقط) ( ) (ثقافيا فقط) ( ) (ترفيهيا فقط) ( )  
- ماذا هي برأيك احتياجات المنطقة ؟

- ماهو تصورك حول النقص الذي تعاني منه المنطقة ؟ (المستوى السكني ضعيف) ( ) (نقص الخدمات التجارية) ( )  
(نقص الخدمات الصناعية) ( ) (نقص خدمات التعليم) ( ) (نقص خدمات الصحية) ( ) (نقص الخدمات الدينية) ( )  
(نقص الخدمات الثقافية والترفيهية) ( ) (اخرى تذكر)

- في حالة تطوير المنطقة التي تسكن فيها ، هل تفضل ان تحافظ المنطقة على طابعها التقليدي ام تفضل التغيير الجذري ؟  
(التغيير الجذري) ( ) (الحفاظ على الطابع التقليدي) ( )

### ج- معلومات حول حركة المرور والنقل في المنطقة :

- كيف تذهب الى عملك يوميا ؟ (مشيا) على الاقدام ( ) (بواسطة الدراجة) ( ) (بواسطة سيارتك الخاصة) ( )  
(بواسطة وسائل النقل العامة) ( )  
- هل تعتقد بضرورة تنشيط القطاع العام للنقل ؟ (نعم) ( ) (كلا) ( )  
- هل تعتقد بأن شبكة النقل العام في المنطقة تؤدي وظيفتها بشكل جيد ؟ (نعم) ( ) (كلا) ( )  
اذا كان الجواب (كلا) فما هو السبب برأيك؟ (وسائل النقل غير كافية) ( ) (وسائل النقل غير مريحة) ( )  
- ماذا تقترح لحل ازمة المرور في المنطقة ؟ (توسيع شوارع المنطقة؟) ( ) (انشاء مجسرات في المنطقة بالاضافة لماموجود حاليا او ما هو مقترح؟) ( ) (اخرى؟) .....

- هل تشجع عملية فصل حركة السابلة عن حركة المركبات ؟ (نعم) ( ) (كلا) ( )

### د- معلومات حول حالة البيئة الطبيعية وخدمات البنية التحتية في المنطقة :

- ماهي انطباعاتك حول نسبة الفضاءات المفتوحة (الحائق والمتزهات) للمنطقة ؟ (متوفرة) ( ) (محدودة) ( ) (معدومة) ( ) .

- اين يلعب الاطفال عادة " ؟ (ضمن متنزهات ) ( ) ، ( داخل الدار ) ( ) ، ( في الشارع ) ( ) ، ( اخرى تذكر )

.....

- ماهو تقييمك لفاعلية مجاري المنطقة ؟ (ممتازة) ( ) ( جيد جدا) ( ) ( جيد) ( ) ( رديئة) ( )
- ماهو تقييمك لنوعية المياه الصحية في المنطقة ؟ (ممتازة) ( ) ( جيد جدا) ( ) ( جيد) ( ) ( رديئة) ( )
- ماهو تقييمك للخدمات البلدية في جمع النفايات ؟ (ممتازة) ( ) ( جيد جدا) ( ) ( جيد) ( ) ( رديئة) ( )
- كيف تتخلص من النفايات يوميا ؟ (من خلال سيارات نقل النفايات) ( ) (ترميها في ساحة عامة) ( ) ( اخرى يرجى ذكرها) .....

- هل تعتقد بأن جو المنطقة الذي تعيش فيها ملوث ؟ (نعم) ( ) (كلا) ( )
- اذا كان جوابك (نعم) .. هل تعتقد ان السبب الاساسي للتلوث هو .. (قلة المساحات الخضراء والتشجير) ( ) (دخان المولدات) ( ) ( عوادم السيارات) ( ) ( اخرى ، يرجى ذكرها) .....
- ماهو نوع الضرر الذي تسببه المولدات ضمن منطقتك ؟ (تلوث بصري) ( ) ، (تلوث ضوضائي) ( ) ، (تلوث هوائي) ( ) .

#### 4- استمارة الحالة الاقتصادية :

- ماهي انواع المهن الرائجة في منطقتك ؟ (تجارية) ( ) ( حرفية) ( ) ( اخرى تذكر رجاء) .....
- ماهي ملكية سكنك الحالي ؟ (ملك) ( ) ( ايجار) ( ) ( مقدار الايجار ) ( اخرى ) .....
- ماهي طبيعته تحديد مستويات الايجار في المنطقة ؟ (حسب المساحة) ( ) (حسب الحالة الانشائية) ( ) (حسب توفر الخدمات او عدم توفرها) ( ) ، (قربها من السوق) (اخرى) ( )
- هل تقوم بعمل صيانته دورية للدار ؟ (نعم) ( ) (كلا) ( ) .

#### خاص لاصحاب المحلات التجارية:

- ماهي ملكية محلك التجاري ؟ (ملك) ( ) ، (ايجار) ( )
- ماهو تقييمك للحالة الانشائية لمحلك التجاري ؟ (جيد انشائيا وعلى مستوى الانتهاءات) ( ) (جيد انشائيا ولكن سيئ على مستوى الانتهاءات) ( ) ( سيئ انشائيا وعلى مستوى الانتهاءات ) ( ) .
- علام يعتمد سرعة تبادل البضائع ؟ (حسب نوع البضاعة) ( ) (قربها من المنطقة التجارية) ( ) (اخرى) .....

- ماهو تقييمك لسرعة تبادل البضاعة في المنطقة ؟ (ممتاز) ( ) ( جيد) ( ) (بطيء) ( ) .

#### 5- اسئلة متفرقة :

- هل تعتقد بضرورة تفعيل المشاركة المجتمعية في تطوير المنطقة ؟ (نعم) ( ) (كلا) ( )
- في حالة قامت جهة ما بالقيام بعمليات تطويرية تنموية للنهوض بواقع المنطقة عمرانيا ، هل تعتقد انه بإمكانك المشاركة في هذه العملية ؟ (نعم) ( ) (كلا) ( )
- ماهو مستوى المشاركة الذي تعتقد انك قادر على القيام به ؟ (تزويد الجهة المخططة بمعلومات حول مشاكل المنطقة فقط) ( ) (تساهم في وضع الحلول فقط) ( ) (تزويد الجهات المخططة بمعلومات حول مشاكل المنطقة فضلا عن المساهمة في وضع الحلول) ( ) ( اخرى تذكر) .....
- في حالة تم تطوير المنطقة ؟ هل تفضل البقاء فيها بعد تطويرها ؟ (نعم) ( ) (كلا) ( )
- كيف تفضل (في حالة تطوير المنطقة) ان يكون التطوير ؟ (بشكل عمودي - ابنية عاليه مثل شارع حيفا) ( ) ، (بشكل افقي - مثل مباني محلة التكاثره) ( ) ، ( اخرى تذكر ) .....





## Saponification of Diethyl Adipate with Sodium Hydroxide Using Reactive Distillation

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### ABSTRACT

This research presents a new study in reactive distillation by adopting a consecutive reaction. The adopted consecutive reaction was the saponification reaction of diethyl adipate with NaOH solution. The saponification reaction occurs in two steps. The distillation process had the role of withdrawing the intermediate product i.e. monoethyl adipate from the reacting mixture before the second conversion to disodium adipate occurred. It was found that monoethyl adipate appeared successfully in the distillate liquid. The percentage conversion from di-ester to monoester was greatly enhanced (reaching 86%) relative to only 15.3% for the case of reaction without distillation. This means 5 times enhancement. The presence of two layers in both the distillate and residual liquids was noticed, the upper (water) layer and the lower (ester) layer. However, water layer was dominant in the distillate. The percentage excess of NaOH solution was calculated with respect to the concentration of monoester (9%-79%) and it was found that increasing the concentration of NaOH solution (until 40%) led to increase in the percentage conversion to monoester. It also led to get a pure monoester in the distillate and made the residual liquid appear as one layer. Maximum conversion had been occurred in the range (40%-60%). After 60% the percentage conversion lowered noticeably.

**Key words:** reactive distillation, consecutive reactions, saponification reaction, monoethyl adipate, diethyl adipate.

### صوبنة ثنائي اثيل اديبيت مع هيدروكسيد الصوديوم باستخدام التقطير التفاعلي

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### الخلاصة

يقدم هذا البحث دراسة جديدة في التقطير التفاعلي باعتماد التفاعل المتسلسل. ان التفاعل المتسلسل المعتمد هو تفاعل صوبنة ثنائي اثيل اديبيت مع محلول هيدروكسيد الصوديوم. ان تفاعل الصوبنة يحدث بخطوتين. وان دور عملية التقطير هو في سحب المركب الوسيط اي احادي اثيل اديبيت من المزيج المتفاعل قبل حدوث التحول الثاني الى ثنائي صوديوم اديبيت. لقد ظهر احادي اثيل اديبيت بنجاح في السائل المتقطر. ان النسبة المئوية للتحويل من الاستر الثنائي الى الاستر الاحادي قد تحسنت بصورة كبيرة ( وصولا الى 86%) نسبة الى 15,3% فقط في حالة التفاعل بدون التقطير. هذا يعني التحسن لخمس اضعاف.

لقد لوحظ وجود طبقتين في كلا السائلين المتقطر والمتبقي. الطبقة العلوية ( الماء ) والطبقة السفلية ( الاستر ) . ولوان طبقة الماء كانت هي السائدة في السائل المتقطر. تم احتساب النسبة المئوية للزيادة في محلول هيدروكسيد الصوديوم بالنسبة الى تركيز الاستر الاحادي (9%-79%) ولقد وجد ان الزيادة في محلول هيدروكسيد الصوديوم ( الى حد 40%) يؤدي الى زيادة النسبة المئوية للتحويل الى الاستر الاحادي. كما تؤدي الى الحصول على الاستر الاحادي نقيا في السائل المتقطر وظهور السائل المتبقي كطبقة واحدة. ان اعظم تحول حصل في المدى (40%-60%). بعد 60% انخفضت النسبة المئوية للتحويل بصورة ملحوظة .

الكلمات المفتاحية: التقطير التفاعلي , التفاعلات المتسلسلة , تفاعل الصوبنة , احادي اثيل اديبيت , ثنائي اثيل اديبيت .

## 1. INTRODUCTION

The technique of reactive distillation was described to be useful for equilibrium-limited reactions such as esterification and ester hydrolysis reactions, **Edreder , et al., 2010**. That is conversion can be increased far beyond what is expected by the equilibrium due to the continuous removal of reaction products from the reactive zone. This helps in reducing capital and investment costs and may be important for sustainable development due to a lower consumption of resources.

Reactive distillation was used with reversible, liquid phase reactions such as the production of ethylene glycol ,**Okasinsld , and Doherty , 1998** . A model was presented to show the difference between the kinetics of the reaction without and with the boiling of the reaction mixture in a staged reactive distillation column.

Catalytic distillation is a branch of reactive distillation which combines the processes of distillation and catalysis to selectively separate mixtures within solutions. Its main function is to maximize the yield of catalytic organic reactions, such as the refining of gasoline , **Babich , and Moulijn , 2003** .

The design and operation for reactive distillation systems are considerably more complex than those involved for either conventional reactors or conventional distillation columns. The development of models for design of reactive distillation columns was proposed, **Taylor, and Krishna, 2000**. **Huss and et al., and Huss, et al., 2003**, presented a hierarchy of methods, models , and calculation techniques that support the design of reactive distillation columns. The approach was illustrated for the production of methyl acetate. They showed the existence of both minimum and maximum reflux. A narrow range of reflux ratios produced high conversions and high purity methyl acetate.

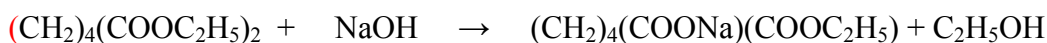
**Huerta-Garrido and Rico-Ramirez , 2004** , presented a simplified methodology for the analysis and design of reactive batch distillation columns based on the McCabe-Thiele method for reactive continuous columns and on the concept of a reactive difference point.

A reactive distillation column for the synthesis of methyl tert-butyl ether (MTBE) was simulated using a steady – state equilibrium stage model, **Jacobs, and Krishna, 1993**. **Gildert , et. al., 2011**, presented advances in process technology through catalytic distillation . A number of recently commercialized catalytic distillation applications were described, such as:

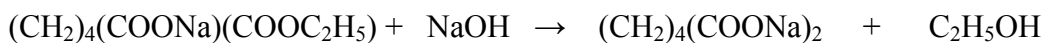
- Butadiene selective hydrogenation.
- Pentadiene selective hydrogenation.
- C<sub>4</sub> acetylene conversion.
- Benzene saturation.

In this research, the reactive distillation technique is applied to a consecutive reaction for the first time. Saponification reaction of diethyl adipate with sodium hydroxide solution was proposed as the consecutive reaction. In this reaction the di-ester converts to disodium adapted by two steps. The first step converts diethyl adipate to monoethyl adipate (which represents the

intermediate product) . The second step converts monoethyl adipate to disodium adipate (which represents the final product). The chemical reactions were represented as follows, **Newberger and Kadlec , 1973 :**



diethyl adipate    sodium hydroxide            monoethyl adipate            ethanol



monoethyl adipate    sodium hydroxide    disodium adipate    ethanol

The objective of this research is to prove that reactive distillation technique can be applied to enhance the conversion of the intermediate product of a consecutive reaction. This can be done by removing the intermediate product from the reaction zone using distillation before converting to the final product. This technique may be applied in many industrial reactions where the intermediate product is the desired product.

## 2. EXPERIMENTAL WORK

Because diethyl adipate material is not available in laboratories neither in market, it should be prepared in laboratory, **Micovic , 2013** . So, the experimental work was split into two parts.

### 2.1 Part I – Preparation of Diethyl Adipate

#### 2.1.1 Materials

Adipic acid (Hopkin & Williams LTD), ethanol (Medical grade 96% purity, Al-Tharthar Co. LTD) , toluene ( Analyt GCC ) , sulfuric acid ( commercial grade).

#### 2.1.2 Equipment

500 ml- distillation flask , condenser ,heater, (0-300°C) thermometers, 500 ml - receiving flask , Büchner suction tube and Büchner flask of 250 ml, 100 ml- graduated cylinder , 50ml- pycnometer , pipet , buret , sample flasks of 25- and 50-ml , refractometer ( Model Optika , no. 2WAJ SN 281006 , Italy ).

#### 2.1.3 Procedure

73 grams of adipic acid is weighed and transferred to the 500 ml - distilling flask . Then 180 cc of ethanol , 90 cc of toluene are added. Few drops of concentrated sulfuric acid are added as a catalyst.

The flask is connected with a condenser. It is heated. An azeotropic mixture of alcohol, toluene , and water begins to distill at approximately 70°C . Distillation is continued until the thermometer in the neck of the flask rises to 80°C . Then heating is suspended.

That was the first part of preparation . The second part begins when the residual liquid in the flask is again heated under vacuum using Büchner suction tube and flask (calibrated using U-tube manometer). Alcohol and toluene distil first . Then the temperature rises and diethyl adipate begins to distill at 137°C. The yield was 78 ml of diethyl adipate.

The FTIR of the ester was performed, as well as its density, refractive index, and boiling point were measured. The density was measured using pycnometer and was found to be  $1.124 \text{ g/cm}^3$  at  $10^\circ\text{C}$  (the ambient temperature). This was satisfactory when compared with the published value of  $1.009 \text{ g/cm}^3$  at  $25^\circ\text{C}$ , **Perry's Handbook, 1984**. Also the refractive index was measured for the prepared amount of ester using the refractometer. It was found to be 1.429. This was again satisfactory when compared with the published value of 1.427, **Langs Handbook, 1934**. The boiling point was recorded to be  $137^\circ\text{C}$ . Again it was fair enough with published  $138^\circ\text{C}$ . These results were reliable to proceed in this research and accomplish the second part of it.

## 2.2 Part II – Saponification of Diethyl Adipate with Sodium Hydroxide using Reactive Distillation

### 2.2.1 Materials

The materials used are: diethyl adipate (prepared in the laboratory), sodium hydroxide solution (Aldrich mark) standardized against standard HCl solution (commercial grade) (standardization of HCl is due to, **Vogel, 1961**).

### 2.2.2 Equipment

The apparatus used consists of (500 ml- distilling flask) connected with adapter, condenser, receiver, and receiving flask to collect the condensate, as shown in **Fig.1**. A thermometer is put in one of the flask's opening to measure the temperature of the boiling liquid. Another thermometer is put in the adapter's opening to measure the temperature of the rising vapour.

### 2.2.3 Procedure

Measured amounts (10 – 50 ml) of prepared diethyl adipate were mixed with standard sodium hydroxide solution of changeable excess amounts (150-350 ml) in the distilling flask and heated. The distillate began to appear at  $100^\circ\text{C}$ . The temperature was found to be constant at  $100^\circ\text{C}$ . After about one hour the distillation was stopped. The distillate and residual liquids were transferred to separating funnels. They were left to separate into two layers. Each layer was transferred to a flask and analysed using FTIR, and titration against standard hydrochloric acid. The conversion to monoester for the distillate was calculated. Results are tabulated in **Table 1**. The refractive index of distillate upper layer was also measured as shown in **Table 2**.

## 3. RESULTS and DISCUSSIONS

**Figs. 2-14** show FTIR analyses results. **Fig. 2** shows FTIR analysis for diethyl adipate alone. It has a peak at 1735 which indicates ester carbonyl group ( $\text{C}=\text{O}$ ) existence. **Figs. 3 and 4** illustrate the existence of unreacted diethyl- with monoethyl adipate in both the upper and lower layers. The conversion to monoester was found to be 74.1%. These results corresponded to 9% excess of NaOH solution. **Figs. 5 and 6** show the results using 15% excess of NaOH solution. They show the presence of both mono- and diester with noticeable reversed concentrations in the two layers of distillate. It has been found that the conversion of di-ester to monoester was increased to 78.9%. This is because increasing NaOH concentration (one of the reactants), leads to increase the extent of reaction. Also, the reaction is irreversible in alkaline solution due to the stabilizing effect caused by resonance of the carbonyl group, **Newberger and Kadlec, 1973**. At higher value of percentage excess of NaOH solution, i.e. 19%, the conversion to monoester was clearly enhanced, reaching 87.5%. This was explained by **Figs. 7 and 8**. Also, it is obvious that monoester appears purely in **Fig. 7** which represents the upper (water) layer of distillate. That's means gaining the intermediate (desired) product at higher



yield and purity . These results are summarized in **Table 1**.

FTIR analyses were carried out for residual liquids. The presence of monoester in the residue was noticed for different values of percentage excess of NaOH solution. FTIR analyses for upper and lower layers of residue are shown in **Figs. 9-14**. It was noticed that mono- and di-ester presented in the two layers .Concentration of monoester cannot be detected by titration of these layers , since NaOH solution presented in these layers in excess values as the second reactant . It was also noticed that at 19% excess of NaOH solution , there was only one layer in the residual liquid as shown in **Figs. 13 and 14**. Increasing percentage excess of NaOH to 79% led to lowering the conversion to mono-ester to 86% as shown in **Table 1**. Another experiment was conducted without distillation to compare the conversion between the two cases , i.e the reaction without distillation and the reactive distillation .It was difficult to calculate monoester concentration using titration in this experiment since monoester and unreacted NaOH solution were being in the same mixture . Therefore; GC analysis and atomic absorption were carried out to indicate the presence of monoester and to measure the quantity of it as illustrated in **Figs. 15 and 16**. It was shown by atomic absorption that the conversion of di-ester to monoester was only 15.3% using 79% of NaOH solution (calculated with respect to monoester). A summary of these results are tabulated in **Table 2**. The dependence of the conversion from di-ester to monoester on the %excess of NaOH solution is drawn in **Fig. 17**. It can be noticed that the curve has second degree shape which indicates the presence of maximum conversion. This means that the increase of percentage excess of NaOH solution increases conversion to approximately 100% at about 40% excess NaOH then further increasing of percentage excess of NaOH (above 60%) lowers the conversion .This can be discussed as follows: at low values of percentage excess of NaOH solution , the conversion increases with increasing NaOH molecules (increasing the concentration of one of reactants), but when percentage excess of NaOH solution increases further, the molecules are hindered to transfer causing reduced values of conversion. The refractive indices of the distillate upper layers were measured . The values were found to be near to that of water (1.3331) , **Langs Handbook , 1934**, as shown in **Table 3**. The explanation of these results is that the ester is slightly soluble in water , **Perry's Handbook , 1984** , so it was appeared as a dispersed phase in water and the refractive index fixed to that of water.

#### 4. CONCLUSIONS

- The technique of reactive distillation is used to increase the conversion of an intermediate product of consecutive reactions.
- Increasing percentage excess of reactant (certain limit) increases the conversion of the intermediate product of a consecutive reaction in the distillate.
- The purity of the intermediate product is increased with increasing percentage excess of the reactant.

#### ACKNOWLEDGMENT

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## NOMENCLATURE

- A limiting reactant (ester)
- B excess reactant (NaOH solution)
- C concentration (mol . l<sup>-1</sup>)

## Subscripts

- o initial ( C<sub>Ao</sub> initial conc. of reactant A)



Figure 1. Apparatus photo.

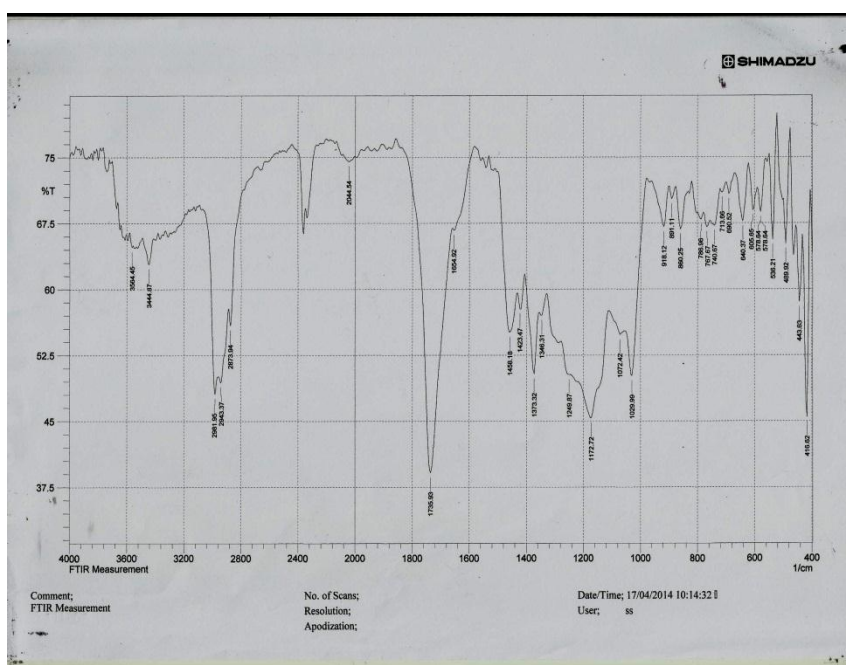
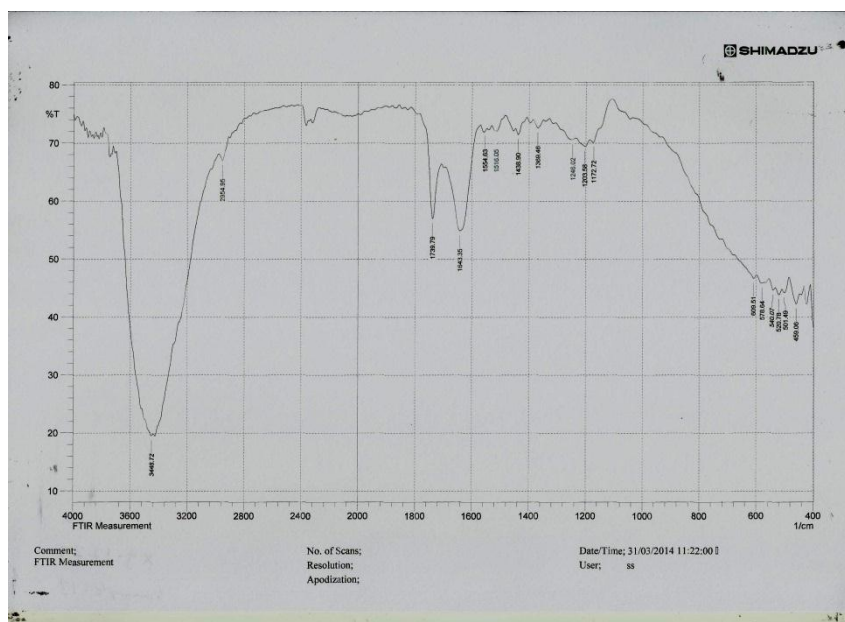
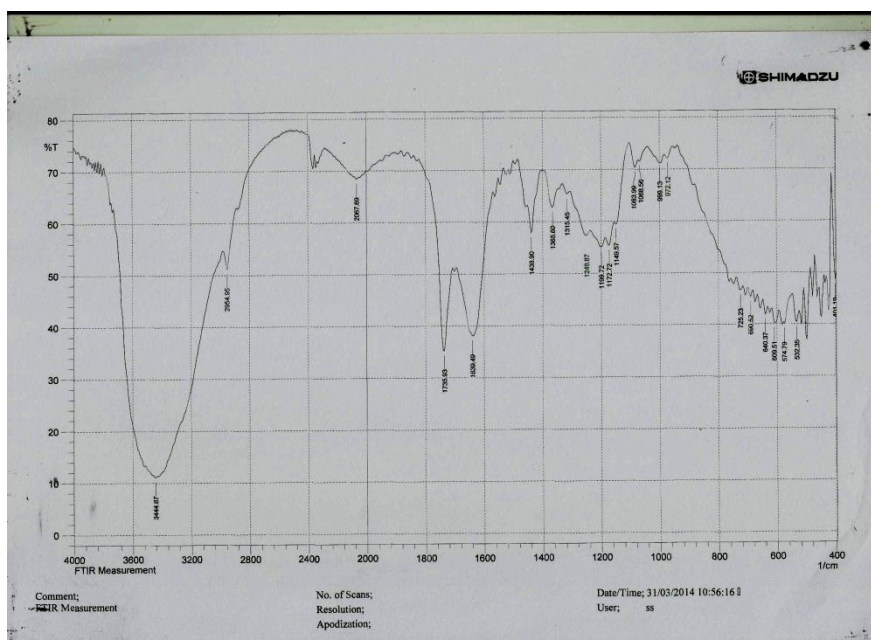


Figure 2. FTIR measurement for diethyl adipate .

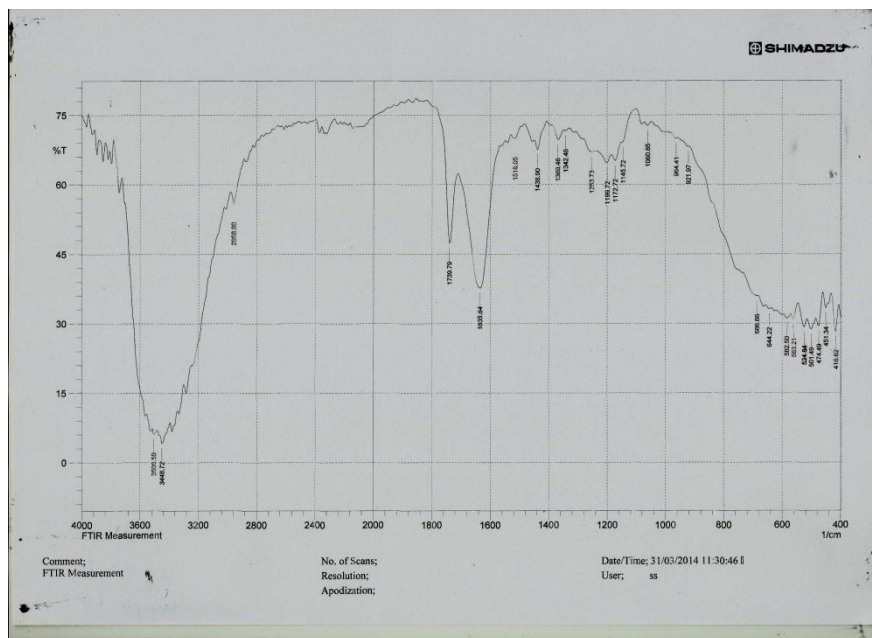


**Figure 3.** FTIR measurement for upper layer of distillate with  $C_{A0}=0.58 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.63 \text{ mol.l}^{-1}$  and 9 %excess of NaOH solution.

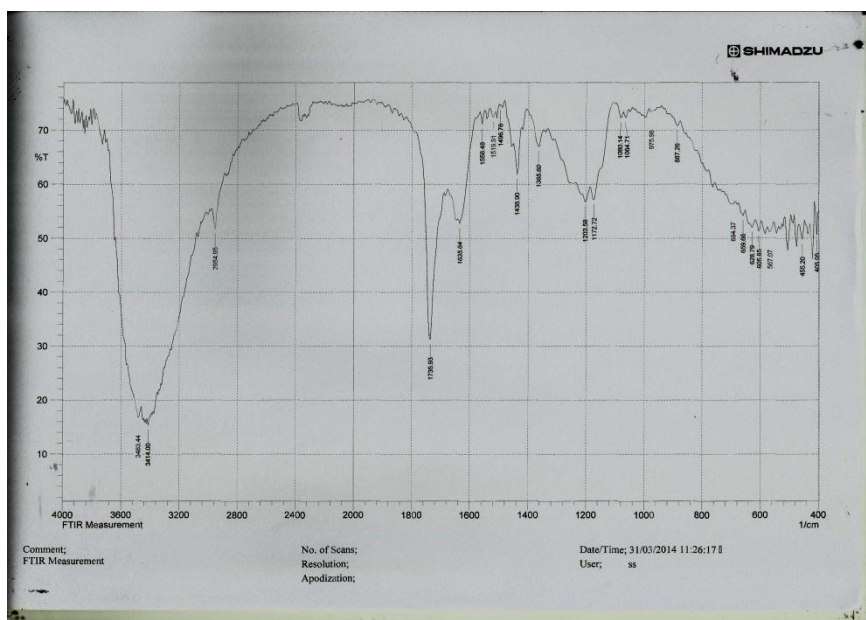


**Figure 4.** FTIR measurement for lower layer of distillate with  $C_{A0}=0.58 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.63 \text{ mol.l}^{-1}$  and 9%excess of NaOH solution.



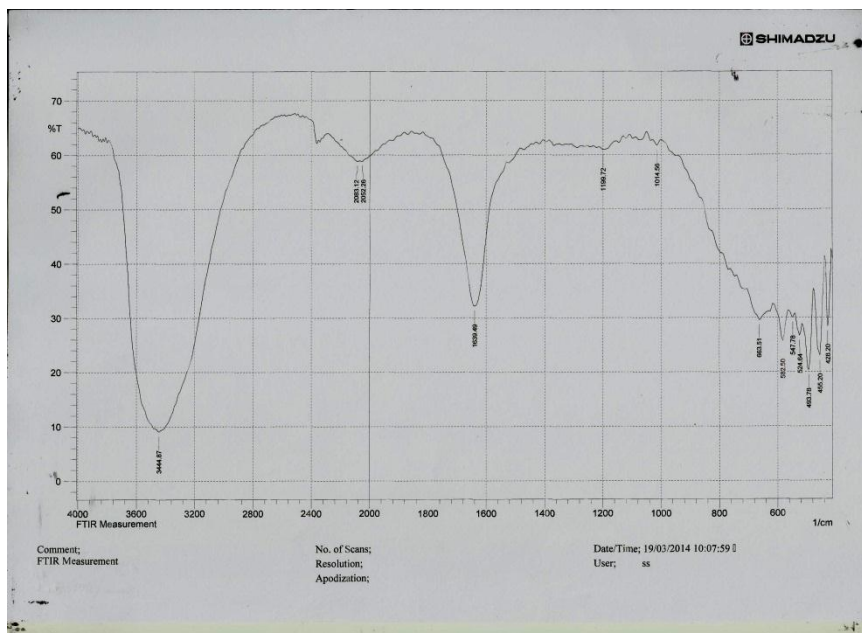


**Figure 5.** FTIR measurement for upper layer of distillate with  $C_{A0}=0.5553 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.6384 \text{ mol.l}^{-1}$  and 15% excess of NaOH solution.

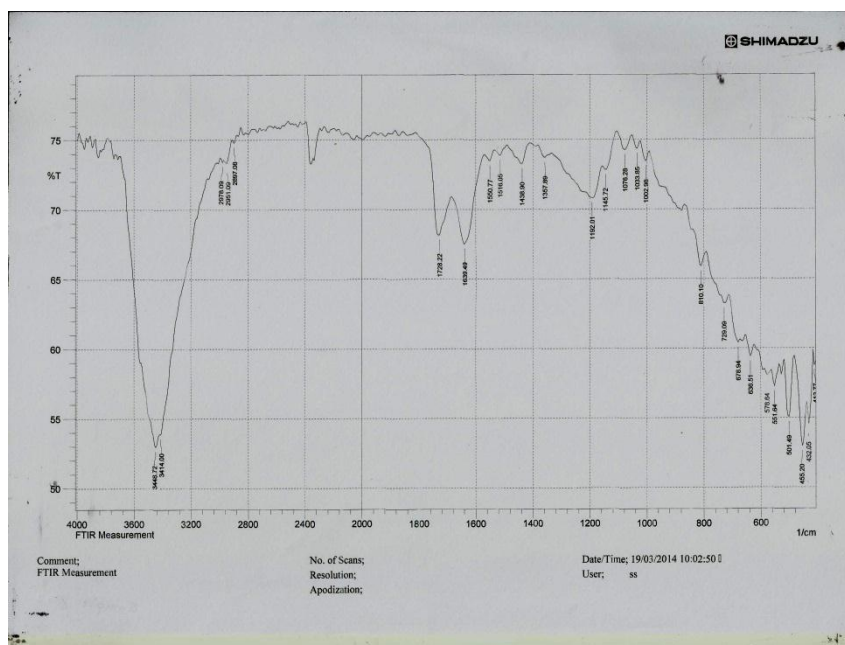


**Figure 6.** FTIR measurement for lower layer of distillate with  $C_{A0}=0.5553 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.6384 \text{ mol.l}^{-1}$  and 15% excess of NaOH solution.

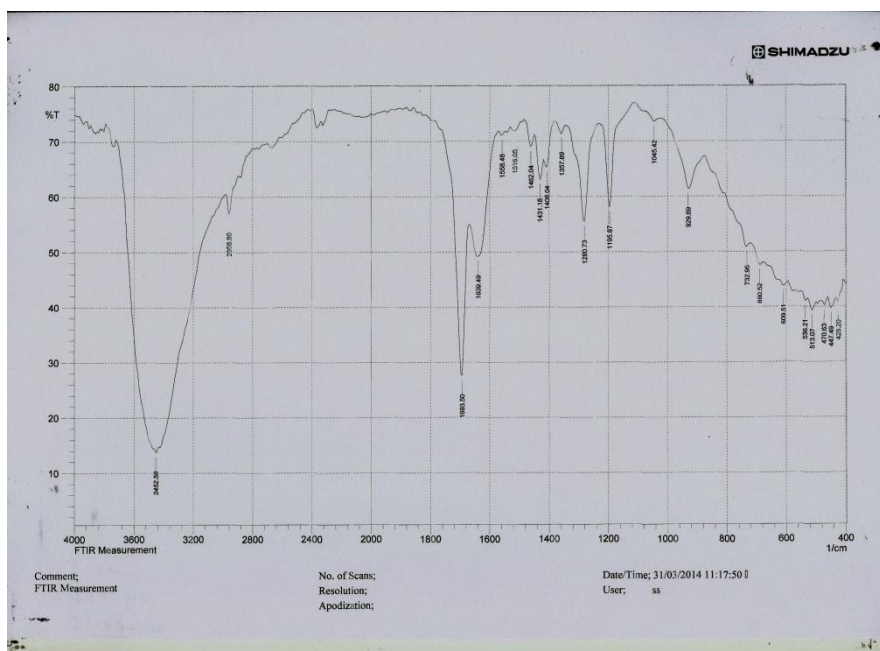




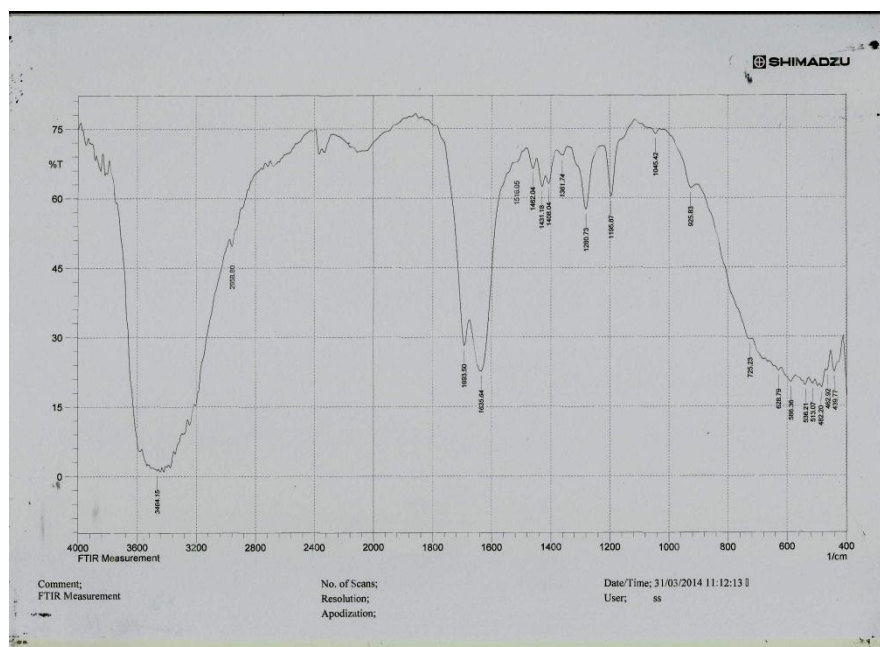
**Figure 7.** FTIR measurement for upper layer of distillate with  $C_{A0}=0.32 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.38 \text{ mol.l}^{-1}$  and 19% excess of NaOH solution.



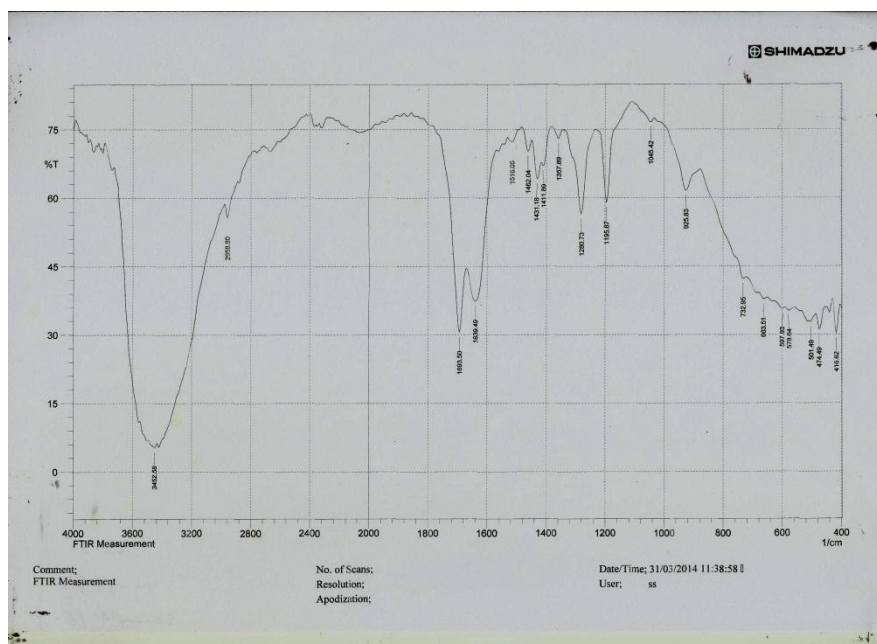
**Figure 8.** FTIR measurement for lower layer of distillate with  $C_{A0}=0.32 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.38 \text{ mol.l}^{-1}$  and 19% excess of NaOH solution.



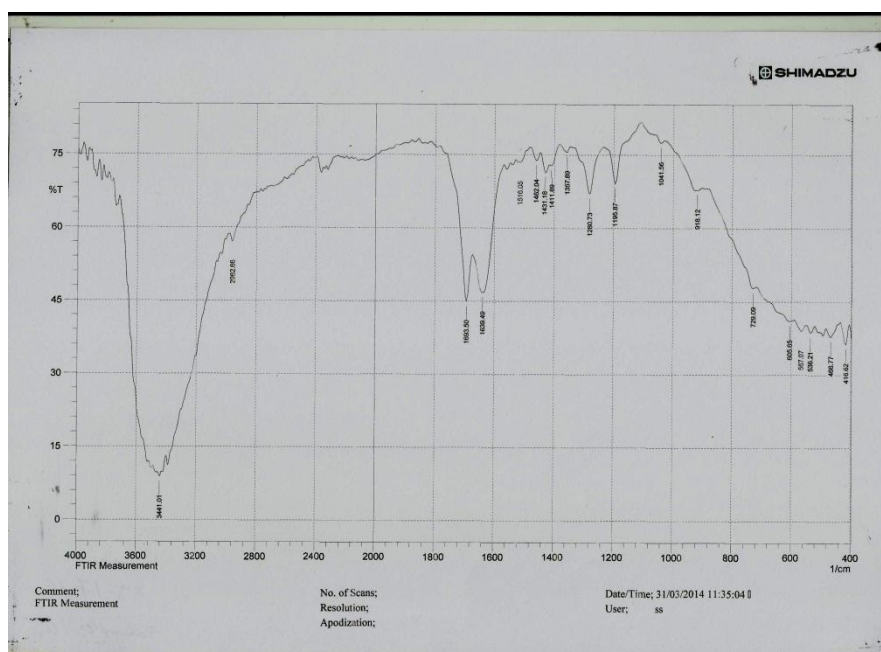
**Figure 9.** FTIR measurement for upper layer of residue with  $C_{A0}=0.58 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.63 \text{ mol.l}^{-1}$  and 9 %excess of NaOH solution.



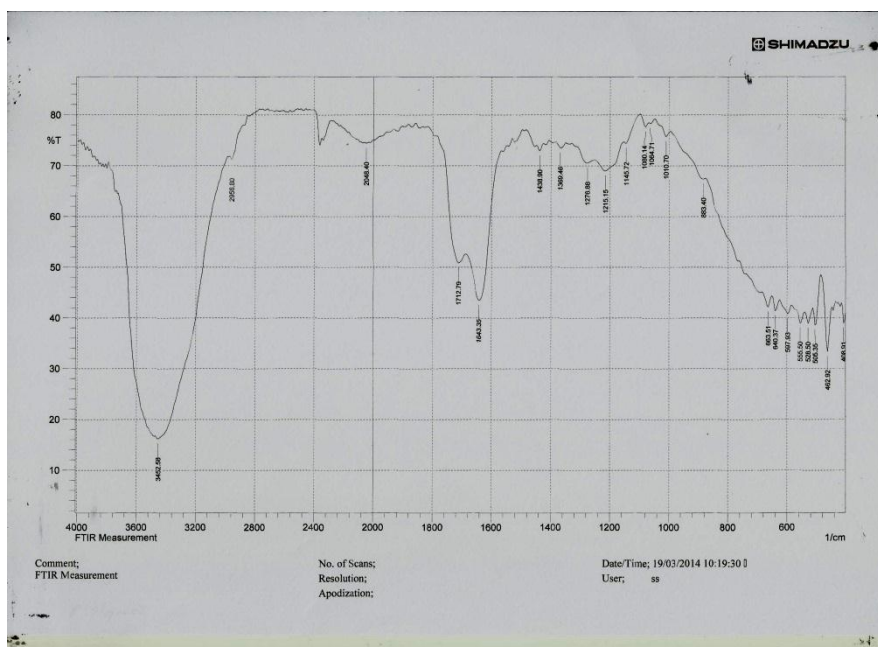
**Figure 10.** FTIR measurement for lower layer of residue with  $C_{A0}=0.58 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.63 \text{ mol.l}^{-1}$  and 9 %excess of NaOH solution.



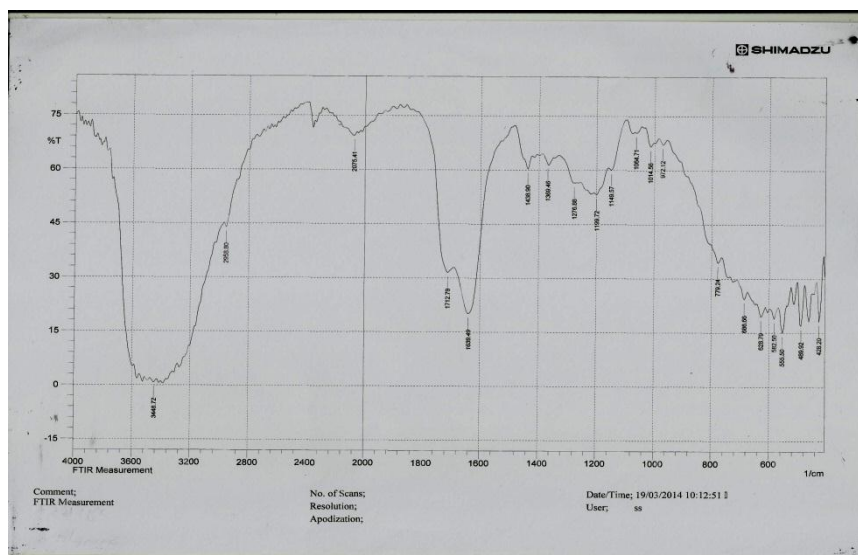
**Figure 11.** FTIR measurement for upper layer of residue with  $C_{A0}=0.5553 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.6384 \text{ mol.l}^{-1}$  and 15 %excess of NaOH solution.



**Figure 12.** FTIR measurement for lower layer of residue with  $C_{A0}=0.5553 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.6384 \text{ mol.l}^{-1}$  and 15%excess of NaOH solution.

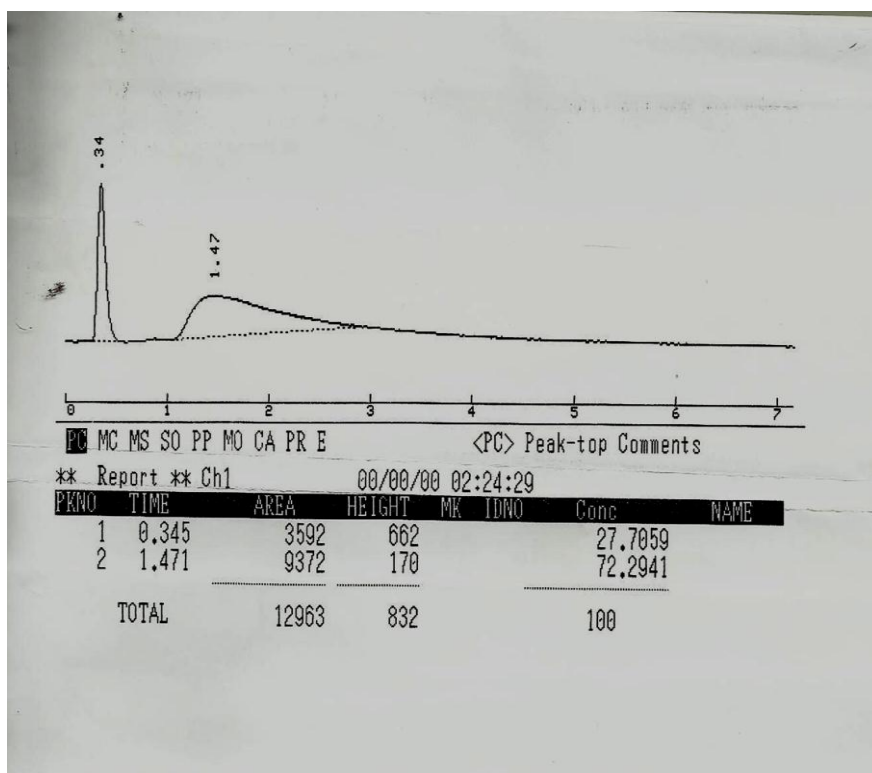


**Figure 13.** FTIR measurement for upper layer of residue with  $C_{A0}=0.32 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.38 \text{ mol.l}^{-1}$  and 19 %excess of NaOH solution.

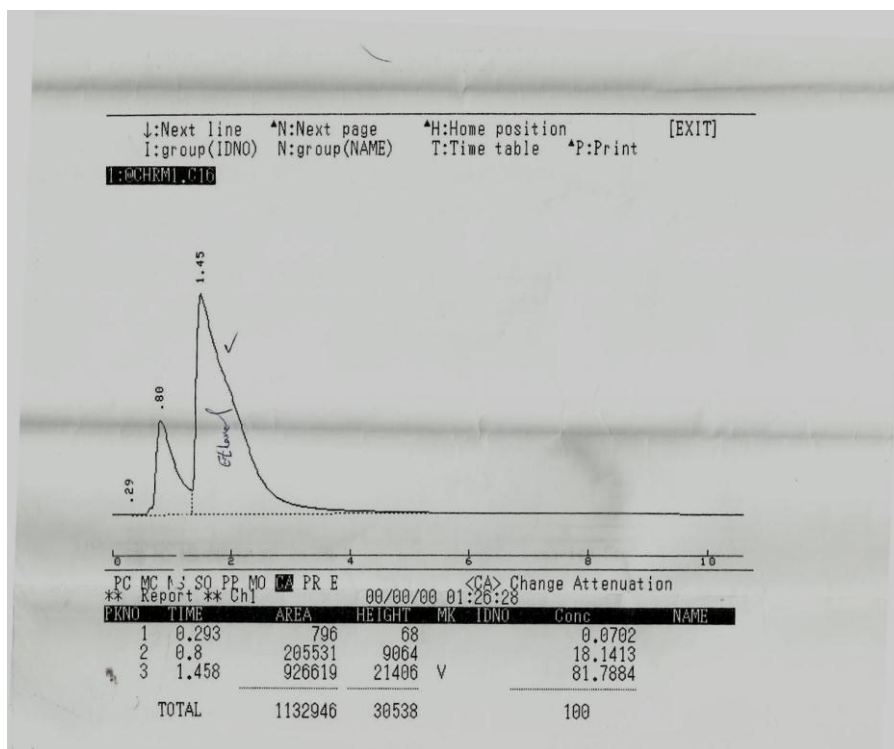


**Figure 14.** FTIR measurement for lower layer of residue with  $C_{A0}=0.32 \text{ mol.l}^{-1}$ ,  $C_{B0}=0.38 \text{ mol.l}^{-1}$  and 19 %excess of NaOH solution.



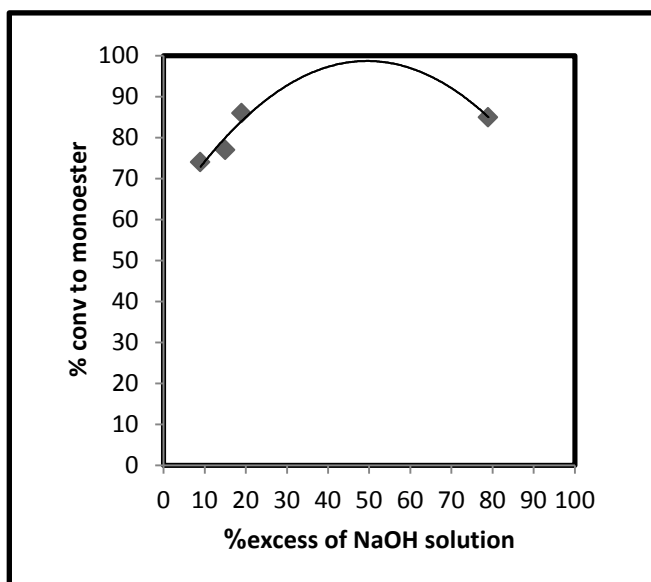


**Figure 15.** GC analysis of diethyl adipate sample saponified without distillation ( $C_{A0}=0.094$  mol.l<sup>-1</sup> and  $C_{B0}=0.24$  mol.l<sup>-1</sup>).



**Figure 16.** GC analysis of ethyl group as standard.





**Figure 17.** The dependence of the conversion (from di-ester to monoester) on %excess of NaOH solution in reactive distillation of saponification of diethyl adipate.

**Table 1.** Percentage conversion to monoester in distillate.

$C_{Ao}$ (mol.l <sup>-1</sup> )	$C_{Bo}$ (mol.l <sup>-1</sup> )	%excess of NaOH sol.	%conversion in distillate
0.58	0.63	9	74.1
0.5553	0.6384	15	78.9
0.32	0.38	19	87.5
0.094	0.24	79	86

**Table 2.**Summary of experimental results.

Technique	%excess of NaOH sol.	%conversion to monoester
without distillation	79	15.3
with distillation	9	74.1
	15	78.9
	19	87.5
	79	86

**Table 3.** Refractive index variation with initial reactants concentrations and percentage excess of NaOH solution.

$C_{Ao}$ (mol.l <sup>-1</sup> )	$C_{Bo}$ (mol.l <sup>-1</sup> )	%excess of NaOH sol.	RI of upper layer of distillate
0.58	0.63	9	1.3383
0.5553	0.6384	15	1.3380
0.32	0.38	19	1.3380
0.094	0.24	79	1.339



## Increasing of Naphthenes Content in Naphtha by Using Y and $\beta$ Zeolite Prepared from Iraqi Kaolin

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### ABSTRACT

This work dealt with separation of naphthenic hydrocarbons from non-naphthenic hydrocarbons and in particular concerns an improved process for increasing the naphthenes concentration in naphtha, The separation was examined using adsorption by Y and  $\beta$  zeolite in a fixed bed process. The concentration of naphthenes in the influent and effluent streams was determined using PONA classification. The effect of different operating variables such as feed flow rate (2- 4 L/hr); bed length (50 - 80 cm) on the adsorption capacity of Y and  $\beta$  zeolite was studied. Increasing the bed length lead to increase the naphthenes concentration, and increasing the flow rate lead to decrease in the concentration of naphthenes, It was found that the decrease in flow rate to 2 L/hr and increase the bed length to 80 cm lead to increase the naphthenes concentration from 6.2 to 24.8 Wt. %.

**Key words:** Adsorption, Naphthenes, Naphtha, Y and  $\beta$  zeolite, Iraqi kaolin.

### زيادة محتوى النفثينات في مقطع النفط باستخدام زيوليت من نوع Y و $\beta$ محضر من طين الكاولين العراقي

سرمد عبد الرزاق رشيد

مدرس مساعد

كلية الهندسة/جامعة بغداد

### الخلاصة

يتعامل هذا البحث مع فصل المركبات الهيدروكربونية النفثينية عن المركبات الهيدروكربونية غير النفثينية، وبصورة خاصة، تحسين عملية زيادة تركيز المركبات النفثينية في مقطع النفط. تم اجراء العملية بطريقة الامتزاز بواسطة الزيوليت من نوع Y و  $\beta$  في العمود الثابت، تم قياس تراكيز المركبات النفثينية في المجرى الداخل والخارج باستخدام طريقة (PONA). تمت دراسة تأثير متغيرات تشغيلية مختلفة مثل معدل جريان اللقيم (2-4 لتر/ساعة) وارتفاع العمود (50-80 سم) على سعة الامتزاز للزيوليت من نوع Y و  $\beta$ . ان زيادة ارتفاع العمود يؤدي الى زيادة تركيز المركبات النفثينية وزيادة معدل الجريان يؤدي الى انخفاض تركيز المركبات النفثينية. وُجدَ أن خفض معدل الجريان الى 2 لتر/ساعة وزيادة طول العمود الى 80 سم يؤدي الى زيادة تركيز المركبات النفثينية من 6.2 الى 24.8 %.



## 1. INTRODUCTION

Environment-related issues nowadays for sure a powerful driving force for the improvement of current refinery processes or the development of new routes for upgrading refinery cuts.

Naphthenes are ring structures where each carbon atom is linked to two hydrogen atoms and to two carbon atoms. This arrangement applies to single-cycle structures. The general formula is ( $C_nH_{2n}$ ), **Calemma, et al., 2013**.

In the refining of petroleum by modern techniques, complex hydrocarbon mixture of the gasoline boiling range are frequently produce which comprise paraffin and naphthene hydrocarbons. The latter have appreciably higher octane numbers than paraffins of the same boiling range, certain naphthenes, particularly cyclohexane, are also of great value in the production of variety of organic chemicals, **Abbas, 2011**.

Several techniques have been forward to separate naphthenes from paraffins such as azeotropic distillation, membrane extraction and liquid-liquid extraction, **Abdul – Raheem, 2003**. However, these methods for separating naphthenes from complex hydrocarbon mixtures are either economically impractical or are effective only with particular mixtures, **Schreiner et al, 1993, Drzaj, et al., 1985**

Adsorption plays an important role in industry of recovery of valuable substances. It's most important uses in the removal of organic contaminants from polluted sources. The relative advantages of adsorption over other conventional advanced treatment methods as mentioned at **Rashid, 2009**, because it can remove both organic as well as inorganic constituents even at very low concentrations, it is relatively easy and safe to operate, both batch and continuous equipment can be used, no sludge formation, the adsorbent can be regenerated to use again and all adsorption processes involve a decrease in the free energy of the system, **Cassidy, 1951, Mohanty et al., 2005**.

Adsorption of material occurs when certain species is selectively retained on the surface, or in the pores or interstices of adsorbent. Forces causing adsorption are the same ones that cause the cohesions in solids and liquids. If these forces are van der Waals then it is physical adsorption or physisorption, if there is an electron transferred or shared then it is chemical adsorption or chemisorption, **Land, 1971**. Adsorbents are natural or synthetic materials of amorphous or microcrystalline structure those need on a long scale include activated carbon, activated alumina, silica gel, and molecular sieve, **Perry and Chilton, 1984**. Zeolites are high capacity selective adsorbents because they separate molecules based upon the size and configuration of the molecule, relative to the size and geometry of the main apertures of the structure, **Mohammed and Abbas, 2014**. Also zeolites adsorb in particular those with permanent which show other interaction effects, with selectivity that it is not found in other solid adsorbents, **Kirk-Othmer, 1983**.

The present study is a trial to increase naphthenes concentration in naphtha fraction by using bed consists of  $\gamma$  and  $\beta$  zeolites prepared from Iraqi kaolin.



## 2. MATERIALS AND EXPERIMENTAL TECHNIQUES

### 2.1 Materials

#### 2.1.1 Feed

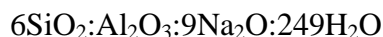
The feed hydrocarbons (naphtha) are obtained from Al – Doura refinery/Iraq. The properties of (naphtha) are given in **Table 1** and the chemical composition of Iraqi kaolin (Doukhla kaolinite) used are given in **Table 2**.

#### 2.1.2 Adsorbent:

##### 2.1.2.1 Synthesis of Y-Zeolite type from Iraqi kaolin

In order to prepare zeolite from kaolin, kaolin was dissolved by the addition of sodium hydroxide (kaolin / NaOH = 1/1.5 by wt.) at 850°C for three hours. A typical zeolite synthesis procedure from clay was performed as follows:

Ten grams of kaolin powder and 12.67 grams of sodium silicate were dispersed in 150 ml of deionized water under constant stirring for 1 hour. The slurry with a molar composition of

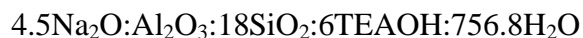


and the pH range of (13-14) were aged at 100°C temperature for 48 hours to form gel slurry. Then the gel slurry was transferred into the polyethylene container to hydrothermally crystallize. Crystallization was carried out at about 100°C. Subsequently, the resultant precipitate was separated from the mother liquor by filtration. The crystalline mass is then washed with deionized water until a pH range of (9-12) and dried at 100°C for 16 hours, **Htay and Oo, 2008**.

##### 2.1.2.2 Synthesis of $\beta$ -Zeolite type from Iraqi kaolin

The kaolin was firstly calcined at 720°C for 4 hours and then was treated with 20 wt% hydrochloric acid HCl solution at 94°C under reflux conditions. The solid with  $\text{SiO}_2/\text{Al}_2\text{O}_3$  molar ratio of 18 was obtained.

In a typical process, 16.0 g of HCl-treated solid was added to a mixture solution composed of 3.2 g sodium hydroxide NaOH and 46.4 g of Tetraethylammonium hydroxide (TEAOH) aqueous solution (15.9 wt%) under stirring. Then the resulted mixture with the following molar chemical composition:



was transferred into a 200 ml autoclave and placed at 170°C for 30 hours. After crystallization, the solid product was filtered, washed, dried and calcined at 100°C and 550°C for 6 hours respectively, **Wan, et al. 2010**.

### 2.2 Adsorption Equipment and Procedure

Experiments were carried out in cylindrical column (2.54 cm diameter, 100 cm length). Three liters glass container is used for feed and connected to a dosing pump (HB 36) for pumping the feed at desired flow rate to the top of the adsorption column. The column is packed with  $\gamma$  and  $\beta$  zeolites.



The bottom of the adsorption column is fitted with a perforated plate to support the zeolite bed with equal volume crystal balls was used in the top to achieve normal distribution and to reduce the channeling. The bottom of adsorption column is fitted with valve. 1L receiver is used to collect the effluent which is analyzed for determining the concentration of naphthens hydrocarbons. The entire apparatus is shown in **Fig.1**.

A certain quantity of  $\gamma$  and  $\beta$  zeolite (50% of each) is heated to 110 °C for three hours to avoid the humidity. The zeolite is put in the adsorption column where it is supported by a perforated plate. The feed is pumped to adsorption bed which is constructed from multiple layers in series depending of the bed length of the experiment using dosing pump at desired product. The feed is passed through the bed and product is collected in 1L glass receiver. The product is analyzed (as described in the following paragraph) at intervals time for obtaining the concentration of naphthene at each time. The feed is continuously flowing through the bed until no change in naphthens concentration between the inlet and outlet streams is observed, which means that the saturation of adsorbent is over.

## 2.4 Analytical Method

The chemical composition of naphtha is described by PONA classification (i.e. the paraffinic, olefinic, naphthenic, and aromatic composition in the naphtha sample).

PONA analysis is (IP 128) carried out depending on the following measurements:

- a- Bromine No. determined by IP 130.
- b- Aniline No. determined by IP 2.
- c- Sample dearomatization made according to ASTM D 1019 – IP 145.
- d- Sample distillation determined by IP 123.

There are four procedures to determine the PONA analysis:

- 1- Procedure A: used when (50%) boiling point (B.P) below 110°C and Bromine No. below (0.5).
- 2- Procedure B: used when (50 %) boiling point above 110 °C and Bromine No. below (0.5).
- 3- Procedure C: used when (50 %) boiling point below 110 °C and Bromine No. above (0.5).
- 4- Procedure D: used when (50 %) boiling point above 110 °C and Bromine No. above (0.5).

## 3. RESULTS AND DISCUSSION

### 3.1 Characterization of Zeolites

#### 3.1.1 X-Ray Diffraction

Powder XRD studies were performed on the calcined samples in order to identify or detect different crystalline phases present in the catalyst. **Figs. 2 - 5** illustrate XRD patterns, HY-Zeolite prepared from kaolin, standard type Y-Zeolite, H $\beta$ -Zeolite prepared from kaolin and standard  $\beta$ -Zeolite. The comparison between the prepared Zeolite and the reference indicates that the preparation method gives good results. This leads to conclusion that our preparation method gives a nearly synthesized indigenous. XRD also shows that there is small reduce in the intensity of the





peaks located around differences regions, which can be explained by the nature of the silica materials, which were used in the preparation method, **Treacy and Higgins, 2001**.

### 3.1.2 Chemical analysis

The chemical analysis composition of the prepared zeolites (Y and  $\beta$  Zeolite) and the commercial zeolites are shown in **Table 3**. The  $\text{SiO}_2/\text{Al}_2\text{O}_3$  molar ratios are 5 and 15.4 which are slightly smaller than that in commercial. However, these ratios are typical of such type of zeolite, the values of  $\text{SiO}_2/\text{Al}_2\text{O}_3$  molar ratio obtained during the treatment times of dealumination for  $\beta$  zeolite as shown in **Table 4**; it refers to increases of  $\text{SiO}_2/\text{Al}_2\text{O}_3$  molar ratio of sodium type of Y and  $\beta$  under the same conditions reaching 8.92 and 24.85 for Y and  $\beta$  Zeolite respectively, this is due to the higher pore diameter of  $\beta$  zeolite (240 nm) with respect to Y zeolite pore diameter (116 nm) and this improves mass transfer through  $\beta$  zeolite, Y zeolite normally has a  $\text{SiO}_2/\text{Al}_2\text{O}_3$  molar ratio of about 10. However, this can be progressively increased to the point where nearly all the alumina is removed as a work published by Guisnet et al. Nevertheless, the concentration of its strong acidic centers passes through a maximum at a molar ratio of  $\text{SiO}_2/\text{Al}_2\text{O}_3$  of 19-25. The values of  $\text{SiO}_2/\text{Al}_2\text{O}_3$  molar ratio obtained during the treatment times of dealumination for Y zeolite are shown in **Table 4**, on the other hand,  $\beta$  zeolite normally has a  $\text{SiO}_2/\text{Al}_2\text{O}_3$  molar ratio of about 32.5. This can be progressively increased to the point where nearly all the alumina is removed as a work published by Anthony et al. However, the concentration of its strong acidic centers passes through a maximum at a molar ratio of  $\text{SiO}_2/\text{Al}_2\text{O}_3$  of 20-30, **Anthony et al., 2001, Hopper and Voorhies, 1972, Guisnet et al., 1984 and Karge and Ladebeck, 1980**.

### 3.1.3 Surface area

The surface areas of the zeolites (H-Y and H- $\beta$ ) were determined by nitrogen physisorption method (BET). The results show that  $\beta$  - Zeolite has higher surface area than Y - Zeolite, i. e. 347 and 334  $\text{m}^2/\text{g}$  respectively.

## 3.2 Breakthrough Results

The transient of naphthenes concentration through the adsorption bed is shown in **Fig. 6**. The concentration ratio  $C_o/C_i$  for naphthenes has its largest value at the beginning of adsorption process and last for a certain time then decreases gradually until the adsorbent becomes saturated with non-naphthenic hydrocarbons feed. At the saturation condition the ratio  $C_o/C_i$  of naphthenes reaches unity indicating no further separation of naphthenes occurs, on the other hand, the results show that Y-zeolite or  $\beta$ -zeolite beds give lower performance than that of mixed zeolite, this may be due to the relation between adsorbents pore size and non-naphthenic compounds molecular size that occur compilation through adsorption.

### 3.2.1 Effect of feed flow rate

Adsorption of non-naphthenic compounds is studied at different flow rates. **Fig. 7** shows the transient values of  $(C_o/C_i)$  at different flow rates.

Results show that increasing the flow rate lead to earlier break points. That is because at high flow rate the quantity of feed mixture to be adsorbed is more and hence break points come early. Also increasing the flow rate will reduce the contact time between the adsorbent and the



adsorbate and hence less enriching degree of naphthenes is obtained, maximum concentration ratio for naphthene achieved at earlier time reaching 3.7 at operating conditions of  $Q=2$  L/h,  $Z=80$  cm, these results are agreement with **Jaber, 2005**.

### 3.2.2 Effect of bed height

Different runs are made to study the variation of separation affinity with varying the bed height of adsorbent. These are illustrated in **Fig. 8**.

In general, increasing bed height leads to increase the degree of enrichment,  $(C_o/C_i)$ . This is because of two reasons; (1) increasing the bed height means increasing the quantity of adsorbent and hence increase the capacity of adsorption of the bed which leaving more naphthenes components in the raffinate, (2) increasing bed height leads to increase the resident time of feed mixture in the bed which cause high degree of enrichment for naphthenes.

In contrast shows that shorter bed lengths are generally responsible for earlier break point, This is because any increase in bed length will increase adsorption capacity of aromatic or parafinic components, causing slow movement of (MTZ) toward the end of the bed, i.e., earlier saturation of bed with the adsorbate, the naphthenes reaches the break through concentration  $C_o/C_i$  equal to one at time of about 50 and 70 min for 50 and 80 cm respectively, also these results are compatible with **Jaber, 2005**.

## 4. CONCLUSIONS

Based on experimental results, the following conclusions are made:

1. Y and  $\beta$  zeolites prepared from Iraqi kaolin gave much closed characteristics to that of commercial types.
2. In general, zeolite is good adsorbent for non-naphthenic compounds. Particularly, bed of mixed types of Y and  $\beta$  zeolite gave higher performance than each separated one.
3. In general, increasing the bed height and decreasing the flow rate lead to increase the separated performance. Increasing bed height to 80 cm (2.5 cm diameter) with flowrate of 2 L/h gave an increase in naphthenic concentration from 6.2 wt % to 24.85 wt %.

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## 6. NOMENCLATURE AND ABBREVIATIONS:

### Nomenclature

Ci	inlet concentration of Naphtha
Co	outlet concentration of Naphtha
Q	volumetric Flow Rate, L/hr
Z	bed length, cm

### Abbreviation

ASTM	American Standard Test Method
B.P	Boiling Point



BET	Brunauer, Emmett and Teller
MTZ	Mass Transfer Zone
PH	Acidity
PONA	Parrafinic, Olefinic, Naphthenic, and Aromatic composition in the Naphtha sample
TEAOH	Tetraethylammonium Hydroxide
XRD	X-Ray Diffraction

**Table 1.** Properties of Naphtha.

Specific gravity at 15.6/15.6 °c	0.675
R.V.P (kg/cm <sup>2</sup> ) at 37.8 °c	0.95
Initial boiling point °c	76 °c
End boiling point °c	186 °c
Aromater % wt.	11.9
Olefin % wt.	0.1
Naphthene % wt.	6.2
Paraffins % wt.	81.9
Bromine No.	1.2
API	61

**Table 2.** Chemical omposition of Iraqi Kaolin (Doukhla Kaolinite) used.

Constituent	Weight (%)
SiO <sub>2</sub>	50.10
Al <sub>2</sub> O <sub>3</sub>	32.80
Na <sub>2</sub> O	0.27
TiO <sub>2</sub>	1.27
Fe <sub>2</sub> O <sub>3</sub>	1.24
MgO	0.24
CaO	0.28
K <sub>2</sub> O	0.66
L.O.I , wt %	12.3

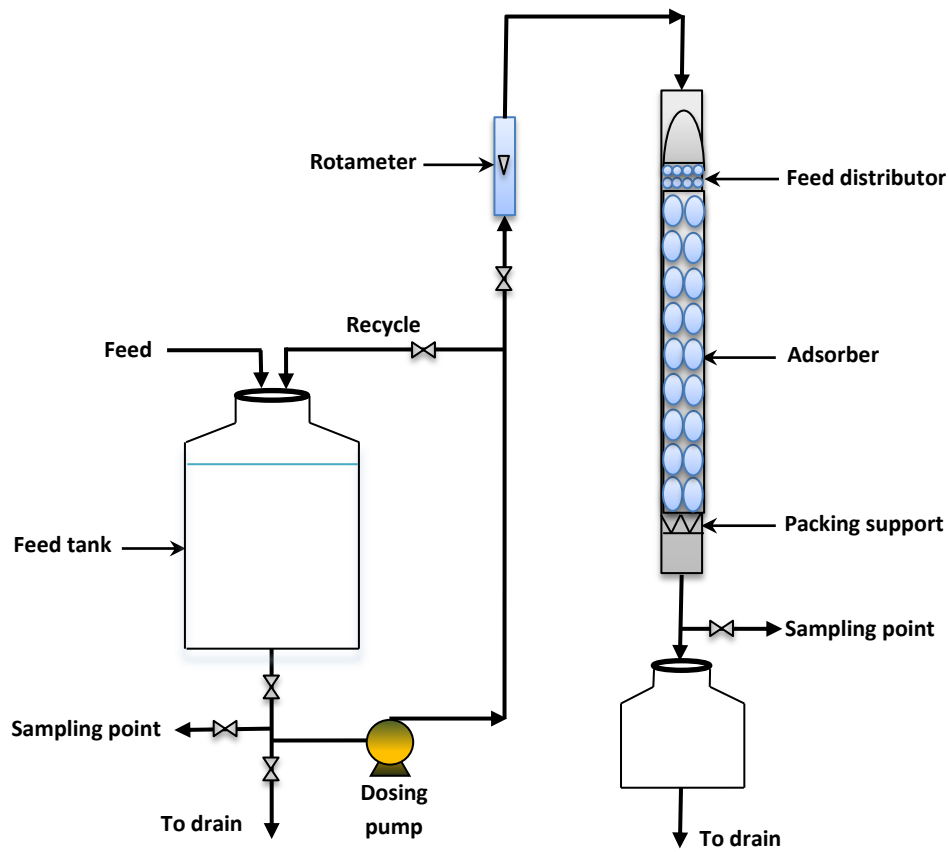


**Table 3.** Chemical analysis of the two types of prepared zeolites and its references.

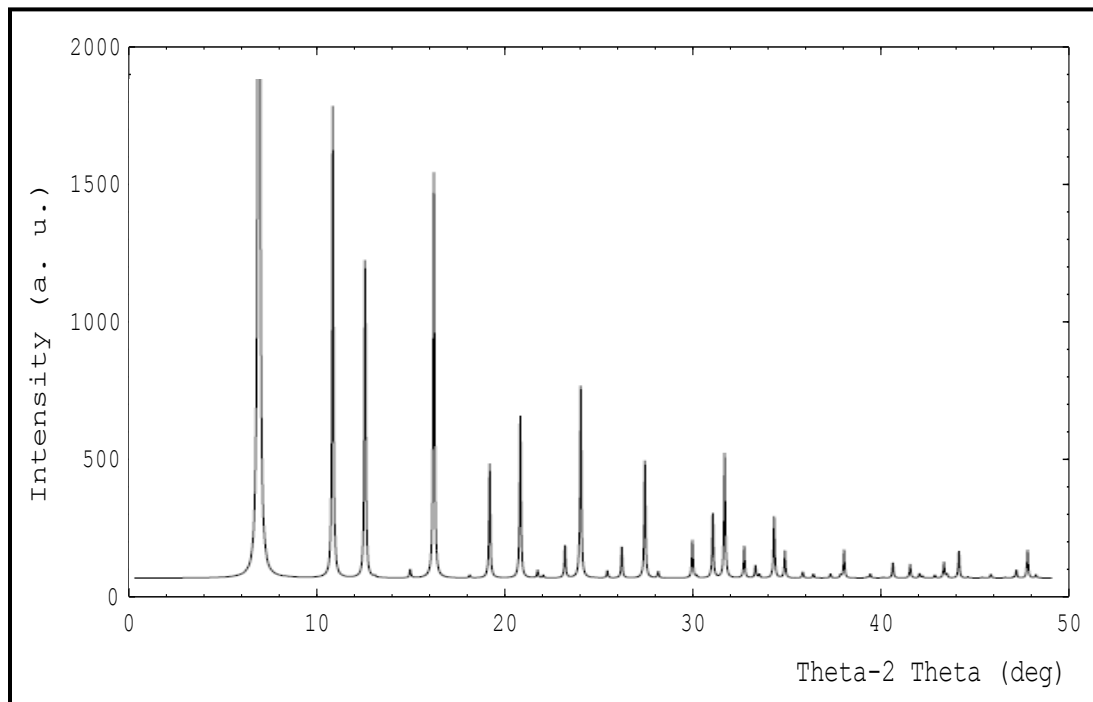
Chemical composition (mol. %)	HY-Zeolite		H $\beta$ -Zeolite	
	Kaolin	Reference	Kaolin	Reference
SiO <sub>2</sub>	5.65	6	17.25	18
Al <sub>2</sub> O <sub>3</sub>	1.13	1	1.12	1
Na <sub>2</sub> O	9.05	9	4.17	4.5
SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> ( <i>molar ratio</i> )	5	6	15.4	18

**Table 4.** Comparative ratios of SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> for Sodium form of Y zeolite and  $\beta$  zeolite dealuminated by acid leaching method.

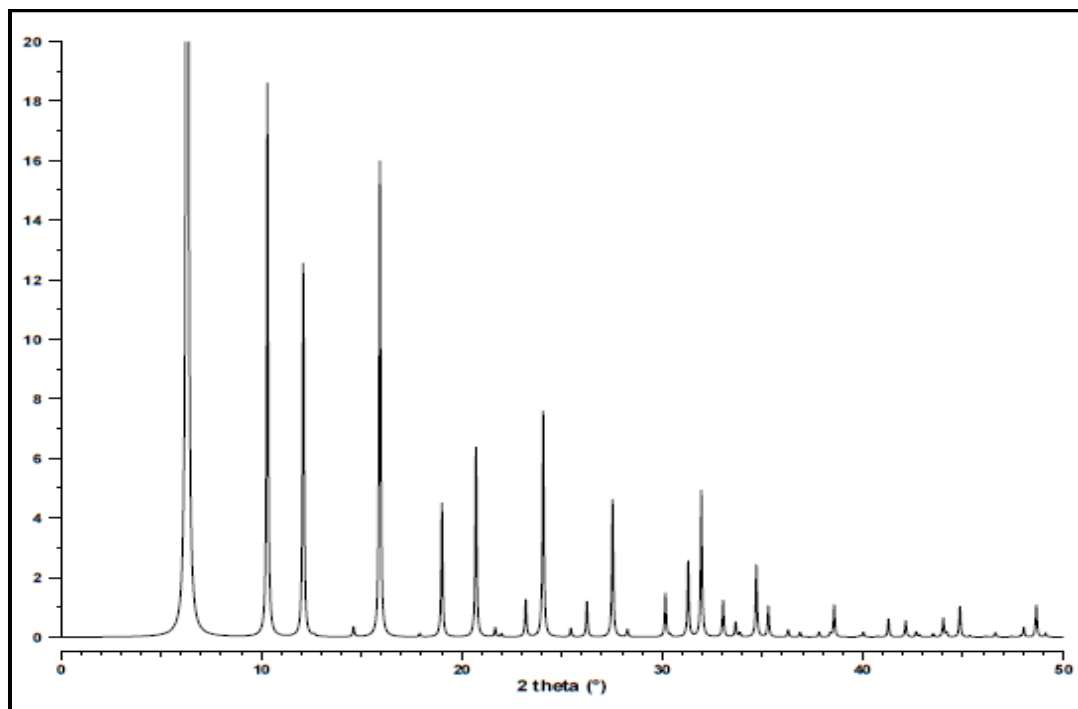
Zeolite type	No. of treatment times with Nitric acid HNO <sub>3</sub>			
	Prepared	One	Two	Three
	SiO <sub>2</sub> to Al <sub>2</sub> O <sub>3</sub> molar ratio			
Y zeolite	5	6.31	7.58	8.92
$\beta$ zeolite	18.4	20.61	22.02	24.85



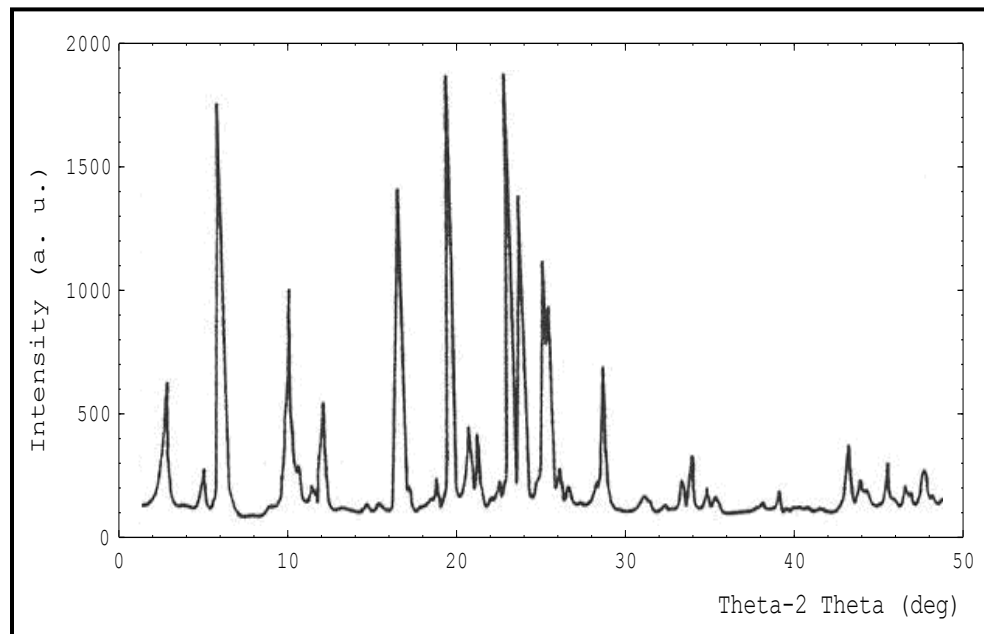
**Figure 1.** Schematic diagram of the experimental rig.



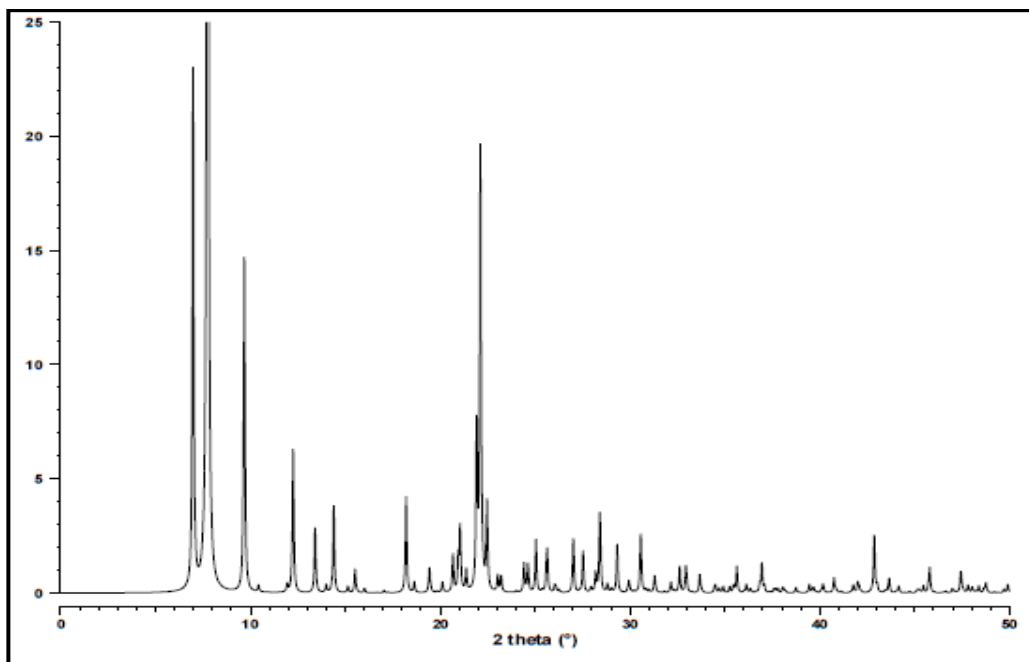
**Figure 2.** XRD of HY- Zeolite prepared from Kaolin.



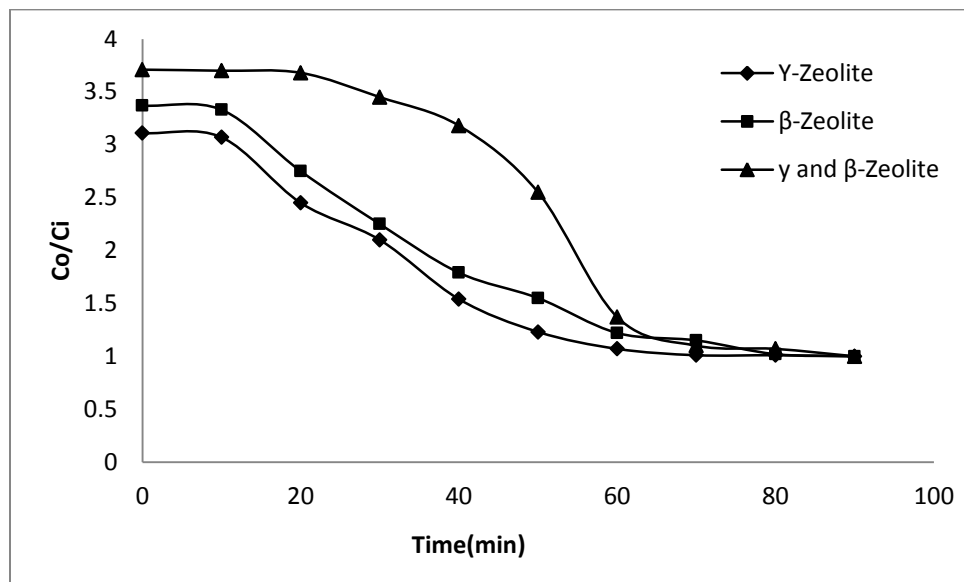
**Figure 3.** XRD of standard type Y- Zeolite, Treacy and Higgins, 2001.



**Figure 4.** XRD of type H $\beta$ - Zeolite prepared from Kaolin.

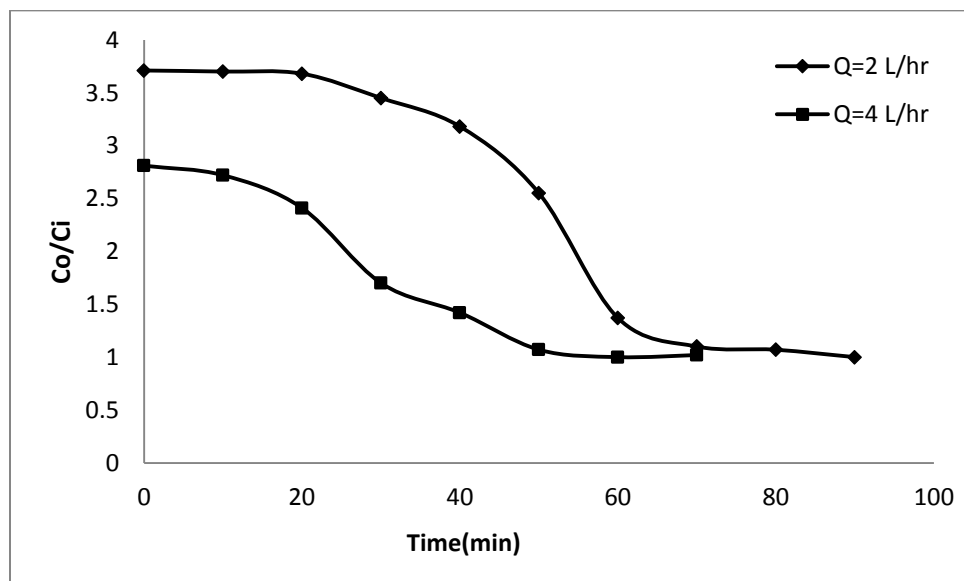


**Figure 5.** XRD of standard  $\beta$  – Zeolite, Treacy and Higgins, 2001.



**Figure 6.** Concentration profile for Naphthenes.

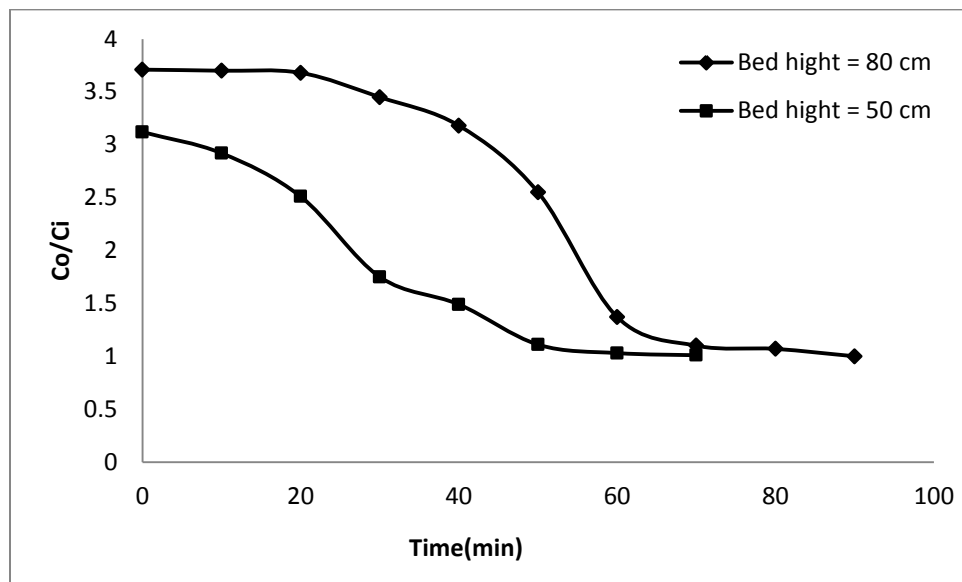
Operating conditions ( $C_i = 6.2$  wt%,  $Q = 2$  L/hr and  $Z = 80$  cm).



**Figure 7.** Effect of feed flow rate on the concentration profile of Naphthenes

Operating conditions ( $C_i = 6.2$  wt % and  $Z = 80$  cm).





**Figure 8.** Concentration profile for Naphthenes at Operating conditions ( $C_i = 6.2$  wt % and  $Q = 2$  L/hr).

## Improving IoT Applications Using a Proposed Routing Protocol

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### ABSTRACT

The main objective of this work is to propose a new routing protocol for wireless sensor network employed to serve IoT systems. The routing protocol has to adapt with different requirements in order to enhance the performance of IoT applications. The link quality, node depth and energy are used as metrics to make routing decisions. Comparison with other protocols is essential to show the improvements achieved by this work, thus protocols designed to serve the same purpose such as AODV, REL and LABILE are chosen to compare the proposed routing protocol with. To add integrative and holistic, some of important features are added and tested such as actuating and mobility. These features are greatly required by some of IoT applications and improving the routing protocol to support them makes it more suitable for IoT systems.

The proposed routing protocol is simulated using Castalia-3.2 and all the cases are examined to show the enhancement that achieved by each case. The proposed routing protocol shows better performance than other protocols do regarding Packet Delivery Ratio (PDR) and latency. It preserves network reliability since it does not generate routing or data packets needlessly. Routing protocol with added features (actuating and mobility) shows good performance. But that performance is affected by increasing the speed of mobile nodes.

**Keywords:** internet of things, routing protocol, wireless sensor network, castalia-3.2.

### تحسين تطبيقات إنترنت الأشياء باستخدام بروتوكول توجيه مقترح

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### الخلاصة

الهدف الرئيسي من هذا العمل هو اقتراح بروتوكول توجيه جديد لشبكة الاستشعار اللاسلكية المستخدمة لخدمة أنظمة إنترنت الأشياء. بروتوكول التوجيه المقترح عليه التكيف مع متطلبات مختلفة من أجل تعزيز أداء التطبيقات الخاصة بإنترنت الأشياء. تم استخدام نوعية الارتباط، وعمق العقدة والطاقة كمقاييس لاتخاذ قرارات التوجيه. المقارنة مع البروتوكولات الأخرى أمر ضروري لإظهار التحسينات التي تم تحقيقها من خلال هذا العمل، وبالتالي تم اختيار بروتوكولات مصممة لخدمة نفس الغرض مثل AODV، REL و LABILE لمقارنة البروتوكول المقترح في هذا العمل معها. لإضافة التكاملية والشمولية، تم إضافة بعض الميزات الهامة واختبارها مثل دعم تطبيقات التفعيل ودعم خاصية الحركة للعقد. هذه الميزات مطلوبة بشكل كبير من قبل بعض تطبيقات إنترنت الأشياء وتحسين بروتوكول التوجيه لدورها أكثر ملائمة لأنظمة إنترنت الأشياء. تم اختبار بروتوكول التوجيه المقترح باستخدام نظام المحاكاة Castalia-3.2 وتم فحص جميع الحالات لإظهار التحسينات التي تم تحقيقها في كل حالة. حقق بروتوكول التوجيه المقترح أداء أفضل من البروتوكولات الأخرى فيما يخص نسبة تسليم البيانات والتأخير. فإنه يحافظ على موثوقية الشبكة لأنه لا يولد حزم البيانات بصورة عشوائية أو بدون حاجة. بروتوكول التوجيه مع الميزات المضافة (دعم المشغلات والتنقل) يظهر أداء جيداً. ولكن يتأثر هذا الأداء من خلال زيادة سرعة العقد المتنقلة.

**الكلمات الرئيسية:** إنترنت الأشياء، بروتوكول توجيه، شبكة الاستشعار اللاسلكية.

## 1. INTRODUCTION

The Internet of Things (IoT) applications are the new area of IT fields, these applications aim to collect the data from different sensing resources and transmit them to the internet, and then take a decision according to the different types of data captured and reply with an action after analyzing the data this action may deal with one or more devices according to the way the IoT server handles and analyzes the data, **Mazhelis, et al., 2013** and **Gubbi, 2013**. The data may be related to environment, business, society or health **Su, et al., 2013, Yang, and Pan, 2013**. Great diversity of IoT applications makes it necessary to build a routing protocol that can handle the differences among these applications and satisfy all the requirements needed to achieve the expected performance. The behavior of these applications must be taken into account during the design process, since IoT application collecting data mechanism contributes in defining the topology, and then imposes the Mechanisms used by the routing protocol to perform its task effectively.

It is essential to select routing metrics that routing protocol can use in the decision process. Link quality is the most important metric to be taken into account. The link quality can be calculated as signal to noise ratio (SNR), or signal to interference ratio (SINR) as an indicator of link status, **Baumann, et al., 2007** and **Rondinone, et al., 2008**. The energy metric will play an important role in routing decision process, **Su, et al., 2013, Patel, et al., 2013** and **Sridevi, et al., 2013**. The energy metric can be calculated as remaining energy or the ratio of the remaining energy to the total energy defined for each node, and sometimes the designer needs to select the node with the highest energy level and this can be done by avoiding the path having a node with minimum energy level, **Baumann, et al., and 2007, Chipara, 2010**. It may be required to use hop count metric to control the packet path and avoid using of path with too many hops which may lead to consume more energy and increase the latency **Machado, et al., 2013, Al-Fagih, 2013, and Farooq, and Jung, 2013**.

Change in mobility state of the nodes confers a kind of complexity to the design. The required Protocol must possess the ability to deal with all nodes regardless of their state. The nodes dealing with this type of routing protocol have to support the dynamic routing. So these nodes can deal with all other nodes without limitations. And that must be done by supporting different mechanisms to deal with messages from other nodes and not by imposing mechanism that are not used by other nodes. This approach facilitates the communication between the heterogeneous nodes and increases the network performance. The IoT routing protocol should serve the actuating data as well as the sensed data. Some IoT applications greatly rely on the data sent by the IoT server to the smart objects. The routing protocol must be fluent in dealing with this type of data and act with the same efficiency that it deals with data obtained from sensors. The powerful simulation tool that may be used to evaluate the mentioned cases is Castalia-3.2, which is designed for simulating wireless sensor network (WSN), Body Area Network (BAN) and generally networks of low-power embedded devices. It is based on the OMNeT++ platform which is an object-oriented modular discrete event simulator, **Boulis, 2009, and Varga, 2003**.

## 2. ROUTING PROTOCOL BASED ON ENERGY AND LINK QUALITY INDICATOR WITH LEVEL CONSTRAINT

End-to-end link quality will be calculated according to number of unreliable links along the path to the destination (SINK node). This mechanism will assign a quality indicator to reflect how many bad links there are in the path. The proposed routing protocol will start when the sink node broadcasts a control packet in the initialization phase including the source address and the remaining energy. This packet will be useful to acquire link quality value of related link and to

define the levels of nodes receiving this packet. Each node on receiving this control packet will wait for a period of time and rebroadcast the control packet to its neighbors after updating the packet fields.

After defining the level, a sink node will start a link quality calculation phase by broadcasting another packet to the neighboring nodes. This packet will have source field, normalized link quality of previous link field and link quality indicator field. Each node will set the link quality bad indicator according to their parents (nodes with level lower than the level of the current node); the node will decide that it has bad link quality if its next level parents have link quality values under  $LQ_{th}$ . So that the node will not broadcast a link quality packet until it receive the link quality packets from its parents, then the node will broadcast its link quality packet to inform its neighbors about its relationship with its parents. The normalized link quality value and bad link quality indicator are calculated according to Eq. (1) and Eq. (2), respectively:

$$\text{Normalized link quality} = \frac{(\text{current lq} * \text{normalized previous lq})}{(\text{current lq} + \text{normalized previous lq})/2} \quad (1)$$

$$\text{Bad indicator} = \text{current bad link indicator} + \text{previous bad link indicator} \quad (2)$$

After completing this process, the node will transmit or forward the data packet according to routing decision process described in algorithm 1:

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**Algorithm 1.** Routing Decision Process.

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- 1- Limit the search process to the parents (current level > next hop level).
- 2- Set the bad link indicator for the related link.
  - If link quality <  $LQ_{TH}$ 
    - o Then set currentbadlink indicator = 1
  - Otherwise
    - o Set currentbadlink indicator = 0
- 3- Search for the route with minimum *Bad indicator*.
  - This condition assumes the availability of sufficient remaining energy of candidate node.
- 4- If there are more than one route with the same Bad indicator value.
  - Search for the route that satisfy the optimization problem:

**Maximize**

$$(\text{Normalized link quality} \times 0.5) + (\text{remaining energy} \times 0.5)$$

$$\text{Subject to} \quad (3)$$

$$\text{Current level} > \text{next hop level}$$

$$(\text{current blqi} + \text{previous blqi})_S = (\text{current blqi} + \text{previous blqi})_O$$

**Where**

blqi: bad link quality indicator.

S: selected route.

O: other routes.

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### 3. ACKNOWLEDGEMENT AND ERROR CHECK

There are two approaches to handle the error check in order to ensure that the packets are delivered correctly to the final destination. The first approach is done by the network layer when the node receiving the packet responds by sending acknowledgement to the sender node. This approach will increase the flow of packets in the network and may cause high latency since the packets have to wait in the network layer TXbuffer until the acknowledgement is received. The packet forwarding and acknowledgement mechanism can be described in the algorithm 2:

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**Algorithm 2.** Packet forwarding and acknowledgement

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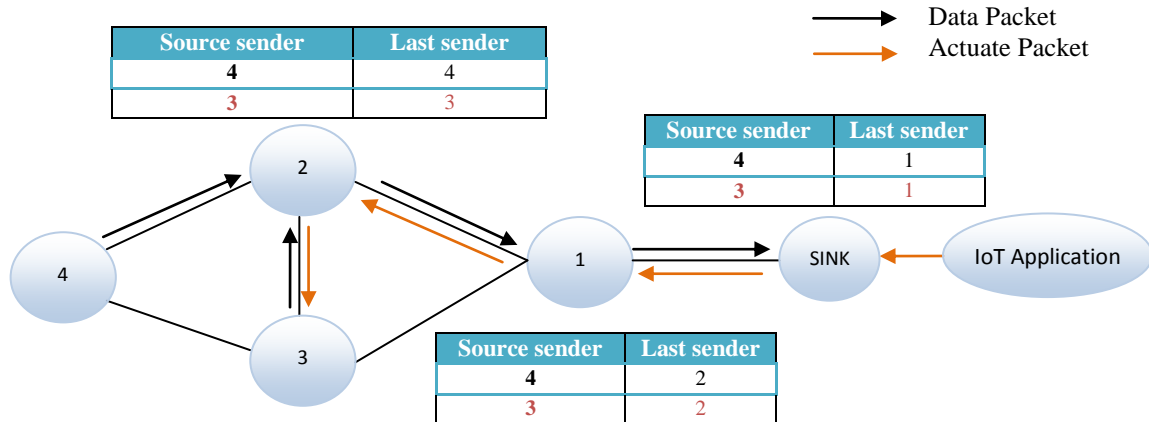
- 1- Find the route to forward the packet.
  - 2- Store a copy of the packet in network layer TXbuffer.
  - 3- Wait for acknowledgement.
    - If acknowledgement is received within specific time.
      - ✓ Remove the copy of specified packet.
    - Else
      - ✓ Send a copy of packet again and wait for acknowledgement.
  - 4- Repeat sending packet until receiving acknowledgement or exhausting all the tries of transmitting as configured in the protocol.
- 

The second approach is done by the MAC layer which is the last layer dealing with the packet; therefore this layer will have error check and retransmission mechanism. In this work, the proposed routing protocol relies on MAC protocol to handle the error check and acknowledgement which is supported by the simulator. The proposed routing protocol is designed to support real time connection, thus the network layer error check mechanism will double the packets that entering the network and may exploit the network resources and badly affect the performance.

### 4. ACTUATING PACKETS ROUTING

The proposed routing protocol handles the actuating packets by exploiting the same algorithm used in the approach in section 2. After implementing the routing tables, the nodes start transmitting their data packets and forwarding them to the SINK node. Each node, on receiving data packets, will implement another table to keep information about the source of data packets. Each node will store the information related to data packets which include the original sender and last forwarder. The SINK node and other forwarders will use this table to extract the next hop toward the destination (smart object of interest). The node will search its table for information related to the original sender which represent the destination of the control packet, the last forwarder will be the next hop of control packet. Forwarding of actuating packet process is shown in **Fig. 1**.





**Figure 1.** Forwarding actuating packet.

## 5. HANDLING MOBILITY

The proposed routing protocol will support both types of nodes, stationary and mobile nodes in order to give nodes the capability to support dynamic routing. The static node will forward their packets according to the proposed routing protocol in section 2. While the mobile nodes will follow a different procedure to send their packets and deliver them to the stationary node in order to ensure delivering them to the destination. Due to mobility, the mobile node may have different neighbors each time it tries to send data packets; therefore the mobile node will not take part in initialization phase to exchange control packets and will not send or forward link quality packets.

Each mobile node that has a data packet to transmit will broadcast RREQ packet to ask for available route to transmit its packet. The mobile node will store the data packet in the TXbuffer until receiving permission from its neighbors. The mobile node also stores its current geographical location to be used in routing decision process. The stationary node, on receiving RREQ packet, replies by sending RREP packet which includes the geographical location and the remaining energy of stationary node. Then the mobile nodes, on receiving RREP packet, will calculate whether the stationary node related to the RREP packet is suitable to be the next hop the destination or not. The routing decision process will be based on geographical locations, link quality and energy. The data transmission mechanism can be described in the algorithm 3:

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### Algorithm 3. Transmitting of mobile node data packet

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- 1- Arriving of data packet from application layer.
- 2- Store a copy of packets in TXbuffer and record the geographical information.
- 3- Broadcast RREQ packet.
- 4- Upon receiving RREP from neighboring node, the mobile node selects the available route according to the following:
  - Store the new geographical information.
  - Calculate the distance to the specified stationary node using the old stored geographical information using Eq. (4):

$$old\ distance = \sqrt{(OGM_x - GS_x)^2 + (OGM_y - GS_y)^2} \quad (4)$$

Where:

*OGM* :The old geographical location of mobile node.

*GS* :The geographical location of stationary node.

- Calculate the distance to the specified static node using the current stored geographical information using Eq. 5:

$$\text{current distance} = \sqrt{(CGM_x - GS_x)^2 + (CGM_y - GS_y)^2} \quad (5)$$

Where:

*CGM* :The current geographical location of mobile node.

- Acquire the energy and link quality information from RREP packet.
- The next hop candidate should satisfy the following conditions:
  - ✓ Sufficient remaining energy:  
Remaining Energy/Initial Energy > 10%
  - ✓ Acceptable link quality value:  
Link quality >  $LQ_{TH}$
  - ✓ Acceptable change in distance to ensure acceptable decreasing in Link quality value:

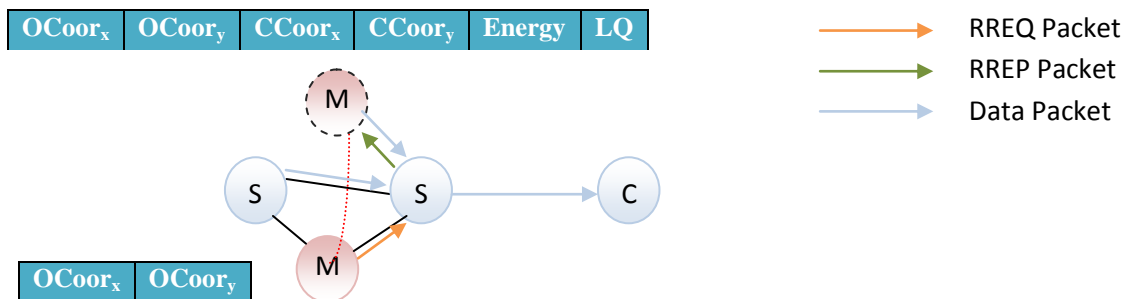
$$\text{current distance} < \text{old distance}$$

OR

$$(\text{old distance} - \text{current distance}) < (0.25 \times \text{old distance})$$

- 5- Send all the data packets in the TXbuffer to the selected static node.
- 6- When no nodes that sent RREP packet can satisfy the condition then Store the packet in TXbuffer and Wait for the next data packet

The stationary nodes have no available routes to the mobile nodes in their routing table, since the mobile nodes do not transmit any control or link quality packets. But the stationary nodes support both stationary and mobile nodes. This mechanism allows the dynamic routing and satisfies the requirement of IoT data Acquisition layer. The mobile nodes route request and data packets transmitting is shown in **Fig. 2**:



**Figure 2.** Route request and data transmitting of mobile nodes.

## 6. RESULTS AND DISCUSSION

### 6.1 Comparison with Other Protocols

The proposed routing protocol is tested as compared to other protocols in order to show the enhancement provided by this protocol which is represented by achieving the best results in different performance criteria. The routing protocols chosen to compare the proposed routing protocol with are:

- **AODV** Flat Routing Protocol v1 (Ad hoc on demand distance vector (**RFC 3561**)).
- **LABILE** Flat Routing Protocol v1 (Labile: Link quality-based lexical routing metric for reactive routing).
- **REL** Flat Routing Protocol ( A Routing Protocol Based on Energy and Link Quality for Internet of Things Applications).

All protocols are simulated using the default configurations equipped with other protocols (AODV, LABILE, REL). These configurations are listed in Table 1 shown below:

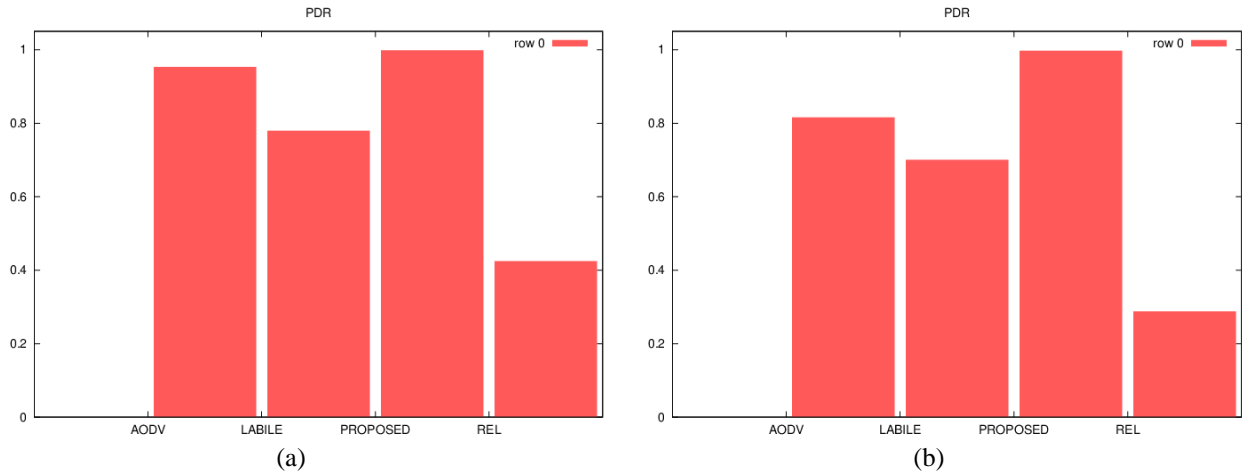
**Table 1.** Configuration used to compare protocols.

Number of nodes	50, 70
Simulation time	100 s
Field(x,y)	(30,30),(36,36)
Deployment	uniform
Initial energy	100
MAC protocol name	Tunable MAC
Application name	Throughput Test
Constant Data Payload	100
Application Packet rate	1
Startup Delay	0

The simulation shows the best results recorded by the proposed routing protocol as compared to other protocols as shown in **Fig. 3**. Since this protocol achieves high packet delivery ratio when tested using different area and number of nodes (PDR exceeds 99%). AODV records the second best result for both cases. For the first case (a), AODV achieves (95.3%). But it cannot keep this level when enlarging the field area and increasing the number of nodes as shown in **Fig. 3** (b). AODV achieves PDR value of 81.548% in the second case. Both REL and LABILE protocol show Bad PDR values, especially when increasing number of nodes and enlarging the area field.

The degradation in PDR value of these protocols is due to lose of large number of packets because of buffer overflow in communication routing layer. The REL and LABILE use mechanisms of routing that keep the packets for long time in the routing layer which may cause collecting large number of packets in this layer, thus losing new packets that are arriving but cannot find valid locations in routing layer buffer to wait for processing. The proposed protocol and AODV have no such problem because the packets do not have to wait in the network layer; the packets are processed and delivered to the MAC layer upon arrival from application or MAC layer. Losing of packets increases with increasing number of nodes and enlarging the field because of larger number of packets will enter the network and need to be processed. This problem may be caused also because of usage of number of hops as a constraint in these

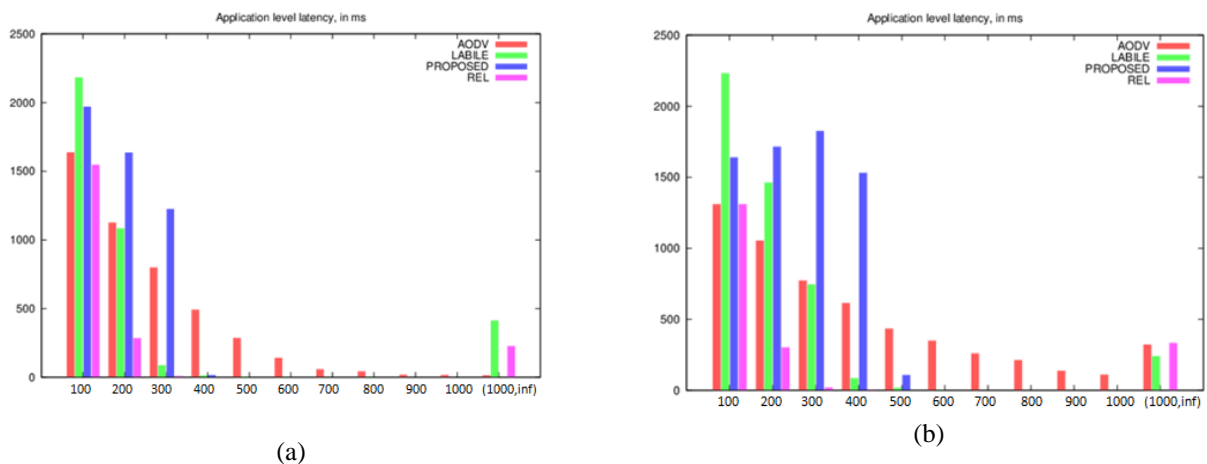
protocols. As depending on large number of hops may allow packets to traverse many hops before been delivered to the SINK node, thus increasing the traffic in the network.



**Figure 3.** Packet delivery ratio (a) 50 nodes, (b) 70 nodes.

The application latency results in **Fig. 4** shows best results for proposed routing protocol as taking into account the number of packets delivered correctly. The LABILE protocol seems to provide good results for large amount of packets (latency of less than 100 ms), but some packets processed by this protocol are delayed to more than 1 second. The same behaviour can be seen related to REL protocol, notice that the packets delivered by this protocol is much less the packets delivered by LABILE protocol. AODV shows reliable behaviour, but the latency recorded by this protocol still does not achieve the requirements, especially for such area fields and number of nodes. **Fig. 4** shows that the proposed protocol can deliver the packets in less than 300 ms for the first case and in less than 500 ms in the second case.

The increasing of number of nodes and enlarging the field will increase the node levels, thus increasing the hops required to reach the destination. The contention to get the carrier will be increased and the nodes that fail to win the carrier have to wait for (0.128 s) before next try to get the carrier in addition to other mechanisms that causes the delay such as back off time (16 ms). The contention problem increased with increasing the packet size, since the transmitting node will keep using the link to transmit a packet while other nodes try to get the link. The contention problem and latency increase with increasing the overhead caused by mechanism of specific protocol. AODV, REL and LABILE use RREQ and RREP mechanism during the initialization phase in order to discover the route to the destination.

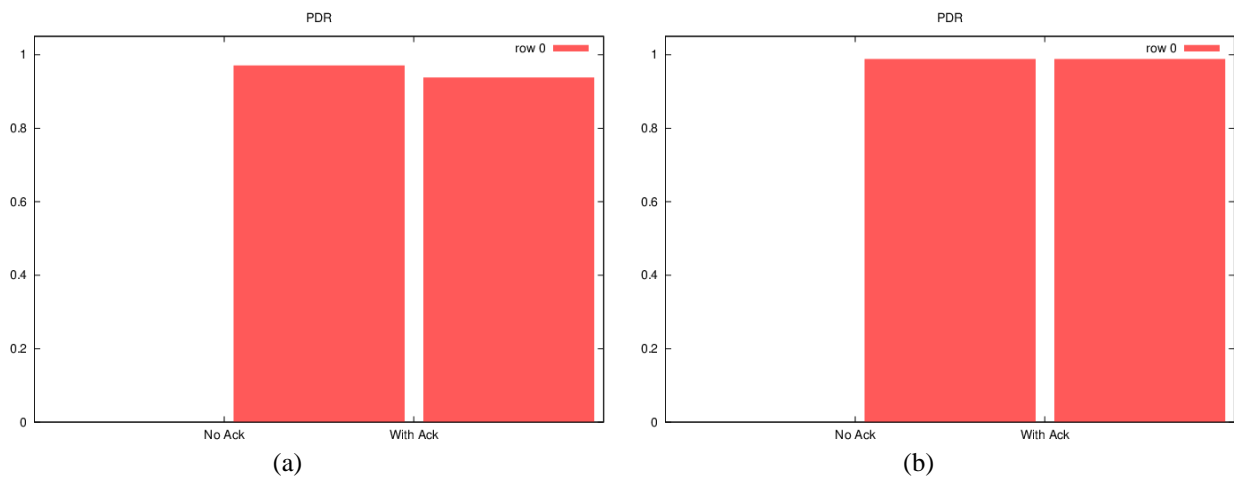


**Figure 4.** Application latency (a) 50 nodes (b) 70 nodes.

Actually, each node has to broadcast different types of packet in order to define the route to SINK node. In spite of that, most of these types will not have high payload, but it may cause high traffic in the network that may cause collision and losing packets, as well as increasing the contention and increasing the latency.

## 6.2 Acknowledgement and Error Check

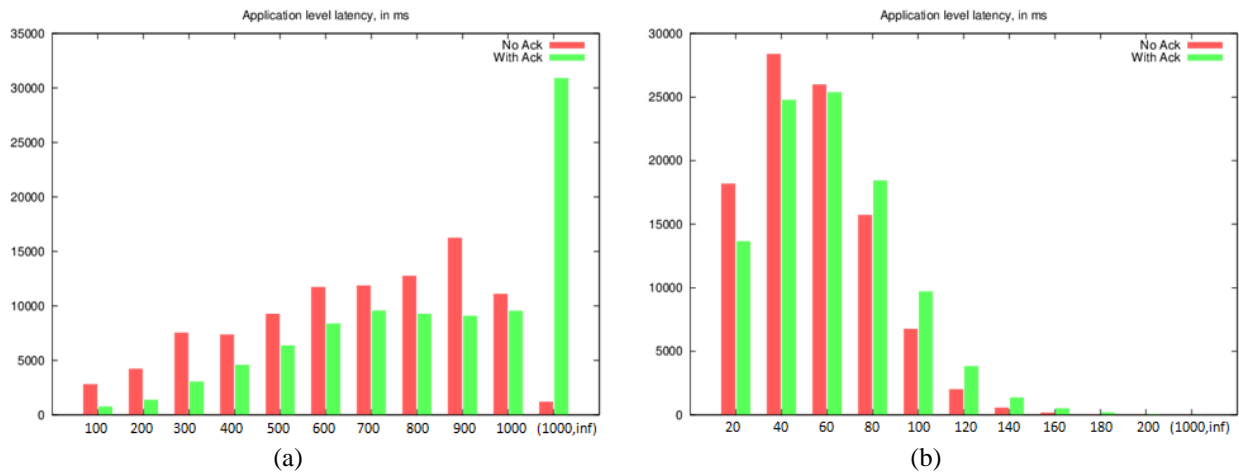
The proposed routing protocol is simulated with and without the acknowledgement mechanism to show the impact of carrying out error check in the network layer. The protocol is tested using two different applications; the first application is throughput test which is using high payload (100 Bytes) and the second application is value reporting application which uses lower payload (12 Bytes). Both experiments are done using 100 nodes and the simulations are run for 1000 seconds. The results in **Fig. 5 (a)** show better packet delivery ratio when relying on MAC protocol for error check. Notice that the acknowledgement mechanism will cause MAC buffer lack problem; therefore it's necessary to use higher MAC buffer in order to reduce the impact of this problem and achieve higher packet delivery ratio (MAC Buffer = 64 or higher). The **Fig. 5 (b)** shows that PDR is not affected when reducing the payload which represents the most normal configurations for wireless sensor network. Notice that reducing data rate of throughput test to 0.5 (sending 1 packet each 2 seconds) will record PDR of 97.1%.



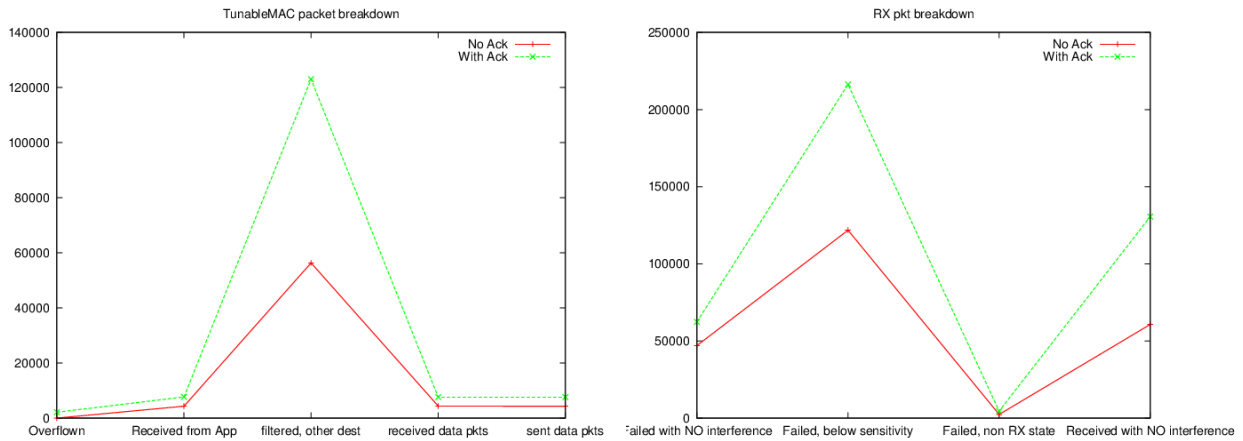
**Figure 5.** PDR for data rate 1 with different applications (a)throughput test (b)value reporting.

The error check mechanism will greatly affect the latency for both types of applications, because this mechanism will increase the number of packets flowing in the network which increases the contention and causes the packets to be delayed until the acknowledgements are received. The application level latency for both applications with/or without acknowledgement is shown in **Fig. 6**. **Fig. 7** shows the increasing of packets when using acknowledgement mechanism, and also shows the overflow caused by this mechanism in spite of enlarging the MAC Buffer.





**Figure 6.** Latency for different applications (a) throughput test (b) value reporting.



**Figure 7.** packets generated due to using proposed protocol

### 6.3 Sensing and Actuating Routing

The proposed routing protocol supporting the actuating capabilities is simulated with 100 nodes and 1000 second for simulation time. The results show acceptable PDR and latency for actuating various nodes which represents different levels in the network. PDR and latency results of actuating nodes are listed in **Table 2**.

**Table 2.** PDR and Latency of different level nodes

	Node 39	Node 2	Node 91
	Level 3	Level 5	Level 8
<b>PDR</b>	94.949%	95.959%	95.959%
<b>Latency</b>	0.33018s – 0.908s	0.84199s – 0.925s	0.81303s – 1.084s

### 6.4 Dynamic Routing Simulation

The routing decision process of mobile nodes is simulated using four mobile nodes which are moving linearly in the field. The configuration of simulation is listed in **Table 3** below:

**Table 3.** Mobility simulation configuration.

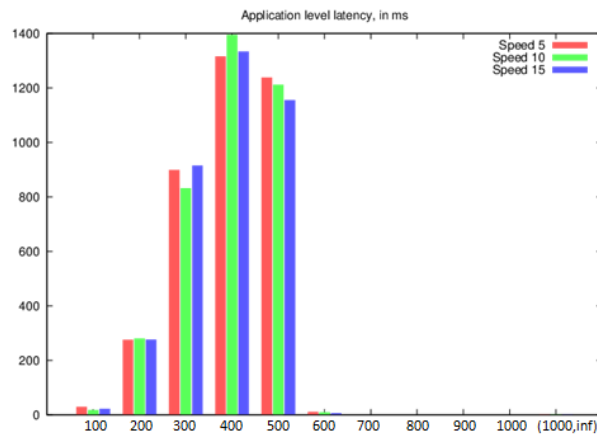
<b>Number of nodes</b>	54			
<b>Simulation time</b>	1000 s			
<b>Field(x,y)</b>	(71,71)			
<b>Deployment</b>	[0..49]->uniform			
<b>Initial energy</b>	100			
<b>[0..49].Mobility manager name</b>	No Mobility Manager (Stationary nodes)			
<b>[50..53].Mobility manager name</b>	Line Mobility Manager (Mobile nodes)			
<b>Mobility manager speed</b>	5,10,15			
	<b>Node 50</b>	<b>Node 51</b>	<b>Node 52</b>	<b>Node 53</b>
<b>Initial location</b>	(0,0)	(71,0)	(35,0)	(0,35)
<b>Destination</b>	(71,71)	(0,71)	(35,71)	(71,35)
<b>Application name</b>	Throughput Test			
<b>MAC protocol name</b>	Tunable MAC			
<b>MAC Buffer size</b>	32			
<b>Application packet rate</b>	1			

The results of simulating the proposed routing protocol for mobile nodes show highly acceptable packet delivery ratio for all mobile nodes with different suggested speed. The PDR decreases slightly when increasing the speed. Actually, it is not possible to completely relate the PDR to the speed of mobile nodes. PDR may depend on many parameters such as end-to-end link quality when mobile node successes in delivering the packet to the stationary node but the stationary node fails in delivering the packet successfully. PDR values for different speeds are listed in **Table 4**.

**Table 4.** PDR of mobile nodes and different speeds.

	<b>Node 50</b>	<b>Node 51</b>	<b>Node 52</b>	<b>Node 53</b>
<b>Speed 5</b>	95.095%	95.595%	93.393%	93.193%
<b>Speed 10</b>	93.693%	92.892%	94.594%	93.793%
<b>Speed 15</b>	93.993%	93.593%	91.991%	91.691%

All cases record acceptable application level latency, since all packets from mobile nodes arrives to their destination with latency ranges between 0.1s - 0.6s. The latency of individual packet may rely on the selection process, since the stationary node must satisfy routing conditions imposed by mobile nodes before the packets can be transmitted. Therefore packets considered to be delivered quickly may be delayed until finding the required node. The latency results of mobile nodes are shown in **Fig. 8**.



**Figure 8.** Latency of mobile nodes packets with different speed.

## 7. CONCLUSIONS

Sensing and actuating IoT applications require that routing protocol must deal with both types of data and forward them correctly to their last destination; each type requires different algorithm. End-to-end link quality and energy are main metrics used to forward the sensed data toward the SINK node and then to internet to be analyzed. While the actuating data can be forwarded using the history of sending sensed data in order find their way to the destination specified by IOT application.

Acknowledgement and error check are not essential to be achieved by the network layer, since it is one of MAC layer task because this layer is the last layer dealing with the packet. Mobility of nodes must be supported and efficiently handled by using the geographical locations of node during the sending of RREQ and RREP messages to the stationary neighboring nodes. Speed is an important factor that affects the performance but other metrics must be taken into account such as link quality and energy.

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## Phenol Removal Using Granular Dead Anaerobic Sludge Permeable Reactive Barrier in a Simulated Groundwater Pilot Plant

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### ABSTRACT

This study investigates the performance of granular dead anaerobic sludge (GDAS) bio-sorbent as permeable reactive barrier in removing phenol from a simulated contaminated shallow groundwater. Batch tests have been performed to characterize the equilibrium sorption properties of the GDAS and sandy soil in phenol-containing aqueous solutions. The results of GDAS tests proved that the best values of operating parameters, which achieve the maximum removal efficiency of phenol ( $=85\%$ ), at equilibrium contact time ( $=3$  hr), initial pH of the solution ( $=5$ ), initial phenol concentration ( $=50$  mg/l), GDAS dosage ( $=0.5$  g/100 ml), and agitation speed ( $=250$  rpm). Fourier transform infrared (FTIR) analysis proved that the carboxylic acid, aromatic, alkane, alcohol, and alkyl halides groups are responsible for the bio-sorption of phenol onto GDAS.

A 2D advection-dispersion, solved numerically by computer solutions (COMSOL Multiphysics 3.5a software which is based on the finite element method, has been used to simulate the equilibrium transport of phenol within groundwater. This model is taking into account the pollutant sorption onto the GDAS and sandy soil which is represented by Langmuir equation. Numerical and experimental results proved that the barrier plays a potential role in the restriction of the contaminant plume migration. Also, the barrier starts to saturate with contaminant as a function of the travel time. A good agreement between the predicted and experimental results was recognized with root mean squared error not exceeded the 0.055.

**Key words:** granular dead anaerobic sludge, phenol, permeable reactive barrier, transport.

### حماية المياه الجوفية من التلوث بالفينول باستخدام الكتلة البايولوجية المازة كجدار تفاعلي نفاذ

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### الخلاصة

تهدف الدراسة الحالية الى معرفة امكانية استخدام الحماء اللاهوائية كمادة مازة عضوية ضمن الحاجز التفاعلي النفاذ في المعالجة الموقعية للمياه الجوفية لازالة الفينول من الطبقة الملوثة ذات الأعماق الضحلة. في اختبارات الدفعة تم دراسة تأثير عدة متغيرات تشغيلية لتحديد خواص عملية الامتزاز للفينول بواسطة الحماء اللاهوائية والتربة الرملية. أن افضل قيم لهذه المتغيرات والتي تم من خلالها الحصول على اعلى كفاءة ازالة للفينول ( $=88\%$ ) هي زمن التماس ( $=3$  ساعة)، الدالة الحامضية ( $=5$ )، التركيز الابتدائي ( $=50$  ملغم/لتر)، كمية المادة الممتزة ( $=5$  غم/100 مليلتر)، وسرعة الاهتزاز ( $=250$  دورة/دقيقة). ان التحليل باستخدام الاشعة تحت الحمراء اثبت ان مجاميع الاروماتيك، الكربوكسيل وهاليدات الالكيل والكحول هي المجاميع الفعالة المسؤولة عن عملية الامتزاز البايولوجي للفينول.

تم حل معادلة انتقال الملوث الذائب ذات البعدين بواسطة برنامج الكومسول الذي يعتمد على طريقة العناصر المحددة لمحاكاة عملية انتقال الفينول خلال المياه الجوفية، ان هذا النموذج يأخذ بنظر الاعتبار عملية امتزاز الملوث على الحماء



اللاهوائية والترربة الرملية والتي تخضع لمعادلة لانكميز. النتائج التي تم الحصول عليها من النماذج الرياضية وكذلك النتائج المختبرية اثبتت بان الجدران التفاعلية النفاذة تلعب دورا مهما في ازالة وتقييد حركة الملوث كما وبينت ان تلك الجدران تبدا بالتشبع بالملوث مع الزمن، اخيرا لوحظ وجود توافق جيد بين النتائج العملية والحلول العددية للنماذج الرياضية حيث كان جذر متوسط مربع الخطأ لا يتجاوز 0.055 .

## 1. INTRODUCTION

The treatment and protection of groundwater and surface water are the significant problems which need to be resolved as fast as possible. Groundwater can be polluted mainly with pollutants from dumping sites, municipal landfills, petrol stations, airports, agriculture, chemical plants, etc. Contaminants from the above mentioned sources flow downward in the unsaturated zone, reach the groundwater and in the form of diluted solution flow horizontally and can pollute surface water like rivers, lakes, etc. There are more than 30 types of technologies for treating groundwater and contaminated soil. Each of them is effective in particular conditions. PRB technology is an interesting method for groundwater remediation and is used when contaminants are in the saturated zone. This novel technique of groundwater remediation is a passive one; contaminants are removed from an aquifer by the flow through a reactive barrier filled with a reactive material, **Mieles, and Zhan, 2012**. The advantages of this technology include treatment of contaminants in the subsurface, complete plume capture, a passive (low energy) treatment approach that has considerably lower operation and maintenance costs and lower long-term performance monitoring costs, **Powell, et al., 2002**.

The most common technology used historically for remediation of groundwater has been ex-situ pump-and-treat technique. This technique is difficult, costly and ineffective most of the time in removing enough contamination to restore the groundwater to drinking water standards in acceptable time frames, **Gillham, and Burris, 1992**. The primary reason for the failure of pump and treat is the inability to extract contaminants from the subsurface due to hydro-geologic factors and trapped residual contaminant mass. Accordingly, PRBs technology was alternative method used to remediate groundwater contaminated with different types of contaminants. Many studies on PRBs using different types of reactive medium such as activated carbon, zeolite and others for treatment of inorganic and organic pollutants in groundwater have been achieved. The batch experiments showed that activated carbon is highly effective in removing of phenol, p-chlorophenol, and p-nitroaniline. Its extraordinarily high surface area and unique surface chemistry account for the difference in capacity with other carbonaceous materials like brown coal, graphite, and coke, **Ambrosini, 2004**. The adsorption and biodegradation processes used in PRB technology were selected to assess the possibility of removal of benzene and phenols from groundwater contaminated by a dumping site located in a city in Upper Silesia, Poland. Groundwater treatment parameters for granulated active carbon as a reactive material in adsorption process were measured with the Freundlich isotherm, and for a mixture of coarse sand and granulated peat in biodegradation process they were determined with the first-order kinetics equation, **Suponik, 2010**. A three series barrier system to treat high concentrations of TCE (= 500 mg/l) in synthetic groundwater was constructed. This system consisted of three reactive barriers using iron fillings as an iron-based barrier in the first column, sugarcane bagasse mixed with anaerobic sludge as an anaerobic barrier in the second column, and a biofilm coated on oxygen carbon inducer releasing material as an aerobic barrier in the third column. The efficiency of the three series barrier system in removing TCE was approximately 84% in which the removal efficiency of TCE by the iron filling barrier, anaerobic barrier and aerobic barrier were 42%, 16% and 25%, respectively, **Teerakun, et al., 2011**.

The regular biological activities of municipal wastewater treatment plants release large quantities of by-product granular dead anaerobic sludge (GDAS). Thus, re-using of this by-

product as a reactive medium in PRBs is attractive in terms of sustainable development, and reduced disposal costs. Accordingly, the aims of the present study are: (1) investigation the sorption of phenol (Ph) onto GDAS and sandy soil; (2) finding the predominant functional groups responsible of phenol removal process depended on the Fourier transfer infrared spectroscopy (FTIR) analysis; and (3) characterization the 2D equilibrium transport of Ph theoretically, using COMSOL Multiphysics 3.5a (2008) software, and compare it with experimental data.

## 2. MATERIALS AND METHODS

### 2.1 Medium and Contaminant

The GDAS was dried at atmospheric temperature for 5 days and, then, sieved into (1/0.6) mm diameter mesh. This portion was washed five times in distilled water and dried at 70°C for 6 hours prior to usage, **Mathews, and Zayas, 1989**. Table 1 shows the physical and chemical characteristics of GDAS used in the present study. These characteristics were measured in the Oil Research and Development Centre / Ministry of Oil / Iraq.

The sandy soil, with porosity of 0.41, was used as aquifer in the conducted experiments. This soil had a particle size distribution ranged from 63  $\mu\text{m}$  to 0.71 mm with an effective grain size,  $d_{10}$ , of 110  $\mu\text{m}$ , a median grain size,  $d_{50}$ , of 180  $\mu\text{m}$  and a uniformity coefficient,  $C_u = d_{60}/d_{10}$ , of 1.73. The hydraulic conductivity and bulk density equal to  $4.22 \times 10^{-3}$  cm/s and  $1.563 \text{ g/cm}^3$ , respectively Phenol (manufactured by BDH, England) was selected as a representative of organic contaminants.

The required tests for specifying the characteristics of the soil and GDAS are carried out at; Iraqi Geological Survey-Ministry of Industry and Minerals, and Oil Research and Development Centre-Ministry of Oil.

### 2.2 Batch Experiments

These tests were carried out to specify the best conditions of contact time, initial pH of the solution, initial concentration of contaminant, dosage of sorbent and agitation speed. Six flasks of 250 ml are employed and each flask is filled with 100 ml of Ph solution which has initial concentration of 50 mg/l and initial pH=5. About 0.25 g of adsorbent was added into each flask and these flasks were kept stirred in the high-speed orbital shaker at 250 rpm. A fixed volume (20 ml) of the solution was withdrawn from each flask after different periods of time. This withdrawn solution was filtered to separate the adsorbent and a fixed volume (10 ml) of the clear solution was pipetted out for the concentration determination of phenol still present in solution. The measurements were carried out using high performance liquid chromatography (HPLC) (SHIMADZU, JAPAN). The adsorbed concentration of phenol on the reactive material was obtained by a mass balance. These tests were conducted with different values of initial pH (3, 4, 5, 6 and 7), initial concentration of Ph (50, 100, 150, 200 and 250 mg/l), adsorbent dosage (0.15, 0.25, 0.5, 1, 2 and 3 g added for 100 ml of solution) and agitation speed (0, 50, 100, 150, 200 and 250 rpm). From the best experimental results, the amount of phenol retained in the GDAS phase,  $q_e$ , was calculated using Eq.(1), **Wang, et al., 2009**:

$$q_e = (C_o - C_e) \frac{V}{m} \quad (1)$$

where  $C_o$  and  $C_e$  are the initial and equilibrium concentrations of phenol in the solution (mg/l),  $V$  is the volume of solution (l), and  $m$  is the mass of GDAS (g).

### 2.3 Description of Equilibrium Isotherm Data

They were produced by plotting the  $q_e$  against the  $C_e$  at constant temperature. Six isotherm models are used for the description of sorption data as follows, **Hamdaoui, and Naffrechoux, 2007**.

- **Langmuir model:** assumes uniform energies of adsorption onto the surface and no transmigration of adsorbate in the plane of the surface. It can be written as:

$$q_e = \frac{q_m b C_e}{1 + b C_e} \quad (2)$$

$q_m$  is the maximum adsorption capacity (mg/g) and  $b$  is the constant related to the free energy of adsorption (l/mg).

- **Freundlich model:** is quantified by:

$$q_e = K_F C_e^{1/n} \quad (3)$$

where  $K_F$  is the Freundlich sorption coefficient and  $n$  is an empirical coefficient indicative of the intensity of the adsorption.

- **Elovich model:** is based on a kinetic principle assuming that the adsorption sites increase exponentially with adsorption, which implies a multilayer adsorption. It can be expressed as:

$$\frac{q_e}{q_m} = K_E C_e \exp\left(-\frac{q_e}{q_m}\right) \quad (4)$$

where  $K_E$  is the Elovich equilibrium constant (l/mg) and  $q_m$  is the Elovich maximum adsorption capacity (mg/g).

- **Temkin model:** assumes that the heat of adsorption of all the molecules in the layer decreases linearly with coverage due to adsorbent–adsorbate interactions, and that the adsorption is characterized by a uniform distribution of the binding energies, up to some maximum binding energy. This model is given by:

$$\theta = \frac{RT}{\Delta Q} \ln K_o C_e \quad (5)$$

where  $\theta (=q_e/q_m)$  is the fractional coverage,  $R$  is the universal gas constant ( $\text{kJ mol}^{-1} \text{K}^{-1}$ ),  $T$  is the temperature (K),  $\Delta Q$  is the variation of adsorption energy ( $\text{kJ mol}^{-1}$ ), and  $K_o$  is the Temkin equilibrium constant (l/mg).

- **Kiselev model:** is known as the adsorption isotherm in localized monomolecular layer and can be expressed by:

$$k_1 C_e = \frac{\theta}{(1-\theta)(1+k_n \theta)} \quad (6)$$

where  $k_1$  is the Kiselev equilibrium constant (l/mg),  $\theta (=q_e/q_m)$  is the fractional coverage, and  $k_n$  is the constant of complex formation between adsorbed molecules.

- **Hill–de Boer model:** describes the case where there are mobile adsorption and lateral interaction among adsorbed molecules. This model is given by:

$$k_1 C_e = \frac{\theta}{1-\theta} \exp\left(\frac{\theta}{1-\theta} - \frac{k_2 \theta}{RT}\right) \quad (7)$$

where  $k_1$  is the Hill-de Boer constant (l/mg), and  $k_2$  is the energetic constant of the interaction between adsorbed molecules (kJ/mol).

## 2.4 Continuous Experiments

**Fig.1** shows the schematic diagram of the bench-scale model aquifer used in the present study. The simulated Ph transport was performed in a two-dimensional tank. The bench-scale model aquifer is contained within a rectangular 6 mm thick Perspex glass tank (100 cm L × 40 cm W × 10 cm D). This means that all sides of the tank were transparent to allow for visual observations. Two vertical perforated plates as partitions covered with filtration screen were used. These partitions are provided the lateral boundaries of the sand-filled middle compartment which has dimensions 80×40×10 cm. The purpose of the two outer compartments, i.e. influent and effluent chambers, was controlling the position of the watertable within the model aquifer deposited in the middle compartment and, in addition, controlling the wetting of this aquifer mass. Each outer compartment has dimensions of 10 cm long, 40 cm width and 10 cm high. The flow through the model aquifer was accomplished by storage tank, two constant head tanks, and flow-meter. One value of flow rate (1000 ml/min) is selected here with corresponding seepage velocity equal to 175.6 m/day.

Sampling plate, **Fig.2**, was placed on the top of the Perspex glass tank to support the sampling ports. This plate contains 4 columns and 2 rows of sampling ports designated from P1 to P8. Aqueous samples from the model aquifer were collected using stainless syringes at specified periods. The contaminant solution was introduced through the model aquifer from cubic source which was located at side of the aquifer. This source (5 cm D x 10 cm W x 10 cm L) was simulated a continuous release of contamination.

At the beginning of each test, the middle compartment was packed with 5 cm depth model aquifer. The model aquifer consisted from three parts. The first part represented by 60 cm long of the sandy soil measured from left side of the tank. The second part represented by 10 cm long barrier of reactive material placed beside the packed soil. Again, 10 cm of the sandy soil represented the third part was placed beside this barrier. The aquifer was then filled with water and left overnight to settle and saturate of this soil. Then, the packed aquifer was flushed at maximum velocity until the effluent water was free of suspended fine material.

Monitoring of Ph concentrations within the aquifer model in the effluent from sampling ports was conducted for a period of 5 day. Water sample of (3-5) ml volume was taken regularly (after 0.5, 1, 2, 3, 4 and 5 day) from each port. The samples were immediately introduced in glass vials and then analyzed by HPLC. At the end of each experiment, the soil was removed from the tank. The tank was soaked in a dilute NaOH solution and then rinsed first with tap water and finally with distilled water to avoid cross contamination between experiments.

A tracer experiment, adopted the same procedure of, **Ujfaludi, 1986**, was performed to determine the effective longitudinal dispersion coefficient for the sandy soil and GDAS.

## 2.5 FTIR Analysis of GDAS

This analysis has been considered as a kind of direct means for investigating the sorption mechanisms by identifying the functional groups responsible for binding of Ph onto GDAS, **Chen, et al., 2008**. The characteristics bands of the GDAS before and after the Ph uptake at pH=5 were used to assess the changes in the functional groups of this material. Flask of 250 ml was filled with 100 ml of contaminant solution with concentration of 50 mg/l and 0.5 g of GDAS was

added. The flask was agitated for equilibrium time at 250 rpm. Infrared spectra of GDAS samples before and after bio-sorption of  $Pb^{+2}$  and Ph were examined using (SHIMADZU FTIR, 800 series spectrophotometer).

### 3. RESULTS AND DISCUSIONS

#### 3.1 Fourier Transform Infrared (FTIR) Analysis

Infrared spectra of GDAS samples before and after bio-sorption of Ph were examined. These spectra were measured within the range  $400-4000\text{ cm}^{-1}$  as shown in **Fig. 3** and **Table 2**. The shifts in the IR frequencies support that aromatic, phosphines, carboxylic acid, alkyl halides, and alcohol groups are responsible for the bio-sorption of phenol onto GDAS, **Doke, et al., 2012**.

#### 3.2 Influence of Batch Operating Parameters

**Fig. 4** shows the effect of contact time and initial pH of solution on phenol sorption using 0.25 g of GDAS added to 100 ml of Ph solution for batch tests at 25 °C. This figure shows that the sorption rate was very fast initially and it's increased with increasing of contact time until reached the equilibrium time ( $\approx 3$  hr). This may be due to the presence of large number of adsorbent sites available for the adsorption of Ph. As the remaining vacant surfaces decreasing, the sorption rate slowed down due to formation of repulsive forces between the Ph on the solid surfaces and in the liquid phase, **El-Sayed et al., 2010**. Also, the increase in the Ph removal as the pH increases can be explained on the basis of a decrease in competition between proton and phenol for the surface sites which results in a lower columbic repulsion of the sorbing phenol. However, further increase in pH values would cause a decreasing in removal efficiency. It is clear from this figure that the maximum removal efficiency of Ph was achieved at initial pH of 5.

**Fig. 5** presents the removal efficiency of Ph as a function of different doses of GDAS ranged from 0.15 to 3 g added to 100 ml of solution. It can be observed that removal efficiency of the GDAS improved with increasing adsorbent dosage from 0.15 g to 0.5 g for a fixed phenol initial concentration.

**Fig. 6** explains that the removal efficiency of Ph decreased from 85% to 44% with increasing the initial concentration from 50 to 250 mg/l. This plateau represents saturation of the active sites available on the GDAS samples for interaction with ions of contaminant.

**Fig. 7** shows that about 8% of the phenol was removed before shaking (agitation speed= zero) and the uptake increases with the increase of shaking rate. There was gradual increase in contaminant uptake when agitation speed was increased from zero to 250 rpm at which about 85% of Ph has been removed. This can be attributed to improving the diffusion of ions towards the surface of the reactive media and, consequently, proper contact between ions in solution and the binding sites can be achieved.

#### 3.3 Sorption Isotherms

The sorption data for phenol on GDAS are fitted with linearized forms of (Langmuir, Freundlich, Temkin, Elovich, Kiselev, and Hill-de Boer) models. Additionally, the sorption data of sandy soil are fitted only with Langmuir and Freundlich models. **Table 3** presents the fitted parameters and coefficient of determination ( $R^2$ ) for each model. It is clear that the Langmuir isotherm model provided the best correlation in compared with other models. Accordingly, this model will be used to describe the sorption of Ph in the partial differential equation (PDE) governed the transport of a solute in the continuous mode.



### 3.4 Longitudinal Dispersion Coefficient

Results of the experimental runs concerned the measurement of longitudinal dispersion coefficient ( $D_L$ ) at different values of velocity ( $V$ ) for soil and GDAS are taken a linear relationship as follows:

$$D_L = 22.900 V + 0.871 \quad R^2=0.9172 \quad [\text{Soil}] \quad (8)$$

$$D_L = 53.944 V + 0.297 \quad R^2=0.9792 \quad [\text{GDAS}] \quad (9)$$

These equations are taken the general form of longitudinal hydrodynamic dispersion coefficient as follows:

$$D_L = \alpha_L V + D^* \quad (10)$$

where  $D^*$  is the effective molecular diffusion coefficient. This means that the longitudinal dispersivity ( $\alpha_L$ ) is equal to 22.9 cm for soil and 53.944 cm for GDAS.

### 3.5 Two-Dimensional Model Development

The contaminant migration in a porous medium is due to advection-dispersion processes; therefore, considering a two dimensional system (unidirectional fluid flow and 2D transient solute transport), the dissolved phenol mass balance equation may be written, as follows:

$$D_x \frac{\partial^2 C_{Ph}}{\partial x^2} + D_y \frac{\partial^2 C_{Ph}}{\partial y^2} - V_x \frac{\partial C_{Ph}}{\partial x} = \frac{\partial C_{Ph}}{\partial t} + \frac{\rho_b}{n} \frac{\partial q}{\partial t} \quad (11)$$

where  $C_{Ph}$  represents phenol mass concentration in water,  $q$  the phenol concentration on solid, and  $\rho_b$  the dry adsorbing material bulk density. Under isotherm conditions, the second term ( $q$ ) on the right hand side of this equation can be substituted by Langmuir model (Eq. (2)). Table 4 is summarized the model geometry, boundary value problem (i.e. governing equations, initial conditions, and boundary conditions), and solution procedure for simulated 2D problem adopted in the present study.

**Fig. 8** describes the predicted surface and contour plot of phenol normalized concentrations across the laboratory 2D sandy soil packed tank in the presence of PRB after 1, 3, 7, and 10 day for flow rate equal to 500 ml/min. It is clear that the propagation of contaminated plume is restricted by the GDAS in the barrier region and the functionality of barrier will decrease with time because the decreasing of retardation factor.

**Fig. 9** explains the effect of the applied flow rate, i.e. velocity of flow, on the extent and concentration magnitudes of the phenol plume. It is clear that the extent of contaminant plume in the longitudinal (X) direction is greater than transverse (Y) direction and this is consistent with assumption of unidirectional velocity adopted here. Also, highest concentrations occur in the sand bed which up-gradient of PRB. It is clear that the functionality of barrier will decrease with increasing the velocity of flow because the increasing penetration of the contaminant plume.

**Figs. 10 and 11** present the comparison between the predicted and experimental results at nodes corresponding to monitoring ports (P1 to P8) during the migration of the phenol plume at different periods of time for flow rate equal to 1000 ml/min. Concentration values in the ports (P1, P2, P3, and P4) located along the centerline of the source area ( $Y=20$  cm) are greater than that in the ports (P5, P6, P7, and P8) deviated from the centerline by 10 cm (i.e.  $Y=10$  cm). Also, one can be recognized the potential functionality of the GDAS in the retardation of the

contaminant migration when compared between the concentrations of ports (P3 and P4) or (P7 and P8). The shape of these curves is taken the S-curve in the ports located at furthest distance from line source such as P3 and P4. A good agreement between the predicted and experimental results can be observed with root mean squared error (RMSE), **Anderson, and Woessner, 1992**, not exceeded the 0.055.

#### 4. CONCLUSION

- Depended on batch tests, the best values of parameters affected on the bio-sorption/sorption process onto GDAS and sandy soil respectively were contact time=3 hr, initial pH of the solution=5, initial concentration=50 mg/l, sorbent dosage= 0.5 g/100 ml, and agitation speed=250 rpm.
- Phenol sorption data on the GDAS and soil were correlated reasonably well by the Langmuir sorption isotherm with coefficient of determination ( $R^2$ ) equal to 0.9944 and 0.9927, respectively.
- As proved by FTIR analysis, the carboxylic acid, aromatic, alkane, alcohol, and alkyl halides groups are responsible for the bio-sorption of phenol onto GDAS.
- The results of 2D numerical model under equilibrium condition proved that the GDAS barrier is efficient in the restriction of contaminant plume and the functionality of the barrier will decrease with increasing the travel time and the velocity of flow. A good agreement between the predicted and experimental results was recognized with RMSE not exceeded the 0.055.

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## NOMENCLATURE

$a$ = empirical constant, l/g.

$b$ = saturation coefficient, mg/g.

$C/C_o$ = normalized concentration.

$C_e$ = equilibrium concentration, mg/l.

$C_o$ = initial concentration of metal, mg/l.

$D^*$ = effective molecular diffusion coefficient, m<sup>2</sup>/sec

$D$ = hydrodynamic dispersion coefficient, m<sup>2</sup>/sec.

$K_F$ = Freundlich sorption coefficient.

$m$ = mass of zero-valent iron in the flask, g.

$n$ = porosity.

$q_e$ = amount of solute removed from solution, mg/kg.

$R$ = retardation factor.

$t$ = travel time, sec.

$V$ = volume of solution in the flask, l.

$V_x$ = velocity of flow in the direction  $x$ , m/sec.

$\alpha_L$ = longitudinal dispersivity, cm.

$\rho_b$ = bulk density of the soil, g/cm<sup>3</sup>.

**Table 1.** Physical and chemical characteristics of GDAS.

Physical properties	GDAS
Actual density (kg/m <sup>3</sup> )	1741.6
Apparent density (kg/m <sup>3</sup> )	609.9
BET surface area (m <sup>2</sup> /g)	94.53
Bed porosity	0.45
Average particle diameter (mm)	0.775
Pore volume (cm <sup>3</sup> /g)	0.544
Chemical properties	GDAS
pH	7.5
Ash content (%)	12
Cation exchange capacity (CEC, meq/100 g)	51.153
Organic volatile solid (V.S, 10 <sup>6</sup> mg/l)	0.135
Non-volatile solid (N.V.S, 10 <sup>6</sup> mg/l)	0.018

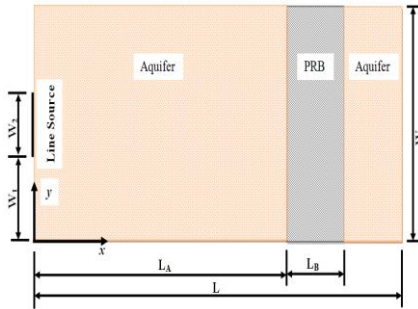
**Table 2.** Functional groups responsible for phenol bio-sorption onto GDAS.

FTIR peak	Wave No. (cm <sup>-1</sup> )	Type of bond	Functional group	Displacement (cm <sup>-1</sup> )
1	514.33	-C-Br <sup>-</sup>	alkyl halides	4
2	796.54	-PH <sup>+</sup>	phosphines	11
3	875.62	-CH <sup>+</sup>	aromatic	13
4	1028.11	-C-O-C <sup>+</sup> ,OH <sup>-</sup>	alcohol, carboxylic acid	4
5	1086.01	-C-O-C <sup>-</sup>	alcohol	2
6	1421.03	-OH <sup>-</sup>	carboxylic acid	3
7	1641.65	-CH <sup>+</sup>	alkane	10
8	1800.99	-C=O <sup>-</sup>	carboxylic acid	4
9	2364.06	-CH <sup>+</sup>	alkane	12
10	2519.21	-OH <sup>-</sup>	carboxylic acid	5
11	2855.78	-CH <sup>+</sup>	alkane	10
12	2922.23	-CH <sup>+</sup>	alkane	8
13	3740.11	-OH <sup>-</sup>	carboxylic acid	5

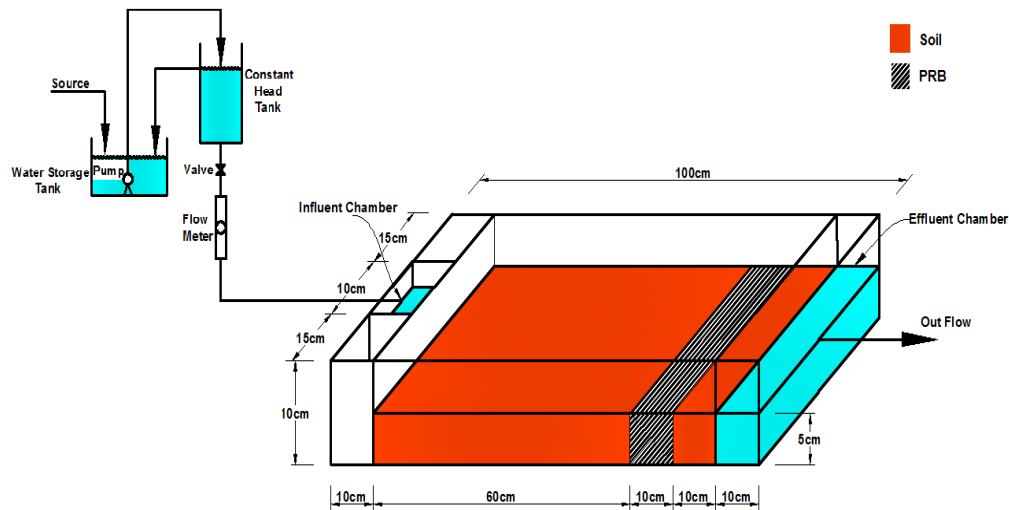
**Table 3.** Parameters of isotherm models for the bio-sorption of Ph onto GDAS and soil.

Isotherm model	Parameter	Phenol			
		GDAS	R <sup>2</sup>	Soil	R <sup>2</sup>
Langmuir	b (l/mg)	0.1410	0.9944	0.0178	0.9927
	q <sub>m</sub> (mg/mg)	0.0252		0.0084	
Freundlich	K <sub>F</sub> (mg/mg)(l/mg) <sup>1/n</sup>	0.0029	0.9663	0.0007	0.9270
	n	1.4764		2.3201	
Elovich	q <sub>m</sub> (mg/mg)	0.0140	0.9297	—	—
	K <sub>E</sub> (l/mg)	0.2749		—	
Temkin	ΔQ (KJ/mole)	13.0124	0.9721	—	—
	K <sub>o</sub> (l/mg)	1.0007		—	
Kiselev	k <sub>1</sub> (l/mg)	0.1389	0.9942	—	—
	k <sub>n</sub>	-0.1396		—	
Hill-de Boer	k <sub>1</sub> (l/mg)	0.0907	0.9338	—	—
	k <sub>2</sub> (KJ/mole)	9.7621		—	

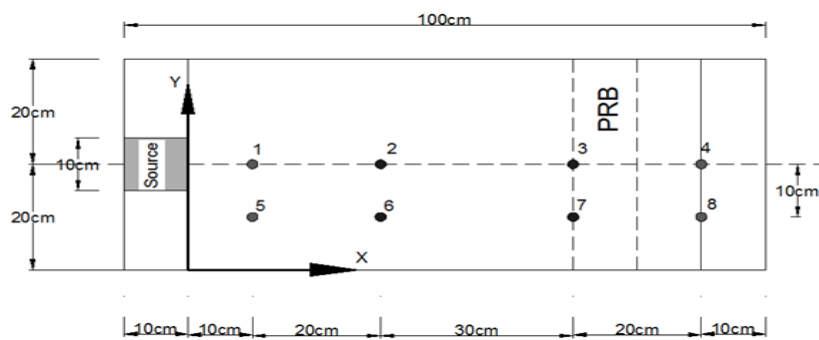
**Table 4.** Model geometry, boundary value problem, and solution procedure for simulated 2D problem adopted in the present study.

Model geometry	Governing equations	Initial/boundary conditions (I.C./B.C.)	Solution procedure
	<b>Aquifer (A)</b> $D_{Ax} \frac{\partial^2 C_A}{\partial x^2} + D_{Ay} \frac{\partial^2 C_A}{\partial y^2} - V_{Ax} \frac{\partial C_A}{\partial x} = R_A \frac{\partial C_A}{\partial t}$	<b>I.C.</b> $C_A(x, y, 0) = 0$ <b>Exterior B.C.</b> <ul style="list-style-type: none"> <li>• <math>C_A(0, y, t) = 0</math> except <math>C_A(0, y, t) = C_o</math> @ <math>W_1 \leq y \leq W_1 + W_2</math></li> <li>• <math>\frac{\partial C_A}{\partial x} = 0</math> @ <math>(L, y, t)</math></li> <li>• <math>\frac{\partial C_A}{\partial y}(x, 0, t) = 0</math> and <math>\frac{\partial C_A}{\partial y}(x, W, t) = 0</math> for <math>0 \leq x \leq L_A</math>, <math>L_A + L_B \leq x \leq L</math></li> <li>• <math>\frac{\partial C_B}{\partial y}(x, 0, t) = 0</math> and <math>\frac{\partial C_B}{\partial y}(x, W, t) = 0</math> for <math>L_A \leq x \leq L_A + L_B</math></li> </ul>	<b>COMSOL Multiphysics 3.5a (2008) software</b>
	<b>PRB (B)</b> $D_{Bx} \frac{\partial^2 C_B}{\partial x^2} + D_{By} \frac{\partial^2 C_B}{\partial y^2} - V_{Bx} \frac{\partial C_B}{\partial x} = R_B \frac{\partial C_B}{\partial t}$	<b>I.C.</b> <ul style="list-style-type: none"> <li>• <math>C_B(x, y, 0) = 0</math></li> </ul> <b>Interior B.C.</b> <ul style="list-style-type: none"> <li>• <math>C_A(L_A, y, t) = C_B(L_A, y, t)</math></li> <li>• <math>C_A(L_A + L_B, y, t) = C_B(L_A + L_B, y, t)</math></li> <li>• <math>-D_{Bx} n_B \frac{\partial C_B}{\partial x} - D_{By} n_B \frac{\partial C_B}{\partial y} + V_{Bx} n_B C_B = -D_{Ax} n_A \frac{\partial C_A}{\partial x} - D_{Ay} n_A \frac{\partial C_A}{\partial y} + V_{Ax} n_A C_A</math> @ <math>(L_A, y, t)</math></li> <li>• <math>-D_{Bx} n_B \frac{\partial C_B}{\partial x} - D_{By} n_B \frac{\partial C_B}{\partial y} + V_{Bx} n_B C_B = -D_{Ax} n_A \frac{\partial C_A}{\partial x} - D_{Ay} n_A \frac{\partial C_A}{\partial y} + V_{Ax} n_A C_A</math> @ <math>(L_A + L_B, y, t)</math></li> </ul>	

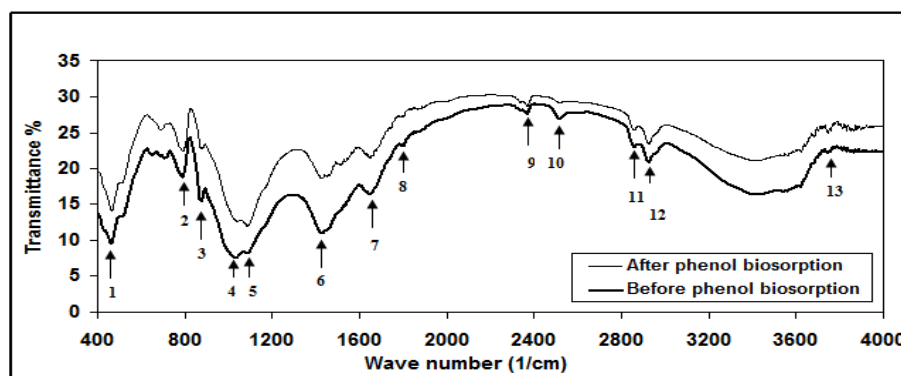




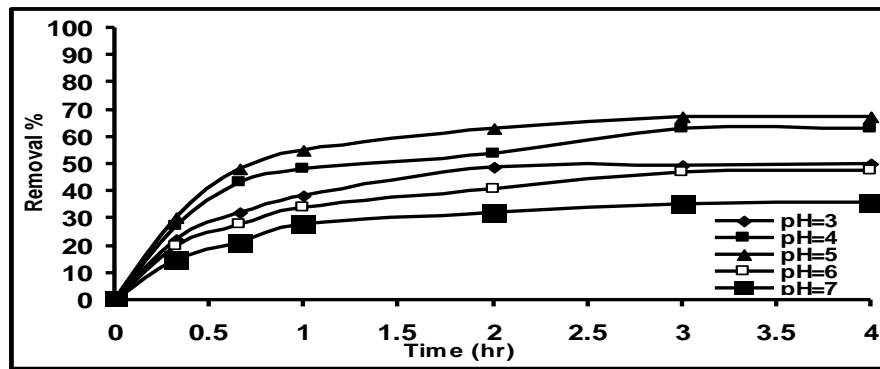
**Figure 1.** Schematic diagram of the bench-scale model aquifer.



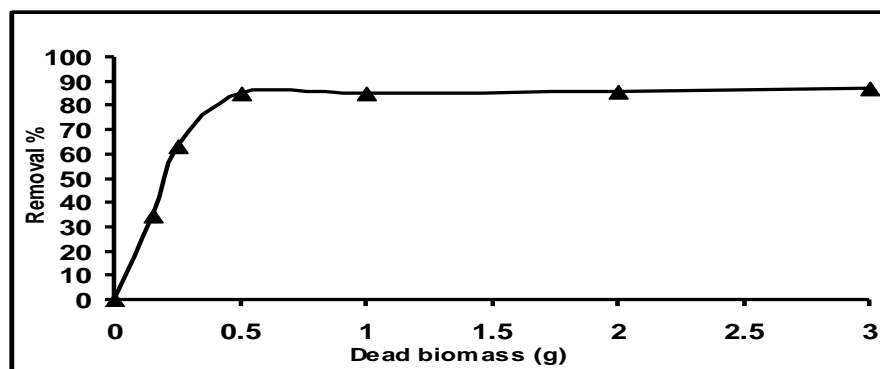
**Figure 2.** Schematic diagram of the sampling plate and sampling ports.



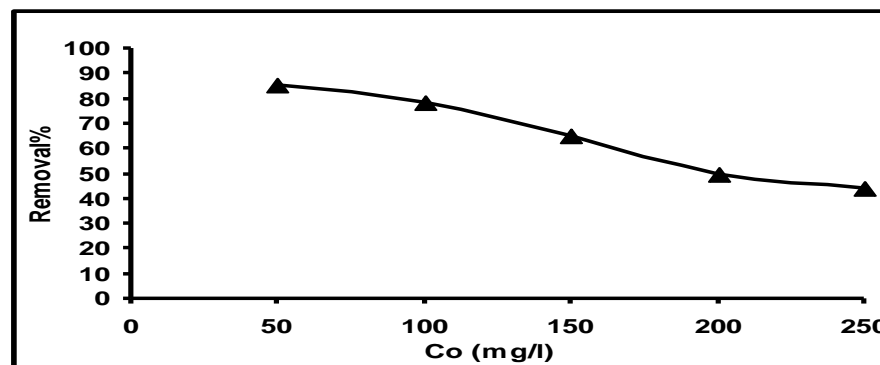
**Figure 3.** FTIR of GDAS before and after bio-sorption of phenol.



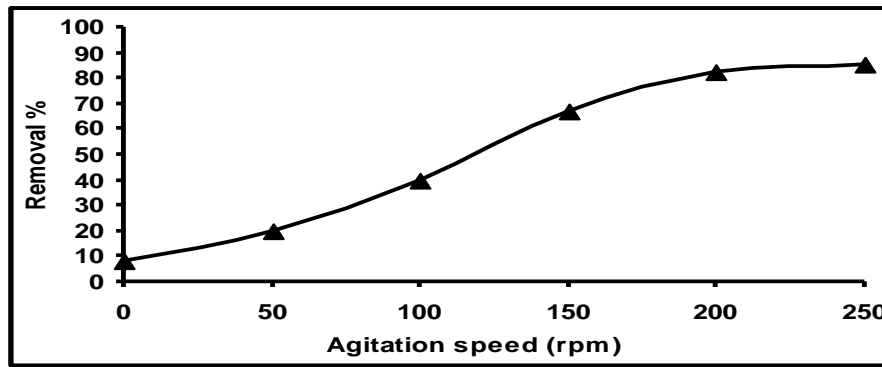
**Figure 4.** Removal efficiency of phenol on GDAS as a function of contact time and initial pH ( $C_0=50$  mg/l; dosage=0.25g/100 ml; agitation speed=250 rpm).



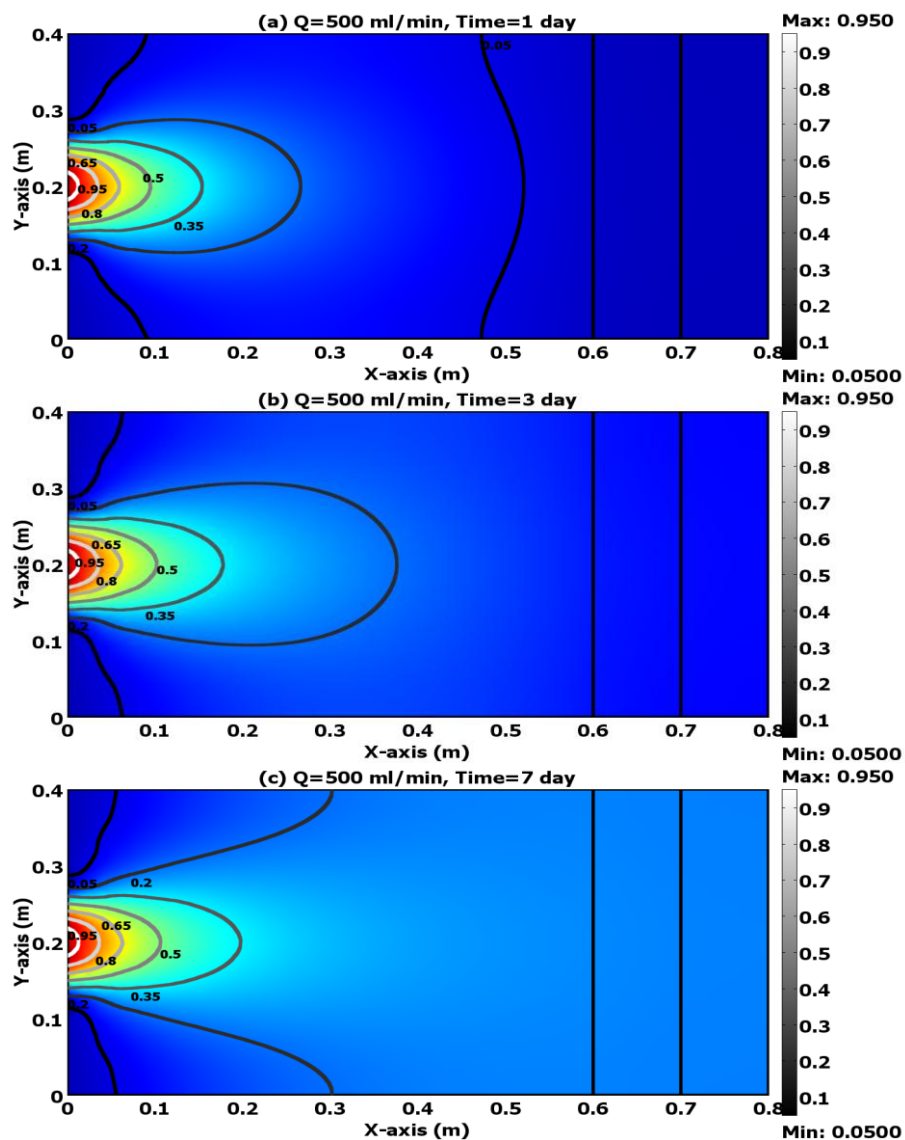
**Figure 5.** Effect of GDAS dosage on removal efficiencies of Ph ( $C_0=50$  mg/l; pH=5;  $t=3$  hr; agitation speed= 250 rpm).

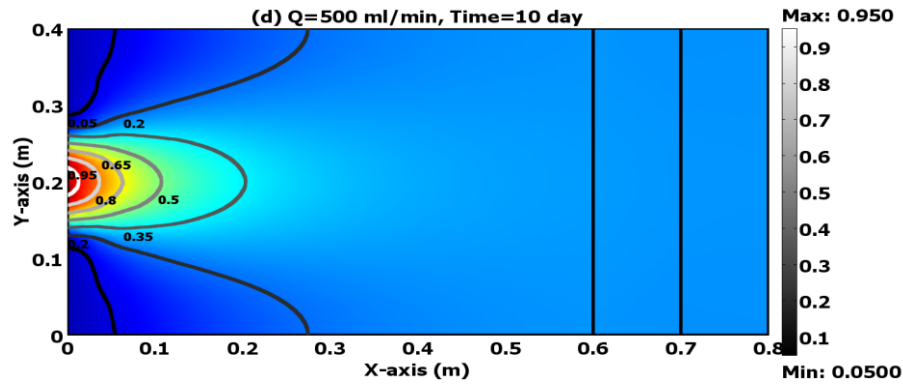


**Figure 6.** Effect of initial concentration on removal efficiency of Ph on GDAS (dosage=0.5 g/100 ml, pH=5,  $t=3$  hr, agitation speed= 250 rpm).

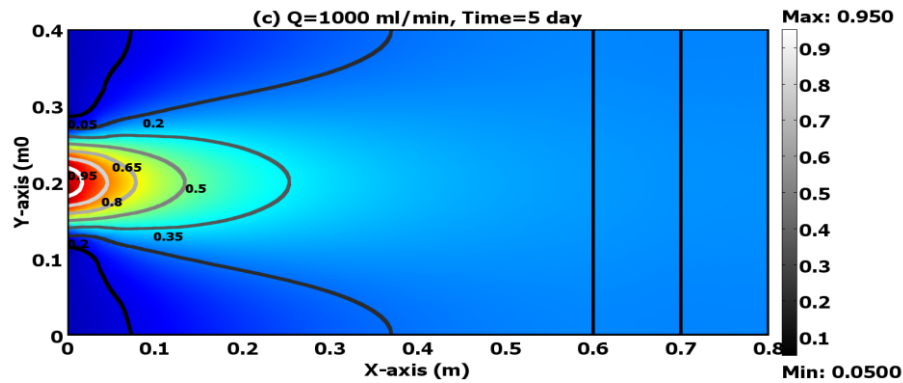
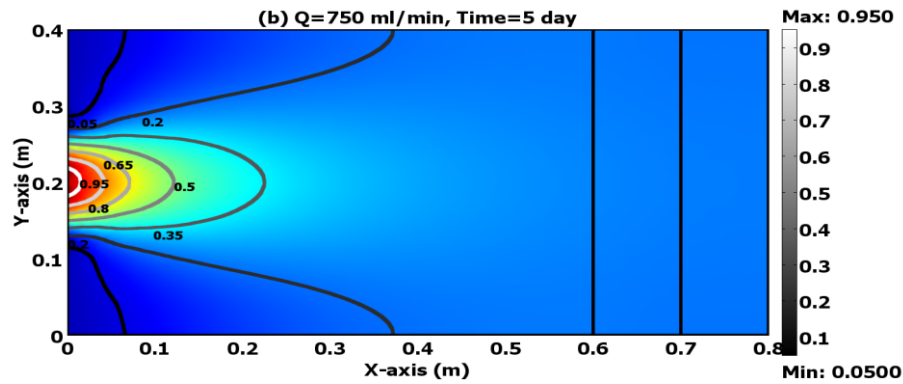
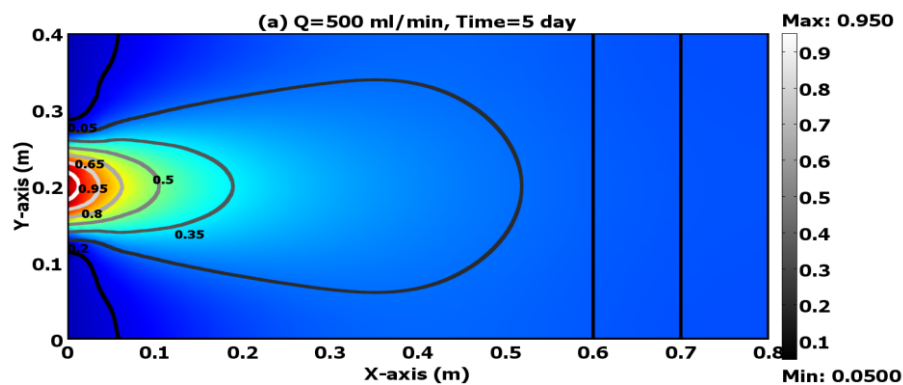


**Figure 7.** Effect of agitation speed on percentage removal of Ph ( $C_o=50$  mg/l, dosage=0.5 g/ 100 ml,  $t=3$  hr, pH=5).

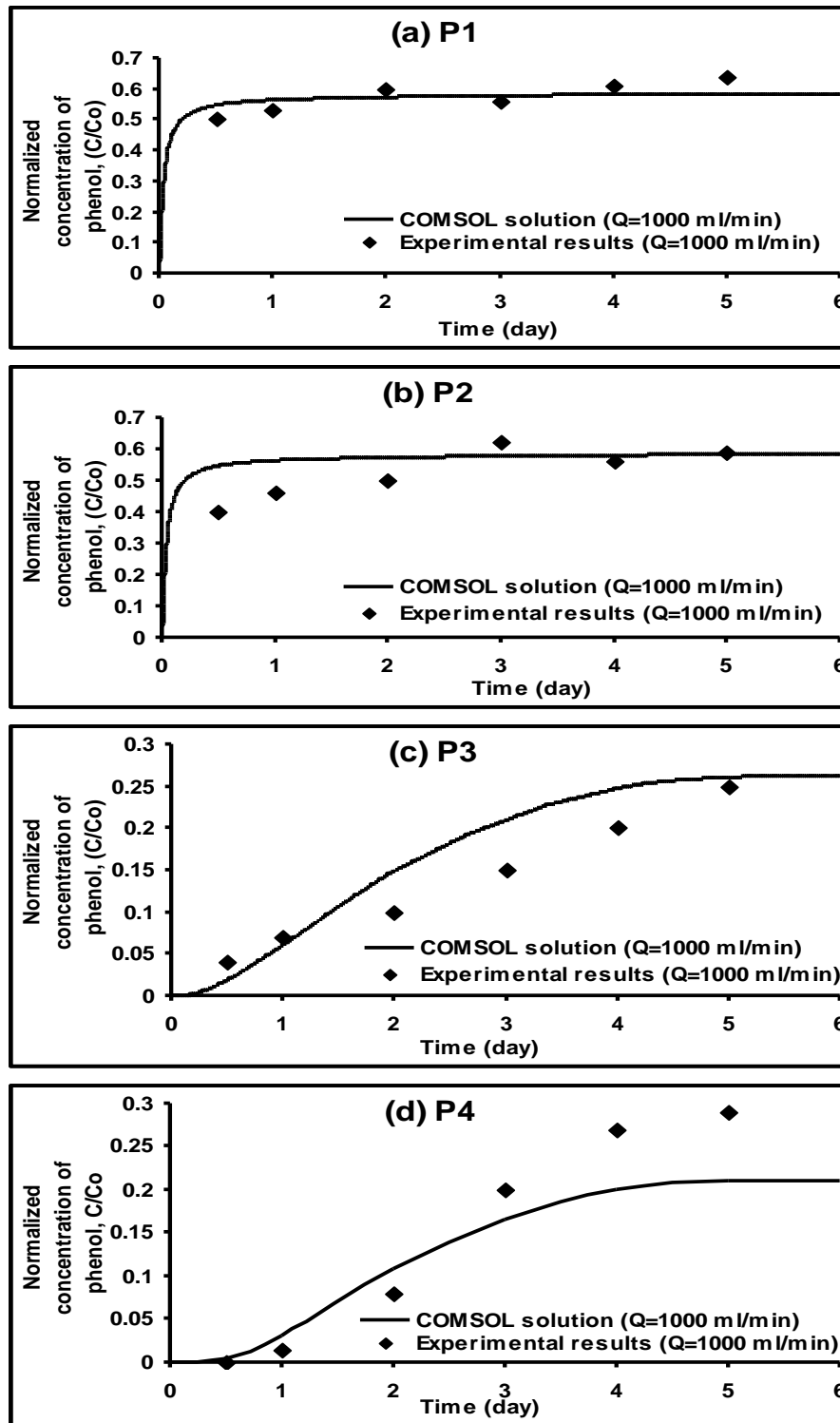




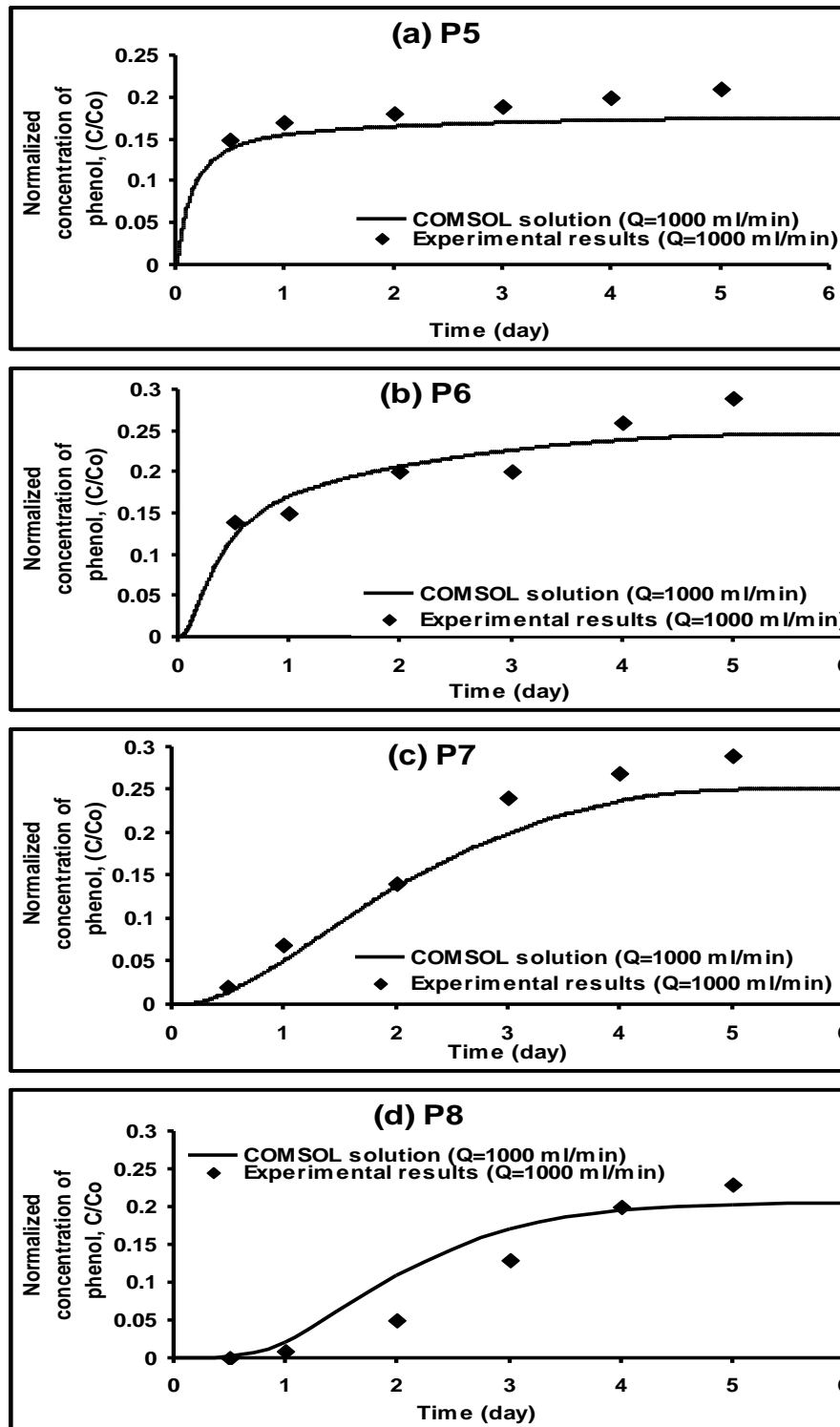
**Figure 8.** Distribution of phenol concentration after (a) 1 (b) 3 (c) 7 and (d) 10 day for flow rate of 500 ml/min using GDAS as PRB.



**Figure 9.** Distribution of phenol concentration after 5 days for flow rate equal to (a) 500, (b) 750 and (c) 1000 ml/min using GDAS as PRB.



**Figure 10.** Breakthrough curves as a result of the phenol transport at ports (a) P1, (b) P2, (c) P3 and (d) P4 using GDAS as PRB.



**Figure 11.** Breakthrough curves as a result of the phenol transport at ports (a) P5, (b) P6, (c) P7 and (d) P8 using GDAS as PRB.



## Solar Photocatalytic Degradation of Diuron in Aqueous Solution by $\text{TiO}_2$

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### ABSTRACT

The solar photocatalytic degradation of diuron, which is one of the herbicides, has been studied by a solar pilot plant in heterogeneous solar photocatalysis with titanium dioxide. The pilot plant was made up of compound parabolic collectors specially designed for solar photocatalytic applications. The influence of different variables such as,  $\text{H}_2\text{O}_2$  initial concentration,  $\text{TiO}_2$  initial concentration, and diuron initial concentration with their relationship to the degradation efficiency were studied. Hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) found to increase the rate of diuron degradation. The best removal efficiency of heterogeneous solar photocatalytic  $\text{TiO}_2$  system was found to be 46.65 % and for heterogeneous solar photocatalytic  $\text{TiO}_2/\text{H}_2\text{O}_2$  system was found to be 80.65 %. Based on these results, the solar photocatalytic degradation by  $\text{TiO}_2/\text{H}_2\text{O}_2$  system could be a useful technology for the treatment of effluents containing diuron.

**Keywords:** Diuron, Photocatalyst, Titanium dioxide, solar, degradation

### تحلل الدوران في محلول مائي بالتحفيز الضوئي بواسطة ثنائي أوكسيد التيتانيوم باستخدام الطاقة الشمسية

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### الخلاصة

تمت دراسة التحلل بالتحفيز الضوئي للمبيد (ديورون - diuron) وهو أحد أنواع مبيدات الادغال/ الأعشاب بواسطة منظومة تعمل بنظام الاكسدة المتقدمة الغير متجانس (التحفيز الضوئي بثنائي أوكسيد التيتانيوم) باستخدام الطاقة الشمسية. تتكون المنظومة الريادية من مجمعات القطع المكافئ المركبة (compound parabolic collectors) مصممة خصيصا لتطبيقات التحفيز الضوئي بالطاقة الشمسية. درست تأثير المتغيرات المختلفة مثل التركيز الأولي لبيروكسيد الهيدروجين والتركيز الأولي لثنائي أوكسيد التيتانيوم والتركيز الأولي للمبيد وتأثيرها على كفاءة الازالة. وجد ان بيروكسيد الهيدروجين يزيد من معدل تحلل المبيد (ديورون). كانت أفضل كفاءة إزالة التحفيز الضوئي باستخدام نظام التحلل بواسطة ثنائي أوكسيد التيتانيوم لوحده تساوي 46.65 % وباستخدام نظام التحلل بواسطة ثنائي أوكسيد التيتانيوم مع بيروكسيد الهيدروجين كفاءة الازالة تساوي 80.65 %. بناء على هذه النتائج فان التحلل بالتحفيز الضوئي بواسطة الطاقة الشمسية باستخدام نظام ثنائي أوكسيد التيتانيوم مع بيروكسيد الهيدروجين يمكن ان تكون تكنولوجيا مفيدة لمعالجة المطروحات الحاوية على مبيد الديورون.

## 1. INTRODUCTION

Pollution of soils and aquatic systems by chemicals used in agriculture is one of the main present environmental problems. Diuron (*N*-(3,4 dichlorophenyl)-*N,N*-dimethylurea), one of the most commonly used herbicides, belongs to the family of halogenophenylureas that represents an important class of contact herbicides applied in pre- and post-emergence to control broadleaf weeds in a wide variety of annual and perennial broadleaf and grass weeds **Field, et al., 1997**, and **Goody, et al., 2002**. Diuron is considered as highly toxic and persistent when applied in high dosages to the soil with a half-life of over 300 days **Malato, et al., 2011**. As a result, it is often detected in groundwater and surface water **Blanchoud, et al., 2004**, **Lapworth and Goody, 2006**. Diuron is suspected to be a carcinogenic and genotoxic compound **Revitt, et al., 2002**. Studies have also shown that it is toxic to photosynthetic organisms at concentrations levels of a few  $\text{mgL}^{-1}$  **Huang, et al., 2004**, **Rupp, et al., 2006**. Diuron is suspected to be a carcinogenic and genotoxic compound **Michaelidou and Nicolaou, 1996**. In this context, the development of technologies and management practices for the minimization of diuron is a necessary task.

Several researchers have developed an intensive effort of research on the chemical **Catalkaya and Kargi, 2007**, physicochemical **Bouras, et al., 2007**, photochemical **Malato, et al., 2009**, **Mazellier, et al., 1997**, heterogeneous photocatalytic **Macounová, et al., 2003**, **Bamba, et al., 2008**, electrochemical **Oturan, et al., 2008** and microbiological **Stasinakis, et al., 2006**, degradation methods of diuron, and the diuron transformation products. Especially, photocatalytic method ( $\text{TiO}_2$ ) is highly promising because it can operate at ambient temperature and pressure with low energy photons.

In the present study, the degradation and mineralization of diuron in water using heterogeneous solar photocatalysis and heterogeneous solar photocatalysis with  $\text{H}_2\text{O}_2$  and  $\text{TiO}_2$  was investigated. The progress of mineralization of diuron was monitored by diuron concentrations.

## 2. EXPERIMENTAL

### 2.1 Reagents

Diuron was obtained from Fluka with 98.5% purity technical grade and was used as received. Titanium dioxide  $\text{TiO}_2$  P25 (99 % purity ( obtained from Fluka Co. Switzerland, with specific surface area of  $50 \text{ m}^2/\text{g}$  corresponding to the mean elementary particle size of  $21 \pm 5 \text{ nm}$ . Hydrogen peroxide  $\text{H}_2\text{O}_2$  (reagent grade, 50% w/v) was obtained from Panreac Co., USA.

### 2.2 Equipment

#### 2.2.1 Compound parabolic collectors (CPC) reactor

Compound parabolic collectors (CPC) are static collectors with a reflective surface formed by two connected parabolic mirrors with an absorber tube in the focus and have been found to provide the most efficient light-harvesting optics for low concentrating systems, **Malato et al., 2009**. They support turbulent flow, have a closed system, are cheap and easy to maintain and as temperature does not play any significant role, there is no need for insulation.

A pilot plant was installed at Baghdad University / Department of Environmental Engineering backyard as shown in **Fig.1**. The hydraulic circuit of the reactor consists of a tank, centrifugal re-circulation pump, solar collector, connecting tubing and valves, **Fig.2**. The plant is designed for

operation in a batch mode. The total volume in the experiments is 20 L and the volume irradiated in the solar collector is 4.46 L.

The solar collector consists of two Compound Parabolic Collectors CPC in series placed on fixed supports inclined  $33^\circ$  (latitude of Baghdad) with respect to the horizontal plane and facing the south, this provides optimized performance as agreed with **Al-Saqqar, 2000**; and **Mahdi et al., 2011**. The CPC reflectors consist of stainless steel plates coated with aluminum foil. The photoreactor is made of two borosilicate glass tubes with 46.4 mm inner diameter, 50.0 mm outer diameter and 1.32 m in length. The connecting tubing is made of PVC with 62.5 mm in diameter.

The 20 L stainless steel tank provides aeration and samples for analysis. The solution is continuously fed to the plug flow reactor from the stainless steel tank by means of a centrifugal pump (Golden pumps, China). The flow rate was constant at  $(1.5\text{ m}^3/\text{hr})$  in all experiments, which corresponds to turbulent flow inside the photoreactor. Flow rate was adjusted by a flow meter (model LZS, Flowtech, Turkey). The pH of the solution was monitored by using a pH meter model (WTW, INOLAB 72, Germany). The pH value was chosen according to previous work of Malato et al., 2009 and Bamba et al., 2008. They indicated that  $\text{pH} = 5$  is the optimal value for the heterogeneous solar photocatalysis with  $\text{TiO}_2$ .

### 2.2.2 Radiometer

Global UV radiation, which is the driving force for the experiments in this work, was measured by UVA ultraviolet radiometer model (UVA-365) wave length 365 nm ultraviolet, with three ranges  $199.9\text{ }\mu\text{W}/\text{cm}^2$ ,  $1.999\text{ mW}/\text{cm}^2$  and  $19.99\text{ mW}/\text{cm}^2$ , from Lutron Electronics Co. LTD, USA. The radiometer was inclined  $33^\circ$  (latitude of Baghdad) with respect to the horizontal plane and facing the south in the same way as the CPCs of solar pilot plant.

## 2.3 Experimental Procedure

The procedure was performed as follows:

1. The solar reactor was cleaned and filled with distilled water to ensure that no other compounds were present in the reactor.
2. The correct amounts of diuron were measured and diluted in distilled water. This solution was introduced to the pilot plant. The pollutants were re-circulated until perfect homogenization and pollutants dissolution were attained. The duration of this phase was (30) min.
3. The reagents were added in different concentrations related to the experiments,  $\text{H}_2\text{O}_2$  (200 - 500 mg/L), and  $\text{TiO}_2$  (200 - 500 mg/L).
4. Regular samples were drawn (each 30 minutes) to measure the main process variables.
5. Global UV irradiation was measured by the UV radiometer when each regular sample was taken.

The intensity of solar radiation depends on season, location, daytimes and weather. It's therefore more accurate to mathematically adjust the experiments by applying a correction factor as shown in Eqs.(1) and (2).

$$t_{30W,i} = t_{30W,i-1} + \Delta t_n \frac{UV}{30} \frac{V_R}{V_T} \quad (1)$$

$$\Delta t_n = t_i - t_{i-1} \quad (2)$$

Where  $t_n$  is the experimental time for each sample, UV is the average solar ultraviolet radiation measured between  $t_{n-1}$  and  $t_n$  where  $t_{30W}$  is the “normalized illumination time”. In all experiments, time refers to a constant solar UV power of 30 W/m<sup>2</sup> which is nearly equivalent to the average UV power of a perfectly sunny day **Jiménez et al., 2011**.

## 2.4 Analysis

The analyses were performed in the laboratories of Environmental Engineering Department/ University of Baghdad. UV-vis spectrophotometer (Model T80 from PG Instrument Ltd, England), **Fig.3**, was used to measure the concentrations of diuron dissolved in water before and after treatment.

## 3. SOLAR HETEROGENEOUS PHOTOCATALYSIS

The heterogeneous solar photocatalytic detoxification process consists of making use of the near ultraviolet UV band of the solar spectrum (wavelength shorter than 400 nm), to photo-excite a semiconductor catalyst in contact with water and in the presence of oxygen, **Munter et al., 2001**. Semiconductors (e.g., TiO<sub>2</sub>, ZnO, Fe<sub>2</sub>O<sub>3</sub>, CdS and ZnS) can act as sensitizers for light-induced redox processes due to their electronic structure, which is characterized by a filled valence band and an empty conduction band. Absorption of a photon of energy greater than the band gap energy leads to the formation of an electron/hole pair. The valence band holes are powerful oxidants depending on the semiconductor and pH. Most organic photodegradation reactions utilize the oxidizing power of the holes either directly or indirectly. In semiconductor electrodes only one species, either the hole or electron, is available for reaction due to band bending, while the complementary reaction takes place in the counter electrode, **Mills and Le Hunte, 1997**. **Fig. 4** shows a drawing, which is used to illustrate photocatalytic processes. It consists of a superposition of the energy bands of a generic semiconductor (valence band VB, conduction band CB) and the geometrical image of a particle, **Malato et al., 2009**.

Absorption of a photon with an energy  $h\nu$  greater than or equal to the band gap energy  $E_g$  generally leads to the formation of an electron/hole pair in the semiconductor particle. These charge carriers subsequently recombine and dissipate the input energy as heat, get trapped in metastable surface states, or react with electron donors and acceptors adsorbed on the surface or bound within the electrical double layer. Simultaneously, in the presence of a fluid (water), spontaneous adsorption occurs (water and pollutant) and according to the redox potential of each adsorbate, an electron transfer proceeds towards acceptor molecules, whereas a positive hole is transferred to a donor molecule. Since the photonic excitation of the catalyst appears at the initial step of the activation of the whole catalytic system, it is necessary that the photon has enough energy to be absorbed by the catalyst, not by the reactants. Subsequently, the activation of the process goes through the excitation of the solid but not through that of the reactants. It is well known that O<sub>2</sub> and water are essential for photooxidation, there is no degradation in the absence of either, **Byrne and Eggins, 1998**.

## 4. RESULTS AND DISCUSSIONS

### 4.1 Effect of Initial TiO<sub>2</sub> Concentration

Heterogeneous photocatalysis method is applied to assess the feasibility to use TiO<sub>2</sub> in the degradation of diuron. Different concentrations of TiO<sub>2</sub> (200, 300, 400 and 500 mg/L) were used. Diuron concentration = 20 mg/L and pH = 5.

**Fig. 5** shows the relation between the degradation removal efficiency and the normalized illumination time  $t_{30w}$  for different initial concentrations of TiO<sub>2</sub>. The best result was obtained at  $t_{30w} = 19$  min, 400 mg/L of TiO<sub>2</sub> with removal efficiency of 46.65 %, above this concentration the degradation of diuron tends to decrease to reach 43.9% at 500 mg/L TiO<sub>2</sub>. The increase in removal efficiency can be explained by the increase in the total surface area (or number of active sites) available for photocatalytic reaction as the dosage of TiO<sub>2</sub> is increased.

However, when TiO<sub>2</sub> was overdosed, the intensity of incident UV light was attenuated because of the decreased light penetration and increased light scattering, which embedded the positive effect coming from the dosage increment and therefore the overall performance was reduced. Therefore the optimum catalyst TiO<sub>2</sub> concentration has to be found in order to avoid excess catalyst and ensure total absorption of efficient photons, **Eissa et al., and 2009. Malato et al., 2011** stated that total disappearance of diuron was obtained at 75 min ( $t_{30w}$ ) with initial concentration of diuron 22 mg/L, 200mg/L of TiO<sub>2</sub>.

### 4.2 Effect of Adding H<sub>2</sub>O<sub>2</sub>

In this experiment, the possibility of increasing the removal efficiency of the heterogeneous photocatalysis was tested by adding different concentrations of H<sub>2</sub>O<sub>2</sub> (200, 300, 400 and 500 mg/L). The optimum TiO<sub>2</sub> concentration 400 mg/L from the previous section was used in these experiments, the initial pH was equal to 5 and the concentration of diuron = 20mg/L.

**Fig. 6** shows the relation between the removal efficiency and the normalized illumination time  $t_{30w}$  for different initial concentrations of H<sub>2</sub>O<sub>2</sub>. An obvious positive influence on the degradation rates was observed by increasing the H<sub>2</sub>O<sub>2</sub> concentration to 400mg/L, the removal efficiency was found to be 80.65 % at  $t_{30w} = 20.4$  min. The increase in removal efficiency can be explained by increasing the number of trapped electrons in the electron/hole pairs and, consequently, avoiding recombination and generating more OH• for oxidizing species. It was expected that increasing the concentration of H<sub>2</sub>O<sub>2</sub> reduces the rate of degradation due to the reaction of hydrogen peroxide with these radicals, and hence acts as an inhibiting agent.

## 5. CONCLUSIONS

1. TiO<sub>2</sub> photocatalyst was found to increase the photocatalytic activity for the degradation of diuron. The degradation rate was strongly affected by TiO<sub>2</sub> concentration.
2. It has been found that experiment with heterogeneous photocatalytic based on TiO<sub>2</sub> enhanced with H<sub>2</sub>O<sub>2</sub> seems to give the best removal efficiency compared with TiO<sub>2</sub> alone experiments.
3. A complete mineralization cannot be attained due to the formation of the intermediates and the final products which are most difficult to degrade.
4. The advantages of TiO<sub>2</sub> photocatalytic process as an oxidative treatment are rapid degradation and simple handling. Therefore, this photocatalytic reaction would be applied to

wastewater treatment works as a new developing methodology for reducing levels of other pesticides and endocrine disrupting chemicals.

5. The best removal efficiency of heterogeneous solar photocatalytic  $\text{TiO}_2$  system was found to be 46.65 % at  $t_{30W} = 19$  min and for heterogeneous solar photocatalytic  $\text{TiO}_2/\text{H}_2\text{O}_2$  system was found to be 80.65 % at  $t_{30W} = 20.4$  min.

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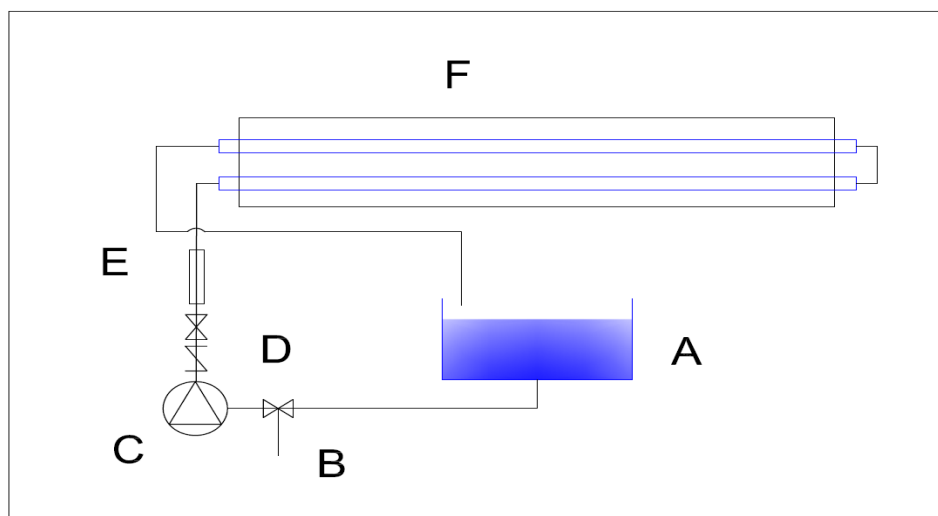
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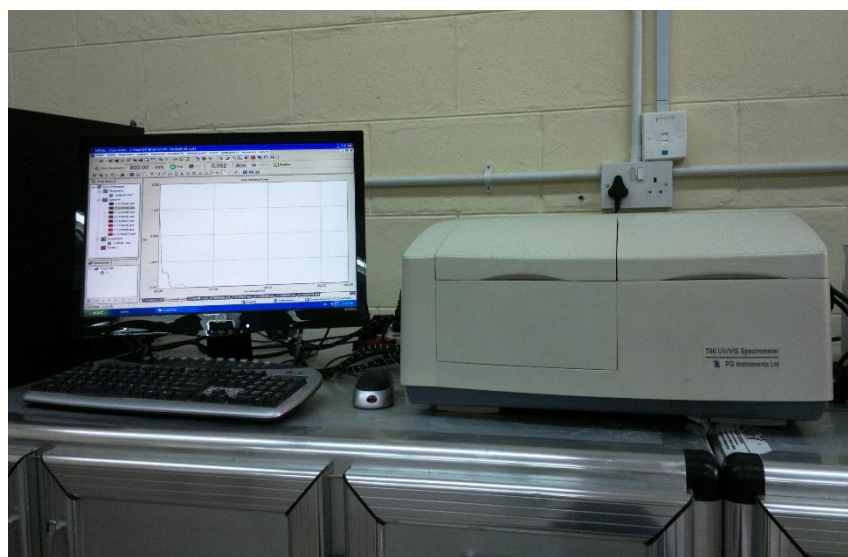
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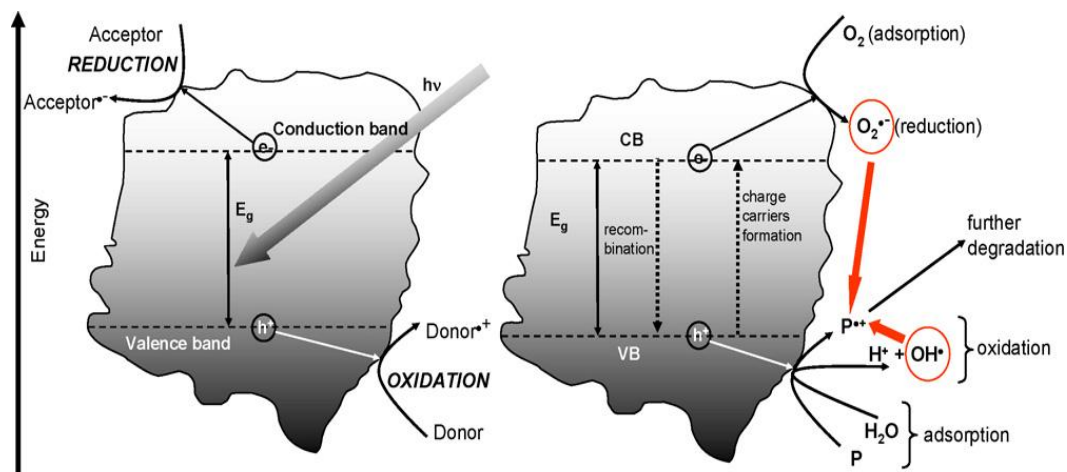
**Figure 1.** CPC at the backyard of the Environmental Engineering Department.



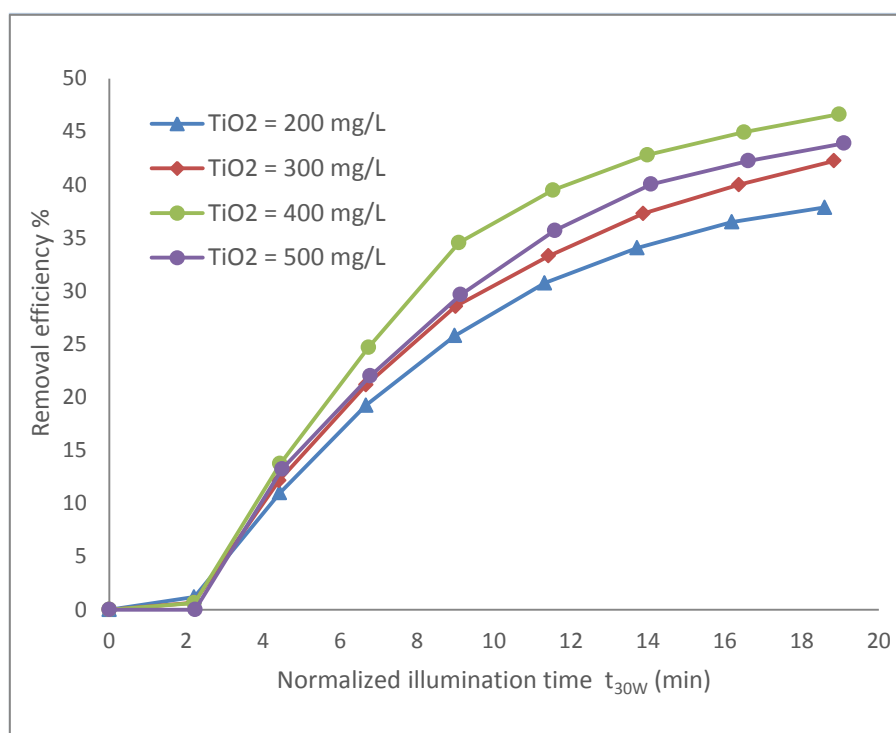
**Figure2.** Schematic representation of the pilot plant (A) tank, (B) drain valve, (C) pump, (D) valve, (E) flow meter and (F) solar collectors.



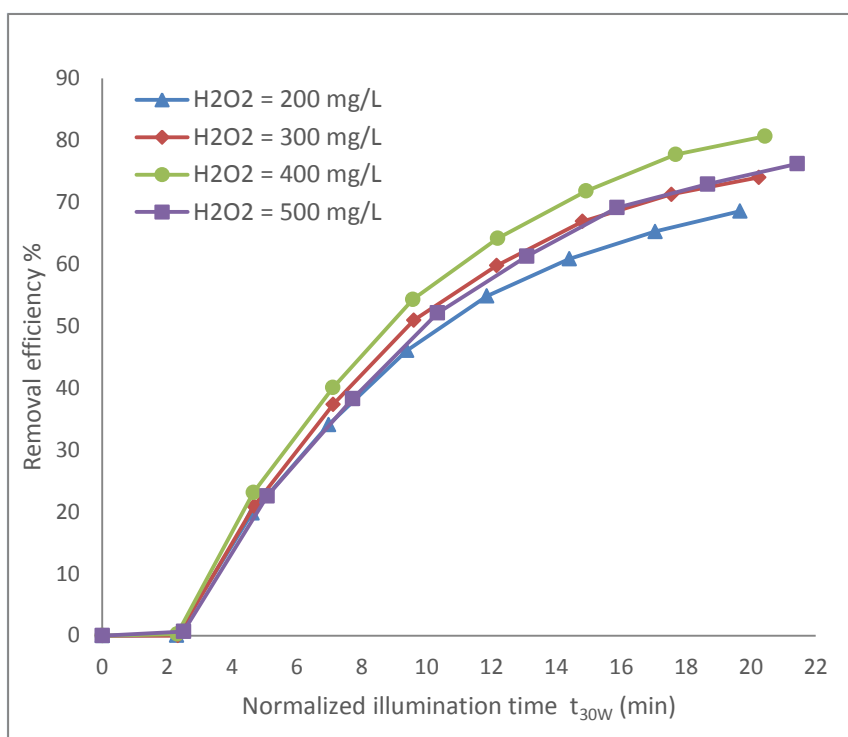
**Figure 3.** UV- vis spectrophotometer.



**Figure 4.** Energy band diagram and fate of electrons and holes in a semiconductor particle in the presence of water containing a pollutant, **Malato et al., 2009**.



**Figure 5.** Effect of initial TiO<sub>2</sub> concentrations on the degradation of diuron by heterogeneous solar photocatalyst system, diuron conc.= 20 mg/L.



**Figure6.**Effect of initial H<sub>2</sub>O<sub>2</sub> concentrations on the degradation of diuron by heterogeneous solar photocatalyst system at diuron conc.= 20 mg/L,TiO<sub>2</sub>=400 mg/L.

## Study the Application of Ultrasonic Technology for Phenol Removal in Petroleum Industry

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### ABSTRACT

In this study, the sonochemical degradation of phenol in water was investigated using two types of ultrasonic wave generators; 20 kHz ultrasonic processor and 40 kHz ultrasonic cleaner bath. Mineralization rates were determined as a function of phenol concentration, contact time, pH, power density, and type of ultrasonic generator. Results revealed that sonochemical degradation of the phenol conversion was enhanced at increased applied power densities and acidic conditions. At 10 mg/L initial concentration of phenol, pH 7, and applied power density of 3000 W/L, the maximum removal efficiency of phenol was 93% using ultrasonic processor at 2h contact time. Whereby, it was 87% using and ultrasonic cleaner bath at 16h contact time and 150 W/L power density. Kinetic models applied to the sonolysis of phenol was evaluated for the first-order, pseudo-first-order, second- order, and pseudo-second-order kinetic models. The experimental data fitted very well the first-order kinetic model.

**Key words:** ultrasonic, son chemical degradation, phenol, petroleum industry, wastewater

### دراسة تطبيق تقنية الموجات فوق الصوتية لإزالة الفينول في الصناعة النفطية

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### الخلاصة

في هذا البحث، تم دراسة إمكانية إزالة الفينول من المياه بتسليط الموجات فوق الصوتية باستخدام نوعين من أجهزة توليد الموجات فوق الصوتية؛ الأول جهاز المعالج بتردد 20 كيلو هرتز والجهاز الثاني هو الحمام الحوضي وبتردد 40 كيلو هرتز. تم دراسة معدلات تحلل الفينول كدالة للتركيز الأولي للفينول، فترة التماس، الدالة الحامضية، ومقدار الطاقة المسلطة، إضافة إلى نوع الجهاز المولد للموجات فوق الصوتية. بينت النتائج إن معدل تحلل الفينول يرتفع بزيادة الطاقة المسلطة في الوسط الحامضي. عند تركيز أولي للفينول 10مقداره ملغم/ لتر ووسط متعادل الحامضية وعند طاقة 3000 واط/ لتر كانت أعلى كفاءة إزالة 93 % باستعمال جهاز المعالج خلال ساعتين. أما عند استخدام جهاز الحمام الحوضي ساعة وبسليط طاقة مقدارها 150 واط/ لتر كانت الإزالة 87% خلال 16 ساعة. كما وتم دراسة حركية تفاعلات تحلل الفينول بواسطة الموجات فوق الصوتية ولوحظ إن انساب موديل لوصف حركية التحلل بالموجات فوق الصوتية يتمثل بالموديل من الدرجة الأولى.

**الكلمات الرئيسية:** فوق الصوتية، التحلل الكيمياوي فوق الصوتي، فينول، الصناعة النفطية، المياه العادمة.



## 1. INTRODUCTION

Water pollution is the discharge of some undesirable materials into water in high amounts exceeds the allowable limits. In other words, water pollution is an issue that comes true by artificial effects, that constraint or prevents and that destroys ecological balance ,**Abd.Razak, et al., 2013**. Many chemicals are released into the environment through waste streams. These chemicals are released by various industries mainly petroleum refineries and processing plants, pharmaceutical production, and petrochemical plants. Among many released hazardous chemicals, phenol is frequently found in effluent from refineries, chemical, and petrochemical industries , **Leili, et al., 2013**.

Treatment of industrial wastewater is a problem of major concern. Recently, stricter regulations are being imposed, which persevere on the need to develop and employ treatment technologies capable to deal with the hazardous pollutants in many industrial waste streams. Wastewaters containing phenols and other toxic petroleum derivatives need careful treatment before discharge into the receiving bodies of water. Biological treatments, activated carbon adsorption, incineration and chemical oxidation are the most widely used methods for treating synthetic organic compounds from industrial wastewaters including petroleum refinery wastewater ,**Díaz et al ., 2007 , Abdelwahab et al ., 2009 , and Kulkarni and Kaware , 2013**.

Biological methods have little or no harmful effects on the environment, because this technique does not involve the use of harmful reagents. However, high concentration of phenol may cause declining of the process. Adsorption is a simple and efficient method to remove organics from wastewater. Activated carbon is the most widely used adsorbent due to its large specific surface area and predominant proportion of micro-pores. However, high regeneration cost and poor mechanical rigidity of activated carbon limit its wider applications. In addition, this technique as well solvent extraction do not degrade the synthetic organics but rather remove it from wastewater and pass it to another phase, which result in the formation of hazardous by products , **EI-Naas et al ., 2010**.

Advanced oxidation processes (AOPs) have appeared in recent decades as a viable alternative for the treatment of effluents containing toxic refractory organics. These processes are able to degrade a large number of organic compounds by reduction-oxidation and free-radical reactions to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ . Among these AOPs, the once that use ozone ( $\text{O}_3$ ) , ultra-violet radiation (UV) , ozone combined UV, ozone with  $\text{H}_2\text{O}_2$  , Hydrogen peroxide with UV , as well as Fenton and photo-Fenton processes , **Pham et al., 2009 and Ricardo et al ., 2010**.

In recent years, considerable interest has been shown in the application of ultrasound power as a promising type of advanced oxidation process for the treatment of hazardous organic contaminants in water. The chemical consequences of high-intensity ultrasound do not arise from an interaction of acoustic waves and matter at a molecular or atomic level. Instead, in liquids irradiated with high-intensity ultrasound, acoustic cavitations (the formation, growth, and collapse of bubbles) provide the primary mechanism for sonochemical effects. During cavitations, bubble collapse produces intense local heating, high pressures, and very short lifetimes; these transient, localized hot spots drive high-energy chemical reactions. These hot spots have temperatures of  $\approx 5000^\circ\text{C}$ , pressures of about 1000 atmo, as well as heating and cooling rates above  $10^{10}$  K/s ,**Suslick and Price, 1999, and Ingole and Khedkar, 2012**. There are no additives introduced into the ultra-sonic system and no byproducts generated by ultrasonic technology. Therefore, there are no anticipated environmental concerns associated with this technology. In contrast to many other processes which are negatively affected when suspended solids of effluent increase, ultrasonic efficiency may even improve by increase of turbidity or suspended solids ,**Mahvi, 2013**.

The aim of this study was to examine the application of ultrasound waves as a new clean technology for phenol destruction in aqueous solutions. Also, study and examine the suitable kinetic model that best describes the experimental results of the sonochemical degradation of phenol.

## 2. MATERIALS AND METHODS

### 2.1. Sonolysis Equipments

Stock solution of concentration 10 mg/L phenol was prepared by dissolving a purified grade phenol in double distilled water. Experimental solutions of the desired concentration were obtained by successive dilution.

The sonication experiments were carried out using two types of ultrasonic wave generators; ultrasonic processor and ultrasonic cleaner bath. Using ultrasonic processor type Sonics Vibracell VCX-750 operating at constant frequency of 20 kHz, sonication reactions were carried out using (300) mL Pyrex beaker **Fig. 1**, alternatively loaded with (50, 100, and 250) mL synthetic wastewater samples. This part of experimental work was performed at different power densities including 600, 1500 and 3000 W/L taking into consideration examining the degradation of contaminants under various pH conditions of 2, 5, 7, 9, and 11. The sonochemical degradation of phenol was evaluated using 5 different initial concentrations of phenol including 1, 2, 5, 8, and 10 mg/L.



**Figure1.** Ultrasonic processor.

Using ultrasonic cleaner bath Model VGT-1860 QT at a frequency of 40 kHz, sonochemical degradation of phenol was carried out in 50 mL-volumetric flasks loaded with phenol aqueous solution **Fig.2**. Effects of the applied power densities (50, 75, and 150 W/L), initial concentration of phenol (1, 2, 5, 8, and 10 mg/L), pH (2, 5, 7, 9, and 11), and contact time up to 24 h on the sonolysis of phenol were considered in this part of the experimental work. pH of solutions was adjusted by 0.1 M sulfuric acid ( $\text{H}_2\text{SO}_4$ ) and 0.1 M sodium hydroxide (NaOH).



**Figure2.** Ultrasonic cleaner bath.

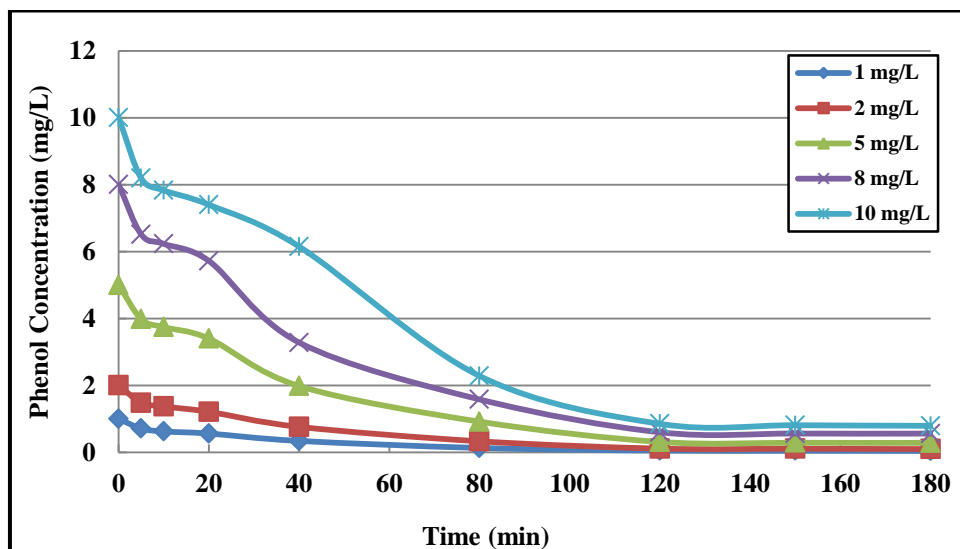
## 2.2. Analysis

Ultra Violet spectrophotometer (Model: T80 UV/VIS Spectrometer PG Instruments Ltd., Australia) was used to measure concentrations of phenol at wavelength ( $\lambda$ ) of (270) nm. Solution pH was measured using a pH meter (Model: WTW, Inolab 720).

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of Initial Concentrations and Contact Time

Sonochemical degradation of phenol was studied under various initial concentrations of phenol which were 1, 2, 5, 8, and 10 mg /L. The experiments were conducted using ultrasonic processor at pH 7, contact time 180 min, and power density 3000 W/L. As given in **Fig.3**, it is well observed that by increasing the initial concentrations of phenol from 1 to 10 mg /L, the sonochemical degradation decreased. This could be attributed to the fact that phenol is hydrophilic in nature. Phenol is moderately soluble compound with a solubility in aqueous solution of 83 g/L with a relatively low vapor pressure ( $4.60 \times 10^{-4}$  atmo). These physiochemical properties preclude significant concentrations of phenol molecule diffusing into the vapor phase of the acoustic cavitation bubbles, so it remains in the bulk of the solution during cavitation. Most of the hydroxyl free radicals formed within the cavity during the sonication might be recombined before they attack phenol molecules in the bulk liquid ,Shawabkeh, et al., 2010.

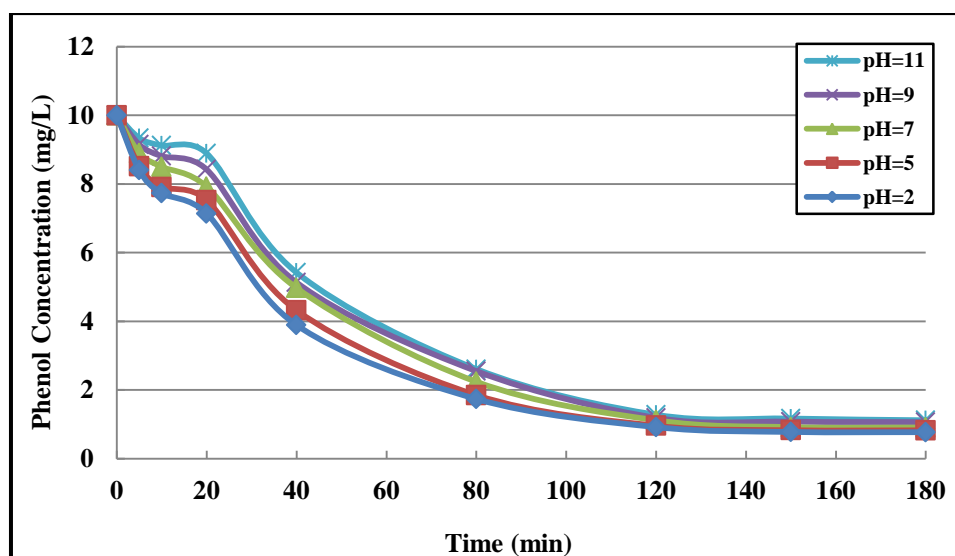


**Figure 3.** Profiles of phenol removal by ultrasonic processor at different initial concentrations.

### 3.2 Effect of pH

The pH of aqueous solutions is a primary parameter that affects and controls the sonochemical degradation process for organics sequestering from aqueous solution due to the influence of pH on the formation of the free radicals ( $\text{OH}^\bullet$ ), the major contributor to the sonolysis process. In this study, the effect of pH on phenol removal was studied at a pH range of 2.0 to 11.0 keeping their initial concentrations at 10 mg /L, power density 600 W/L, and contact time of 180 min. **Fig. 4** illustrates the effect of pH on the removal of phenol by sonolysis process.

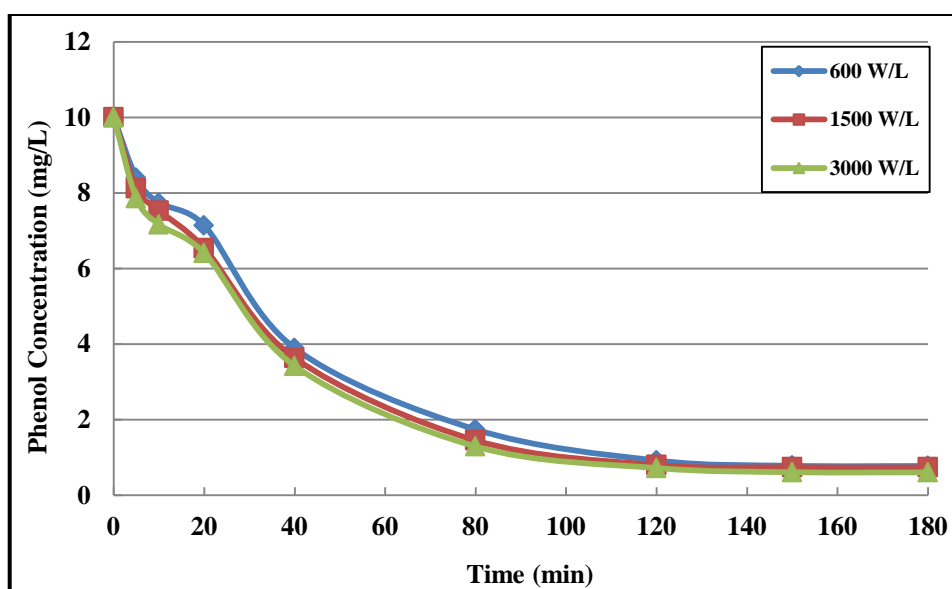
The effect of pH on the sonolytic degradation of phenol compounds almost drops to zero at higher pH values, more specifically at pH value greater than the pKa value for the phenol compounds dissociation, **Tauber, et al., 2000**.



**Figure4.** Effect of pH on phenol removal using ultrasonic processor.

### 3.3 Effect of Power Density

The most important parameter for the application of ultrasonic waves is the power input. Increasing the ultrasonic power will increase the energy of cavitations, lower the threshold limit of cavitations, and enhance the quantity of the cavitation bubbles. The destruction of volatile compounds more likely occurs inside the cavitation bubbles thus the rate of sonochemical degradation should be related to the number of bubbles present if each bubble releases enough energy to “burn” the volatile pollutant, **Jiang, et al., 2002** and **Ye, et al., 2010**. In this study, a set of experiments were carried out to examine the effect of power density on sonochemical degradation of phenol at initial concentrations of 10 mg/L using the ultrasonic processor. Three different power density values were applied which were 600, 1500, and 3000 W/L. **Fig. 5** presents the effect of different power densities on the profiles of phenol removal at constant ultrasonic frequency of 20 kHz. However, as given in this Figure, a relatively limited increase of phenol sonolysis rate was observed with increasing the applied power.

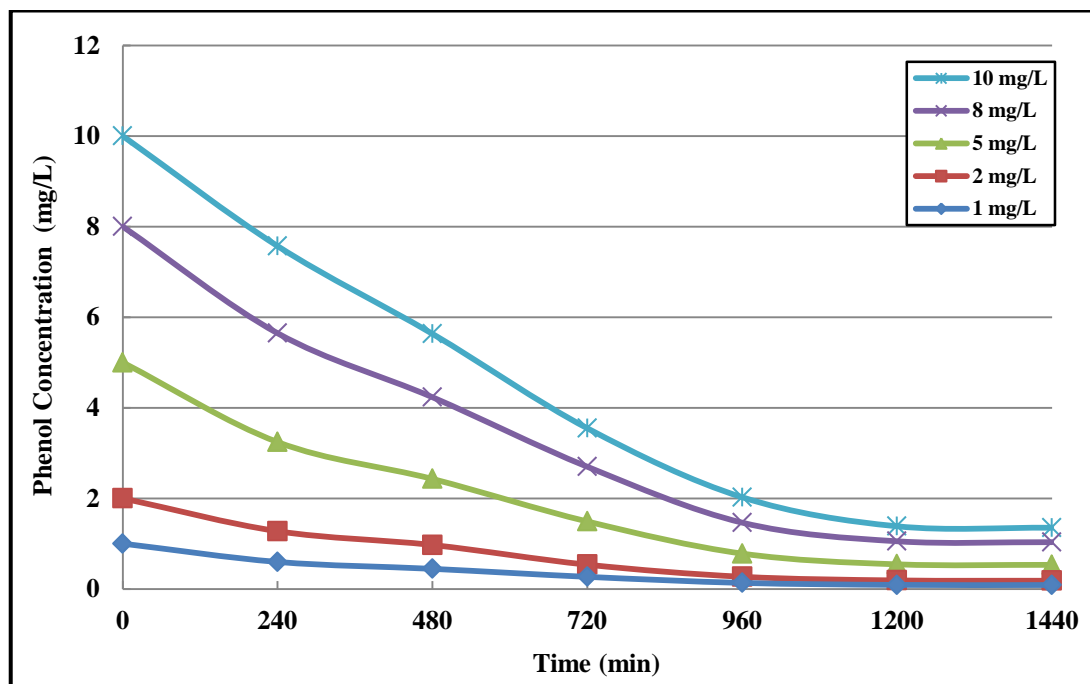


**Figure 5.** Effect of power density on phenol removal using ultrasonic processor at 20 kHz.

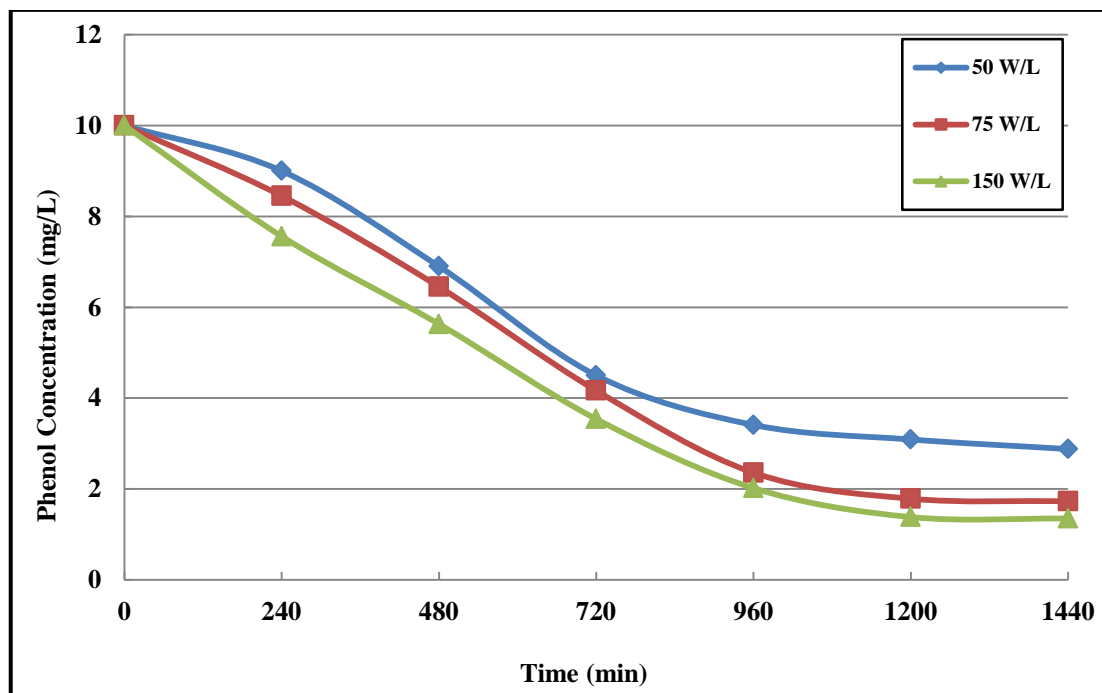
### 3.4 Effect of the Type of Ultrasonic Waves Generator

Additional sets of experiments were carried out to examine the efficiency of ultrasonic cleaner bath for phenol removal as an alternative type of ultrasound wave generator.

The effects of initial concentration and contact time, as well as power density on phenol sonochemical degradation were taken into consideration to evaluate the performance of the ultrasonic cleaner bath as shown in **Figs. 6** and **7**.



**Figure 6.** Phenol removal profiles by ultrasonic cleaner bath at 40 kHz.



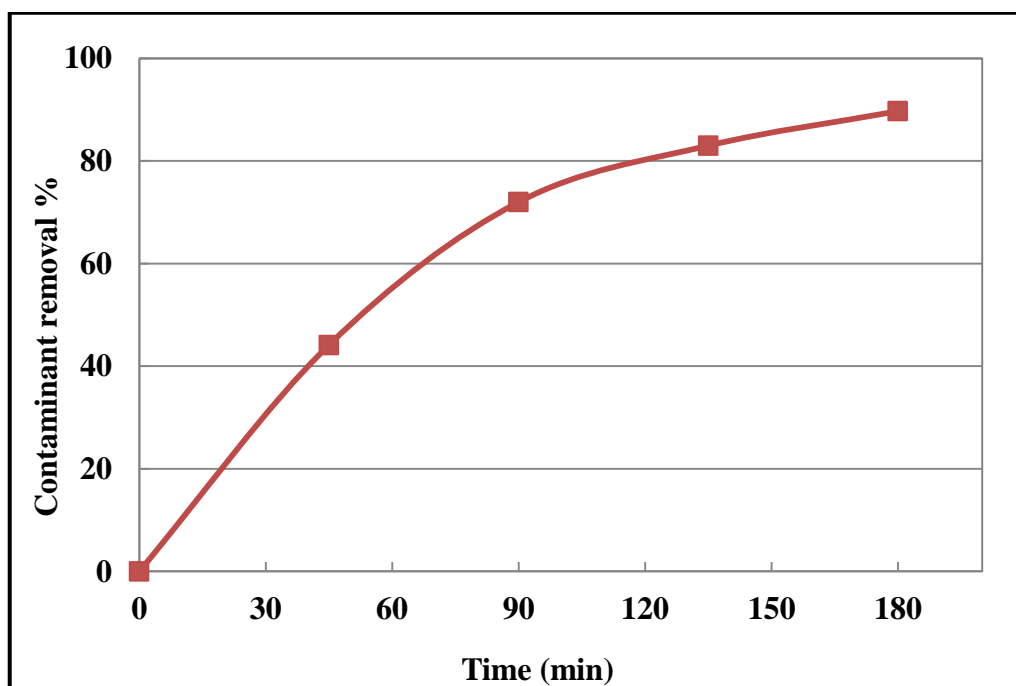
**Figure 7.** Effect of power density on phenol removal by ultrasound cleaner bath at 40 kHz.



### 3.5 Ultrasound Treatment of Actual Samples of Refinery Wastewater

A set of experiments were carried out using actual samples of refinery wastewater in order to investigate the reliability and effectiveness of the suggested approach of using ultrasonic treatment for phenol removal.

Samples of actual wastewater were freshly collected from the influent of Al-Daura petroleum refinery in Baghdad on a monthly basis for the purposes of the present study. **Fig. 8** illustrates the profile of phenol removal efficiency in real refinery wastewater. **Table 1** presents the quality of the actual samples of wastewater with respect to phenol and COD before and after the ultrasound treatment.



**Figure 8.** Profile of phenol removal in real samples of refinery wastewater at pH 7 and power density of 3000 W/L.

**Table 1.** Concentrations of phenol and COD in the actual samples wastewater before and after sonication treatment process

Constituent	Maximum Concentration (mg/L)		% removal
	Before ultrasonic treatment	After ultrasonic treatment	
COD	120	8.40	93
Phenol	7.50	0.53	93

### 3.6 Sonication Kinetics

Four well known kinetic models were applied in this study to test the experimental data in order to describe the behavior of sonochemical degradation process for further scale-up. The kinetic models are first order, pseudo-first order, second order, and pseudo-second order as follows:

#### 1. First-order kinetics model

The experimental data were fitted according to simple first-order rate as shown in Eq. (1):

$$C_t = C_o e^{-k_1 t} \quad (1)$$

Where:

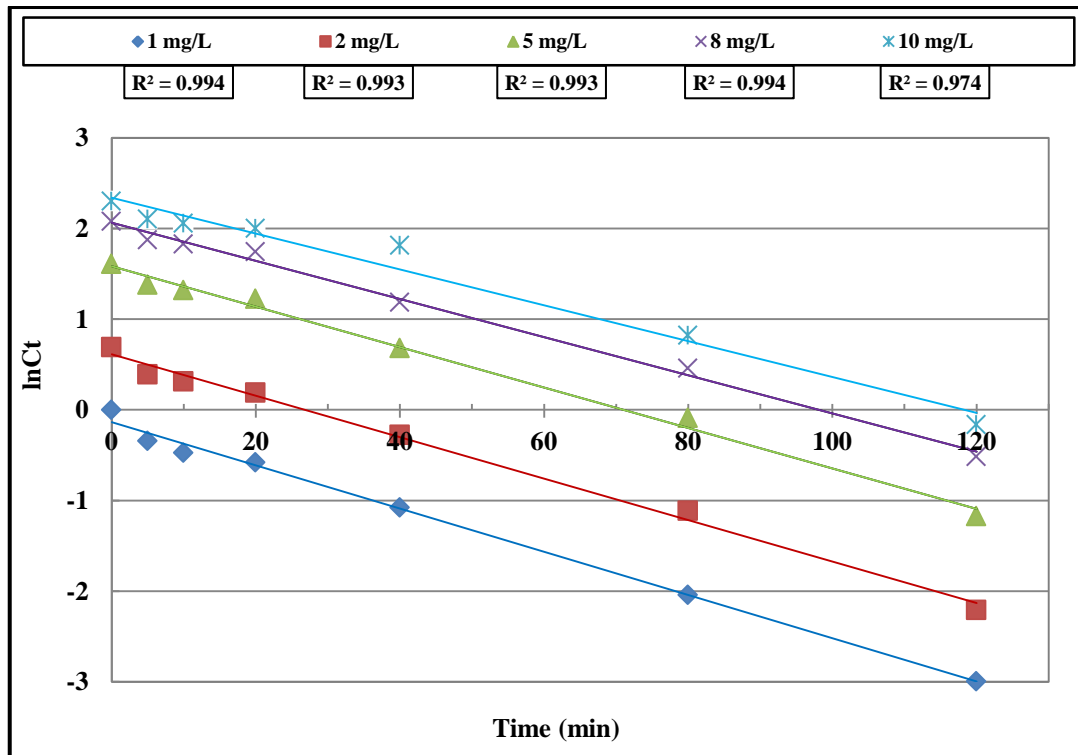
$C_o$  = the initial concentration of pollutant, mg/L

$k_1$  = first-order constant rate,  $\text{min}^{-1}$

$t$  = time, min

$C_t$  = the concentration of pollutant at any time, mg/L

$k_1$  is estimated from the slope by plotting  $\ln C_t$  versus time  $t$ , as shown in **Fig.9** for phenol removal efficiencies using ultrasonic processor.



**Figure 9.** First-order kinetic of phenol degradation.

### 2 Pseudo-first-order kinetics

The second proposal is to assume a pseudo-first order kinetic model which is described by Eq. (2) as follows:

$$\frac{t}{C_t} = \frac{t}{C_e} + \frac{1}{k C_e^2} \quad (2)$$

Where:

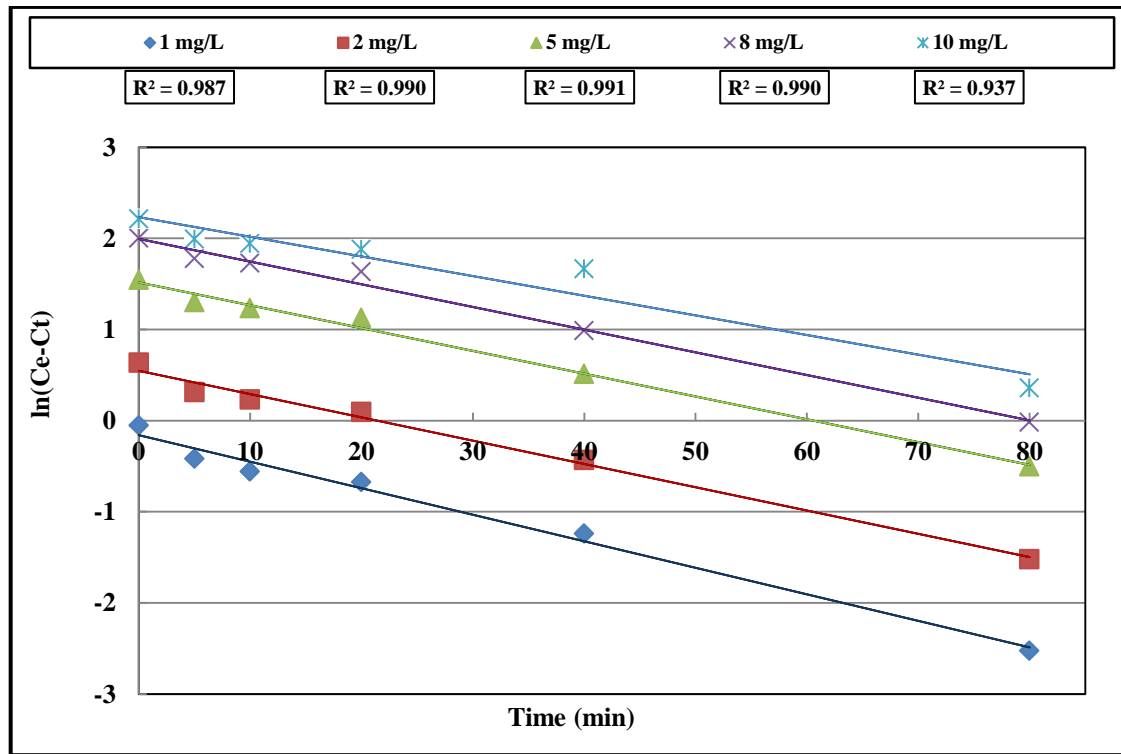
$C_t$  = the concentration of pollutant at time  $t$ , mg/L

$C_e$  = the equilibrium pollutant concentration, mg/L

$t$  = time, min.

$k$  = the pseudo-first-order rate constant, L/mg.min.

$k$  is estimated from the slope after plotting  $\ln(C_e - C_t)$  versus  $t$ , as shown in **Fig. 10**.



**Figure 10.** Pseudo-first-order kinetic of phenol degradation .

### 3 Second-order kinetics model

The proposal of having a second-order kinetic model will be examined here. The second-order kinetic equation model as in Eq. (3):

$$\frac{1}{C_t} = \frac{1}{C_0} + K t \quad (3)$$

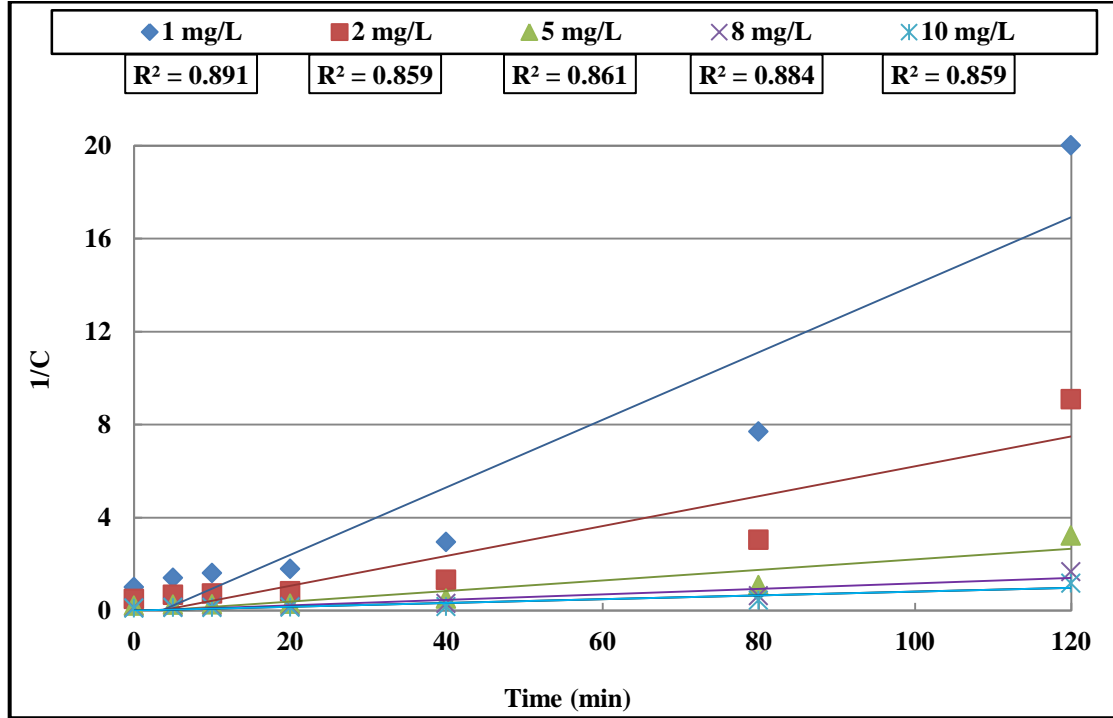
Where:

$C_o$  = the initial pollutants concentration, mg/L

$k$  = the second-order degradation rate constant, L/mg.min.

$t$  = time, min.

$k$  can be estimated from the slope after plotting  $1/C$  versus  $t$ , as demonstrated in **Fig.11**.



**Figure 11.** Second-order kinetic of phenol degradation.

#### 4. Pseudo-second-order kinetics

The fourth proposal is to assume a pseudo-second order kinetic model which is described by Eq. (4) as follows:

$$\frac{t}{C_t} = \frac{t}{C_e} + \frac{1}{k C_e^2} \quad (4)$$

Where:

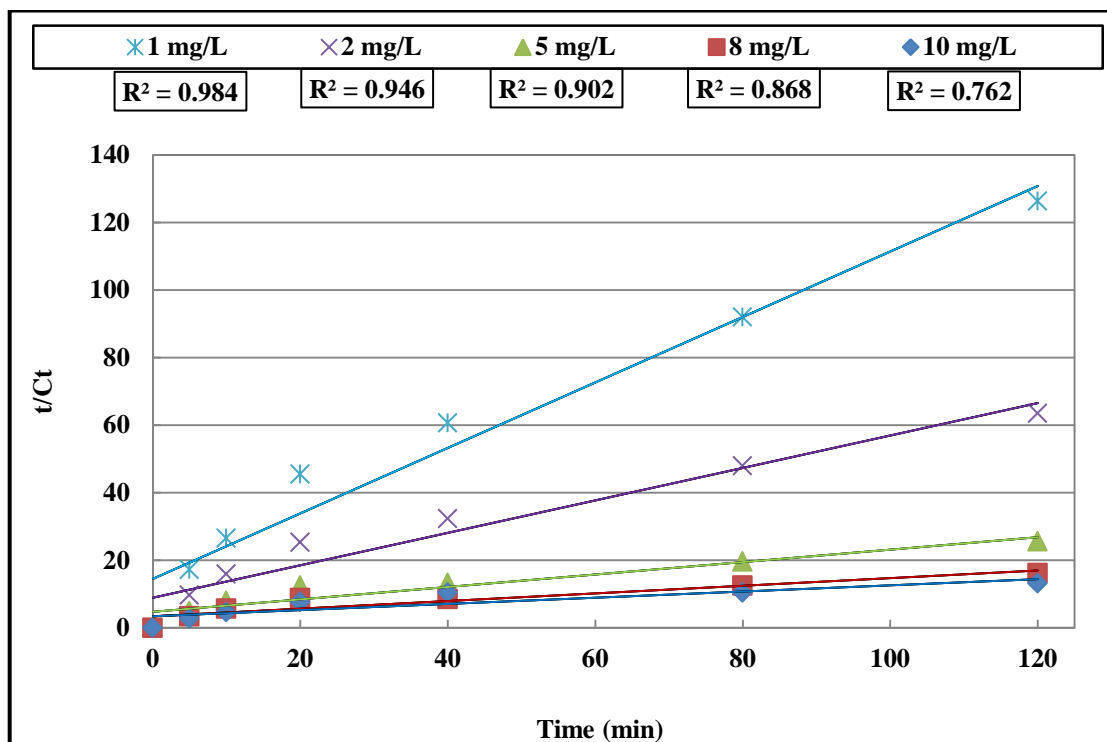
$C_e$  = the equilibrium pollutants concentration, mg/L

$k$  = the pseudo-second-order degradation rate constant, L/mg.min.

$t$  = time, min.

$C_t$  = the concentration of pollutant at time  $t$ , mg/L

$k$  can be estimated from the slope after plotting  $t/C_t$  versus  $t$  as shown in **Fig. 12**.



**Figure 12.** Pseudo-second-order kinetic of phenol degradation.

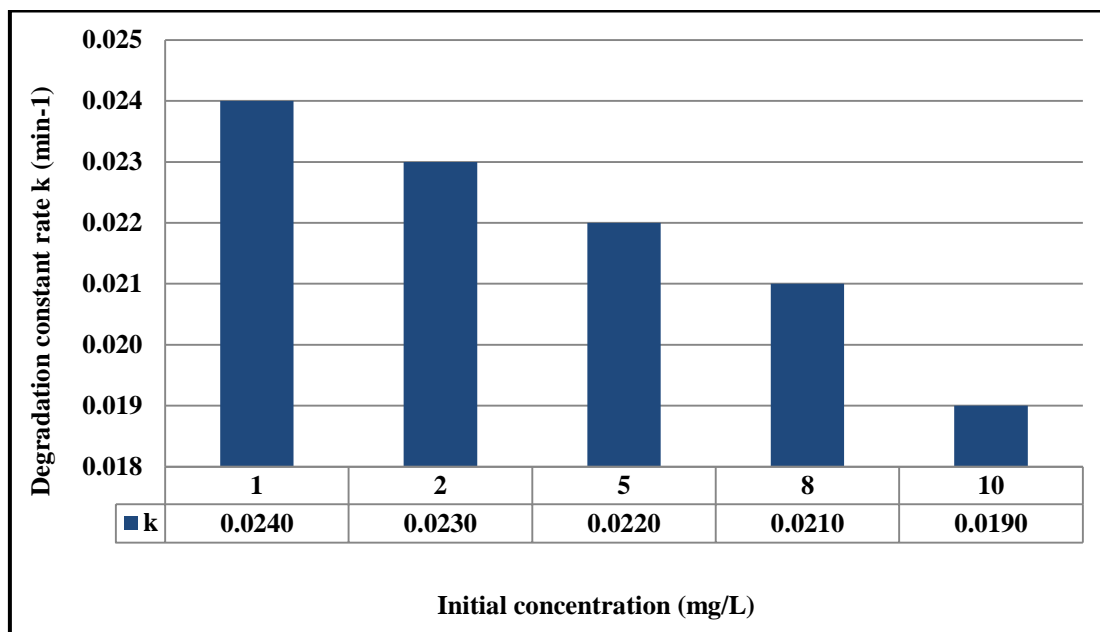
**Table 1.** summarizes the correlation coefficients of the kinetic study of ultrasonic process for phenol sonochemical degradation.

**Fig.13** summarizes the effect of initial concentrations on degradation rate constants for phenol.

**Table 1.** Correlation coefficients ( $R^2$ ) of phenol kinetic model.

Type of Kinetic model	Initial Concentration (mg/L)				
	1	2	5	8	10
First-order	0.994	0.993	0.993	0.995	0.974
Pseudo-first-order	0.987	0.990	0.991	0.990	0.937
Second-order	0.891	0.859	0.861	0.884	0.859
Pseudo-second-order	0.984	0.946	0.902	0.868	0.762

The sonication kinetic study indicated that the degradation kinetics of phenol follows the first-order kinetics with correlation coefficients up to 0.995.



**Figure 13.** Effect of initial concentrations on the degradation rate constants of phenol for the first order kinetic model .

From **Fig. 13**, it is evident that the sonochemical degradation rate depends on the initial concentration of the phenol. Since the life time of hydroxyl radicals is very short (only a few nanoseconds), they can only react at or near the location where they are formed. A low phenol concentration logically the percentage of reduction in pollutant concentration was enhanced, comparing with high concentration at the same time, leading to an increase in the degradation rate constant.

#### 4. CONCLUSSIONS

In this study, the maximum removal efficiencies were 93 and 87% using ultrasonic processor and ultrasonic cleaner bath, respectively at pH 7, 10 mg/L initial concentration of phenol, applied power densities of 3000 W/L for ultrasonic processor and 150 W/L for ultrasonic cleaner bath. Results revealed that equilibration times for sonolysis of phenol were achieved at 2 and 16 h for ultrasound processor and ultrasound cleaner bath.

Results showed that the removal efficiencies of phenol increased with increasing power density up to 93% using 20 kHz ultrasonic processor at pH 7 and power density of 3000 W/L. Similar behavior was observed using 40 kHz ultrasonic cleaner bath. However, the removal efficiency of phenol using the ultrasonic cleaner bath was 87% at pH 7 and power density of 150 W/L. Kinetic study revealed that the sonochemical degradation rate increased with decreasing the initial concentrations of phenol.

This study demonstrated that the phenol sonochemical degradation can be described by first-order model with  $R^2$  of 0.995 using 20 kHz ultrasound processor.





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## Testing and Commissioning of a Low-Speed Wind Tunnel (LSWT) Test Section

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### ABSTRACT

The calibration of a low-speed wind tunnel (LSWT) test section had been made in the present work. The tunnel was designed and constructed at the Aerodynamics Lab. in the Mechanical Engineering Department/University of Baghdad. The test section design speed is 70 m/s. Frictional losses and uniformity of the flow inside the test section had been tested and calibrated based on the British standards for flow inside ducts and conduits. Pitot-static tube, boundary layer Pitot tube were the main instruments which were used in the present work to measure the flow characteristics with emphasize on the velocity uniformity and boundary layer growth along the walls of the test section. It is found that the maximum calibrated velocity for empty test section is 55 m/s. Three speeds are tested for uniformity and walls boundary layer at inlet and mid-section of test section. The results show that the flows are uniform at inlet and mid-section with turbulent flow from inlet to outlet.

**Key words:** Wind Tunnel, Test Section Calibration, Turbulent Flow

### معايرة مقطع اختبار لنفق هوائي وإطية السرعة

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### الخلاصة

في هذا العمل تمت معايرة مقطع اختبار لنفق هوائي وإطية السرعة. تم تصميم وتركيب النفق (في عمل سابق) في مختبر الهوائيات بقسم الهندسة الميكانيكية-جامعة بغداد. السرعة التصميمية لمقطع الاختبار هي 70 م/ثا. تم اختبار ومعايرة الخسائر الاحتكاكية والتجانس للجريان داخل مقطع الاختبار بالاعتماد على المواصفات البريطانية للجريان داخل الانابيب والانفاق. انبوب Pitot-static وانبوب Pitot للطبقة المتاخمة استخدمتا كوسائل رئيسية في البحث الحالي لقياس خواص الجريان مع التشديد على تجانس السرعة وتنامي الطبقة المتاخمة لجدران مقطع الاختبار. تم معايرة السرعة القصوى لمقطع الاختبار وهو فرغ وقد كانت 55 م/ثا. ثلاث سرعات تم اختبارها لقياس التجانس والطبقة المتاخمة للجدران عند الدخول والمقطع النصفى لمقطع الاختبار. النتائج اظهرت ان الجريان منتظم عند الدخول والمقطع النصفى بجريان مضطرب من المدخل حتى المخرج.

## 1. INTRODUCTION

Wind tunnel is rapid, economical and accurate mean for conducting aerodynamic researches and obtaining aerodynamic data to support design decisions. There is a considerable and growing volume of aerodynamic research in the development of aircrafts, automobiles, marine's vehicles, and architectural structures. The first step in the design of a tunnel is to determine the shape and size of test section based on the intended use of the facility. The test section size, speed and design will determine the required power. The overall aerodynamic objective for most wind tunnels is to obtain a flow in the test section that is as near as possible to a parallel steady flow with uniform speed throughout the test section. **Swanson and Gillis 1944**, had shown three categories of flow non-uniformities, these were the airspeed change along longitudinal and vertical axis of the tunnel and variation of the air-flow angle in the region of model. Calibrations were made by surveying the flow over the plane perpendicular and parallel to the airstream at the position to be occupied by the model. Pitch, yaw and Pitot-static tube with manometers measuring static, total and air flow angularity. **Pope 1961** had discussed the air-flow measuring instruments and presented the data obtained when calibrating low-speed, and high speed wind tunnels. The methods for the measurement of flow in pipes and ducts are illustrated in the **British Standards (BS 1042) 1968**. Pressure losses associated with tunnel geometry, flow irregularities and boundary layer growth mean that the pressure difference measured by the pitot tubes may not accurately represent the true dynamic pressure within the tunnel test section **Edwards 2000**. A new longer test section and contraction installation produced a thicker boundary layer on the test section walls and then increased the air velocity along test section. The wind velocity in the test section of the Low Speed Wind Tunnel (LSWT) at the Mechanical Engineering Department of university of Baghdad is obtained from pressure measurements using pitot tubes located at the entrance and mid section of the tunnel test section. Static pressure and velocity distributions in the wind tunnel test section have been investigated mainly with the objective of determining the static pressure gradient in the test section so that buoyancy corrections should be made for models. The recent installation of a new test section for LSWT has made it necessary to perform tests to determine a new calibration. Pressure data was acquired from standard pitot probe at various positions within the tunnel test section over a large velocity range.

## 2. LOW SPEED WIND TUNNEL DESCRIPTION

An open circuit wind tunnel was designed and constructed, **Hussain et al., 2011**. The assembled wind tunnel is shown in **Fig. 1** which shows dimensions and components. A brief description of the tunnel components are given below.

### 2.1 Contraction Section and Settling Chamber

The contraction section and settling chamber were made of steel sheets and both have rectangular cross section. A contraction ratio of 8.94:1 is used in the equations discussed in **Hussain and et. al. 2011** at the Mechanical Engineering / University of Baghdad. The settling chamber contains three screens and is connected to the bell mouth at the inlet and contraction inlet at the exit section. The contraction section is joined to the test section by a mating flange.

## 2.2 Test Section

The test section of (0.7 m x 0.7 m) was designed to be suitable size for different models sizes. The wood thickness of (30 mm) is used to prevent wall curvature due to suction or negative gage pressure inside test section. The test section also provides with Plexiglas window on one side of the test section to allow viewing the model setting inside wind tunnel. A square cross section as shown in **Fig. 1** is chosen with constant taper of right and left walls to prevent the effect of boundary layer growth along walls (buoyancy effect). The test section is supported with flanges at either ends of the sections for fastening with other sections.

## 2.3 Diffuser

The diffuser is made of steel sheets and it is used to connect the test section with the fan housing by converting the square cross section of 700 mm at diffuser inlet plane to circular cross section at exit plane of 1500 mm. The length of diffuser is 6000 mm as shown in **Fig. 1**. Rubbers are used to reduce vibration and provide an air tight seal between sections. A coarse screen is fixed to protect the fan from damage.

## 2.4 Power Plant

Axial flow fan driven by a 75hp, AC current motor of 3000 rpm is used to provide the power to overcome the pressure losses along the tunnel sections. The axial fan is mounted on the fan housing and fixed by bolts on the ground. The motor speed control is from zero to 3000 rpm, a control unit is used to give increments to the motor rotation from zero to max speed of rotation.

# 3. EXPERIMENTAL EQUIPMENT

## 3.1 Pitot Tube

The **British Standards** Pitot tube or as called boundary layer Pitot tube is shown in **Fig. 2-a** which is made from stainless steel tube of (4.5 mm) outer diameter and (415 mm) in the overall length. The head of hypodermic tubing is (1 mm) diameter. This instrument is used to measure the total pressure at the test section. The boundary layer velocity profile is measured using Pitot-tube with static tube to measure the dynamic pressure through layer. This pitot tube is also used to measure the boundary layer thickness, by traversing it through the boundary layer and normal to the wall, until reaching to maximum reading. Then, the distance travelled by the tube relative to the wall, which is arbitrary, represents the boundary layer thickness. The distance read from the ruler is fixed on the traversing mechanism.

## 3.2 Static Tube

The static tube is used to measure the static pressure of the flow. It consists of a steel tube (2.4 mm) outer diameter, with head sealed by soldering and finished to take a hemisphere nose as shown in **Fig. 2-b**. Four static holes of (0.5 mm) diameter and (19.5 mm) away from the blocked end are made to measure the pressure. The (2.4 mm) tube is joined to a (4.5 mm) diameter copper tube. The static tube is fixed perpendicular to the x-y plane and used with Pitot tube to measure the dynamic pressure of boundary layer.

## 3.3 The Pitot - static tube

This instrument is used to measure the dynamic, total and static pressures of the non-viscous flow at the centre of the wind tunnel test section for three speeds of the tunnel. These values were used during the calibration of the wind tunnel. The Pitot static tube is mounted

co-axially, with the Pitot tube inside the static tube. It consists of a stainless steel tube (5 mm) outer diameter with a blunt nose; the four static holes are (0.5 mm) diameter and (30 mm) away from the nose. The diameter of the Pitot tube is (1 mm). **Fig. 2-c** shows the details of the Pitot-Static tube.

### 3.4 The Micro Manometer

The Dwyer Series 475 Mark III Handheld Digital Manometer is ideal for field calibration, monitoring or trouble shooting HVAC systems, clean rooms or a wide range of other low pressure pneumatic systems. This handy instrument measures positive, negative or differential pressures of air and natural gases in ranges from (0.249 kPa) to (10.34 bar). Dual push pads on the front panel control on-off, auto zero, and pressure unit selection were provided as shown in **Fig. 2-d**. The device was calibrated with total error reading percentage of 0.6% by **the Iraq central organization for standardization and quality control**.

### 3.5 Traversing Mechanism

In order to carry out the measurements at various stations inside the test section, a vertical traverse unit was manufactured specially to fix and move the instruments vertically using DC motor connected to a slide plate with upward and downward movement of the instruments as shown in **Fig. 2-e**. A controller unit is used with push buttons to move the instrument accurately to a specified position. Side ruler was used to measure the vertical movement of the slide part of the traversing mechanism.

## 4. EXPERIMENTAL PROCEDURES

The following experimental procedures were followed in the present work:

- 1- The laboratory were prepared for the experiment specially stagnation pressure by opening all doors and windows to the atmosphere.
- 2- The measuring tubes were mounted in the traversing mechanisms and adjusted for measuring.
- 3- The connection between the measuring tubes and micro manometer were made by a P.V.C tubes.
- 4- The micro manometer was operated and adjusted to the desired unit.
- 5- The fan was then adjusted to give the desired speed using controlling unit. In the present work (10, 30 and 45 m/s)
- 6- (10-15) minutes were allowed for the rig to reach the steady state.
- 7- The laboratory temperature was recorded at the beginning and end of the experiment. The maximum temperature variation detected was (3° C).

### 4.1 Total Mean Velocity

The total mean velocity of the flow inside the test section could be measured using Pitot static tube at the centre of the square shape cross section. The Cartesian coordinates are illustrated in the **Fig. 3** for the inlet or mid plane of the test section. The coordinate will be reliable for all calibration tests.

### 4.2 Experimental Grid Arrangement

To calibrate the test section flow uniformity, two planes are selected for this calibration, the first one at inlet plane and the other at model mounting position (middle plane). These sections are discretized into grid points as shown in **Fig. 3** as recommended by **Hussain 1989** depending on the **British Standards 1968** for the calibration flow inside



conduits and tunnels. The points are distributed as shown in **Fig. 3** near the walls to survey boundary layer effects. To measure the dynamic pressure at each point, Pitot tubes are mounted to the traverse system to move vertically at each row points beginning from lower surface to the upper surface depending on the ruler fixed on the traverse unit.

#### 4.3 Longitudinal Static Pressure Measurements

The buoyancy effect along the test section must be measured using static tube with micro manometer. The static pressure along the test section centre line was measured at four positions along the test section.

### 5. DATA PROCESSING

#### 5.1 Total Mean Velocity

The local mean velocity at the test section and at the boundary layer was calculated from the measured dynamic pressure, which is the difference between the total pressure and the static pressure;

$$V = \sqrt{\frac{\Delta P}{0.5 * \rho_{\infty}}} \quad (1)$$

Where  $\Delta P$  is the dynamic pressure measured by micro-manometer in (Pa), and  $\rho_{\infty}$  is the density calculated from a barometric pressure measurement, a test section static pressure measurement relative to the atmosphere and a test section temperature determination along with the equation of state. From the manual book of the pitot tube device, the density could be found from the following equations;

$$\rho_{\infty} = 1.325 \times P_B T \quad (2)$$

where  $P_B$  is the barometric pressure in inches of mercury.  $T$  is the absolute temperature (indicated temperature in °F plus 460).

For standard sea level air properties,

$$V = \sqrt{\frac{\Delta P}{0.5 * 1.225}} = 40.406 * \sqrt{\Delta P} \quad (3)$$

#### 5.2 Boundary Layer Characteristics

The wall boundary layer velocity profile could be measured and fitted with power law function to find the boundary layer characteristics as displacement thickness, momentum thickness and shape function using Simpson's 1/3 Rule for equal interval in the y-direction. These characteristics may be defined as follows;

$$\delta^* = \int_0^{\delta} \left( 1 - \left( \frac{U}{U_e} \right) \right) dy \quad (4)$$

$$\theta = \int_0^{\delta} \left( 1 - \left( \frac{U}{U_e} \right) \right) \left( \frac{U}{U_e} \right) dy \quad (5)$$

$$H = \frac{\delta^*}{\theta} \quad (6)$$

Where  $U/U_e$  is the velocity profile of the flow near the tunnel wall at specified position.

### 5.3 Velocity Error Analysis

The local mean-velocity ( $V$ ) was given by equation;

$$V = cc \sqrt{h} \quad (7)$$

where  $cc$  is constant depends on the equation (1) parameters. Thus, to find the relative error, it will be differentiated logarithmically, then;

$$\frac{dV}{V} = \frac{1}{2} \times \frac{dh}{h} \quad (8)$$

where ( $dh$ ) is the absolute error in the dynamic pressure head, and it is calculated as;

$$dh = \sqrt{((h - h_m)^2 + (\delta h)^2)} \quad (9)$$

The first term in the R.H.S of equation (9) represents the deviation from the mean ( $h_m$ ) of all measured values of ( $h$ ), and it is calculated as  $(\frac{\sum_{i=1}^n h_i - h_m}{n})$ , where ( $n$ ) is the number of points, where as the second term represents the error of the measurements.

As example, the error in the velocity 30 m/s at the test section inlet without the model as presented in are calculated using the measured values of the dynamic pressure head at the mesh points where the mean value  $h_m$  is (55.56138 mmH<sub>2</sub>O), and deviation from the mean was (0.824093 mmH<sub>2</sub>O). The error of measurements was taken as (0.5 mmH<sub>2</sub>O). Hence, from equation (9), the absolute error ( $dh$ ) was calculated as (0.96391mmH<sub>2</sub>O), thus, from Eq. (8), the velocity relative error will be ( $\pm 0.8674\%$ ).

## 6. CFD SIMULATION

A three dimensional flow had been simulated using COMSOL 3.5 commercial programme. Turbulent flow with  $\kappa$ - $\omega$  turbulence model was used to simulate the flow inside wind tunnel. Three velocities were simulated and presented to study the flow characteristics and behaviour through the test section. The simulation may be represented with the boundary conditions illustrated in **Fig. 4** where the inlet velocity was measured from the wind tunnel inlet section using flow anemometer. Unstructured tetrahedral elements were used with total number of 12000 elements. **Fig. 5** shows a generated free mesh by the programme for the flow inside the wind tunnel. Stationary segregated solution method was used with tolerance  $10^{-5}$  and the maximum numbers of iterations were 2000 step. The solutions were represented in to contours for the pressure and velocity distributions.

## 7. RESULTS AND DISCUSSIONS

The wind tunnel total velocity was calibrated and presented in **Fig. 6**. The Pitot static tube was fixed at the test section inlet plane to record the total mean velocity by using micro-manometer. The figure relates the input current to the fan with total velocity which is ranged from 0 to maximum speed. It is found that the velocity at the test section had maximum value of 55 m/s. The discrepancy in the designed and measured velocity may be attributed to the fan design blade.

As shown in **Fig. 7**, the uniformity distributions of the inlet velocity across the inlet plane of test section for 10, 30 and 45 m/s respectively are clearly flatten at the core section as expected. Small regions at the test section walls are shown to be distorted due to presence of boundary layer on the wall surface. The velocities 30 and 45 m/s show a deep valley at the centre of the section due to the wake of frontal Pitot-static tube which was fixed to measure

the inlet velocity. This Pitot must be removed from the inlet section after measuring the velocity to a specified value.

The mid section velocity uniformity is illustrated in **Fig. 8** for different inlet velocities of 10, 30, and 45 m/s respectively. The distributions are fair enough for different velocities and the discrepancies may be attributed to the corner stationary flows of the test section. The velocities distributions show an important behaviour at the centre regions, where the maximum values are distributed in the y-direction while no similar distribution are found in x-direction, this may be attributed to the divergence angle of the test section for the upper and lower surfaces which are tilted to prevent buoyancy effect along the test section.

**Figs. 9, 10, 11, and 12** show velocity profiles at the inlet and mid planes of test section for horizontal and vertical centre axes. As shown the flows are flattened at the centre location except at the side walls where the boundary layer growth is the major influence to the uniformity of the test section and symmetrical distribution along the vertical and axial axis.

The velocity profiles along the diagonals of the inlet and mid planes are shown in **Figs. 13, 14, 15, and 16**. It could be seen that, as the test section velocity increased the profiles became inflated slightly specially at velocity 30 m/s which may be attributed to the wall boundary layer effects on the core velocities.

It is important to find the velocity profiles across the boundary layer of the test section walls. Since the flow is symmetric across different axis as illustrated in the previous figures, the boundary layer on the lower surface is measured by finding a velocity profiles at the mid section for three velocities 10, 30 and 45 m/s. As can be seen, turbulent velocity profiles are clearly appeared in **Figs. 17, 18 and 19**. A power law was used to find a curve fitting for the experimental data. Equations are shown in the figures, and good fittings are evaluated for the velocity profiles. The boundary layer characteristics (displacement thickness, momentum thickness) could be calculated for these profiles and are given in the **Table 1**. No boundary layer separations are obvious through test section walls. By assuming the boundary layer thickness is linear with distance. Taking the relation from **schlichting**,

$\delta(x) = .37 x \left( \frac{ux}{v} \right)^{\left( -\frac{1}{5} \right)}$ , one obtains a boundary layer thickness of 20.8 mm for flow at the test section at velocity 10 m/s if the boundary layer begins at the inlet of the test section. The measured thickness for this velocity at mid section is 19 mm, which is good prediction to the boundary layer thickness. Most of results are shown in the **Table 1**. It could be noticed that the boundary layer thickness increased with increasing velocity which may be attributed to the traverse pressure gradient normal to the wall which increases the boundary thickness. Same thing may be noticed for momentum thicknesses and shape factor which give an indication for shear stress and frictional losses along the test section.

**Figs. 20, 21**, show the flow inside wind tunnel for inlet velocity equal to 1.23 m/s experimentally which gives 10 m/s at the test section. One notes that the pressure at the test section is under the atmospheric pressure with minus value and the velocity also equal to 10 m/s as measured experimentally. **Figs. 22, 23, 24, and 25** have same distributions with inlet velocities 3.5 m/s for 30 m/s and 5.25 m/s for 45 m/s respectively.

The static pressure along test section is represented in **Fig. 26**. The figure shows a gradual decrement in the static pressure although it is small but could be represented as a linear behaviour for all three velocities. For velocity 30 m/s as example,

$$D = (p_{out} - p_{in}) * A = (-0.53 + 0.57) * 1000 * (0.7 * 0.7) = 19.6 \text{ N}$$
$$C_D = \frac{D}{0.5 \rho_{\infty} V_{\infty}^2} = \frac{19.6}{0.5 * 1.23 * 30^2} = 0.035$$

The drag coefficient for the model inside test section must be corrected due to presence of the boundary layer growth along walls of test section. **Pope,1978**, presented a method for calculating buoyancy effects on the models inside test section. The static pressure gradient shrinking streamlines transiting down the test section. The squeezing effect accounted and added to the pressure gradient effect. The total drag increment with squeezing effect is;

$$\Delta D_B = -\frac{\pi}{2} \lambda t^2 \left( \frac{dp}{dl} \right)$$

where  $\lambda$  correction factor, and  $t$  is the body thickness.

## 8. CONCLUSION

The overall aerodynamic objectives for most wind tunnels is to obtain a flow in the test section that is as near as possible to a parallel steady flow with uniform speed throughout the test section. The wind velocity in the test section of the Low Speed Wind Tunnel (LSWT) at the Mechanical Department of university of Baghdad is obtained from pressure measurements using pitot tubes located at the entrance and mid section of the tunnel test section. The static pressure along the test section centre line was measured at four positions along the test section. The local mean velocity at the test section and at the boundary layer was calculated from the measured dynamic pressure. The inlet and mid plane of test section for 10, 30 and 45 m/s are clearly flatten at the core section. A power law was used to find a curve fitting for the experimental data of boundary layer on the lower surface, and good fittings are evaluated for the velocity profiles, which mean the flow is turbulent. The static pressure along the test section was a linear behaviour.

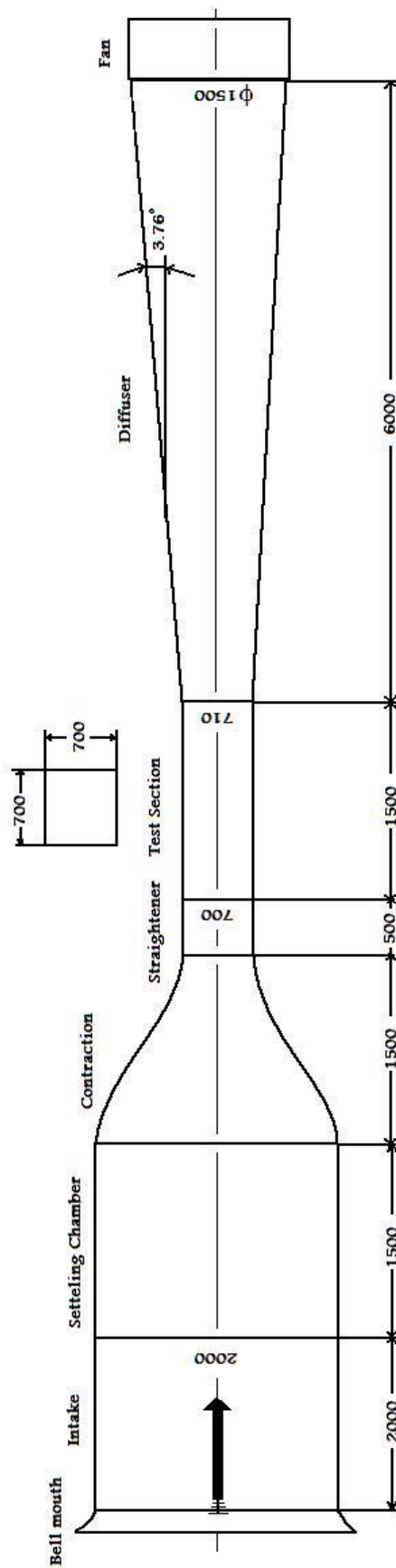


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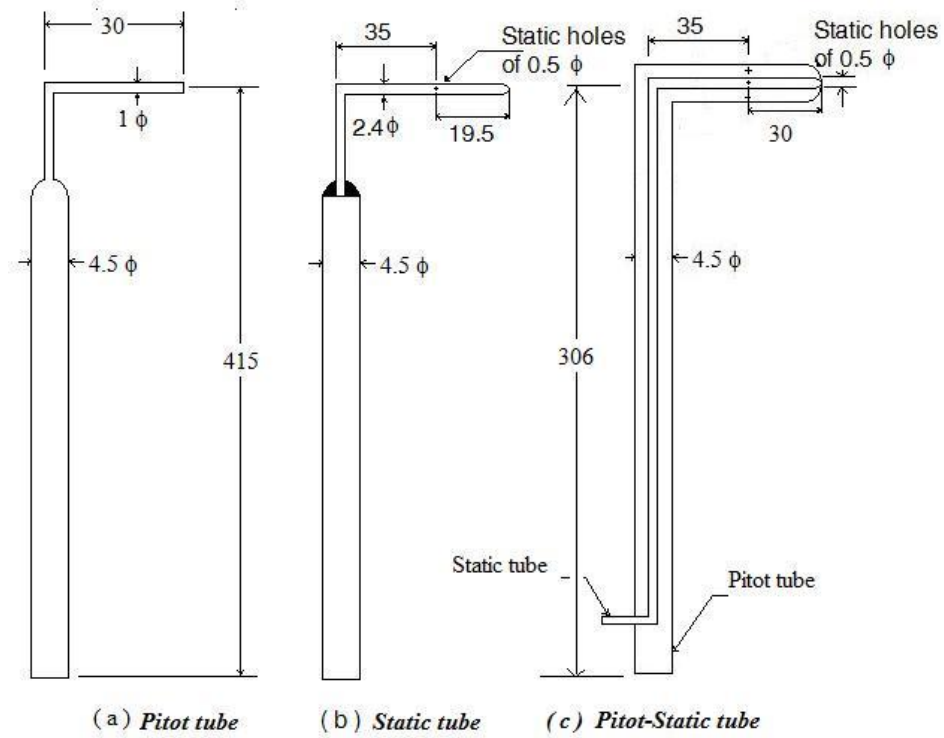
## NOMENCLATURE

$\Delta P$	$(P_o - P_\infty)$	Pa
$C_D$	drag coefficient	
$D$	drag force	N
$D_B$	buoyancy Drag	N
$dp/dl$	pressure gradient	Pa/m
$H$	shape factor	
$P_\infty$	free stream Static pressure	Pa
$P_o$	total Pressure	Pa
$t$	body thickness	M
$U$	local velocity	m/s
$U_e$	boundary layer edge velocity	m/s
$V$	total mean velocity	m/s
$\delta$	boundary layer edge	m
$\delta^*$	boundary layer displacement thickness	m
$\theta$	boundary layer momentum thickness	m
$\lambda$	correction factor	
$\nu$	kinematic viscosity	$m^2/s$
$\rho_\infty$	free stream density	$m^3/kg$

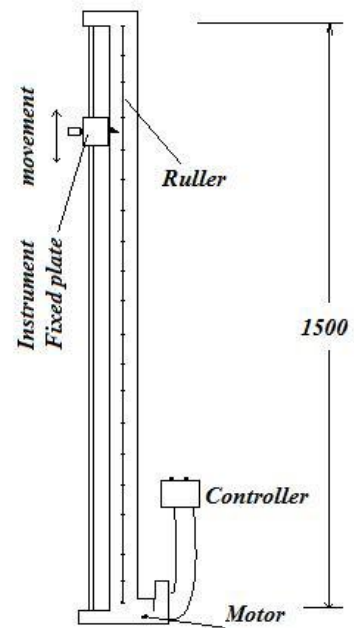


**Figure 1.** Wind tunnel dimensions (all are in mm).



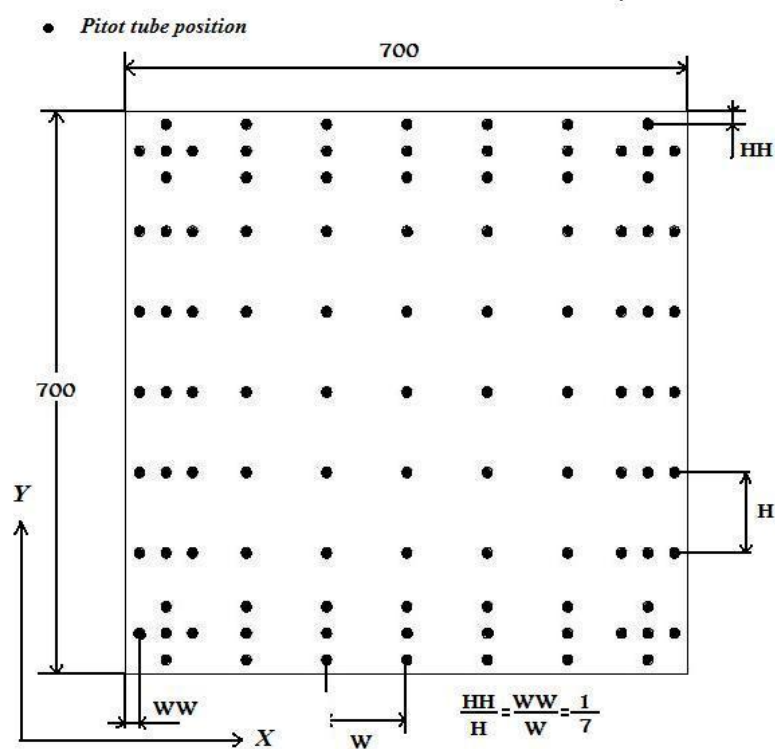


(d) Micro-manometer

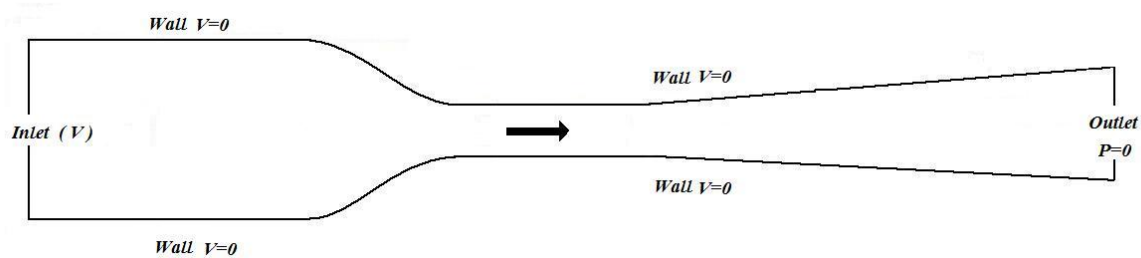


(e) Traverse system

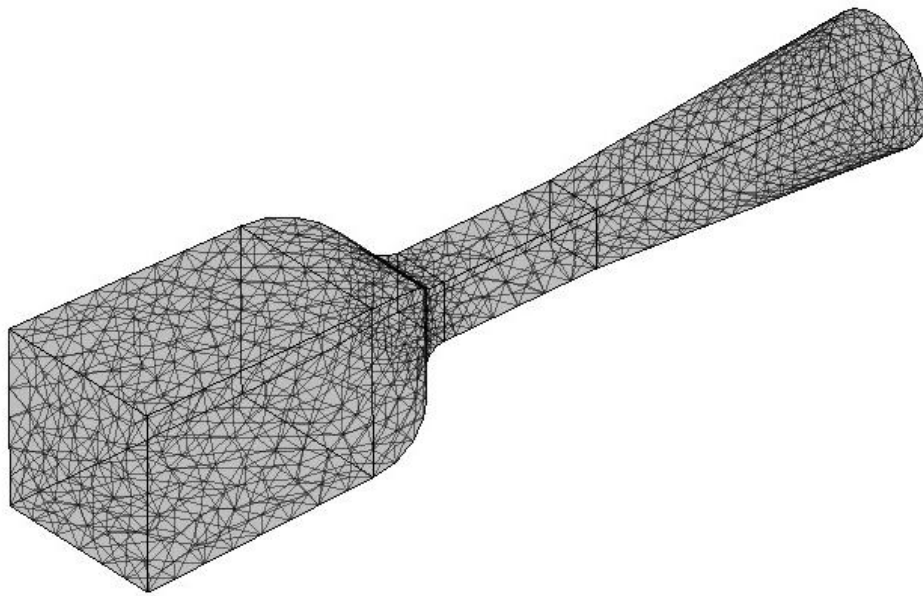
**Figure 2.** Types of measurement instruments (all dimensions are in mm).



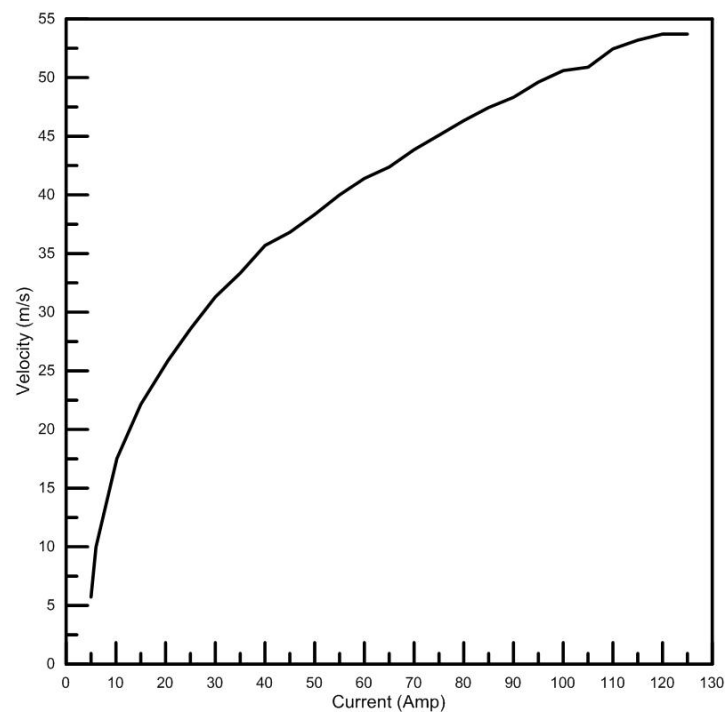
**Figure 3.** Mesh arrangement at the test section (all dimensions are in mm).



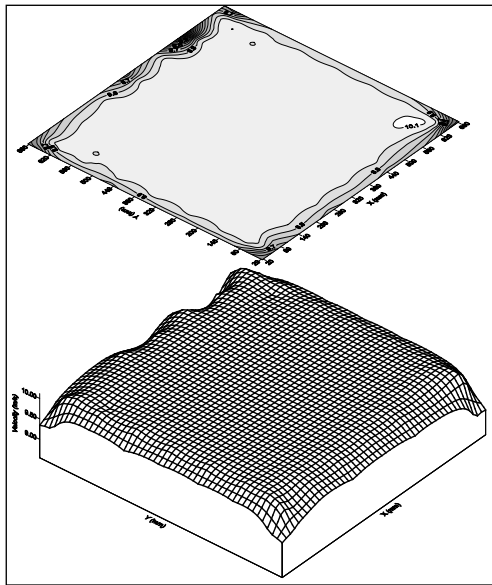
**Figure 4.** Wind tunnel CFD boundary conditions.



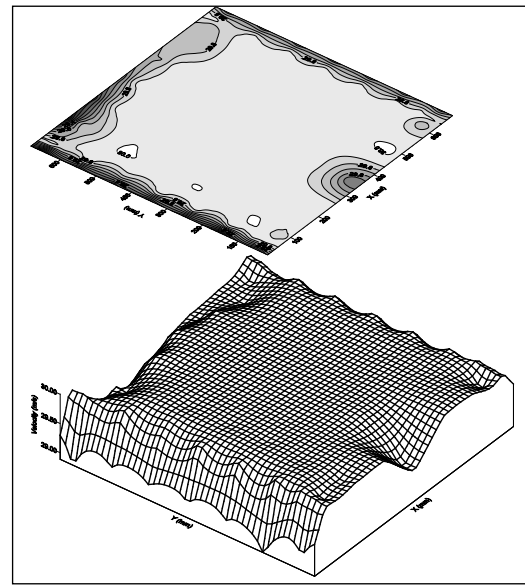
**Figure 5.** Wind tunnel discretization using COMSOL 3.5 program.



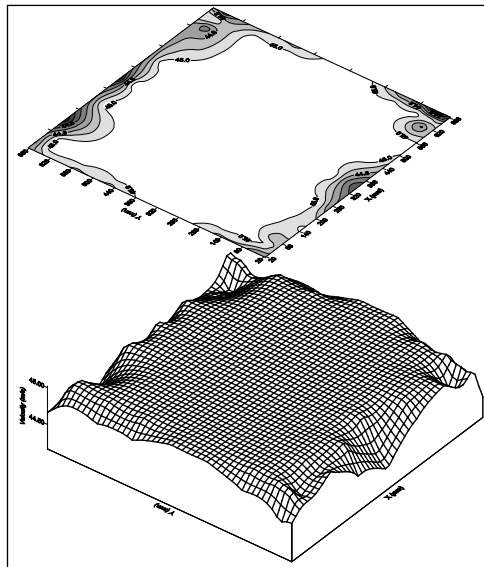
**Figure 6.** Total velocity as a function of the fan input current.



Velocity = 10 m/s

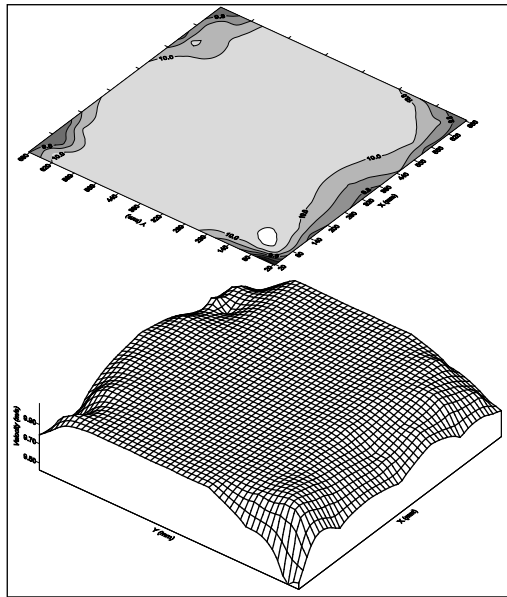


Velocity = 30 m/s

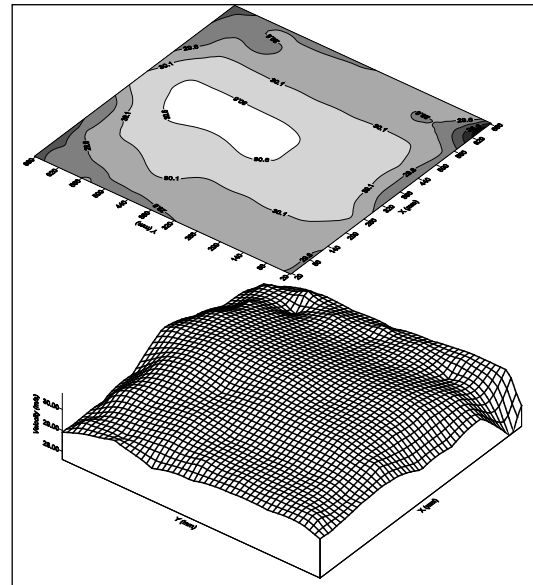


Velocity = 45 m/s

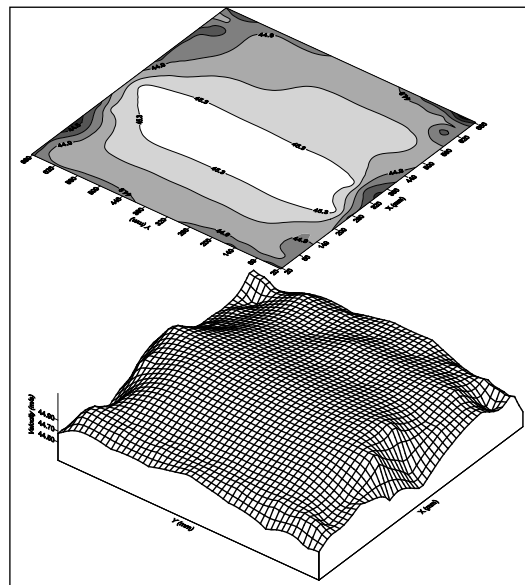
**Figure 7.** Velocity uniformity across the inlet plane of the test section for 10, 30, and 45 m/s.



Velocity = 10 m/s

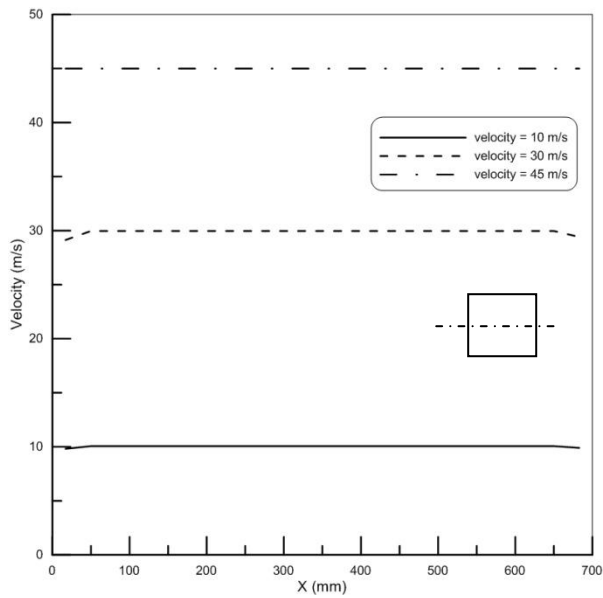


Velocity = 30 m/s

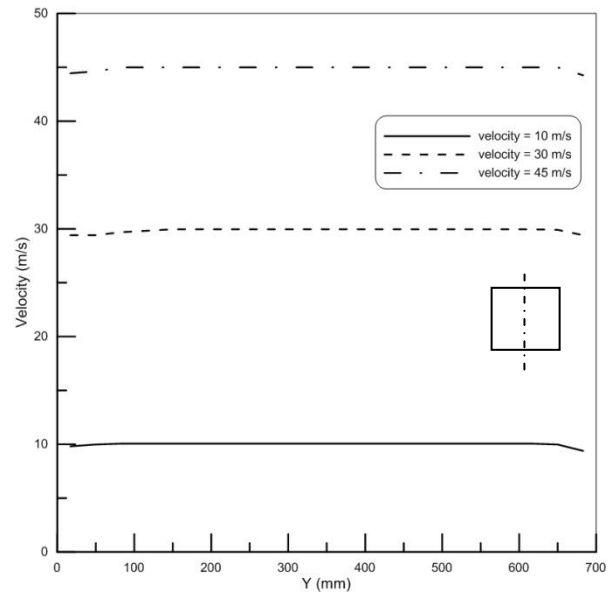


Velocity = 45 m/s

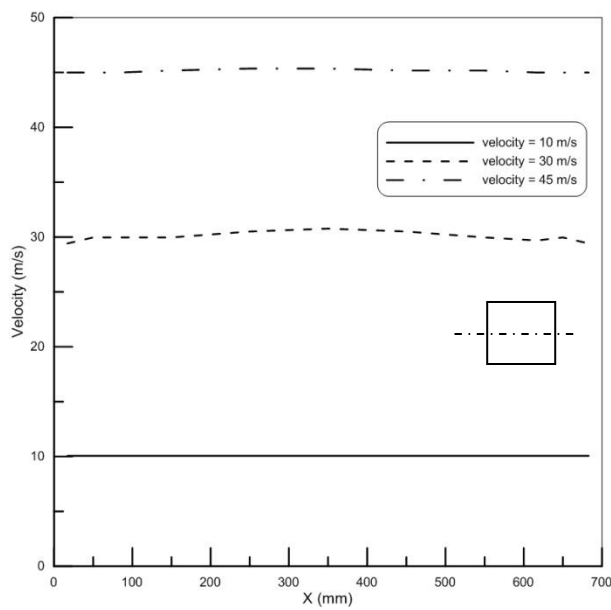
**Figure 8.** Velocity uniformity across the mid plane of the test section for 10, 30, and 45 m/s.



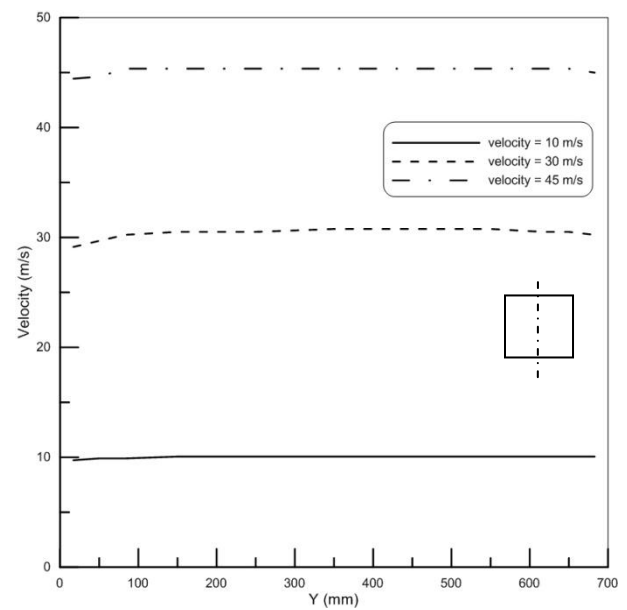
**Figure 9.** Test section velocity of the horizontal axis at the inlet plane.



**Figure 10.** Test section velocity of the vertical axis at the inlet plane.

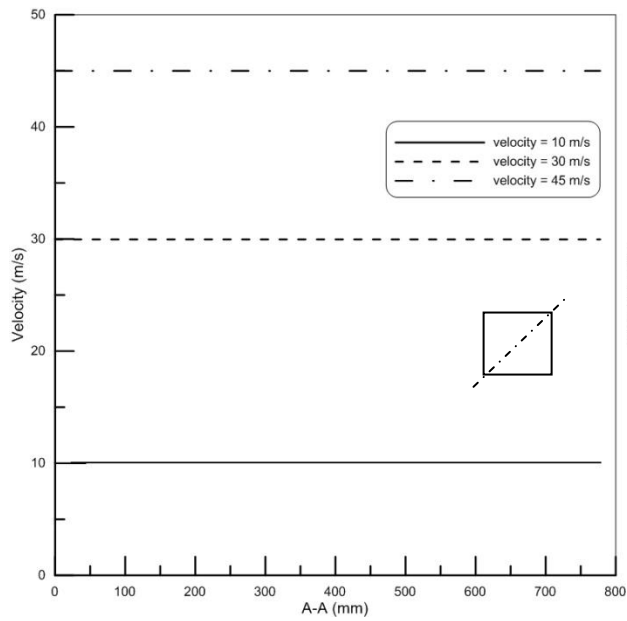


**Figure 11.** Test section velocity of the horizontal axis at the mid plane.

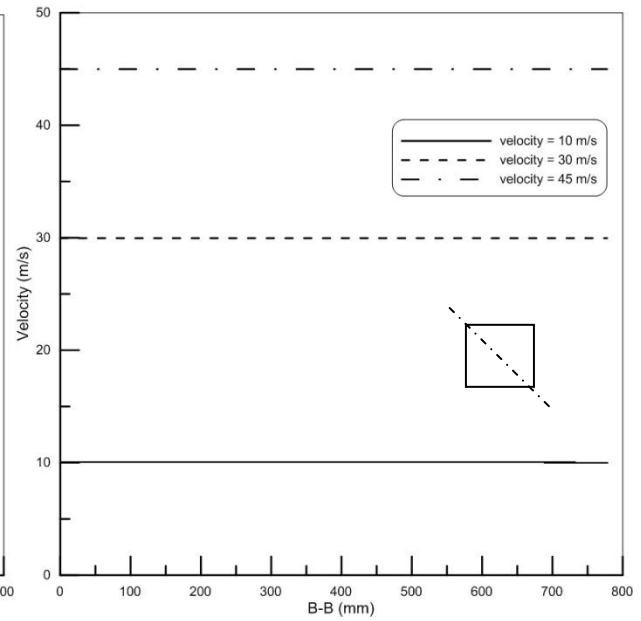


**Figure 12.** Test section velocity of the vertical axis at the mid plane.

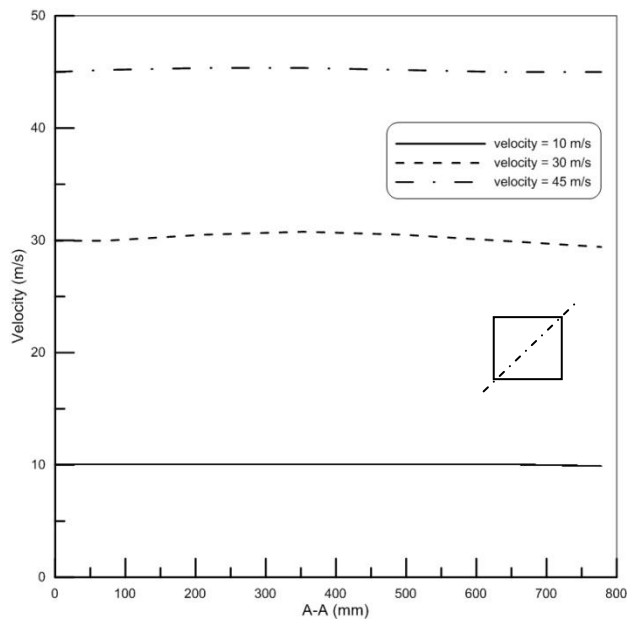




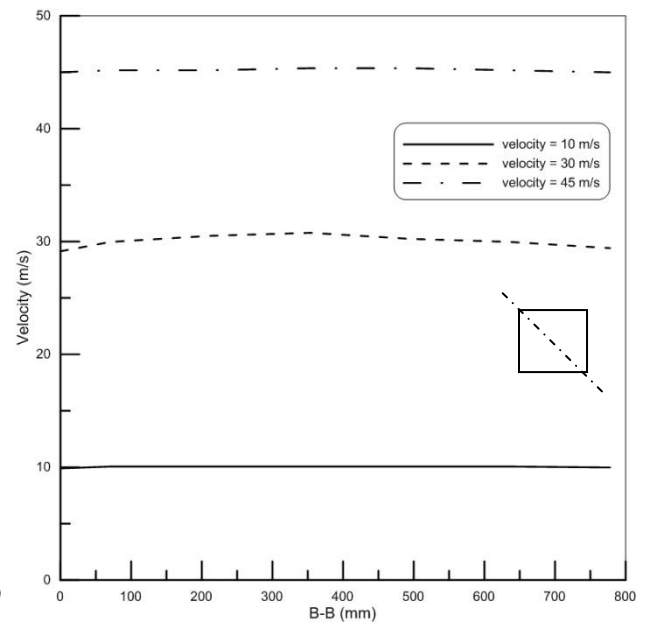
**Figure 13.** Test section velocity of the diagonal a-a at the inlet plane.



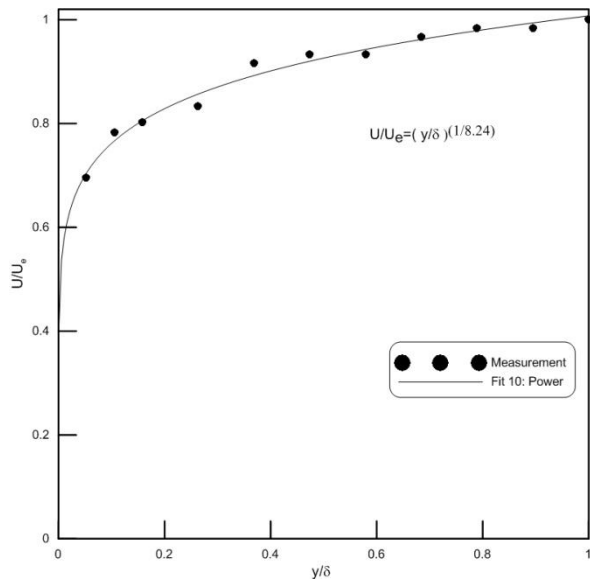
**Figure 14.** Test section velocity of the diagonal b-b at the inlet plane.



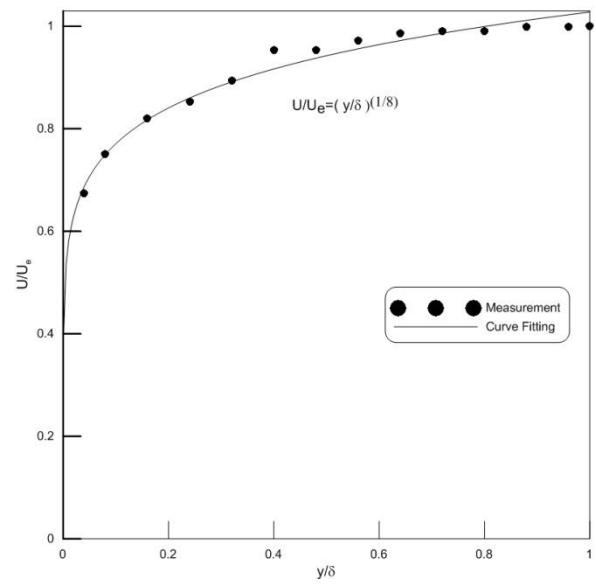
**Figure 15.** Test section velocity of the diagonal a-a at the mid plane.



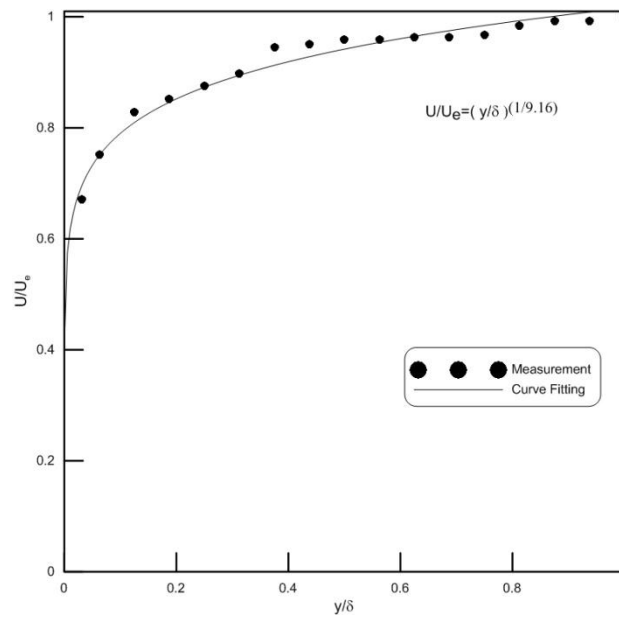
**Figure 16.** Test section velocity of the diagonal b-b at the mid plane.



**Figure 17.** The boundary layer velocity profile over the lower surface of the test section velocity = 10 m/s at mid plane.



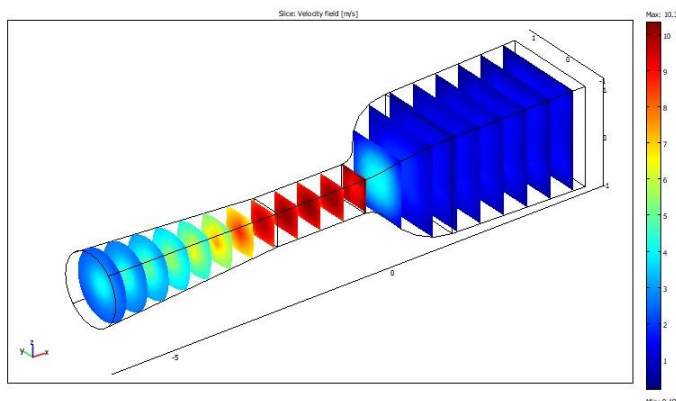
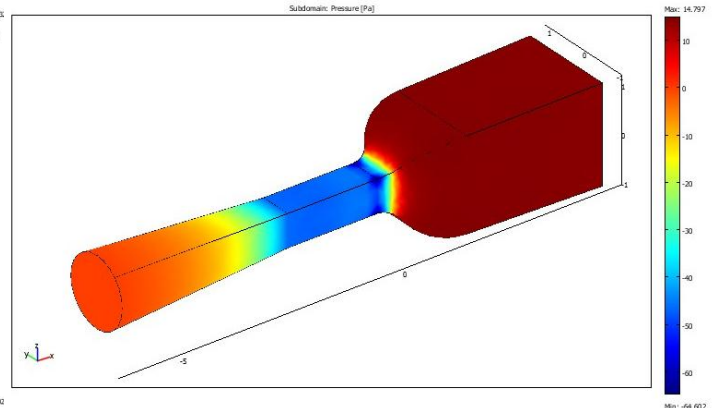
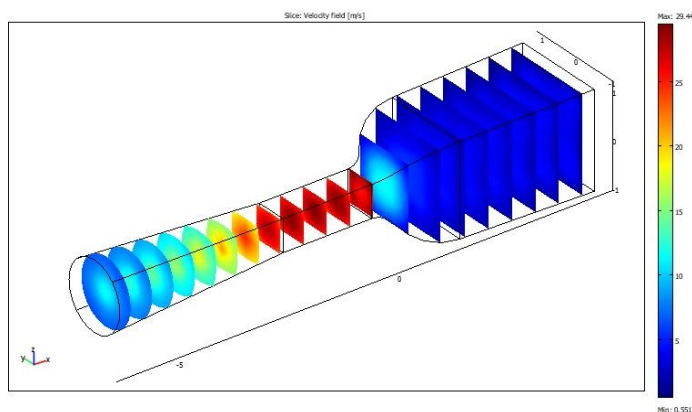
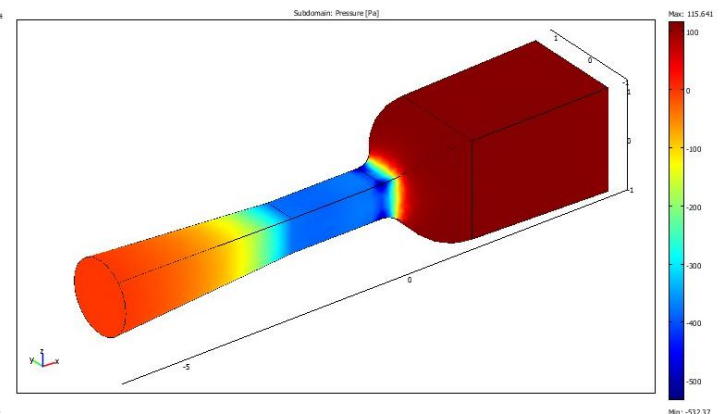
**Figure 18.** The boundary layer velocity profile over the lower surface of the test section velocity = 30 m/s at mid plane.

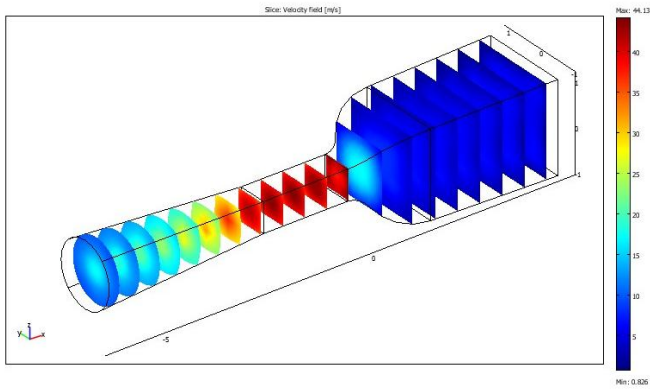


**Figure 19.** The boundary layer velocity profile over the lower surface of the test section velocity = 45 m/s at mid plane.

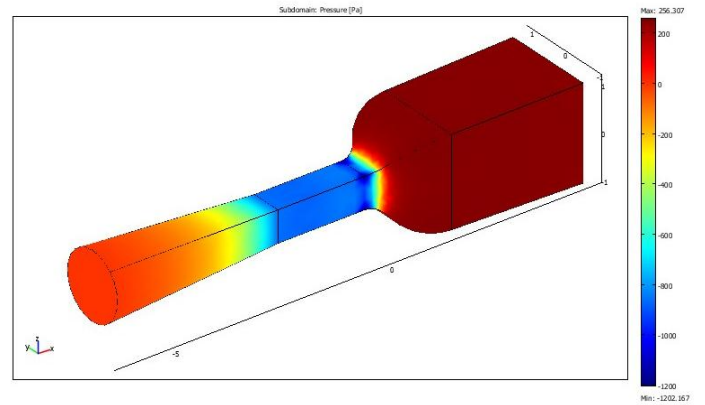
**Table 1.** Boundary layer characteristics inside wind tunnel test section.

Velocity (m/s)	$\delta$ (mm)	$\delta^*$ (mm)	$\Theta$ (mm)	H (mm)
10	19	1.9644E-03	1.58571E-03	0.81
30	25	2.65196E-03	2.12962E-03	0.803
45	32	3.0E-03	2.471E-03	0.82

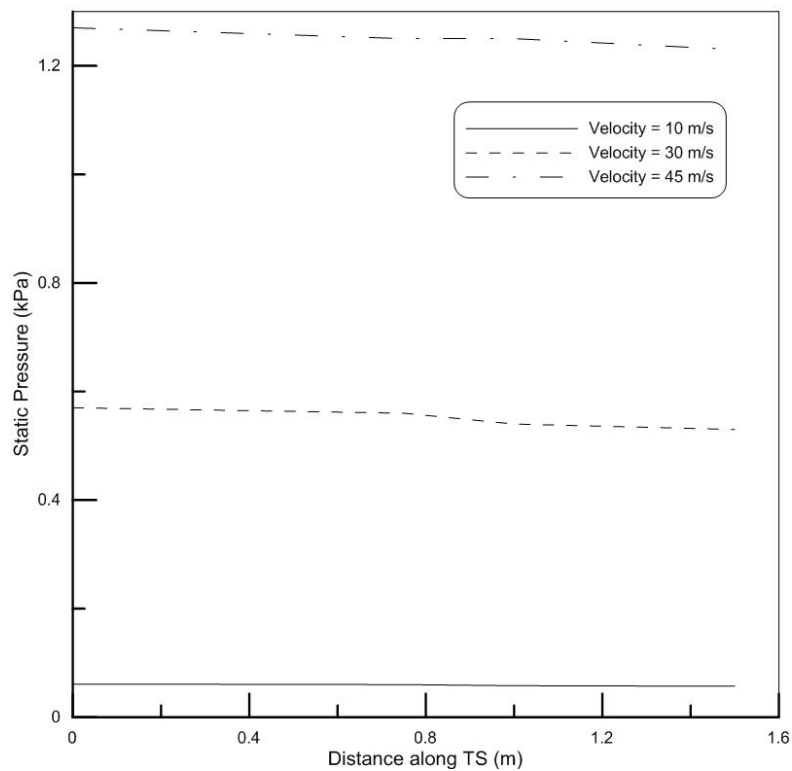

**Figure 20.** Flow field and pressure simulation inside wind tunnel when inlet velocity 1.23 m/s

**Figure 21.** Pressure distribution inside wind tunnel when inlet velocity 1.23 m/s

**Figure 22.** Flow field and pressure simulation inside wind tunnel when inlet velocity 3.5 m/s

**Figure 23.** Pressure distribution inside wind tunnel when inlet velocity 3.5 m/s.



**Figure 24.** Flow field and pressure simulation inside wind tunnel when inlet velocity 5.25 m/s.



**Figure 25.** Pressure distribution inside wind tunnel when inlet velocity 5.25 m/s.



**Figure 26.** Static pressure along test section for three velocities values.

## Removal of Nickel and Cadmium Ions from Wastewater by Sorptive Flotation: Single and Binary systems

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### ABSTARCT

The removal of heavy metal ions from wastewater by sorptive flotation using Amberlite IR120 as a resin, and flotation column, was investigated. A combined two-stage process is proposed as an alternative of the heavy metals removal from aqueous solutions. The first stage is the sorption of heavy metals onto Amberlite IR120 followed by dispersed-air flotation. The sorption of metal ions on the resin, depending on contact time, pH, resin dosage, and initial metal concentration was studied in batch method. Various parameters such as pH, air flow rate, and surfactant concentration were investigated in the flotation stage. Sodium lauryl sulfate (SLS) and Hexadecyltrimethyl ammonium bromide (HTAB) were used as anionic and cationic surfactant respectively. The sorption process, which is PH dependent, shows maximum removal of metal ions at pH 7. Langmuir and Freundlich isotherm expressions were found to give both a good fit to the experimental data. Kinetic data correlated well with Lagergren second order kinetic model, and flotation step enhanced the removal efficiency of nickel and cadmium from wastewater from about 75% to 94% and reduce turbidity so it can dispense with the filtering process, which is expensive technology. It is believed that flotation separation has great potential as a clean water and wastewater treatment technology.

**Key words:** heavy metals; sorption; flotation; kinetics; turbidity.

### أزالة ايونات النيكل والكاديوم من المياه الملوثة بطريقه الامتزاز والتعويم: النظام الاحادي والثنائي

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كلية الهندسة / جامعة بغداد

### الخلاصة

تمت دراسة ازالة ايونات النيكل والكاديوم من المياه بواسطة الامتزاز والتعويم باستخدام راتنج مثل الامبرلايت وعامود التعويم. تعتبر عملية دمج المرحلتين مرحلة الامتزاز ومرحلة التعويم طريقة فعالة لازالة ايونات المعادن الثقيلة من المياه. تبدأ العملية بمرحلة الامتزاز على راتنج الامبرلايت تتبعها عملية التعويم بواسطة الفقاعات المشتتة. تمت دراسة سلوك الامتزاز على الراتنجات بطريقة الدفعة و يعتمد على الوقت، الدالة الهيدروجينية، وزن الراتنج، و التركيز (الكمية المعدة). ومرحلة التعويم، والتي تعتمد على الدالة الهيدروجينية وسرعة جريان الهواء وتركيز مادة التعويم، كما تم استخدام نوعين من مواد التعويم وهي كبريتات لويل الصوديوم، وثلاثي مثيل بروميد الامونيوم كمادتي تعويم موجبه وسالبه على الترتيب. و قد تم تحليل البيانات المختبرية بواسطة موديلات لانكمير و فريندلخ. وتم احتساب الثوابت الخاصة بهذه الموديلات ووجد ان تعبير لانكمير وتعبير

فريدلخ يمثل ملائمة جيدة ومقاربة في تمثيل هذه البيانات المختبرية. كما وتم اختبار البيانات الحركية من الدرجة الاولى و الثانية , تبين انها ملائمة مع الدرجة الثانية اكثر من ملائمتها مع الدرجة الاولى للنظامين الفردي والثنائي. النتائج تشير الى ان الامبريلايت (IR 120) يمكن استخدامه بكفاءة عالية لازالة المعادن الثقيلة من المياه . اما عملية التعويم فتعتبر خطوة مهمة لتعزيز كفاءة ازالة النيكل والكاديوم من مياه الصرف الصحي حوالي (75٪ إلى 94٪) وللمحد من العكورة لذلك يمكن الاستغناء عن عملية الترشيح، والتي تعتبر تقنية مكلفة. كما وتحتل عملية الفصل بالامتزاز والتعويم مكانة كبيرة باعتبارها تقنية واعدة في تكنولوجيا المياه النظيفة و معالجة مياه الصرف الصحي.

**الكلمات الاستدلالية :** معادن ثقيلة , أمتزاز , تطويف , حركية , عكوره.

## 1. INTRODUCTION

Heavy metals are generally considered to be those whose density exceeds  $5 \text{ g/cm}^3$ , **Nocito et al., 2007**. Removal of heavy metals from wastewater is of primary importance because they are not only causing contamination of water bodies and are also toxic to many life forms. Industrial processes generate wastewater containing heavy metal contaminants. Since most of heavy metals are non degradable into nontoxic end products, their concentrations must be reduced to acceptable levels before discharging them into environment. Otherwise these could pose threats to public health and/or affect the aesthetic quality of potable water, **Aslam, et al, 2004**. According to World Health Organization (WHO) the metals of most immediate concern are nickel, cadmium, chromium, copper, zinc, iron, mercury and lead, **WHO, 1984**.

Nickel ions represent a serious environmental problem since they are widely used in many industries and general applications. Among them are: industrial effluents, industrial fertilizers, catalysts, gears, magnets, airbag valves, electronics, tooth protects, exhaust smokes, stainless steels, etc, **Arsalani, et al., 2009**. Its removal is of major concern because nickel compounds are carcinogenic and also can cause asthma. Another common adverse health effect of Ni (II) is skin allergy, **Aslam, et al., 2010**. In addition to nickel, cadmium is consider one of the most toxic metals affecting the environment, the source of cadmium are mining and metallurgy of cadmium, cadmium electroplating, , is widely used in pigments, as heat stabilizers for plastics, for corrosion resistance of steel and cast iron, metal plating, phosphate fertilizer, mining, pigments, alloy industries, in soldering and brazing and in the battery industry (Ni - Cd batteries), and ceramic industries waste waters contain undesired amounts of  $\text{Cd}^{2+}$  ions is highly toxic and there is some evidence that it is carcinogenic, **Hiatt and Huff, 1975**. Sorptive flotation involves the preliminary abstraction or scavenging of metal ions using appropriate sorbents which exists in fine or ultrafine particle size range, subsequently he process was followed by a flotation stage for solid – liquid separation of the metal –loaded sorbent particles from the treated clean solution.

The aim of the present work is to study the removal of nickel, and cadmium ions from wastewater by sorptive flotation method using Amberlite IR120 and Amberlite CG50 as an exchanger resins and bubble column for flotation. In addition, investigate the parameters that influence the separation efficiency, such as contact time, pH, and dose of resin, and initial metal concentrations, air flow rate, surfactant type. Also this study aims at determining isotherm model and kinetic models for this system.



## 2. MATERIAL and EXPERIMENTAL PROCEDURE

### 2.1 Materials

Analytical grade reagents were used in experimental studies. Nickel nitrate Hexahydrate  $\text{Ni(NO}_3)_2 \cdot 6\text{H}_2\text{O}$  and Cadmium nitrate tetrahydrate  $\text{Cd(NO}_3)_2 \cdot 4\text{H}_2\text{O}$  were used for preparing synthetic solutions. pH adjustments were carried out by using 0.1N  $\text{HNO}_3$  and 0.1N  $\text{NaOH}$ . Amberlite IR120 strong acid cation exchange resin from (Rohm and Hass) and Amberlite CG50 resin from (Hopkin and Williams Company, UK) was used, its physical and chemical properties are given in **Tables 1 and 2** respectively. Sodium lauryl sulfate  $\text{C}_{12}\text{H}_{25}\text{NaO}_4\text{S}$  (SLS) and Hexadecyl trimethyl ammonium bromides (HTAB) as anionic and cationic surfactants, respectively.

**Table1.** Properties of Amberlite IR120.

Matrix	Styrene
Functional group	Sulfonic acid (strong acid)
Particle size(mm)	0.3-1.2
Maximum temperature °C	120
pH range	0-14
Total capacity(equiv/l)	1.8

**Table 2.** Properties of Amberlite CG50.

Matrix	Macroporous crosslinked methacrylate
Functional groups	-COO
Physical form	Dry fine powder
Ionic form as supplied	H <sup>+</sup> weak acid
Total exchange capacity	10 meq/g min
Moisture content	10% max
Particle size	Nominally 100 to 200 mesh (US Std) 75 to 150 $\mu\text{m}$

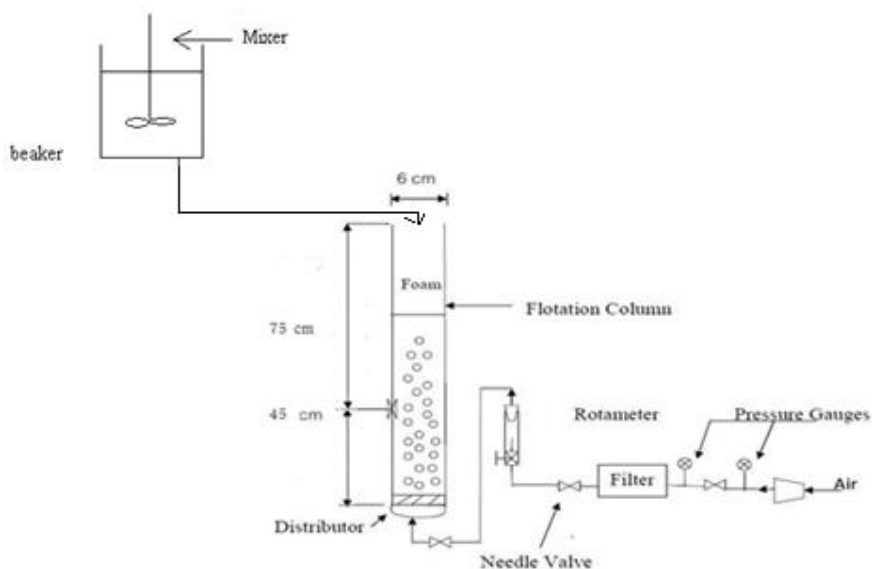
### 2.2. Apparatus

Batch experiments were carried out in Lap Mixer (Cole Parmer, USA). WTW series ion lab pH-meter used for pH measurements. GBC 933 plus Atomic Absorption Spectrometer AAS was used to measure concentrations of soluble nickel and cadmium ions.

### 2.3. Equilibrium studies

Batch equilibrium experiments have been carried out to find the optimum PH, time, and equilibrium isotherms. The procedure involved filling the flask with 1L of heavy metal ions solution of 25-200 ppm. About 1 g of adsorbent was added into flask. Resins and solution dumped into a flask and after mixing at 400 rpm, the solution and the resin allowed for equilibrium for 50 min in the mixer. The adsorbent and the solution were separated through filter paper. The effect of pH for heavy metal ions removal using ion exchangers was studied in pH range of 3-8 amount of resin

0.25- 3 g, concentration of heavy metal ions 25-200 ppm. Sorption isotherm studies were carried out with different initial concentrations of metal ions while maintaining the resin dosage at constant level. For pH effects, 25-200 mg/l of metal ions and ion exchange resins amberlite IR120 dose 1000 mg/1L were used. Kinetic experiments were conducted by using a known weight of resin dosage and optimum metal ion concentration. After regular intervals of time, suitable aliquots were analyzed for metal ions concentrations and recorded. The rate constants were calculated by using the conventional rate expression. After the sorption stage the solution was placed in the flotation column. The flotation tests were carried out in a bubble column (acrylic) of 6 cm inside diameter and 120 cm in height. **Fig.1** shows a schematic diagram of experimental apparatus. Air supplied by the compressor was fed to the column through a pre – calibrated rotameter. Air entered the column was dispersed as bubbles into liquid. Feed inter with different metal concentration was poured gently at the top of the column. At the same time, the column was pressurized so as not to weep the liquid through the holes. Perforated plate of the air distributor was used which has 25 holes with 0.05 cm diameter. The holes are arranged in the equilateral triangular pitch through the whole area which are located inside the column. The column was operated at batch mode as far as the liquid phase and continuous flow with respect to air. This column contains six taps of 0.2 cm inside diameter, these taps arranged at interval of 15 cm and used to draw samples from the column , samples were taken at preset time intervals as 2 , 5, 10 and 15 min, samples were withdrawn slowly to minimize entrainment of air bubbles. Between experiments, the column was cleaned using  $\text{HNO}_3$ , and then rinsed three times with double distilled water. Metal contents of solution were analyzed by AAS.



**Figure 1.** Schematic diagram of the experimental set-up.

### 3. RESULTS and DISCUSSION

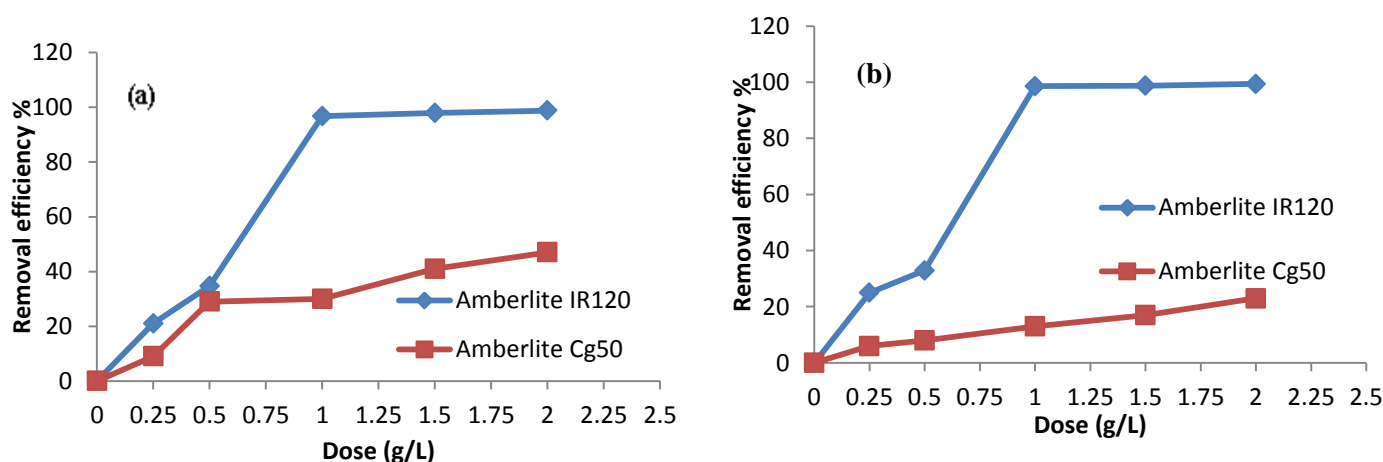
#### 3.1. Effect of Resin Type

Two types of Resin were used in this study to find out the most efficient resin

- 1- weak acid ion exchange resin ( Amberlite CG50 )

## 2- Strong acid ion exchange resin (Amberlite IR120)

**Fig.2** shows the effect of resin type on the removal efficiency of  $\text{Cd}^{2+}$  and  $\text{Ni}^{2+}$  ions, respectively, from these figures it can be seen that the strong ion exchange resin (Amberlite IR120) is more efficient than weak acid ion exchange resin (Amberlite CG50), were the removal efficiency when using 2 g dose of amberlite IR120 reaches about 98.8% and 99.4% for nickel and cadmium respectively, while for the same dose of CG50 it reaches 23% and 47% for nickel and cadmium respectively, and this is because of the ability of the sulfuric acid group to exchange cations or split neutral salts also because the strong acid ion exchange resin useful across the entire pH range, **Wheaton and Lefevre, 2000**, so the decision towards use strong acid ion exchange resin Amberlite IR 120.

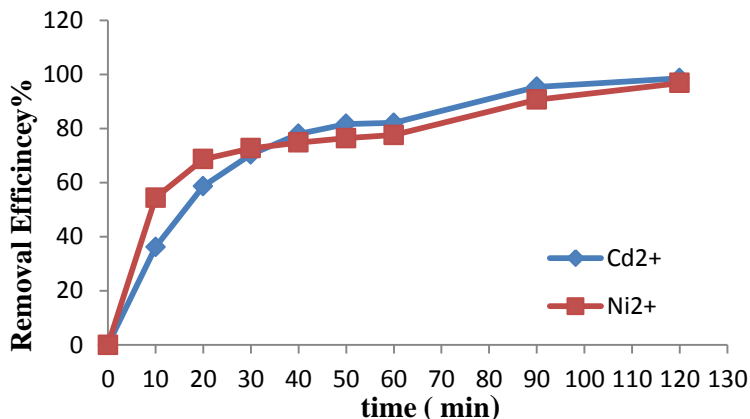


**Figure 2.** Effect of resin type on removal of (a)  $\text{Cd}^{2+}$  (b)  $\text{Ni}^{2+}$  with different dosages at (t,120min ; PH, 7; mixing rate 400 rpm; initial metal concentration 100 mg/L).

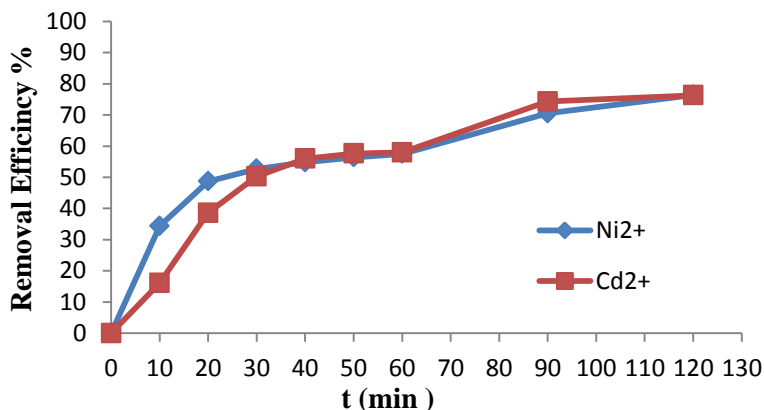
### 3.2. Effect of Contact Time

The effect of contact time on the sorption of metal ions by Amberlite IR120 was studied by adding 1 g /L of resin to 100 mg/L of contaminated solution. The solution was mixed for different time intervals. **Fig.3** shows the effect of contact time on the sorption of nickel, and cadmium. From this figure it can be seen that the percentage of metal removal increased with increasing time and it reached the plateau value at 2 hr for nickel and cadmium ions. The same behavior were noticed by **Onundi et al., 2010**, also the results shows that within the first 30 min uptake metal ions removal by the resin were relatively fast, which is 72.7% for nickel and 70.4% for cadmium, a few progressive increase between 30 to 60 min and after 60 min the percentage of removal efficiency reached 96.8% and 98.6% for nickel and cadmium respectively. The initial sorption rate was very fast due to the existence of greater number of resin sites available for the sorption of metal ions. As the remaining vacant surface sites decreasing, the adsorption rate slowed down due to formation of repulsive forces between the metals on the solid surface and in the liquid phase. The decreasing of Mass transfer leads to increase the uptake of metal ions with contact time. This is a critical parameter for best removal of metal ions in the waste water. The ion exchange rate and the equilibrium removal efficiency of cadmium was faster than nickel while in binary system a

decreasing in removal efficiencies are noted because of the competition between two metal in the solution the results are plotted in **Fig. 4**, the same behavior were noticed by **El-Sayed et al., 2010**.



**Figure 3.** Effect of contact time on removal of Ni<sup>2+</sup> & Cd<sup>2+</sup> ions (pH 7; amount of resin 1g/L; mixing rate 400 rpm; initial metal concentration 100 mg/L; single system).

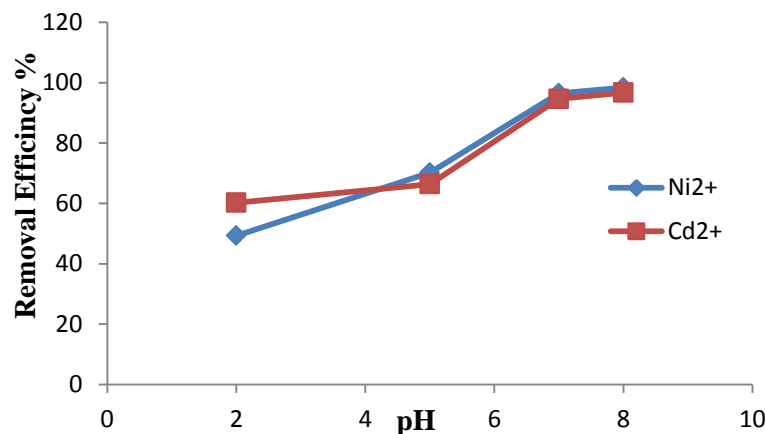


**Figure 4.** Effect of contact time on removal of Ni<sup>2+</sup> & Cd<sup>2+</sup> ions (pH 7; amount of resi 1g/L; mixing rate 400 rpm; initial metal concentration 100 mg/L, binary system).

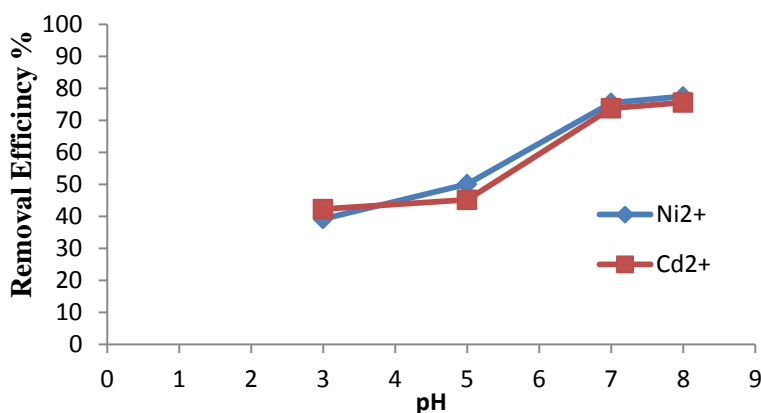
### 3.3. Effect of pH

The effect of pH was examined by adjusting the pH in range of 2-8. Hydronium ion concentration is a parameter affecting the ion exchange process. This is partly because hydrogen ions themselves are strongly competing adsorbate and the solution pH influences the ionization of surface function group.; 100 mg/L metal solution was used. Resin amounts of 1 g/L were added to the beaker and solution were mixed at 400 rpm at temperature 25°C. The sorption of metal ions increases with an increase in pH. Up to pH 5, the increase in sorption is gradual, which however, increase drastically at pH > 5. At higher pH ≥ 7.0, Cd<sup>2+</sup> and Ni<sup>2+</sup> ions sorption become nearly constant, the amount of sorbate was found to decrease because the surface area of the sorbent were

more Protonated and competitive sorption occurred between  $H^+$  protons and free metal ions toward the fixation sited, **Onundi, et al., 2010**. Therefore,  $H^+$  ions react with ionic functional groups on the surface of the sorbent and result in restriction of the number of the binding sites favorable for the sorption of metal ions; pH affects both the surface charge of adsorbent and the degree of ionization of heavy metals in solution. The results are plotted in **Figs. 5 and 6** for single and binary systems, respectively. From these figures it can be seen that the removal efficiency reached 98.4% and 96.7% for nickel and cadmium ions, respectively, for single system while for binary system it reaches 75.5% and 73.8% for nickel and cadmium, respectively.



**Figure 5.** Effect of pH on removal of  $Ni^{2+}$  &  $Cd^{2+}$  ions (contact time 2 hr; amount of resin 1g/L; mixing rate 400 rpm; initial metal concentration 100 mg/L; single system).

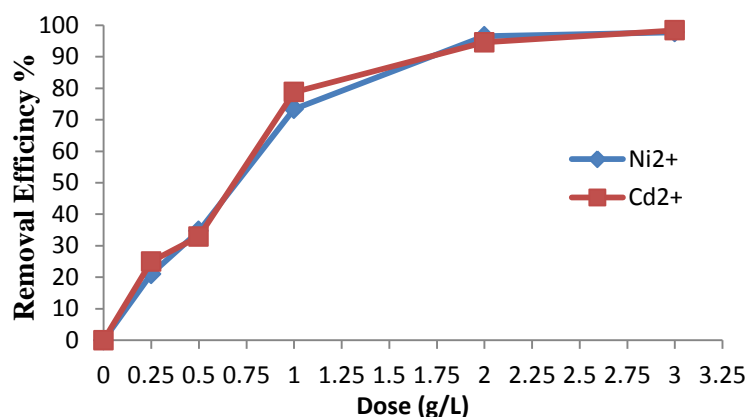


**Figure 6.** Effect of pH on removal of  $Ni^{2+}$  &  $Cd^{2+}$  ions (contact time 2 hr; amount of resin 1g/L; mixing rate 400 rpm; initial metal concentration 100 mg/L; binary system).

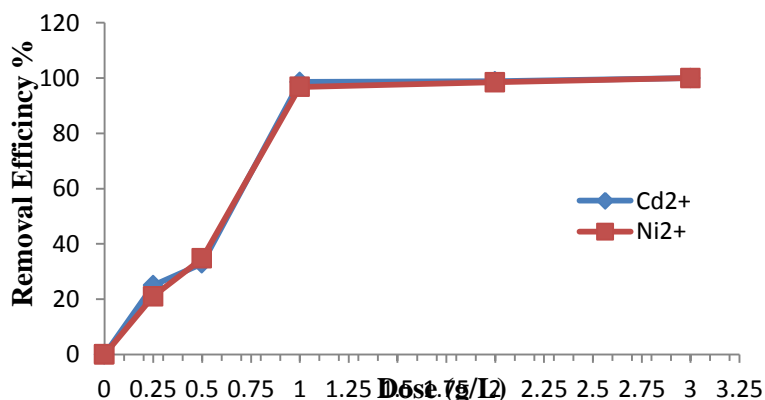
### 3.4. Effect of Resin Dose:

The resin amount also one of the important parameters to obtain the quantities uptake of metal ion. The dependence of metal sorption on resin amount was studied by varying the quantity of Amberlite IR120 0.25, 0.5, 1, 2 and 3 g/L in 100 mg/L of metal solution, pH 7 and contact time 2 hr. The mixing speed of 400 rpm remained constant and temperature was maintained at 25°C. The results are plotted in **Figs. 7 and 8**. These figures reveals that the removal of metal ions increase with

increases in resin dosage from 0.25 to 1 g/L, the removal remain unchanged above 1 g/L of Amberlite IR120, Obviously that by increasing the resin amount, the sorption density, and the amount of adsorbed metal ion per unit mass increases, **Rafati, et al., 2010**. A small increase in the removal efficiency can be noticed when the amount of resin increased from 1 to 3 g/L because 1g/L was enough to adsorb nearly all metals existing in the solution and reach very high removal efficiencies. The increasing in the resin amount resulted in a decrease in the contact time required to reach equilibrium. The results were expected because for a fixed initial metal concentration, increasing sorbent amount provides greater surface area or ion exchange sites or adsorption site, **Gupta and Bhatta, 2009**.



**Figure 7.** Effect of resin dose removal of Ni<sup>2+</sup> & Cd<sup>2+</sup> ions on Amberlite IR120 on (pH 7; Time 120 min; mixing rate 400 rpm; initial metal concentration 100 mg/L; single system).



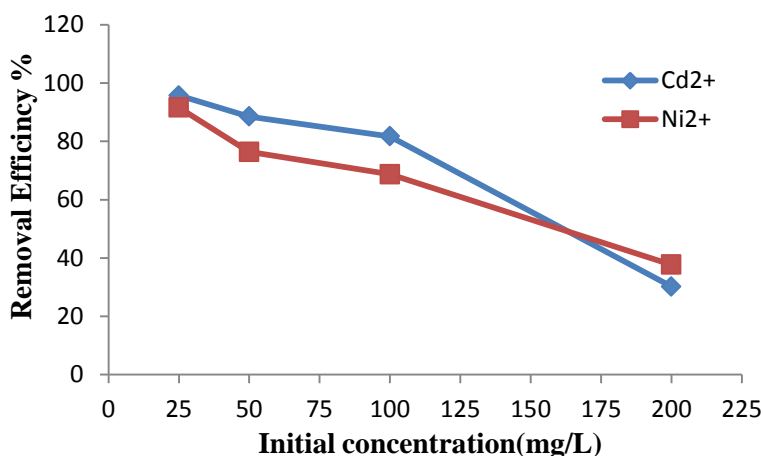
**Figure 8.** Effect of resin dose removal of Ni<sup>2+</sup> & Cd<sup>2+</sup> ions on Amberlite IR120 on (pH7; Time 120 min; mixing rate 400 rpm; initial metal concentration 100 mg/L; binary system).

### 3.5. Effect of Initial Concentration

Experiments were done by using 1 g/L of resin, pH 7, contact time 120 min, and constant shaking speed, 400 rpm with different initial metal concentrations 25, 50, 100, 200 mg/L for Ni<sup>2+</sup> and Cd<sup>2+</sup> ions. **Fig.9** shows the effect of varying metal concentrations on the sorption under the best



conditions. The results show that the increase in initial metal ion concentration decreases the sorption percentage removal. This behavior due to that 1 g of resin may contain enough exchangeable sites for the concentration range 25-50 mg/L, but when the concentration increases to 100 and 200 mg/L the exchangeable sites in 1 g will not be enough to accumulate these concentrations so that the depletion in percentage removal was obvious. The maximum cation exchange resin percent was obtained as 95.7% and 91.6% for  $\text{Ni}^{2+}$  and  $\text{Cd}^{2+}$  for single system while it reaches 57.6% and 67.4% for  $\text{Ni}^{2+}$  and  $\text{Cd}^{2+}$  for binary system, respectively. This decrease in the removal efficiency is due to competition between metals  $\text{Ni}^{2+}$  and  $\text{Cd}^{2+}$  for binding sites presented in the resin. The adsorption phenomena depend on the charge density of cations. The charges of metal ions are the same (+2); therefore  $\text{Cd}^{2+}$  (biggest diameter) have minimum sorption while  $\text{Ni}^{2+}$  (least diameter) have maximum sorption.



**Figure 9.** Effect of initial metal concentration on removal of  $\text{Ni}^{2+}$  &  $\text{Cd}^{2+}$  ions on Amberlite IR120 (pH 7; amount of resin 1g/L; Time 120 min; mixing rate 400 rpm; single system).

### 3.6. Sorption Isotherms

Sorption isotherms are very powerful tools for the analysis of sorption process. Sorption isotherms establish the relationship between the equilibrium pressure or concentration and the amount of adsorbate adsorbed by the unit mass of adsorbent at a constant temperature, **Sevgi, 2007**. Langmuir and Freundlich isotherm models are widely used to investigate the sorption process.

#### 3.6.1 Langmuir Isotherm Model

Langmuir sorption isotherm models the monolayer coverage of sorption surfaces and assumes that sorption occurs on a structurally homogenous adsorbent and all the sorption sites are energetically identical. The saturated monolayer curve can be represented by the expression, **Rao, et al., 2006**:

$$q_e = \frac{q_{max} b C_e}{1 + b C_e} \quad (1)$$

A linear form of this equation is:

$$\frac{C_e}{q_e} = \frac{1}{q_m b} + \frac{C_e}{q_m} \quad (2)$$

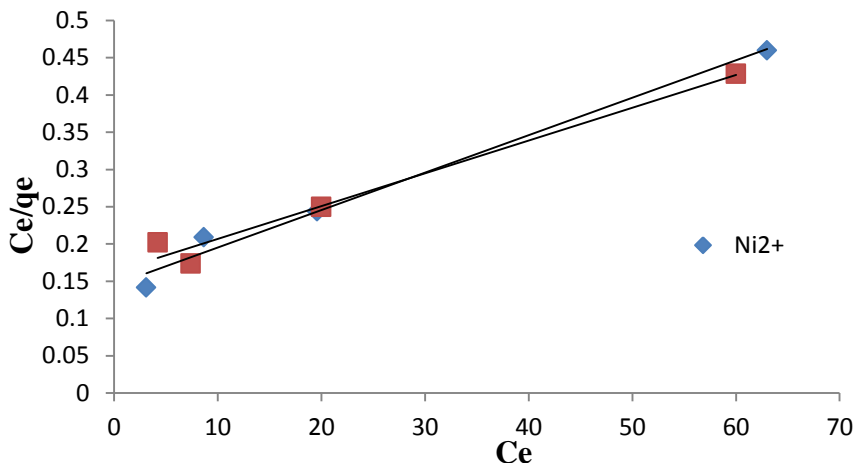
Where:

$b$  = is constant related to the affinity of the binding site ( $L \text{ mg}^{-1}$ ).

$q_e$  = the sorbed metal ions on the biomass ( $\text{mg g}^{-1}$ ).

$C_e$  = metal ions concentration in the solution at equilibrium ( $\text{mg L}^{-1}$ ).

$q_m$  = maximum sorption capacity for a monolayer coverage ( $\text{mg g}^{-1}$ ). The linear Langmuir plots are obtained by plotting  $C_e/q_e$  vs.  $C_e$  (**Fig. 10**).



**Figure 10.** Langmuir isotherm for ion exchange of  $\text{Ni}^{2+}$  &  $\text{Cd}^{2+}$  ions on Amberlite IR120 (concentration 100 mg/l, amount of resin 1g/l ;Time 120 min ; mixing rate 400 rpm).

### 3.6.2 Freundlich Isotherm Model

Freundlich equation is derived to model the multilayer sorption and for the sorption on heterogeneous surfaces. The Freundlich isotherm theory says that the ratio of the amount of solute adsorbed onto a given mass of sorbent to the concentration of the solute in the solution is not constant at different concentrations, **Rao, et al., 2006**. The Freundlich equation is:

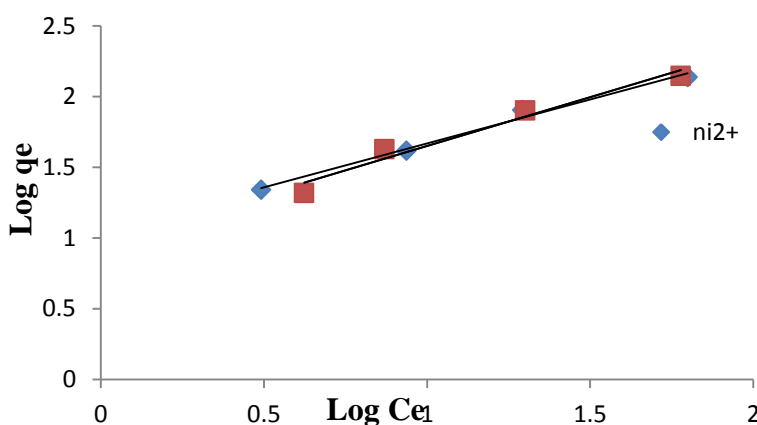
$$q_e = K_f C_e^{1/n} \quad (3)$$

Where:  $K_f$  and  $n$  = the Freundlich constants

A linear form of equation 3 is:

$$\log q_e = (1/n) \log C_e + \log K_f \quad (4)$$

where  $q_e$  is the amount of solute adsorbed per unit weight of adsorbent ( $\text{mg/g}$ ),  $C_e$  is the equilibrium concentration of solute in the bulk solution ( $\text{mg/L}$ ),  $K_f$  is a constant indicative of the relative adsorption capacity of the adsorbent ( $\text{mg/g}$ ),  $1/n$  is a constant indicative of the intensity of the adsorption. The linear Freundlich plots are obtained by plotting  $\log q_e$  versus  $\log C_e$  from which the adsorption coefficients could be evaluated (**Fig. 11**). All constants determined from Langmuir and Freundlich isotherms are given in **Tables 3 and 4** for single and binary system.



**Figure 11:** Freundlich isotherm of  $\text{Ni}^{2+}$  &  $\text{Cd}^{2+}$  ions on Amberlite IR 120 (pH7, concentration 100 mg/l; amount of resin 1g/L; Time 120 min; mixing rate 400 rpm).

**Table 3.** Parameters of Langmuir and Freundlich isotherms for ion exchange of  $\text{Ni}^{2+}$  &  $\text{Cd}^{2+}$  ions on Amberlite IR120 (single system).

Model	Parameters	$\text{Ni}^{2+}$	$\text{Cd}^{2+}$	Model	Parameters	$\text{Ni}^{2+}$	$\text{Cd}^{2+}$
Langmuir equation	qm(mg/g)	227.27	200	Freundlich equation	$K_f$ (mg/g)	11.155	9.143
	b (l/mg)	0.0270	0.0345		1/n	0.621	0.689
	$R^2$	0.9771	0.986		$R^2$	0.9884	0.961

**Table 4.** Parameters of Langmuir and Freundlich isotherms for ion exchange of  $\text{Ni}^{2+}$  &  $\text{Cd}^{2+}$  ions on Amberlite IR120 (binary system).

Model	Parameters	$\text{Ni}^{2+}$	$\text{Cd}^{2+}$	Model	Parameters	$\text{Ni}^{2+}$	$\text{Cd}^{2+}$
Langmuir equation	qm(mg/g)	140.84	243.9	Freundlich equation	$K_f$ (mg/g)	3.634	1.438
	b (l/mg)	0.0126	0.004		1/n	0.6718	0.8438
	$R^2$	0.9937	0.9925		$R^2$	0.9946	0.9981

### 3.7. Kinetics of Sorption

The study of sorption kinetics of heavy metal removal from waste water is significant as it provides valuable insights into the reaction pathways and into the mechanism of sorption reaction. Monitoring a kinetic experiment helps to study how the sorption system is affected by process variables and to understand the step which limit sorption. In addition the sorption kinetics describes the solute uptake rate which in turn controls the residence time of sorbate uptake at the solid – solution interface .Therefore it is important to predict the rate at which sorbate is removed from aqueous solutions in order to design appropriate treatment processes. Kinetic studies were performed by using 100 mg/L concentration, pH was adjusted to 7, resin mass was 1 g and 400 rpm for 120 min.

### 3.7.1. Pseudo-First Order Reaction Kinetic

Simple linear equation for Pseudo-first order reaction kinetic is, Lagergren, 1989.

$$\ln (q_e - q_t) = \ln q_e - k_1 t \quad (5)$$

where  $k_1$  is the rate constant of the first-order adsorption,  $q_t$  is the amount of heavy metal adsorbed at time  $t$  (mg/g) and  $q_e$  is the amount of heavy metal adsorbed at saturation (mg/g). Plot of  $\ln (q_e - q_t)$  versus  $t$  allows calculation of the rate constant  $k_1$  and  $q_e$ .

### 3.7.2. Pseudo-Second Order Reaction Kinetic

Pseudo-second order reaction kinetic can be expressed as, Ho and Mckay, 1999:

$$\frac{t}{q_t} = \frac{1}{h} + \left(\frac{1}{q_e}\right)t \quad (6)$$

$h = k_2 q_e^2$  that can be regarded as the initial sorption rate as  $t \rightarrow 0$ . Under such circumstances, the plot of  $t/q_t$  vs.  $t$  should give a linear relationship, which allows the computation of  $q_e$ ,  $K_2$  and  $b$ . A comparison of sorption rate constants, experimental and calculated  $q_e$  values for the pseudo- first and pseudo second order reaction kinetics of removal of  $\text{Ni}^{2+}$  and  $\text{Cd}^{2+}$  for single and binary systems are tabulated in **Tables 5 and 6**, respectively.

**Table 5.** Comparison of sorption rate constants, experimental and calculated  $q_e$  values for the pseudo-first- and –second-order reaction kinetics of removal of  $\text{Ni}^{2+}$  &  $\text{Cd}^{2+}$  ions by Amberlite IR120 for single component systems.

Metal	$q_e$ experimental mg/g	Pseudo-first-order			Pseudo-second-order		
		$k_1 * 10^3 \text{ min}^{-1}$	$q_e$ calculated mg/g	$R^2$	$k_2 * 10^{-3} \text{ g/mg h}$	$q_e$ calculated mg/g	$R^2$
$\text{Ni}^{2+}$	98.3	0.0375	66.254	0.9848	$1.408 * 10^{-3}$	102.04	0.9942
$\text{Cd}^{2+}$	98.6	0.0365	76.624	0.9689	$7.14 * 10^{-4}$	107.52	0.9796

**Table 6.** Comparison of sorption rate constants, experimental and calculated  $q_e$  values for the pseudo-first- and –second-order reaction kinetics of removal of  $\text{Ni}^{2+}$  &  $\text{Cd}^{2+}$  ions by Amberlite IR120 for binary component systems.

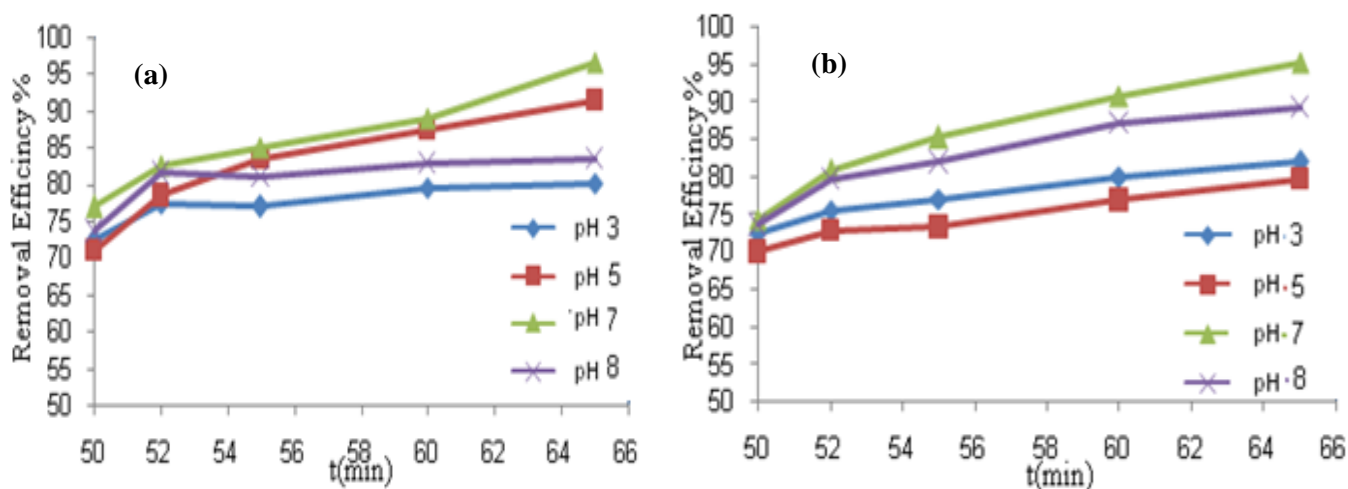
Metal	$q_e$ experimental mg/g	Pseudo-first-order			Pseudo-second-order		
		$k_1 * 10^3 \text{ min}^{-1}$	$q_e$ calculated mg/g	$R^2$	$k_2 * 10^{-3} \text{ g/mg h}$	$q_e$ calculated mg/g	$R^2$
$\text{Ni}^{2+}$	38.2	0.0361	29.189	0.9662	$9.08 * 10^{-4}$	45.66	0.9945
$\text{Cd}^{2+}$	39.15	0.0375	25.888	0.935	$1.235 * 10^{-3}$	42.918	0.9911

## 4. FLOTATION

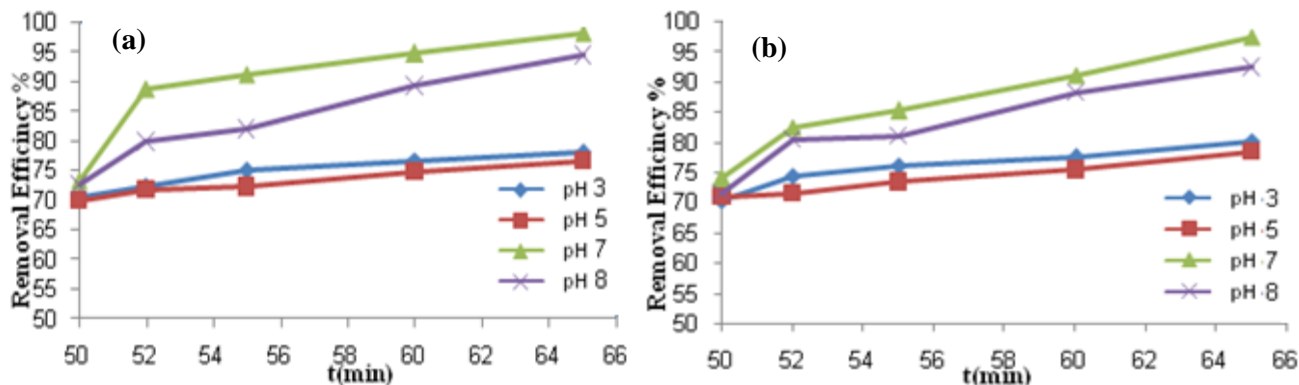
After the completion of the sorption stage, the solution transferred to the second stage (flotation stage), and study removal efficiency for different time intervals 2,5,10,15 min at different pH value 3,5,7 and 8 with two types of surfactant, Sodium Lauryl Sulphate (SLS) and Hexadecyltrimethyl ammonium bromides (HTAB) as cation and anion surfactant respectively with different surfactant concentration 100 , 200 and 300 mg/L.

### 4.1 Effect of pH

Several works related to the foam separation techniques point out that pH plays an important role in flotation. Depending on pH, different interfacial properties and reaction routes may be found, **Matis and Mavros, 1991**. The effect of pH on the removal of nickel & cadmium ions by bubble column are shown in **Figs. 12 and 13** by plotting the removal ratios versus time at various pH values .As shown in these figures the removal ratios increase after approximately 5 minute from the beginning of the run. It was found that the highest removal achieved when the pH of the solution was between 7-8, this result was similar to **Turtureanu, et al., 2008**. They suggested that the flotation of nickel and cadmium ions, has significantly values of removal efficiency at pH 7 -8 because at pH higher than 8 the metals will precipitates as hydroxide and flotation is a precipitate flotation process.



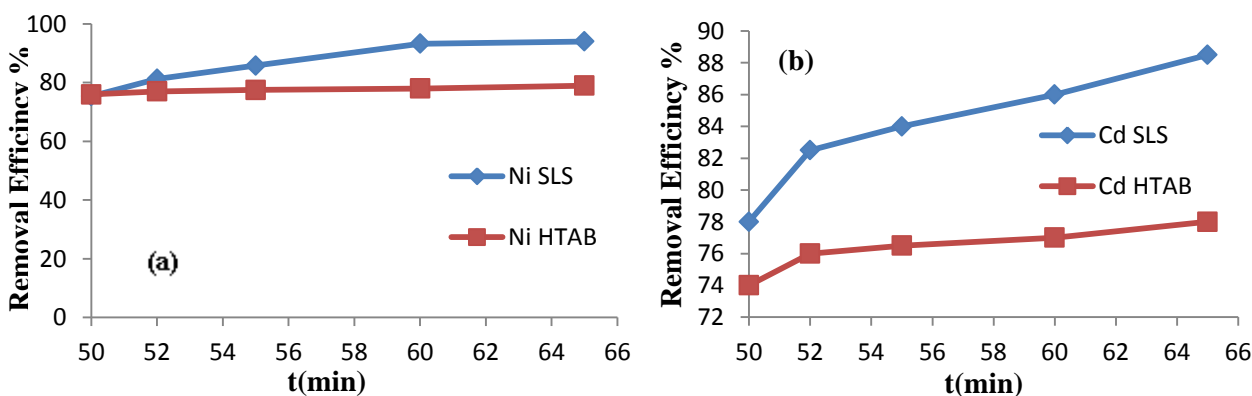
**Figure 12.** Effect of pH on the removal efficiency of (a) Cd<sup>2+</sup> (b) Ni<sup>2+</sup> (concentration 100 mg/L; Q=500 ml/min; SLS=100 mg/L; single system).



**Figure 13.** Effect of pH on the removal efficiency of (a)  $\text{Ni}^{2+}$  (b)  $\text{Cd}^{2+}$  (concentration 100 mg/L;  $Q=500$  ml/min; SLS=100 mg/L; binary system).

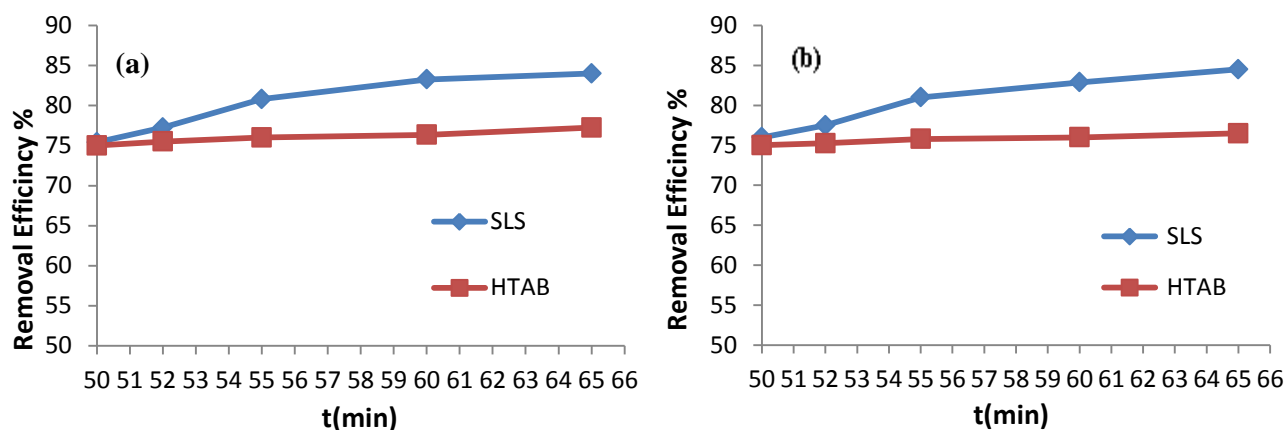
#### 4.2 Effect of Surfactant Type

The type of surfactant plays a significant role in foam flotation. The type of collector needed depends on the pH of the solution. In general, anionic collectors are needed at pH 1-7 because the metal ions are in cationic forms. at very high pH, cationic collectors would be needed if the metal ions were present as anions, **Zoubolis and Matis, 1987**. The removal rate of  $\text{Ni}^{2+}$  and  $\text{Cd}^{2+}$  ions from water was studied at two different types of surfactant (sodium lauryl sulfate and Hexadecyltrimethyl ammonium bromide) in order to show the effect of adding anionic and cationic surfactant on the removal rate of metal ions. The effects are shown in **Figs. 14 and 15** by plotting the (R %) versus time. From these figures, it can be seen that the anionic surfactant (SLS) at pH 7 is more efficient than the cationic surfactant (HTAB) at the same pH, no significant removal rate was obtained using (HTAB), **Al-Obaidi, 2011**.



**Figure 14.** Effect of surfactant type on the removal ratio of (a)  $\text{Ni}^{2+}$  (b)  $\text{Cd}^{2+}$  (concentration 100 mg/L;  $Q=500$  ml/min; SLS=100 mg/L; HTAB=100 mg/L; single system).

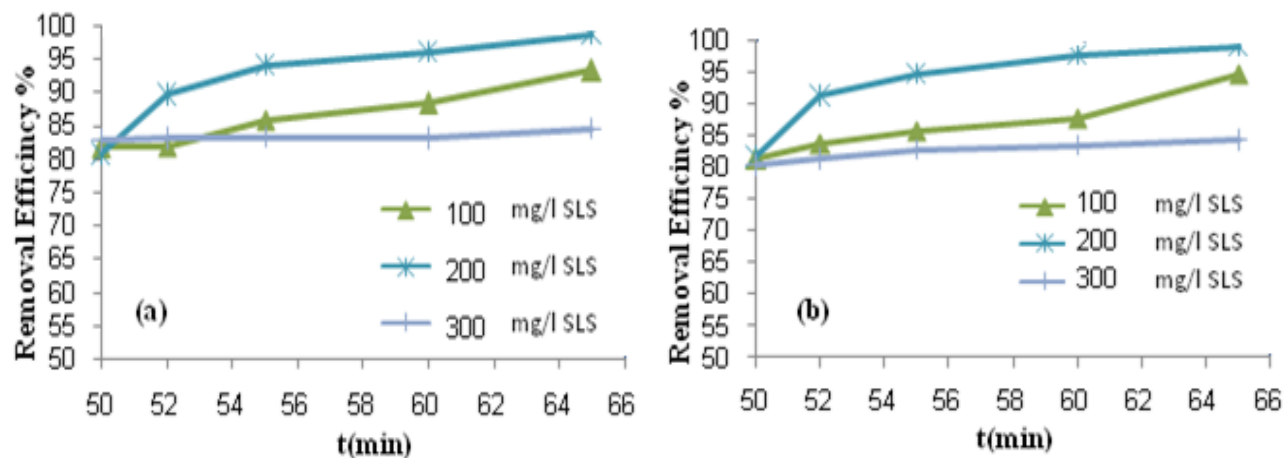




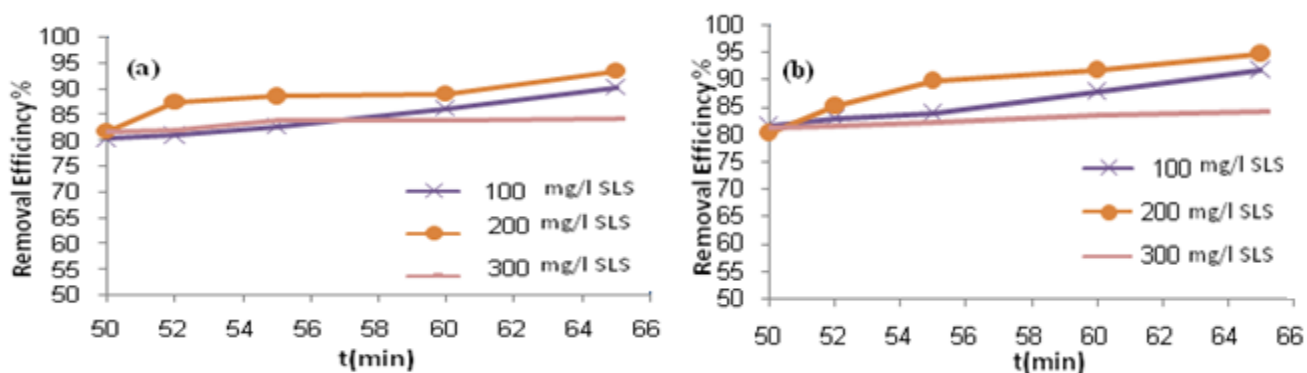
**Figure 15.** Effect of surfactant type on the removal of (a) Ni<sup>2+</sup> (b) Cd<sup>2+</sup> (concentration 100 mg/L; Q=500 ml/min; SLS=100 mg/L; HTAB=100 mg/L; binary system).

#### 4.3 Effect of Surfactant Concentration

The key to floatability (or non floatability) of chemical species is hydrophobicity. Substances are rendered hydrophobic by addition of the appropriate collector, in which the polar groups are eliminated by adsorption leaving non-polar groups exposed to solution. An important factor relates to the ratio of collector to metal ion. Usually a small excess of collector is added to guarantee maximum removal of the metallic ions in solution. Excessive collector should be avoided, not only due to higher cost, but also because of other negative effects, such as large foam losses, micelle formation, competition between the metal-collector complex and free collector ions for bubble surface sites and the potential toxicity of residuals amounts of collector in the effluent, **Scorzelli, et al., 1999**. The ions are completely soluble at pH 7 and the removal rates are strongly dependent on collector concentration requiring higher collector concentration for complete removal and at high pH the ions are insoluble, the effect of different SLS concentrations on the Ni<sup>2+</sup> and Cd<sup>2+</sup> removal efficiency at pH=7 are presented in **Figs. 17 and 18** respectively. From these figures, it can be seen that at low surfactant concentration 50 mg/L low removal was obtained, this may be attributed to the presence of insufficient amounts of surfactant required for complete flotation, **Ghazy, et al., 2008**. The separation efficiency improves with increasing surfactant concentrations up to 200 mg/L. Further increasing in surfactant concentration up to 300 mg/L results in decreasing in the removal efficiency. The decreasing in the metal removal for raised collector concentration can be due to competition between collagen collector complex and free ion collectors for a place in the surface of the bubble, **Medina, et al., 2005, Mohammed, et al., 2014**.



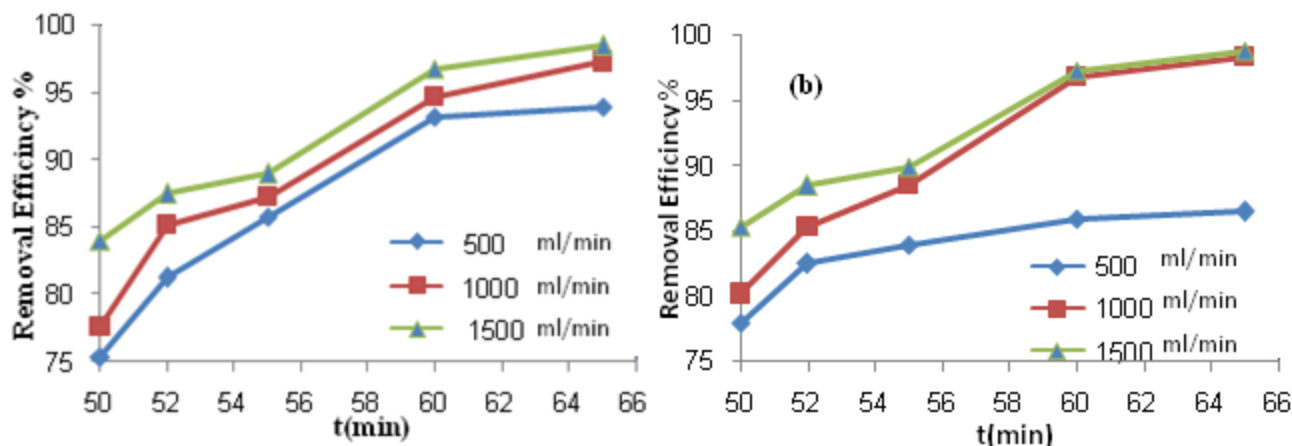
**Figure 16.** Effect of surfactant concentration on the removal efficiency of (a)  $\text{Ni}^{2+}$  (b)  $\text{Cd}^{2+}$  (concentration 100 mg/L;  $Q=500$  ml/min; SLS=100 mg/L; single system).



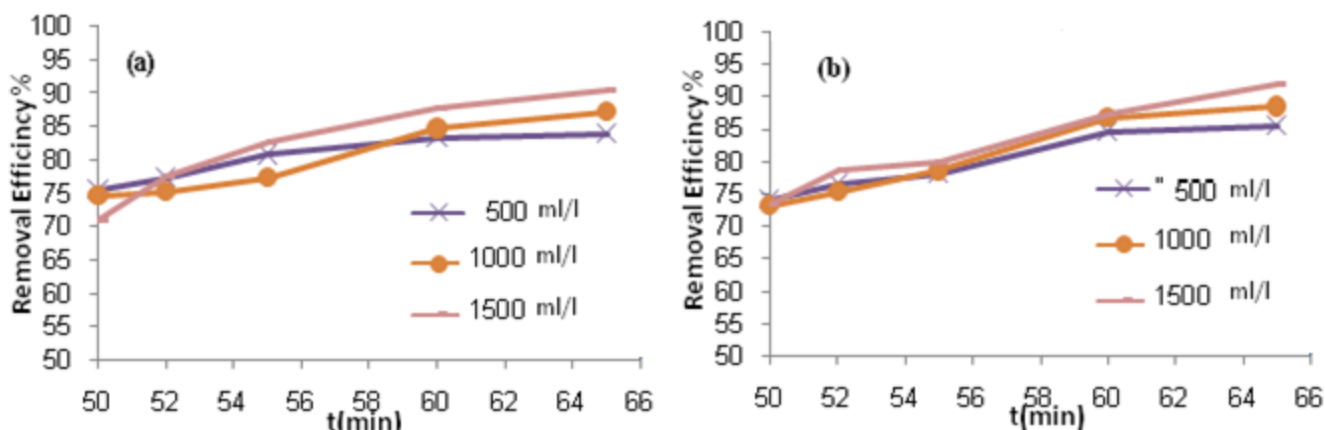
**Figure 17.** Effect of surfactant concentration on the removal efficiency of (a)  $\text{Ni}^{2+}$  (b)  $\text{Cd}^{2+}$  (concentration 100 mg/L;  $Q=500$  ml/min; SLS=100 mg/L; binary system).

#### 4.4 Effect of Air Flow Rate

The effect of gas flow rate 500, 1000 and 1500 ml/min on the removal efficiency of  $\text{Ni}^{2+}$  and  $\text{Cd}^{2+}$  in the bubble column was investigated. The results are shown in **Figs. 18 and 19** for pH=7 as gas flow rate increased, the removal ratio increased, This is because increased gas flow rate causes early bubble detachment, large fluid activities (stress) at the bottom section and bubble coalescence and (mostly) break up, **Sulaymon and Mohammed, 2010**. This results in a large number of small bubbles which leads to increasing surface area available for adsorption metal-collector.



**Figure 18.** Effect of Air flow rate on the removal ratio of (a) Ni<sup>2+</sup> (b) Cd<sup>2+</sup> (concentration 100 mg/L; SLS=100 mg/L; single system).



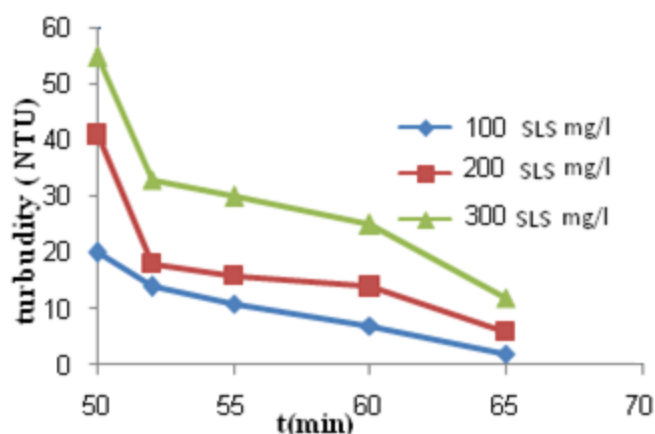
**Figure 19.** Effect of Air flow rate on the removal ratio of (a) Ni<sup>2+</sup> (b) Cd<sup>2+</sup> (concentration 100 mg/L; SLS=100 mg/L; binary system).

## 5. TURBIDITY

Turbidity is the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample, **Asano, 2007**. In our case turbidity caused by 3 different things (Amberlite IR120 resin, Ni<sup>2+</sup> and Cd<sup>2+</sup> ions, and SLS as a surfactant). The practical benefit of sorptive flotation process include turbidity decreasing from the wastewater, and by flotation process we will not need the filtering process, which is a complex and expensive one compared to the process of flotation. There is now interest in the technology as a pretreatment step in Ultrafiltration membrane plants and in desalination reverse osmosis plants, **Edzwald, 2010**, and by reducing turbidity the process of removing heavy metals from wastewater completed and here we find the benefit of sorptive flotation.

### 5.1 Turbidity with Different Surfactant Concentration

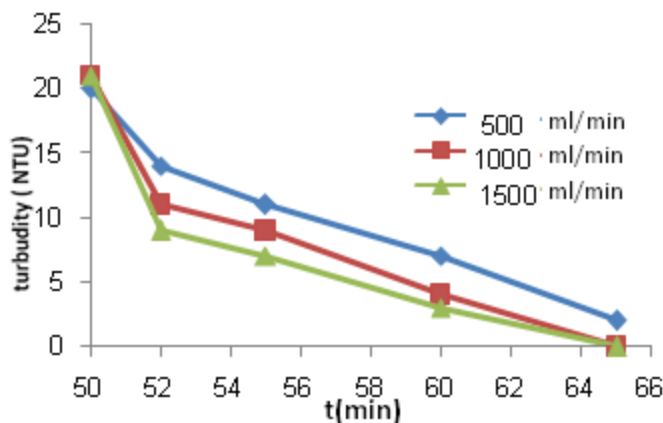
From **Fig. 20** obviously turbidity rate dropped during the flotation process with different surfactant concentration. In the beginning of flotation process the contaminated water include three different contaminants metals and resin from the sorption stage and surfactant that added after sorption stage, the initial turbidity increase with increasing surfactant concentration. From this figure it can be noticed that starting the flotation process the turbidity decrease immediately in the first 2 min and almost fades after 15 min. the turbidity reduction efficiency reaches 90%, 85.3% and 78% for 100 mg/L, 200 mg/L and 300 mg/L SLS concentration, respectively. From these result we realized the fact that the flotation process is very useful and conceders to be very effective process to remove turbidity, and also we find out that with increasing of the surfactant concentration will decrease the turbidity removal efficiency.



**Figure 20.** Turbidity with different surfactant concentration (resin dose 1g/L; Q=500 ml/L).

### 5.2 Turbidity with Different Flow Rates

Water flow rate has a significant influence in reducing turbidity due to increasing the bubble rise velocity. The effect of air flow rate on the turbidity removal is shown in **Fig. 21**. The experimental results showed that at 500 ml/min the turbidity decrease about 90 % while in 1500 ml/min the removal efficiency of turbidity is about 100%.



**Figure 21.** Effect of Air flow rate on the removal of turbidity (resin dose 1g/L; concentration=100 mg/L; SLS=100 mg/L).

#### 4. CONCLUSION

The following conclusions are exacted from the present study:

- 1- Amberlite IR120 strong acid cation exchange resin is a better alternative to Amberlite CG50 weak acid cation resin for the removal of nickel and cadmium ions from wastewater.
- 2- The optimum pH for metal ions sorption on to Amberlite IR120 is about 7.
- 3- The linear Langmuir and Freundlich, isotherms were used to represent the experimental data. Langmuir and Freundlich both results good fitting to the experimental data for the two metals.
- 4- The monolayer adsorption capacity of nickel and cadmium calculated from Langmuir model was obtained 227.27, 200 mg/g for nickel and cadmium respectively.
- 5- By applying the kinetic models to the experimental data, it was found that the adsorption of nickel and cadmium ions on Amberlite IR120 resin followed second order kinetics.
- 6- The anionic surfactant SLS was found to be more efficient than HTAB. Removal efficiency increase with increasing SLS concentration up to 200 g/l for both metals while above this concentration the removal efficiency decrease due to the competition between colligend collector complex and free ion collectors for a place in the surface of the bubble.
- 7- Removal efficiency increase with increasing air flow rate , because of the large number of small bubbles which leads to increasing surface area available for adsorption metal-collector
- 8- Flotation process very effective in reducing turbidity so it can dispense with the filtering process, which is expensive technology by the flotation process.

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التنمية العمرانية المستدامة في مركز الكرخ التاريخي

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ميثم حسن مهدي الصفار



## Study on Safety Construction Management Plan

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### ABSTRACT

After studying the reality of application to occupational safety in new Iraqi building projects and sampling the situation with that in developed and neighboring countries, researcher found that there is a big gap in the level of safety application conditions, this indicates the need for a quick and clear reference for local engineers to use it on site for safety conditions in their projects. As a case study the researcher studied a huge project in the United Arab Emirates. This project considered for safety requirements to highest grades. This case study may be far away from the projects in Iraq, but we hope to rise the Iraqi work level in the near future. After seeing the way of administration work and how they were rated the severity of each phase of the work, an idea was built about the most dangerous situations in projects with multiple floors buildings. To find multiple solutions to the risk, researchers identified 46 cases with their ratings, type of perceived risk in each case, and displayed a format survey to the most important specialized institutions and companies operating in Iraq and the United Arab Emirates. Finally the researcher takes the results, and format a software that any user can use in his personal computer to study the expected risk, how to avoid it and how to deal with it if it happens.

**Key Word:** construction management safety.

### دراسة في خطة ادارة الانشاء والسلامة

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### الخلاصة

بعد دراسة واقع حال مستوى تطبيق السلامة المهنية في مشاريع بناء العراق الجديد ومقارنة ذلك الحال بما هو عليه في البلدان المتطورة والبلدان المجاورة وجد الباحث ان هنالك فجوة كبيرة في مستوى تطبيق شروط السلامة ومن ذلك تكونت الفكرة في ايجاد مرجع سريع وواضح يستطيع المهندسون المحليون الاستعانة به موقعياً لتطبيق شروط السلامة في مشاريعهم. لذلك قام الباحث بدراسة حالة لمشروع ضخم في دولة الامارات العربية المتحدة تم فيه تطبيق شروط السلامة بأعلى الدرجات ونحن نعلم ان الحالة الدراسية قد تكون بعيدة نوعاً ما عن نوع المشاريع المطبقة في العراق ولكننا نأمل ان يرتقي مستوى العمل في العراق الى ذلك الحجم في المستقبل القريب. وبالفعل بعد الاطلاع على طريقة ادارة العمل وكيف تم تصنيف درجة خطورة كل مرحلة من مراحل العمل أصبح لدى الباحث تصور عن اهم الحالات الخطورة في مشاريع البنايات متعددة الطوابق ولكي يكون لدينا حلول متعددة للمخاطر قام الباحث بتحديد 46 حالة مع تصنيفاتها ونوع المخاطر المتوقعة لكل حالة وعرضها بصيغة استبيان شمل اهم المؤسسات المتخصصة والشركات العاملة في العراق ودولة الامارات وخرج الباحث بنتائج تم تبويبها بصيغة برنامج حاسوبي يستطيع اي مستخدم ان يستعمله في حاسوبه الشخصي موقعياً وبمجرد الضغط على مربع اي حالة نستطيع معرفة الخطر المتوقع وكيفية تجنبه وطريقة التعامل معه ان حدث. مع عمل جزء نظري لشرح طريقة التعامل مع البرنامج الحاسوبي.



## 1. INTRODUCTION

After independence the construction industry has grown significantly. In civil engineering projects many works big or small are executed, for the execution of these works skilled and unskilled labor along with machines and equipment are employed. With the introduction of machines for increasing the output of the work, the number of the accidents also increasing. It is a hard fact where the safety ends, accident start. Any work completed without accidents results economical. Nobody wants to be injured, but it happens so sudden that one cannot help. On the one hand accidents cause injury to the worker and agony to his family and on the other hand they cause mental tension and financial burden to the owner. Though the social concern of the safety of construction workers and their protection against injury is quite evident since long, but so far no tangible results have been observed. The survey of occupational injury and illness incidence carried out in 1992 shows that up to 14.5% workers suffer from these injuries. The breakup of occupational injury in different industries is shown in **Table 1, Gupta, 2005**.

When management found itself in the problem, by legislation, of having to pay for injuries in the job, it was decided that it would be financially better to stop the injuries from happening. This decision by the industry all over the world gave birth to the organized industrial safety movement. Management concentrated heavily, if not entirely, on correcting the hazardous physical conditions that exist in work place in the early years of safety movement. This showed a significant decline in the death rate (deaths per million men –hours worked) during the first 20 years of the safety movement, Petersen, 1971, after Mirza, 2001.

The interest in safety awareness among construction industry and the whole industry at large has greatly increased in the past decade. This can be attributed to many factors. Recognition of relationship between safety management and the return on investment is one of the factors, **www.arab\_eng.org ,2007**.

Up until 1970, there were no codes that required safety of the employees at their worksites in United States, **www.arab\_eng.org ,2007**. At that time, the Occupational Safety and Health Administration (OSHA) was formed to establish a safe workplace, which is defined as free of both health hazards and dangerous conditions for all employees. OSHA has since produced the Occupational Safety and Health Standards. The standards are continually updated. Specific standards for the construction industry are classified as 29 (CFR) 1926 code of federal regulations, here in after called the standard all employers are required to implement these standards to ensure that any persons employed by them would be free from any danger while at the workplace. Since 1970, the standards have grown to include nearly all worksite activities, **www.arab\_eng.org ,2007**.

The Objective of this research is to establish a practical and effective program for the prevention of and response to incidents and injuries, and to assign specific responsibilities to contractors and owners and their supervisors in the recognition, evaluation and control of hazardous activities or conditions within their respective areas of contract responsibility.

## 2. SAFETY DEFINITION

In order to understand safety, it is necessary to consider what is meant by “safety”. Depending on one’s perspective, the concept of aviation safety may have different connotations, such as **Berardinis, 1999**.

zero accidents (or serious incidents), a view widely held by the travelling public; construction works: manufactures work;

the freedom from danger or risks, i.e. those factors which cause or are likely to cause harm;

the attitude towards unsafe acts and conditions by employees (reflecting a “safe” corporate culture);

the degree to which the inherent risks in aviation are “acceptable”;

the process of hazard identification and risk management; and the control of accidental loss (of persons and property, and damage to the environment).

Safety is a condition in which the risk of harm or damage is limited to an acceptable level. The safety hazards creating risk may become evident after an obvious breach of safety, such as an accident or incident, or they may be proactively identified through formal safety management programme before an actual safety event occurs. Having identified a safety hazard, the associated risks must be assessed. With a clear understanding of the nature



of the risks, a determination can be made as to the “acceptability” of the risks. Those found to be unacceptable must be acted upon. **Berardinis, 1999.**

Safety management is centered on such a systematic approach to hazard identification and risk management — in the interests of minimizing the loss of human life, property damage, and financial, environmental and societal losses. **Keller, 1998.**

**Safety** is the state in which the risk of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management. (*Researcher*)

### 3- Safety Cycle

Safety cycle given the number and a potential relationship of the factors that may affect safety, an effective (SMS safety management system) is required. An example of the type of systematic process required is shown in **Fig.1, Abdul-Rahman, 1988.**

Hazard identification is the critical first step in managing safety. Evidence of hazards is required and may be obtained in a number of ways from a variety of sources, for example: **Bush, 1975.**

- a) Hazard and incident reporting systems;
- b) Investigation and follow-up of reported hazards and incidents;
- c) Trend analysis;
- d) Feedback from training;
- e) Flight data analysis;
- f) Safety surveys and operational oversight safety audits;
- g) Monitoring of normal operations;
- h) State investigation of accidents and serious incidents; and
- i) Information exchange systems.

Each hazard identified must be evaluated and prioritized. This evaluation requires the compilation and analysis of all available data. The data is then assessed to determine the extent of the hazard; is it a “one-of-a-kind” or is it systemic? A database may be required to facilitate the storage and retrieval of the data. Appropriate tools are needed to analyse the data. Having validated a safety deficiency, decisions must then be made as to the most appropriate action to avoid or eliminate the hazard or reduce the associated risks. The solution must take into account the local conditions, as “one size” does not fit all situations. Care must be taken that the solution does not introduce new hazards. This is the process of risk management.

Once appropriate safety action has been implemented, performance must be monitored to ensure that the desired outcome has been achieved, for example: **Saudi Aramco, 1993.**

- a) The hazard has been eliminated (or at least the associated risks have been reduced in probability or severity).
- b) The action taken permits coping satisfactorily with the hazard.
- c) No new hazards have been introduced into the system.

If the outcome is unsatisfactory, the whole process must be repeated.

### 4- Factors Affecting System Safety

The factors affecting safety within the defined system can be looked at two ways: first, by discussing those factors which may result in situations in which safety is compromised; and second, by examining how an understanding of these factors can be applied to the design of systems in order to reduce the likelihood of occurrences which may compromise safety.



The search for factors that could compromise safety must include all levels of the organization responsible for operations and the provision of supporting services. Safety starts at the highest level of the organization, **DiBerardinis,1999** and these factors are:

#### **4-1 Active failures and latent conditions**

Active failures are generally the result of equipment faults or errors committed by operational personnel. Latent conditions, however, always have a human element. They may be the result of undetected design flaws. They may be related to unrecognized consequences of officially approved procedures. There have also been a number of cases where latent conditions have been the direct result of decisions taken by the management of the organization. For example, latent conditions exist when the culture of the organization encourages taking short cuts rather than always following approved procedures. The direct consequence of a condition associated with taking short cuts would materialize at the operational level by non-adherence to correct procedures. However, if there is general acceptance of this sort of behavior among operational personnel, and management is either unaware of this or takes no action, there is a latent condition in the system at the management level. **Keller and Associates, 1989.**

#### **4-2 Equipment Faults**

The likelihood of system failures due to equipment faults is in the domain of reliability engineering. The probability of system failure is determined by analyzing the failure rates of individual components of the equipment. The causes of the component failures may include electrical, mechanical and software faults. **DeReamer,1980.**

A safety analysis is required to consider both the likelihood of failures during normal operations and the effects of continued unavailability of any one element on other aspects of the system. The analysis should include the implications of any loss of functionality or redundancy as a result of equipment being taken out of service for maintenance. It is therefore important that the scope of the analysis and the definition of the boundaries of the system for purposes of the analysis be sufficiently broad so that all necessary supporting services and activities are included.

The techniques for estimating the probability of overall system failure as a result of equipment faults and for estimating parameters, such as availability and continuity of service, are well established and are described in standard texts on reliability and safety engineering. These issues will not be addressed further in this manual. **Keller and Associates, 1989.**

#### **4-3 Human Error**

An error occurs when the outcome of a task being performed by a human is not the intended outcome. The way in which a human operator approaches a task depends on the nature of the task and on how familiar the operator is with it. Human performance may be skill-based, rule-based or knowledge-based. Errors may be the consequence of lapses in memory, slips in doing what was intended, or the result of mistakes which are conscious errors in judgment. A distinction should also be made between honest or normal errors committed in the fulfillment of assigned duties, and deliberate violations of prescribed procedures or accepted safe practices. **Saudi Aramco,1993.**

#### **4-4 System Design**

Given the complex interplay of human, material and environmental factors in operations, the complete elimination of risk is an unachievable goal. Even in organizations with the best training programmers and a positive safety culture, human operators will occasionally make errors. The best designed and maintained equipment will occasionally fail. System designers must therefore take into account the inevitability of errors and failures. It is important that the system be designed and implemented in such



a way that, to the maximum extent possible, errors and equipment failures will not result in an accident. In other words, the system is “*error-tolerant*”. **Hinze, and Gambatese,2003**. The hardware and software components of a system are generally designed to meet specified levels of availability, continuity and integrity. The techniques for estimating system performance in terms of these parameters are well established. When necessary, redundancy can be built into the system to provide alternatives in the event of failure of one or more elements of the system.

The performance of the human element cannot be specified as precisely; however, it is essential that the possibility of human error be considered as part of the overall design of the system. This requires an analysis to identify potential weaknesses in the procedural aspects of the system, taking into account the normal shortcomings in human performance. The analysis should also take into account the fact that accidents rarely, if ever, have a single cause. As noted earlier, they usually occur as part of a sequence of events in a complex situational context. Therefore, the analysis needs to consider combinations of events and circumstances in order to identify sequences that could possibly result in safety being compromised. **DeReamer1980**.

Developing a safe and error-tolerant system requires that the system contain multiple defenses to ensure that, as much as possible, no single failure or error will result in an accident, and that when a failure or error occurs, it will be recognized and remedial action taken before a sequence of events leading to an accident can develop. The need for a series of defenses rather than just a single defensive layer arises from the possibility that the defenses themselves may not always work perfectly. This design philosophy is called “defenses-in-depth”.

For an accident to occur in a well-designed system, gaps must develop in all the defensive layers of the system at the critical time when that defense should have been capable of detecting the earlier error or failure. An illustration of how an accident event must penetrate all defensive layers is in **Fig.2, Saudi Aramco,1993**.

## 5- SAFETY MANAGEMENT PROCESS

Strategies to reduce or eliminate the hazards are then developed and implemented with clearly established accountabilities. The situation is reassessed on a continuing basis, and additional measures are implemented as required.

The steps of the safety management process outlined in **Figs.2-4** are briefly described below:

### 5-1 Collect the data.

The first step in the safety management process is the acquisition of relevant safety data — the evidence necessary to determine safety performance or to identify latent unsafe conditions (safety hazards). The data may be derived from any part of the system: the equipment used, the people involved in the operation, work procedures, the human/equipment/procedures interactions, etc.

### 5-2 Analyses the data.

By analyzing all the pertinent information, safety hazards can be identified. The conditions under which the hazards pose real risks, their potential consequences and the likelihood of occurrence can be determined; in other words, *What* can happen? *How*? and *When*? This analysis can be both qualitative and quantitative.

### 5-3 Prioritize the unsafe conditions.

A risk assessment process determines the seriousness of hazards. Those posing the greatest risks are considered for safety action. This may require a cost benefit analysis.

### 5-4 Develop strategies.

Beginning with the highest priority risks, several options for managing the risks may be considered, for example:  
1) Spread the risk across as large a base of risk-takers as practicable. (This is the basis of insurance.)



- 2) Eliminate the risk entirely (possibly by ceasing that operation or practice).
- 3) Accept the risk and continue operations unchanged.
- 4) Mitigate the risk by implementing measures to reduce the risk or at least facilitate coping with the risk. When selecting a risk management strategy, care is required to avoid introducing new risks that result in an unacceptable level of safety.

#### **5-6 Approve strategies.**

Having analyzed the risks and decided on an appropriate course of action, management's approval is required to proceed. The challenge in this step is the formulation of a convincing argument for (perhaps expensive) change.

#### **5-7 Assign responsibilities and implement strategies.**

Following the decision to proceed, the "nuts and bolts" of implementation must be worked out. This includes a determination of resource allocation, assignment of responsibilities, scheduling, revisions to operating procedures, etc.

#### **5-8 Re-evaluate situation.**

Implementation is seldom as successful as initially envisaged. Feedback is required to close the loop. What new problems may have been introduced? How well is the agreed strategy for risk reduction meeting performance expectations? What modifications to the system or process may be required?

#### **5-9 Collect additional data.**

Depending on the re-evaluation step, new information may be required and the full cycle reiterated to refine the safety action.

Safety management requires analytical skills that may not be routinely practiced by management. The more complex the analysis, the more important is the need for the application of the most appropriate analytical tools. The closed loop process of safety management also requires feedback to ensure that management can test the validity of its decisions and assess the effectiveness of their implementation. **Guldenmund, 2000.**

### **6- SAFETY ECONOMICS**

The conference of the International Roundtable on Construction Safety and Health, (Frankfurt 1995) identified four major interventions to affect the risk factors:

- Improved site planning and management
- Improved training of workers and supervisors
- New construction technologies
- Markedly improved performance monitoring and data.

Therefore, to prevent accident, money must be spent. Provisions of safety equipment, planning and design of safe construction procedure need financial supports. One of the objectives in project management is to maximize profit through the safe construction work. Evidently effective safety management is profit maker for construction companies. Accidents are associated with high direct and indirect costs hence, construction and safety professionals should control these costs. Efforts have been made over the years to establish bases on which total losses can be established from measurable costs. But in every instance, it has been found that the total losses exceed by far the amount reimbursable by the insurance companies. **Mirza, 2001.**

The types of losses that can result from accidents, injuries or unsafe conditions are shown below. **Mirza, 2001.** These include the direct, indirect and hidden costs of injury or fatality all of them may be not applicable for every specific instance, and cost of many are difficult to determine.

- Payments for settlement of injury or death claims
- Cost of rescue operations and equipment
- Expenditures of emergency equipment
- Loss of function and operations income





- Cost for corrective actions to prevent reoccurrences
- Degradation of efficiency of operations because of loss of experienced and trained personnel
- Increased insurance cost
- Loss of public confidence, and by their revenue
- Loss of prestige
- Degradation of morale

## 7- FACTORS THAT IMPROVING THE CONSTRUCTION SAFETY

In their study, **Jaselskis, et al., 1996**, presented the results of a complementary study which tended to be more quantitative in comparison to other prior studies. The results pointed to several project-level factors that are statistically significant in improving safety performance. Further, the study provided contractors, specialty contractors and owners with objective strategies to achieve better safety performance.

- Increase time devoted to safety
- Provide greater detail in the written safety program
- Increase the number of safety meetings between upper management and field safety representative
- Increase number of informal inspection
- Increase number of meetings for safety performance

While, **Sawacha, et al., 1999**, discussed various variables that influence safety on construction sites. The impacts of the historical, economical, psychological, technical, procedural, organizational and environmental issues were considered in terms of how these factors were linked with the level of site safety. The results of research suggested that variables related to organization policy are the most dominant group of factors influencing safety performance in the United Kingdom construction industry.

**Evelyn, et al., 2005**, presented the results of a postal survey of contractors in Singapore. The findings revealed that site accidents were more likely to happen when there are:

- Inadequate company policies.
- Unsafe practices.
- Poor attitudes of construction personnel.
- Poor management commitment.
- Insufficient safety knowledge.
- Training of workers.

The study recommended that the project managers must pay more attention regarding the factors identified above to help enhance safety performance on construction sites and reduce the frequency of accidents.

## 8- OWNER'S AND CONTRACTOR'S SAFETY PERFORMANCE

**Hancher, et al., 1998**, Focused the analysis on four indicators of contractors and owners safety performance, and they were as follows:-

- The Experience Modification Rate (EMR).
- The (OSHA) Recordable Incident Rate (RIR).
- The Lost Time Incident Rate (LTIR).
- The Workers' Compensation Claims Frequency Indicator (WCCFI).



The data presented in this study reveal:

- Different OSHA incident rates for contractors who keep track of accidents versus those contractors who do not;
- Different EMR and RIR for small versus large contractors; and
- A different WCCFI for union versus open shop contractors.

While, **Hinze and Wilson, 2000**, conducted a study on a selected group of large, primarily industrial firms to assess their safety records. The findings revealed that companies with good safety performance can still make improvements through implementing specific safety practices.

A study by **Hinze and Gambatese, 2003**, concluded that specialty contractors and owners safety performance was consistently influenced in part by a number of factors. The factors shown to improve safety performance include:

- Minimizing worker turnover.
- Implementing employee.
- Drug testing.
- Training of workers.

**Sang, 2006**, presented two objectives in his study:

- Identify the role of the safety programs and management's opinions toward safety practices within roofing companies, and,
- Obtain detailed injury and illness types/body parts and determine how this information related to costs.

## **9- SAFETY REGULATIONS IN CONSTRUCTION PROJECTS IN IRAQ**

Many Iraqi local contractors have started works in Iraq since 1930. In 1970 one main state company (The State Construction Contracting Company) had started in execution of very large important projects, then followed in 1987 established many state companies, such as, **Ali, 2009**.

### **9-1 Public companies:**

These companies working under the Law No. 22 for year 1997 and these are some of their companies are:

- Al-Rasheed General Company for Constructive Contracting and it specialized by (constructive building, foundations and piles).
- Al-Mansoor General Company for Constructive Contracting and it specialized by (constructive building).
- Al-Farouk General Company for Constructive Contracting and it specialized by (constructive buildings, piles).
- Al-Mutasim General Company for Constructive Contracting and it specialized by (constructive building).
- Ashour General Company for Constructive Contracting and it specialized by (roads).

There is a big gap between Iraqi companies and other countries related to:

- The lack of safety culture in companies and their managers and crafts.
- The workers attitudes and behaviors towards the risks not safely.
- The employer does not provide safety equipment such as personal protective equipment (PPE).
- Safety is not one of the priorities of the companies such as cost, time and quality.



Usually all the state and local companies award many of their works of different type to small local subcontractors, then local subcontractor in order to reduce their costs and hence awarded the subcontractors did not follow the safety regulation in the following aspects:

- Firefighting system
- Lighting of the project
- Guarding the projects
- Fencing of the projects
- Concerning the workers in :
  - a. Not having toilets which match the number of labors.
  - b. Not using the safety clothes (over all).
  - c. Not using safety boots (safety shoes).
  - d. Not using helmets during the works.
  - e. Not using glass and safety measures during welding.
- Concerning the safety measure at the sites :
  - a. Not using prepare fence for the working areas and not having warning signs.
  - b. Not using guarding signs for the people toward entry into work area.
  - c. Not insuring the safety of the works or the third party as this done by the main contractor according to the Contract Conditions for Civil Engineering Works.

The Contract Conditions for civil engineering works in its latest addition has emphasized on the safety measures and regulation as this will reduce accident and hence reduce the cost of the projects and making sure that the project has three main items which are the quality of work, cost of the project, and execution of the project.

In order that the main contractors to have the ISO certificate in the near future they have to follow and execute the safety regulation (OSHA or OHSAS 18001) concerning with safety.

## 9-2 Private companies:

There are many companies work in private sector and they work under the law No. 21 for year 1997, and these works include (roads, paving and constructive building). These companies suffering such as the public companies above form the lack of safety in construction projects.

## 10-Filed Work

The field work is defined in three stages:

### 10-1 Stage one:

#### Case study (Palace Tower):

(Palace Towers) is one of the largest and beautifulness developments at the Dubai Silicon Oasis (DSO),**Fig.4**. The Palace Towers offer a balance between work and home; in addition to a premier lifestyle of endless opportunities with easy access to business areas of DSO and it's easy to get the maximum out of work and play at the same time.

Palace Towers offer a host of amenities from a fully equipped gym to two separate 20/10mt. pools for residential and office complex to shopping and dining facilities' Every one of the 424 spacious residential apartments is tastefully appointed, with contemporary layouts and designs that combine the convenience of today's lifestyle with timeless elegance. For the business user, the 150 high-tech office suites provide a central and prestigious location from which to work.



The Safety Management Plan of this project means get rid of danger, risk, or injury, while many things that could go wrong are around.

This could happen by being aware, educating yourself and others about safety issues which will not only keep accidents to a minimum, it will help to save lives.

The ultimate goal in accident prevention is "zero" disabling injuries and no lost work-time. However, there are many barriers to achieving this goal, the most important of which is the human attitude.

From this case study (Palace Tower), In addition to full details of project information, location, Stakeholders Profile and safety management plan researcher make a lot of a good information to this research.

### **10-2 Stage two:**

#### **Interviews and Questionnaires;**

All people from many levels concerned by the public construction projects ,within the construction contract companies, were chosen to be interviewed and subjected to a well-designed questionnaire.

Questionnaire is the most important work of the research as it enters the details of the safety work directly where they were when the study most of the cases in which possible cause of risk and identify potential risks and negative consequences of her and left the answer on how to avoid those risks and to address the matter to the questionnaire, which included 54 Foundation Inc. government, and is worth mentioning that the response has been received from 42 enterprises and companies only a number is relatively good and is also noted that most of the answers were close, and this convergence by type of case.

### **10-3 Stage three:**

#### **Development the computer safety program:**

In this computer safety program, the researchers enter the details of the safety work directly for most of the cases in which possible cause of risk and identify potential risks and negative consequences of it and the answer on how to avoid those risks, which included 46 activity which included many risks and their mitigation action to be taken **Fig.4**, shows the flow chart of the program.

The program is designed in a Visual Basic 6 language, which is a Form of several Forms and all his work shows it. Some of these forms are show in **Figs5,6,7,8,9**. Thus, the rest of the Forms and the art form made the background color of color button it. Project either out of the total of the first Form there is a button to exit.

## **11- CONCLUSION**

This study is a case study for safety construction project, the researcher focus on safety management can best be described as a set of actions or procedures relating to health and safety in the workplace by management to achieve the followings:

1. Preventing environmental pollution and minimizing risks in the activities carried out in the organization.
2. Providing information and training for people at all levels so they can effectively meet their responsibilities.
3. Identification, assessment and control of all workplace hazards and risks.
4. Enhance interested party satisfaction.
5. Incorporate health and safety responsibilities into job descriptions for all workers and encourage workers to identify unsafe work situations.
6. Responsibilities should be assigned for such things as induction training, first aid, emergency procedures and workplace inspections.



7. Ensure that all workers fully understand their responsibilities for health and safety.
8. Construction can be a hazardous business. This is widely recognized by everyone in the construction industry. When accidents happen, the costs are high – in people, profits and productivity.
9. One of the best ways to avoid injuries and minimize costs is through good planning and co-ordination – both before and on the job. This should start when the decision is made to go ahead with the project, and should consider all stages and parties associated with the work. So everyone involved in a construction project is responsible under the act, including: Clients, Designers/ advisers, Main Contractors, Subcontractors and Employees.  
In short, everyone involved with a construction project of any kind from planners, designers and supervisors through to on-site workers have a role to play in the management of health and safety during a construction project. This level of duty for each doesn't go beyond what is reasonable for them to take.

## 12- RECOMMENDATION

The researchers propose the following recommendations:-

1. to make a comparison study between this project and other project with similar specifications with fixing for some affecting factors in the project plan.
2. to apply such study on industrial project to obtain the requirement of plan and safety management which may be different than the requirement of commercial and residential projects.

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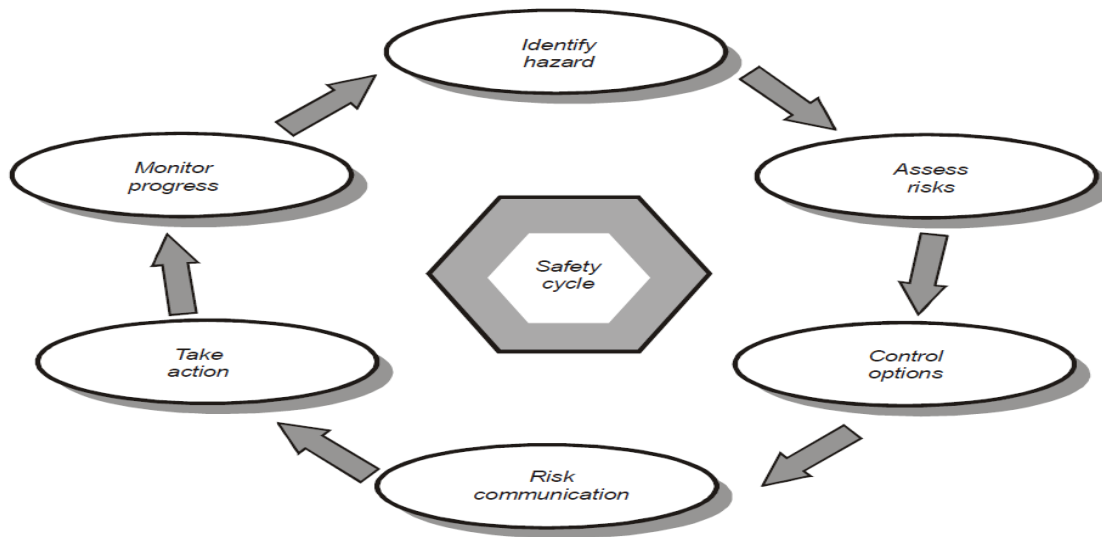
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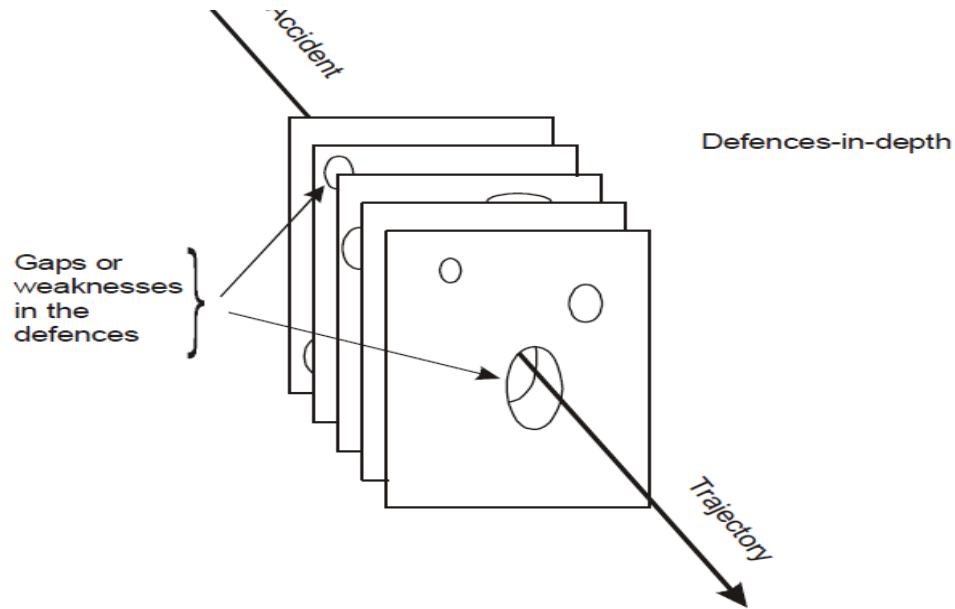
**Table 1.**Occupational injury rate.

Sa. No.	Industry	% of total injury
1	Finance insurance.	2.0
2	Services	4.9
3	Whole sale and retail trade	7.2
4	Agriculture, forestry	7.7
5	Transportation utilities	8.5
6	Manufacturing	10.2
7	Mining	10.5
8	construction	14.5

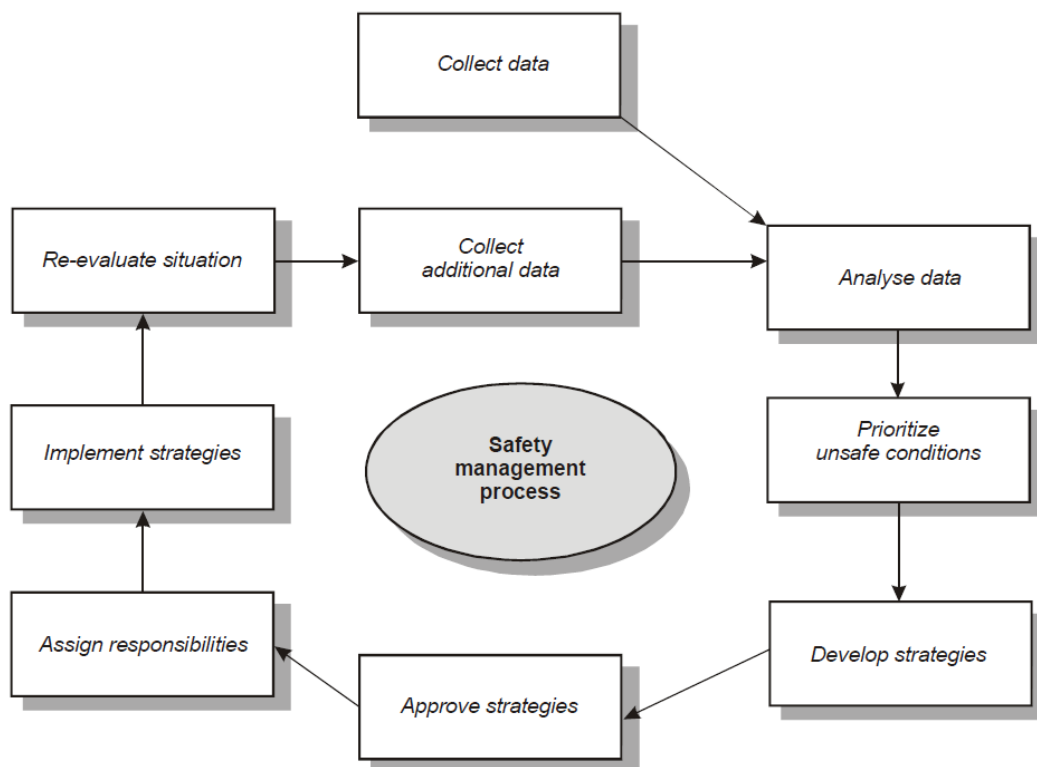


**Figure 1.**Safety cycle, Abdul-Rahman A., 1988.





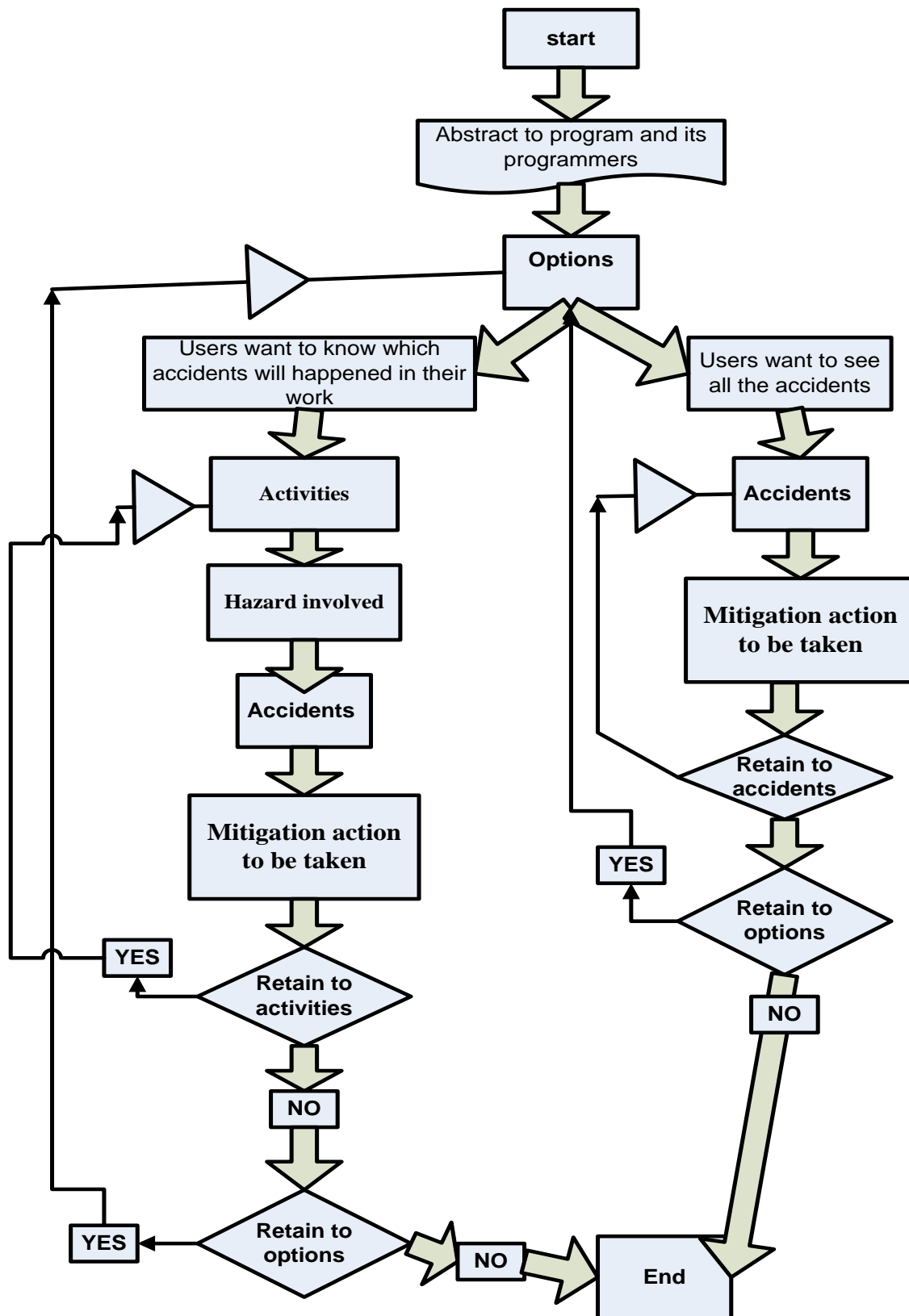
**Figure 2.**Defensive layers, Saudi Aramco,1993.



**Figure 3.**Safety management process, DeReamer, 1980.



**Figure 4.**Palace towers.



**Figure 5.**Flow chart for the computer program.



**ACTIVITIES AND RISK ASSESSMENT**

**ACTIVITIES**

Access to Work Areas

**HAZARD INVOLVED**

Tripping/falling from height haphazard climbing

**RISK**

Injury to body/break bones

**MITIGATION ACTION TO BE TAKEN**

Only provided access ladders and scaffolds to be used. Handrails and toe board shall be provided as required.

Exit

1. Access to Work Areas

2. Clearing the site

3. Concrete breaking

4. Crane Operations

5. Cranes and Lifting Plant Supply

6. Cutting of steel

7. COMPRESSOR

8. Dredging excavation

9. Equipment use on the works

10. ELECTRIC MACHINERY/TOOLS etc.

11. FUEL STORAGE (PETROL, DIESEL)

12. General marine works and quay works

13. General Site Operations

14. General Work in Area

15. Grouting

16. Grouting Joints

17. GAS CUTTING

18. GAS CYLINDER

19. HDPE Welding

20. House keeping

21. HAND TOOLS

22. Lifting of forms and steel cages

23. Lifting of heavy objects

24. LADDERS

25. Mobilize on site: Cranes

26. Mobilize and assembly of crawler crane

27. MANUAL HANDLING OF LOADS

28. MATERIAL HANDLING BY CRANE, FORK LIFT Etc...

29. MOVEMENT OF TRAILER/VEHICLES IN PROJECT AREA

30. Person walking in the swing area of crane/excavator

31. Placing concrete

32. Rigger for lifting of sheet piles

33. Spillage of oil and fuel

34. Stripping form work

35. Trail pit excavation

36. Using circular saws to timber

37. Worker facilities

38. WORKING IN CONFINED SPACE

39. WORKING AT HEIGHT

40. PAINTING

41. PORTABLE GENERATOR

42. STORAGE OF MATERIAL (SCAFFOLDING MATERIAL Etc.)

43. WORKING NEAR MOBILE PLANT LIKE EXCAVATOR / SHOVEL / CONCRETE PUMPS / CRANES/etc...

44. WELDING

45. WORKING IN HOT WEATHER

46. WALKING OVER SITE

Exit

Figure 6. FormNo. 1 of the computer program.

**GENERAL HAZARD IDENTIFICATION AND RISK ASSESSMENT**

1. Access to Work Areas

2. Clearing the site

3. Concrete breaking

4. Crane Operations

5. Cranes and Lifting Plant Supply

6. Cutting of steel

7. COMPRESSOR

8. Dredging excavation

9. Equipment use on the works

10. ELECTRIC MACHINERY/TOOLS etc.

11. FUEL STORAGE (PETROL, DIESEL)

12. General marine works and quay works

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41. PORTABLE GENERATOR

42. STORAGE OF MATERIAL (SCAFFOLDING MATERIAL Etc.)

43. WORKING NEAR MOBILE PLANT LIKE EXCAVATOR / SHOVEL / CONCRETE PUMPS / CRANES/etc...

44. WELDING

45. WORKING IN HOT WEATHER

46. WALKING OVER SITE

Exit

Figure 7. FormNo. 2 of the computer program.



ACTIVITIES	HAZARD INVOLVED	RISK	MITIGATION ACTION TO BE TAKEN
Crane Operations	Failure of wire rope	Fatality or serious injury	Wire rope should have a valid test certificate. Wire rope to be inspected regularly. Any damage found in the wire rope. The same should be replaced with certified ones.
	Boom failure	Fatality or serious injury	The boom shall be inspected regularly. Painting of boom to be done regularly to avoid rusting. Boom should be fitted by experienced mechanic and periodic checks to be carried
	Bumping or crushing of personnel by loads	Fatality, serious injury	Certified operators + Riggers + Banks men. Only authorized personnel to operate crane and direct loads.

Figure 8. FormNo. 4 of the computer program.

ACTIVITIES	HAZARD INVOLVED	RISK	MITIGATION ACTION TO BE TAKEN
GAS CYLINDER	In-adequate identification of gas cylinders	Fire accident/Injury to the Personals / Damage to the equipment	All the gas cylinders will have a color coding to distinguish the difference
	Storage of oxygen along with flammable gas cylinders	Fire accident/Injury to the Personals / Damage to the equipment	With reference with color coding the flammable and other cylinders shall be kept in different location as marked

Figure 9. FormNo. 18 of the computer program.



44

ACTIVITIES

WELDING

HAZARD INVOLVED	RISK	MITIGATION ACTION TO BE TAKEN
Emission of fumes	Suffocation	The welding activity shall be carried out in a ventilated area
Inhaling of fumes	Respiratory disorders	A suitable mask shall be provided/The welder shall wear it
Generation of small metal pieces/ hot slag etc	Burns/ eye injury	Suitable PPE (protective shield/goggles and, clothing shall be worn by the operator
Generation of heat	Burns	The welding area shall be protected for other persons and a protective clothing shall be worn by welder/welding operator
Potential risk of fire	Burns, loss of life, heat stroke, inflammation	All the combustible materials and flammable materials shall be removed from the area and kept clean
Improper earth connections of welding equipment, operator wearing wet clothing and his body perspiration, Welding cables laying in wet conditions, Using non standard cables and misuse of cables. Improper cable connections and cable joints.	Potential risk of Electric Shock	All the welding equipments shall be earthed properly, the welders and welding operators shall ensure proper protective clothing, his body is not wet and the welding cables are not laying in wet condition while welding, only authorized personals shall operate

Exit

start Ahmed CLOSED-QUESTL... Form1 Form2 44 Microsoft... 11:27 p

Figure 10. FormNo. 44 of the computerprogram.