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Index

المحاسبة الإدارية البيئية وعلاقتها بالجودة الشاملة دراسة تطبيقية على شركة السكر السودانية

Environmental Management Accounting and its Relationship to Total Quality Management
An Applied Study on the Sudanese Sugar Company

د.طيبة يعقوب الهادي
أستاذ مساعد – كلية الأعمال – كليات الأصالة
د. سايرا محمد كمال
أستاذ مساعد – قسم المالية – كليات الأصال
Dr. Tayba Yaqoub Al-Hadi
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المستخلص:

تهدف هذه الدراسة إلى تحليل دور المحاسبة الإدارية البيئية في تحسين جودة التقارير المالية في ظل تطبيق مبادئ إدارة الجودة الشاملة، وذلك من خلال دراسة تطبيقية على شركة السكر السودانية. وقد سعت الدراسة إلى توضيح كيفية إسهام هذا النوع من المحاسبة في توفير معلومات دقيقة وموثوقة تساعد الإدارة في اتخاذ القرارات، وتحقيق التكامل بين الأداء المالي والبيئي.

اعتمدت الدراسة على المنهج الوصفي التحليلي، واستخدمت الاستبانة كأداة رئيسية لجمع البيانات من عينة مكونة من (137) مفردة من العاملين والأكاديميين، حيث تم تحليل البيانات باستخدام مجموعة من الأساليب الإحصائية، مثل معامل ارتباط بيرسون، ومعامل ألفا كرونباخ، واختبار كاي تربيع.

تتمثل مشكلة الدراسة في قصور نظم المحاسبة التقليدية عن استيعاب التكاليف البيئية وعدم الإفصاح عنها بصورة كافية، مما يؤثر سلبًا على جودة التقارير المالية ويحد من قدرتها على التعبير الصادق عن الأداء الفعلي للمنظمات.

وقد توصلت الدراسة إلى وجود علاقة ذات دلالة إحصائية بين تطبيق المحاسبة الإدارية البيئية وتحسين جودة التقارير المالية، كما أظهرت النتائج وجود تأثير معنوي للتكاليف البيئية على دقة وشفافية التقارير المالية، إضافة إلى وجود ضعف نسبي في وعي بعض القيادات الإدارية بأهمية هذا المدخل المحاسبي.

وأوصت الدراسة بضرورة تطوير النظم المحاسبية بما يضمن إدماج التكاليف البيئية، وتعزيز التأهيل المهني للمحاسبين، بالإضافة إلى الالتزام بالمعايير الدولية المتعلقة بالإفصاح البيئي، بما يسهم في تحسين جودة المعلومات المحاسبية وتحقيق التنمية المستدامة

(Hasan et al., 2024)

الكلمات المفتاحية:

المحاسبة الإدارية البيئية، الجودة الشاملة، جودة التقارير المالية، الأداء البيئي، التنمية المستدامة.

Environmental Management Accounting and its Relationship to Total Quality Management :An Applied Study on the Sudanese Sugar Company

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Abstract:

This study aims to analyze the role of Environmental Management Accounting (EMA) in improving the quality of financial reporting under the principles of Total Quality Management (TQM), through an applied study on the Sudanese Sugar Company.

The study adopts a descriptive-analytical approach and uses a questionnaire distributed to a sample of 137 respondents, including employees and academics. Statistical methods such as Pearson correlation, Cronbach's alpha, and Chi-square test were used for data analysis.

The study problem lies in the inability of traditional accounting systems to adequately capture and disclose environmental costs, which negatively affects the quality of financial reports.
The results indicate a statistically significant relationship between EMA and financial reporting quality, as well as a significant impact of environmental costs on reporting transparency.
The study recommends improving accounting systems, enhancing professional training, and adopting international environmental disclosure standards.

المقدمة

شهدت بيئة الأعمال المعاصرة تحولات جوهرية نتيجة التقدم الصناعي والتكنولوجي، الأمر الذي أدى إلى تزايد الضغوط على المنظمات لتحمل مسؤولياتها البيئية والاجتماعية، ولم يعد التركيز مقتصرًا على تحقيق الأرباح فقط، بل أصبح من الضروري تحقيق التوازن بين. (Gray, 2010)تحقيق التوازن بين الأبعاد الإقتصادية والبيئية والإجتماعية
وفي ظل هذه التحولات، برزت الحاجة إلى تطوير النظم المحاسبية التقليدية، التي كانت تركز بشكل أساسي على الجوانب المالية دون الاهتمام الكافي بالتكاليف البيئية، مما أدى إلى ظهور المحاسبة الإدارية البيئية كأحد الاتجاهات الحديثة التي تهدف . ,.Burritt et al) (2002 الي دمج البعد البيئي ضمن النظام المحاسبي
كما يرتبط هذا التوجه بمفهوم إدارة الجودة الشاملة، التي تسعى إلى التحسين المستمر وتقليل الأخطاء وتعزيز كفاءة الأداء، الأمر الذي (Huynh, 2024). الأمر الذي ينعكس إيجابيا على جودة التقارير المالية وموثوقيتها

مشكلة الدراسة

على الرغم من التطور الكبير في الفكر المحاسبي، إلا أن العديد من المنظمات لا تزال تعتمد على نظم تقليدية لا تأخذ في الاعتبار التكاليف البيئية، ولا تفصح عنها بشكل كافٍ، مما يؤدي إلى ضعف جودة التقارير المالية وعدم قدرتها على التعبير الصادق عن الأداء الحقيقي .

الفجوة البحثية

تتمثل الفجوة البحثية في قصور النظم المحاسبية التقليدية عن استيعاب التكاليف البيئية ودمجها ضمن التقارير المالية، وهو ما أكدت علىه العديد من الدراسات الحديثة (Mukwarami et al., 2023).

أسئلة الدراسة

السؤال الرئيسي:

هل تؤثر المحاسبة الإدارية البيئية على جودة التقارير المالية؟

الأسئلة الفرعية:

1. مامدى تطبيق المحاسبة الادارية البيئية في المنظمات الصناعية ؟
2. ما اثر التكاليف البيئية على جودة التقارير المالية ؟ (" عبد الله 2019)
3. ما العلاقة بين المحاسبة الإدارية البيئية ومبادئ إدارة الجودة الشاملة؟
4. ما المعوقات التي تواجه تطبيق المحاسبة الإدارية البيئية؟
5. كيف يمكن تحسين جودة التقارير المالية من خلال تطبيق المحاسبة البيئية؟

أهداف الدراسة

تهدف هذه الدراسة إلى تحقيق مجموعة من الأهداف، من أهمها:
1.قياس أثر تطبيق المحاسبة الإدارية البيئية على جودة التقارير المالية
2.تحليل دور التكاليف البيئية في تحسين دقة وموثوقية المعلومات المحاسبية
3 .دراسة العلاقة بين المحاسبة الإدارية البيئية وإدارة الجودة الشاملة
4.تحديد المعوقات التي تواجه تطبيق المحاسبة البيئية في المنظمات

أهمية الدراسة

تكتسب هذه الدراسة أهميتها من عدة جوانب، من أبرزها:
* تطوير الفكر المحاسبي من خلال إدماج البعد البيئي .
* دعم اتخاذ القرار من خلال معلومات دقيقة .
* تحسين جودة التقارير المالية(Dechow & Schrand, 2010)
* تحقيق الاستدامة البيئية(Gray, 2010) .

فرضيات الدراسة

بناءً على مشكلة الدراسة وأهدافها، تم صياغة الفرضيات على النحو التالي:
1 .توجد علاقة ذات دلالة إحصائية بين تطبيق المحاسبة الإدارية البيئية وجودة التقارير المالية
2 .يوجد تأثير ذو دلالة إحصائية للتكاليف البيئية على جودة التقارير المالية
3 .توجد علاقة ذات دلالة إحصائية بين المحاسبة الإدارية البيئية وتطبيق مبادئ إدارة الجودة الشاملة

منهج الدراسة

اعتمدت الدراسة على المنهج الوصفي التحليلي، الذي يُعد من أكثر المناهج ملاءمة لمثل هذه الدراسات، حيث يتيح وصف الظاهرة محل الدراسة وتحليلها بشكل علمي دقيق. وقد تم استخدام مجموعة من الأساليب الإحصائية، من أهمها

*معامل ارتباط بيرسون لقياس العلاقة بين المتغيرات.
* معامل ألفا كرونباخ لقياس ثبات أداة الدراسة .
*إختبار كاي تربيع لقياس دلالة الفروق.

أهداف المحاسبة الإدارية البيئية

تسعى المحاسبة الإدارية البيئية إلى تحقيق مجموعة من الأهداف، من أهمها:

* تحديد وقياس التكاليف البيئية المرتبطة بالأنشطة المختلفة.
* دعم اتخاذ القرار من خلال توفير معلومات دقيقة.
* تحسين كفاءة استخدام الموارد الطبيعية .
* تقليل التلوث والآثار البيئية السلبية.
*تعزيز الشفافية في التقارير المالية

ومن أهم أهداف المحاسبة البيئية هو تحسين جودة المعلومات المحاسبية بما يدعم اتخاذ القرارات الإدارية السليمة.

أهمية المحاسبة الإدارية البيئية

تنبع أهمية المحاسبة الإدارية البيئية من دورها في تحقيق العديد من المنافع للمنظمات، ومن أبرزها:

* تحسين الأداء البيئي للمنظمة
* تقليل التكاليف من خلال ترشيد استخدام الموارد
* تحقيق ميزة تنافسية

تعزيز ثقة المجتمع في المنظمة . كما تؤدي إلى تحسين جودة التقارير المالية من خلال توفير معلومات أكثر دقة وشفافية.* (Dechow & Schrand, 2010)

فوائد المحاسبة الإدارية البيئية

يمكن تقسيم فوائد المحاسبة البيئية إلى عدة مستويات:

1-على مستوى المنشأة:

*تخفيض التكاليف البيئية
*زيادة الربحية
*تحسين الكفاءة التشغيلية

2-على مستوى الصناعة

*تحسين استخدام الموارد
*تقليل التلوث الصناعي

3-على مستوى الحكومة

*دعم السياسات البيئية
*تقليل الأعباء الاقتصادية الناتجة عن التلوث

وقد أوضح (أ.د عصام الدين محمد متولي، 2008) أن المحاسبة البيئية تسهم بشكل كبير في تحقيق التنمية المستدامة من خلال الربط بين الاقتصاد والبيئة.

معوقات تطبيق المحاسبة الإدارية البيئية

رغم أهمية المحاسبة البيئية، إلا أن هناك عدة معوقات تحد من تطبيقها، ومن أبرزها:

*صعوبة قياس التكاليف البيئية
*عدم وضوح المعايير المحاسبية
*ضعف الوعي الإداري
*صعوبة الفصل بين التكاليف البيئية والاقتصادية

وقد أكدت الدراسات أن هذه التحديات تمثل عائقًا رئيسيًا أمام تطبيق المحاسبة البيئية في العديد من المنظمات (Mukwarami et al., 2023).

أساليب المحاسبة الإدارية البيئية

تتعدد الأساليب المستخدمة في المحاسبة البيئية، ومن أهمها:

*محاسبة التكاليف البيئية
*تحليل دورة حياة المنتج
*محاسبة تدفق المواد
*التكلفة على أساس النشاط البيئي

وتهدف هذه الأساليب إلى تحسين دقة قياس التكاليف البيئية وتحليلها بشكل علمي(يوسف، 2017).

ثانياً: جودة التقارير المالية

تُعد جودة التقارير المالية من أهم المفاهيم في الفكر المحاسبي، حيث تعكس مدى قدرة المعلومات المحاسبية على تلبية احتياجات المستخدمين، وتمكينهم من اتخاذ قرارات سليمة.

وقد أشار (يوسف، 2017) إلى أن جودة التقارير المالية تعتمد على مجموعة من الخصائص النوعية التي تضمن دقة المعلومات وموثوقيتها.

خصائص جودة التقارير المالية

تنقسم خصائص جودة التقارير المالية إلى
:

الخصائص الأساسية:

* الملائمة (Relevance).
* التمثيل الصادق(Faithful Representation).

الخصائص المعززة:

*القابلية للمقارنة.
*القابلية للتحقق.
*التوقيت المناسب.
*القابلية للفهم.
وهذه الخصائص تمثل الأساس في تقييم جودة المعلومات المحاسبية.
(محمد، 2020)

أهمية جودة التقارير المالية

تكمن أهمية جودة التقارير المالية في:
*دعم اتخاذ القرار.
*تعزيز الثقة بين المنظمة والمستخدمين .
*تحسين كفاءة الأسواق المالية .
*تقليل المخاطر .
كما تسهم في تحقيق الشفافية والمصداقية في عرض الأداء المالي(Dechow & Schrand, 2010) .

ثالثاً: إدارة الجودة الشاملة

تُعد إدارة الجودة الشاملة من المفاهيم الإدارية الحديثة التي تهدف إلى تحسين الأداء بشكل مستمر، من خلال التركيز على جودة العمليات والمخرجات، ومشاركة جميع العاملين في تحقيق الأهداف وقد عُرفت بأنها فلسفة إدارية تعتمد على التحسين المستمر، والتركيز على العميل، وتقليل الأخطاء(Huynh, 2024).

مبادئ إدارة الجودة الشاملة

تعتمد إدارة الجودة الشاملة على مجموعة من المبادئ، من أهمها:
*التحسين المستمر
*التركيز على العميل
*العمل الجماعي
*تقليل الأخطاء
*اتخاذ القرارات بناءً على البيانات

رابعاً: العلاقة بين المحاسبة البيئية والجودة الشاملة

تُعد العلاقة بين المحاسبة الإدارية البيئية وإدارة الجودة الشاملة علاقة تكاملية، حيث يسهم كل منهما في تحسين الأداء العام للمنظمة. فمن جهة، توفر المحاسبة البيئية معلومات دقيقة حول التكاليف البيئية، ومن جهة أخرى، تعمل الجودة الشاملة على تحسين العمليات وتقليل الأخطاء، مما يؤدي إلى:
*تحسين جودة التقارير المالية .
*زيادة الشفافية .
*تقليل الأخطاء المحاسبية.
*تعزيز الثقة في المعلومات .
وقد أكدت الدراسات الحديثة وجود علاقة إيجابية بين تطبيق المحاسبة البيئية وتحسين جودة التقارير المالية في ظل إدارة الجودة الشاملة
.(Hasan et al., 2024)

ثالثا: الدراسة التطبيقية:

- أولا : مجتمع وعينه الدراسه:

يتكون مجتمع الدراسة من العاملين في مصنع سكر الجنيد شركة السكر السودانية كما تم إختيار مفردات عينه البحث من مجتمع الدراسة جيث تم توزيع عدد (150) استمارة منها (100) استمارة تم توزيعها بالمصنع و(50) استمارة على عينة من الأكاديمين تم استرجاع عدد (137) استماره بنسبة استرجاع بلغت (91.3%)
إعتمدت هذه الدراسه على وسيلة الاستبانه كاداة رئيسية للحصول على البيانات والمعلومات اللازمه لموضوع الدراسة وتتكون الاستمارة من قسمين :

القسم الأول : يشتمل على البيانات الخاصة بافراد عينة الدراسة(البيانات الشخصية).
القسم الثاني: ويشمل بيانات الدراسة الاساسية.

مقياس الدراسة:

كما تم قياس درجة الاستجابات المحتملة على الفقرات الي تدرج خماسي حسب مقياس ليكرت الخماسي في توزيع اوزان اجابات افراد العينة والذي يتوزع من اعلى وزن له والذي اعطيت له 5 درجات والذي يمثل في حقل الاجابة اوافق بشدة الي ادني وزن له والذي اعطي 1 درجة واحدة وتمثل في حقل الاجابة لا اوافق بشدة وبينهما ثلاثة اوزان. وقد كان الغرض من ذلك هو إتاحة المجال أمام أفراد العينة لإختيار الاجابة الدقيقة حسب تقدير أفراد العينةكما هو موضح في جدول رقم(1) مقياس درجة الموافقة حسب مقياس ليكرت الخماسي

درجة الموافقة	الوزن النسبي	النسبة المئوية	الدلالة الاحصائية
أوافق بشدة	5	80% %فاكثر	درجة موافقة مرتفعة جدا
أوافق	4	% 70 فاكثر	درجة موافقة مرتفعة
محايد	3	50 الي اقل من 70%	درجة موافقة متوسطة
لا أوافق	2	20الي اقل من 50%	درجة موافقة منخفضة
لا اوافق بشدة	1	اقل من 20%	درجة موافقة منخفضة جدا

المصدر : إعداد الباحث من نتائج الدراسة الميدانية 2016م.

صدق أداة الدراسة:

يقصد بصدق او صلاحية أداة القياس أنها قدرة الأداة على قياس ماصممت من أجله وبناء على نظرية القياس الصحيح تعني الصلاحية التامة خلو الاداة من أخطاء القياس سواء كانت عشوائية او منتظمة وقد أعتمدت الدراسة في قياس صدق اداة الدراسة على كل من :

إختبار صدق محتوي المقياس

بعد إعداد الصيغة الأولية لمقاييس الدراسة، عُرضت أداة الدراسة على (6) من المحكمين والخبراء المتخصصين للتحقق من صدق المحتوى ومدى ملاءمة الفقرات لأهداف الدراسة، من حيث الشمولية ودقة الصياغة اللغوية. وقد طُلب منهم إبداء ملاحظاتهم واقتراح التعديلات المناسبة. وبعد إسترجاع الاستبيانات تم تحليل آرائهم والأخذ بملاحظاتهم، حيث أُجريت تعديلات على بعض الفقرات وحُذفت أخرى وصُححت الصياغة اللغوية. وبذلك اعتبر الباحث هذه الإجراءات دليلاً على تحقق الصدق الظاهري وصدق المحتوى .للأداة، وتم إعتماد الاستبانة في صورتها النهائية

صدق الإتساق الداخلي:

تم التحقق من صدق الإتساق الداحلي لأداة الدراسة وكل محور من محاورها ومدي إرتباط هده الفقرات المكونة لها مع بعضها البعض والتأكد من عدم التداخل بينها ، وتحقق الباحث من ذلك بإيجاد معاملات الارتباط معامل إرتباط بيرسون والجداول التالية توضح ذلك:

المحور الأول :

جدول رقم(2)يوضح نتائج إختبار الصدق لمقياس عبارات المحور الاول:

العبارات	معامل الارتباط	مستوي المعنوية
1/ تحليل المعلومات المستمدة من النظام المحاسبي يحقق التطور بإعتباره أداة للقياس والرقابة وقياس الانشطة.	0.69	0.000
2/ الحاجة لأسلوب ملائم لتخصيص وتحميل التكاليف اللبيئية والتمييز بينها وبين التكاليف الأخري يساعد في تطبيق مفاهيم الفكر المحاسبي.	0.70	0.001
3/ الالتزام بالإفصاح عن أنشطة المنظمات يمكن من توثيق وتقييد الإجراءات المحاسبية.	0.40	0.003
4/ فعالية المحاسبة الإدارية البيئية يؤدي الي تحسين صورة أنشطة منظمات الأعمال.	0.56	0.000
5/ الإعتماد على الفكر المحاسبي من منظور المحاسبة الإدارية البيئية يساعد في تقليل مخاطر الرقابة للأنشطة الإقتصادية للمنظمات.	0.64	0.002

6/ المحاسبة الإدارية البيئية تساعد على التخطيط المستقبلي للمنشأة من خلال المبادئ العلمية المحاسبية.	0.79	0.000

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م.

الجدول (2) يوضح معاملات الإرتباط بين كل فقرة من فقرات المحور الأول والذي يبين أن معاملات الإرتباط لجميع الفقرات دالة حيث نجد أن جميع قيم مستوي المعنوية أقل من مستوي الدلالة 0.05 وتعني هذه القيم توافر درجة عالية عن مستوي معنوية 0.05 من صدق الاتساق الداخلي لفقرات المحور الاول ومن ثم يمكن القول بأن المقاييس التي إعتمدت علىها الدراسة لقياس عبارات المحور الاول والذي يقيس فرضية الدراسة الاولي(هنالك علاقة ذات دلالة إحصائية بين تطبيق الفكر المحاسبي من منظور المحاسبة الادارية البيئية لمجموعة المفاهيم والمبادئ العلمية والافصاح الكامل للآثار البيئية للأنشطة الإقتصادية لمنظمات اللأعمال) تتمتع بالصدق . (2018)على، .الداخلي لعباراتها مما يمكنها من الإعتماد على هذه الإجابات في تحقيق أهداف الدراسة وتحليل نتائجها

المحور الثاني:

يوضح نتائج إختبار الصدق لمقياس عبارات المحور الثاني) 3(جدول رقم

العبارات	معامل الارتباط	مستوي المعنوية
يعد دور المحاسبة الادارية البيئية وسيلة لضبط ورقابة الآثار للانشطة من خلال التقارير المالية.	0.70	000.0
يعتبر تطبيق المحاسبة الادارية البيئية مهم في المنظمات لقياس جودة الأداء الفعلى للأنشطة المختلفة.	0.79	000.0
عدم تطبيق المحاسبة الإدارية البيئية بصورة سليمة يزيد من الاضرار التي تحدث في المنظمات.	0.82	000.0
المحاسبة الإدارية البيئية تعكس مدي تطبيق تحطيط المبيعات والأرباح بالمنظمات.	0.76	000.0
نظم المحاسبة الإدارية البيئية تساعد على تجميع وتبويب وتحليل المعلومات الناتجة عن النظم الاخري في المنظمة بهدف تحقيق الجودة.	0.74	000.0
التطورات التقنية في المنظمات تساعد على تفعيل دور المحاسبة الإدارية البيئية وتقليل الآثار البيئية للأنشطة.	0.79	000.0

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م.

الجدول (3) يوضح معاملات الإرتباط بين كل فقرة من فقرات المحور الثاني والذي يبين أن معاملات الإرتباط لجميع الفقرات دالة عن مستوي معنوية 0.05 حيث نجد ان جميع قيم مستوي المعنوية أقل من مستوي الدلالة0.05 وتعني هذه القيم توافر درجة عالية من صدق الإتساق الداخلي لفقرات المحور الثاني ومن ثم يمكن القول بأن المقاييس التي إعتمدت علىها الدراسة لقياس عبارات المحور الاول والذي يقيس فرضية الدراسة الثانية (المحاسبه الادارية البيئية لها تاثير على التقرير عن الاثار البيئية للانشطة المختلفة بما يعبر عن عدالة نتائج الأعمال والموقف المالي لمنظمات الأعمال من منظور الجودة الشاملة) تتمتع بالصدق الداخلي لعباراتها مما يمكنها من الإعتماد على هذه الإجابات في تحقيق أهداف الدراسة وتحليل نتائجها.

ب/ إختبار الثبات:

يقصد بالثبات أن المقياس يعطي نفس النتائج إذا أعيد تطبيقه على نفس العينة بإستخدامSPS S الوصفي والإستدلالي. (د. عز عبدالفتاح ، مقدمة في الإفصاح ، القاهرة: دار النهضة العربية، الطبعة الأولي،1981، ص560).

في نفس الظروف والشروط وبالتالي فهو يؤدي الي الحصول على نفس النتائج أو نتائج متوافقة في كل مرة يتم فيها إعادة القياس. وهنالك عدة طرق للتحقق من ثبات المقياس منها طريقة التجزئة النصفية وطريقة ألفا كرنباخ للتأكد من الإتساق الداخلي للمقاييس، وقد إعتمدت الدراسة لإختبار ثبات أداة الدراسة على معامل ألفا كرنباخ والذي يأخذ قيما تتراوح بين الصفر والواحد صحيح ، فاذا لم يكن هنالك ثبات في البيانات فإن قيمة المعامل تكون مساوية للصفر، وعلى العكس إذا كان هنالك ثبات تام في البيانات فإن قيمة المعامل تساوئ الواحد صحيح. أي أن زيادة معامل ألفا كونباخ تعني زيادة دليل على إنخفاض الثبات الداخلي,60% مصداقية البيانات ،كما أن إنخفاض القيمة وفيما يلي نتائج إختبار الثبات لمحاور الدراسة:

جدول رقم (4) يوضح نتائج إختبار ألفا كرنباخ (Cronbach Alpha) لعبارات الدراسة

محاور الدراسة	عدد العبارات	ألفا كرنباخ
المحور الأول	6	0.89
المحور الثاني	6	0.90
إجمالي العبارات	12	0.90

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م.
يوضح الجدول رقم (4) نتائج إختبار الثبات حيث بلغت قيم ألفا كرونباخ لجميع العبارات اكبر من% 60 وتعني هذه القيم توافر درجة عالية من الثبات الداخلي لجميع محاور الدراسة حيث بلغت قيمة ألفا كرونباخ للمقياس الكلي 0.90 وهو ثبات مرتفع ومن ثم يمكن القول بان المقاييس التي إعتمدت علىها الدراسة لقياس جميع محاور الدراسة تتمتع بالثبات الداخلي لعباراتها مما يمكننا من الإعتماد على هذه الإجابات في تحقيق أهداف الدراسة وتحليل نتائجها.

خامسا: أساليب التحليل الإحصائي المستخدم في الدراسة:

1/ إختبار الصدق حيث تم إستخدام كل من :
أ/ إختبار الصدق الظاهري. ب/ إختبار الصدق البنائي.
2/ إختبار الثبات وأعتمدت الدراسة على – معادلة ألفا – كرونباخ.
3/ أساليب الإحصاء الوصفي : وذلك لوصف خصائص مفردات عينة الدراسة من خلال :
أ/ التوزيع التكراري لعبارات فقرات الإستبانة.
وذلك للتعرف على التوزيع التكراري لإجابات أفراد العينة على عبارات فروض الدراسة.
ب/ الوسط الحسابي الموزون:
تم إعتماد هدا الأسلوب الإحصائي لوصف أراء أفراد العينة حول متغيرات الدراسة بإعتباره أحد مقاييس النزعة المركزية، وهو أكثر عمومية من الوسط الحسابي، حيث أن الوسط الحسابي الإعتيادي يعد حالة خاصة من الوسط الحسابي المرجح عندما ينظر الي كافة المفردات بنفس الأهمية (الوزن).
ج/ الإنحراف المعياري:
تم إستخدام هذا المقياس لمعرفة مدي التشتت في أراء المستجيبين قياسا بالوسط الحسابي المرجح.
4/ إختبار (كاي تربيع) لدلالة الفروق:
وتم إستخدام هذا الاختبار لإختبار الدلالة الإحصائية لفروض الدراسة عند مستوي معنوية 5%
ويعني ذلك أنه إذا كانت قيمة (كاي تربيع) المحسوبة عند مستوي معنوية أقل من 5% يرفض فرض العدم وهذا يعني وجود فروق ذات دلالة معنوية وتكون الفقرة إيجابية). أما إذا كانت قيمة (كاي تربيع) عند مستوي معنوية أكبر من 5% فذلك معناه قبول فرض العدم وبالتالي عدم وجود فروق ذات دلالة إحصائية وتكون الفقرة سلبية.

تحليل بيانات الدراسة الأساسية

تحليل البيانات الأولية:

من خلال البيانات العامة التي تم جمعها عن المبحوثين بواسطة القسم الأول من الإستبانة، وبإستخدام التكرارات الإحصائية تم تحديد خصائص عينة الدراسة، وذلك بهدف التعرف على صفات مجتمع المبحوثين من حيث التركيبة العلمية والعملية والإجتماعية، حيث أن هذه الصفات تمثل متغيرات قد يؤثر تغيرها في نتيجة هذه الدراسة إذا ما أعيد تطبيقها في وقت لاحق، وكذلك قد يؤثر تغيرها في نتائج الدراسات المماثلة إذا ماطبقت على نفس مجتمع عينة الدراسة. وفيما يلي توزيع عينة الدراسة تبعا للمتغيرات الشخصية:
1/ توزيع أفراد العينة حسب العمر:
جدول رقم(5)التوزيع التكراري لأفراد العينة وفق متغير العمر

العمر	العدد	%النسبة
أقل من 30 سنة	28	20.4
30 وأقل من 40 سنة	26	19
40وأقل من 50 سنة	39	28.5
50 سنة فأكثر	44	32.1
المجموع	137	%100

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م
يتضح من الجدول رقم(5) أن أفراد العينة الذين تتراوح أعمارهم بين 50 سنة فأكثر بلغ عددهم 44 شخصا 32 مما يدل على مقدرتهم نسبة %العالية لفهم مفردات الإستبانة.
2/ توزيع أفراد العينة حسب المؤهل العلمي:
جدول رقم (6) التوزيع التكراري لأفراد العينة وفق متغير المؤهل العلمي

المؤهل العلمي	العدد	%النسبة
بكلاريوس	64	46.7

دبلوم عالي	14	10.2
ماجستير	36	26.3
دكتوراة	23	16.8
المجموع	137	100%

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

يتضح للباحث من الجدول رقم (6) أن أفراد العينة من المستوي التعلمي – الجامعي- بلغ عددهم (64) بنسبة (46.7%) بينما بلغت نسبة حملة التعلم فوق الجامعي) دبلوم عالي، ماجستير، دكتوراة) 53.3% ويتضح من ذلك أن جميع أفراد العينة ممن يحملون درجات جامعية وفوق الجامعية حيث بلغت نسبتهم (100 %) مما يدل على جودة التأهيل العلمي لأفراد العينة وبالتالي قدرتهم على فهم عبارات الإستبانة بشكل جيد والإجابة علها بدقة.

3/ توزيع أفراد العينة حسب التخصص العلمي:

جدول رقم (7) التوزيع التكراري لأفراد العينة وفق التخصص العلمي

التخصص	العدد	النسبة%
محاسبية	39	28.5
تكاليف ومحاسبة إدارية	7	5.1
إدارة أعمال	32	23.4
إقتصاد	19	13.9
علوم مصرفية ومالية	4	2.9
نظم معلومات	2	1.5
أخري	34	24.8
المجموع	137	%100

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

يتضح للباحث من الجدول رقم (7) أن أفراد العينة من تخصص (المحاسبة والتكاليف والمحاسبة الإدارية) بلغ عددهم (46) بنسبة (33.6%) فيتضح من ذلك أن غالبية أفراد العينة من التخصصات ذات صلة بموضوع الدراسة حيث بلغت نسبته(33.6%) مما يدل على مدي معرفة أفراد العينة بطبيعة موضوع الدراسة وبالتالي قدرتهم على فهم عبارات الإستبانة بشكل جيد والإجابة علها بدقة.

4/ توزيع أفراد العينة حسب المؤهل المهني:

جدول رقم (8) التوزيع التكراري لأفراد العينة وفق متغير المؤهل المهني

المؤهل المهني	العدد	النسبة%
زمالة المحاسبين القانونين السودانية	23	16.8
زمالة المحاسبين القانونين العربية	18	13.1
زمالة المحاسبين القانونين البريطانية	2	1.5
زمالة المحاسبين القانونين الأمريكية	0	0
لايوجد	94	68.6
المجموع	137	%100

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

يتضح للباحث من الجدول رقم (8) أن أفراد العينة الذين يحملون مؤهلات مهنية بلغت نسبتهم في العينة المبحوثة(31.4%) منهم نسبة (16.8%) من حملة الزمالة السودانية ونسبة (13.1%) من حملة الزمالة العربية ونسبة (1.5%) من حملة الزمالة البريطانية ويتضح من ذلك أن هنالك تمثيل كبير لحملة الزمالة المهنية في عينة الدراسة مما يساعد على الإجابة بشكل مهني على عبارات محاور الدراسة.

5/ توزيع أفراد العينة حسب المسمي الوظيفي:

جدول رقم (9) التوزيع التكراري لأفراد العينة وفق متغير المسمي الوظيفي

الوظيفة	العدد	النسبة%
مديرإدارة علىا	26	19
مديرإدارة	24	17.5
مدير ورشة	10	7.3
محاسب	28	20.4
مراجع	9	6.6
أكاديمي	15	10.9
المجموع	137	%100

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

يتضح للباحث من الجدول رقم (9) أن أفراد العينة من المحاسبين والمراجعين بلغ عددهم (37) بنسبة (27%) بينما بلغت نسبة المدراء (مدير إدارة، مديرإدارة علىا، مدير ورشة) في العينة (42.8%) . كما تضمنت العينة نسبة (10.9%) من المستويات الوظيفية الأخري مما يدل على أن هذه العينة المبحوثة مؤهلة وظيفيا وكادر لا يستهان به.

6/ توزيع أفراد العينة حسب سنوات الخبرة:

جدول رقم (10) التوزيع التكراري لأفراد العينة وفق متغير سنوات الخبرة

سنوات الخبرة	العدد	النسبة%
أقل من 5	24	17.5
5 وإقل من 10 سنوات	16	11.7
10وأقل من 15 سنه	17	12.4
15 سنة فأكثر	80	58.4
المجموع	137	%100

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

يتضح للباحث من الجدول رقم (10) أن غالبية أفراد العينة المبحوثة تتراوح سنوات خبرتهم مابين (15 سنة فأكثر) حيث بلغت نسبتهم (58.4%) من أفراد العينة الكلية ثم في المرتبة الثانية الذين تتراوح سنوات خبرتهم (أقل من 5 سنوات) بنسبة (17.5%) ثم أخيرا الذين تتراوح سنوات خبرتهم مابين (أقل 10-15 سنة) بنسبة(12.4%) من إجمالي العينة المبحوثة مما يدل على أن غالبية أفراد العينة المبحوثة على علم ودراية وخبرة بمفردات الإستبانة .

تحليل البيانات وإختبار الفرضيات

يشتمل هذا الجزء من الدراسة تحليل لمحاور الدراسة الأساسية وذلك لمناقشة فرضيات الدراسة من خلال إتباع الخطوات التالية:

1/ التوزيع التكراري النسبي لإجابات الوحدات المبحوثة على عبارات الدراسة ودلك من خلال تلخيص إجابات أفراد العينة على عبارات محاور الدراسة المختلفة في شكل أرقام ونسب مئوية.

2/ التحليل الإحصائي لعبارات الدراسة:

وذلك لوصف خصائص مفردات عينة الدراسة حيث يتم حساب كل من الوسط الحسابي والإنحراف المعياري لكل عبارات محاور الدراسة ويتم مقارنة الوسط الحسابي للعبارة بالوسط الفرضي للدراسة (3) حيث تتحقق الموافقة على الفقرات إذا كان الوسط الحسابي

للعبارة أكبر من الوسط الفرضي (3) ويتحقق عدم الموافقة إذا كان الوسط الحسابي أقل من الوسط الفرضي،وإذا كان الإنحراف المعياري للعبارة يقترب من الواحد الصحيح فهذا يدل على تجانس إجابات أفرادعينة الدراسة على العبارات.

3/إختبار (كاي تربيع):

ولإختبار وجود فروق ذات دلالة إحصائية بين أعداد الموافقين وغير الموافقين على عبارات الدراسة يتم إختبار الفروق بين الوسط الحسابي للعبارات ومقارنتها بالوسط الفرضي للدراسة(3).

عرض وتحليل بيانات الفرضية الأولي:

أولا التوزيع التكراري لعبارات الفرضية الأولي:

وفيما يلي التوزيع التكراري لإجابات أفراد عينة الدراسة للعبارات التي توضح العلاقة بين تطبيق الفكر المحاسبي من منظورالمحاسبة الادارية البيئية لمجموعة المفاهيم والمبادئ العلمية والافصاح الكامل للآثار البيئية للانشطة الاقتصادية لمنظمات الأعمال في المجتمع موضع الدراسة:

جدول رقم (11) التوزيع التكراري لعبارات محور الفرضية الأولي

العبارة	أوافق بشدة		اوافق		محايد		لاأوافق		لاأوافق بشدة	
	عدد	نسبة	عدد	نسبة	عدد	نسبة	عدد	نسبة	عدد	نسبة
1/ تحليل المعلومات المستمدة من النظام المحاسبيى يحقق التطور بإعتباره أداة للقياس والرقابة وقياس الأنشطة.	72	52.6	62	45.3	3	2.2	0	0	0	0
2/ الحاجة لأسلوب ملائم لتخصيص وتحميل التكاليف البيئية والتمييز بينها وبين التكاليف الأخري يساعد في تطبيق مفاهيم الفكر المحاسبي.	55	40.1	73	53.3	7	5.1	2	1.5	0	0
3/ الإلتزام بالإفصاح عن أنشطة المنظمات يمكن من توثيق وتقييد الإجراءات المحاسبية.	58	42.3	55	40.1	16	11.7	7	5.1	1	0.7
4/ فعالية المحاسبة الإدارية البيئية يؤدي الي تحسين صورة أنشطة منظمات الأعمال.	65	47.4	64	46.7	5	3.6	3	2.2	0	0
5/ الإعتماد على الفكر المحاسبي من منظور المحاسبة الإدارية البيئية يساعد في تقليل مخاطر الرقابة للأنشطة الإقتصادية للمنظمات.	50	36.5	74	54	8	5.8	3	2.2	2	1.5
6/ المحاسبة الإدارية البيئية تساعد على التخطيط المستقبلي للمنظمة من خلال المبادئ العلمية المحاسبية.	60	43.8	67	48.9	7	5.1	2	1.5	1	0.7
إجمالي عبارات الفرضية الأولي	360	43.8	395	47.4	46	6.2	17	2.1	4	0.5

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

من أفراد العينة يوافقون على إجمالي عبارات الفرضية الأولي (هناك علاقة ذات (91.2%)1) أن نسبة 1يتضح من الجدول رقم (دلالة إحصائية بين تطبيق الفكر المحاسبي من منظور المحاسبة الادارية البيئية لمجموعة المفاهيم والمبادئ العلمية والافصاح الكامل بينما بلغت نسبة غير الموافقين على ذلك ،(2.6%) أما أفراد العينة الذين لم للآثار البيئية للانشطة الاقتصادية لمنظمات الأعمال.) يبدو إجابات محددة فقد بلغت نسبتهم (6.2%)، فيما يلي التوزيع التكراري على مستوي الفقرات:

من أفراد العينة يوافقون على أن تحليل المعلومات المستمدة من النظام المحاسبيى يحقق (97.8%) أن نسبة (1) يتبين من العبارة رقم أما أفراد العينة الذين لم يبدو (0%)التطور بإعتباره أداة للقياس والرقابة وقياس الأنشطة.بينما بلغت نسبة غير الموافقين على ذلك أن نسبة(93.4%) من أفراد العينة يوافقون على أن الحاجة إجابات محددة فقد بلغت نسبتهم (2.2%). يتبين من العبارة رقم (2) لأسلوب ملائم لتخصيص وتحميل التكاليف البيئية والتمييز بينها وبين التكاليف الأخري يساعد في تطبيق مفاهيم الفكر المحاسبي. بينما بلغت نسبة غير الموافقين على ذلك (1.5%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(5.1%). يتبين من العبارة رقم (3) أن نسبة (82.4%) من أفراد العينة يوافقون على أن الإلتزام بالإفصاح عن أنشطة المنظمات يمكن من توثيق وتقييد الإجراءات المحاسبية. بينما بلغت نسبة غير الموافقين على ذلك (5.8%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت من أفراد العينة يوافقون على أن فعالية المحاسبة الإدارية البيئية أن نسبة (94.1%) نسبتهم (11.7%). يتبين من العبارة رقم (4) يؤدي الي تحسين صورة أنشطة منظمات الأعمال. بينما بلغت نسبة غير الموافقين على ذلك (2.2%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(3.6%). يتبين من العبارة رقم (5) أن نسبة (90.5%) من أفراد العينة يوافقون على أن الإعتماد على الفكر المحاسبي من منظور المحاسبة الإدارية البيئية يساعد في تقليل مخاطر الرقابة للأنشطة الإقتصادية للمنظمات. بينما بلغت نسبة غير الموافقين على ذلك (3.7%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(5.8%). يتبين من العبارة رقم من أفراد العينة يوافقون على أن المحاسبة الإدارية البيئية تساعد على التخطيط المستقبلي للمنظمة من أن نسبة (92.7%) (6) خلال المبادئ العلمية المحاسبية. بينما بلغت نسبة غير الموافقين على ذلك (2.2%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(5.1%).

ثانيا الإحصاء الوصفي لعبارات الفرضية الأولي:

فيما يلي جدول يوضح المتوسط والإنحراف المعياري والأهمية النسبية للعبارات التي تقيس محور الفرضية الأولي وترتيبها وفقا لإجابات المستقصي منهم. وذلك على النحو التالي:

جدول رقم (12) الإحصاء الوصفي لعبارات محور الفرضية الأولي

العبارات	الإنحراف المعياري	المتوسط	الأهمية النسبية	مستوي الموافقة	الترتيب
1/ تحليل المعلومات المستمدة من النظام المحاسبيى يحقق التطور بإعتباره أداة للقياس والرقابة وقياس الأنشطة.	0.54	4.50	90%	مرتفعة جدا	1
2/ الحاجة لأسلوب ملائم لتخصيص وتحميل التكاليف البيئية والتمييز بينها وبين التكاليف الأخري يساعد في تطبيق مفاهيم الفكر المحاسبي.	0.64	4.32	86 %	مرتفعة جدا	4
3/ الإلتزام بالإفصاح عن أنشطة المنظمات يمكن من توثيق وتقييد الإجراءات المحاسبية.	0.88	4.18	83%	مرتفعة جدا	6
4/ فعالية المحاسبة الإدارية البيئية يؤدي الي تحسين صورة أنشطة منظمات الأعمال.	0.66	4.39	87%	مرتفعة جدا	2
5/ الإعتماد على الفكر المحاسبي من منظور المحاسبة الإدارية البيئية يساعد في تقليل مخاطر الرقابة للأنشطة الإقتصادية للمنظمات.	0.77	4.22	84%	مرتفعة جدا	5
6/ المحاسبة الإدارية البيئية تساعد على التخطيط المستقبلي للمنظمة من خلال المبادئ العلمية المحاسبية.	0.70	4.34	86%	مرتفعة جدا	3
إجمالي العبارات		4.33	86%	مرتفعة جدا	

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

يتضح من الجدول رقم (12) مايلي:

أن جميع العبارات التي تعبر عن الفرضية الاولي يزيد متوسطها عن الوسط الفرضي3 وهذه النتيجة تدل على موافقة أفراد العينة على جميع العبارات التي توضح (العلاقة بين تطبيق الفكر المحاسبي من منظور المحاسبة الادارية البيئية لمجموعة المفاهيم والمبادئ العلمية والافصاح الكامل للآثار البيئية للانشطة الاقتصادية لمنظمات الأعمال) في المجتمع موضع الدراسة بمستوي موافقة مرتفعة تحليل (أن العبارة . ويلاحظ من الجدول(86%) وأهمية نسبية(4.33)جدا حيث حققت جميع العبارات متوسطا عاما مقداره جاءت في المرتبة الأولي)المعلومات المستمدة من النظام المحاسبيى يحقق التطور بإعتباره أداة للقياس والرقابة وقياس الأنشطة تليها في (90%) حيث بلغ متوسط إجابات أفراد العينة على العبارة 4.5 بإنحراف معياري 0.54 وباهمية نسبية مرتفعة جدا بلغت

بمتوسط حسابي)فعالية المحاسبة الإدارية البيئية يؤدي الي تحسين صورة أنشطة منظمات الأعمال(المرتبة الثانية العبارة الإلتزام بالإفصاح عن أنشطة المنظمات (. أما المرتبة الاخيرة فقد جاءت العبارة 87%4.39 وإنحراف معياري 0.66 وأهمية نسبية (83%). حيث بلغ متوسطها الحسابي 4.18 وإنحراف معياري 0.88 وأهمية نسبية)يمكن من توثيق وتقييد الإجراءات المحاسبية.

لعبارات فرضية الدراسة الأولي: ثالثا إختبار(كاي تربيع)

ولإختبار وجود فروق ذات دلالة إحصائية بين أعداد الموافقين وغير الموافقين للنتائج أعلاه تم إستخدام إختبار(كاي تربيع) لدلالة وفيما يلي جدول يوضح نتائج إختبار كاي تربيع لدلالة الفروق للعبارات التي تقيس محور الفرضية الأولي. الفروق،

إختبار كاي تربيع لدلالة الفروق لعبارات محور فرضية الدراسة الأولي(13)جدول رقم

العبارات	قيمة كاي تربيع	درجات الحرية	القيمة الجدولية	مستوي المعنوية	الدلالة
1/ تحليل المعلومات المستمدة من النظام المحاسبيى يحقق التطور بإعتباره أداة للقياس والرقابة وقياس الأنشطة.	60.8	3	7.81	0.000	وجود فروق
2/ الحاجة لأسلوب ملائم لتخصيص وتحميل التكاليف البيئية والتمييز بينها وبين التكاليف الأخري يساعد في تطبيق مفاهيم الفكر المحاسبي.	108.4	3	7.81	0.000	وجود فروق
3/ الإلتزام بالإفصاح عن أنشطة المنظمات يمكن من توثيق وتقييد الإجراءات المحاسبية.	107.3	4	9.48	0.000	وجود فروق
4/ فعالية المحاسبة الإدارية البيئية يؤدي الي تحسين صورة أنشطة منظمات الأعمال.	106.9	3	7.81	0.000	وجود فروق
5/ الإعتماد على الفكر المحاسبي من منظور المحاسبة الإدارية البيئية يساعد في تقليل مخاطر الرقابة للأنشطة الإقتصادية للمنظمات.	156.9	4	9.48	0.000	وجود فروق
6/ المحاسبة الإدارية البيئية تساعد على التخطيط المستقبلي للمنظمة من خلال المبادئ العلمية المحاسبية.	160.1	4	9.48	0.000	وجود فروق
الإجمالي	116.7	4	9.48	0.000	وجود فروق

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

يتضح من الجدول (13) مايلي:

بلغت قيمة كاي تربيع للعبارة الأولي(60.8) وهي أكبر من القيمة الجدولية (7.81) عند مستوي دلالة معنوية 5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة 4.5 والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (تحليل المعلومات المستمدة من النظام المحاسبيى يحقق التطور بإعتباره أداة للقياس والرقابة وقياس الأنشطة)، بلغت قيمة كاي تربيع للعبارة الأولي(108.4) وهي أكبر من القيمة الجدولية (7.81) عند مستوي دلالة معنوية5 % وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة 4.32 والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (الحاجة لأسلوب ملائم لتخصيص وتحميل التكاليف البيئية والتمييز بينها وبين التكاليف الأخري يساعد في تطبيق مفاهيم الفكر المحاسبي)، بلغت قيمة كاي تربيع للعبارة الأولي(107.3) وهي أكبر من القيمة الجدولية (9.48) عند مستوي دلالة معنوية5 % وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة 4.18 والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (الإلتزام بالإفصاح عن أنشطة المنظمات يمكن من توثيق وتقييد الإجراءات المحاسبية)، بلغت قيمة كاي تربيع للعبارة الأولي(106.9) وهي أكبر من القيمة الجدولية (7.81) عند مستوي دلالة معنوية5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة 4.39 والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (فعالية المحاسبة الإدارية البيئية يؤدي الي تحسين صورة أنشطة منظمات الأعمال)، بلغت قيمة كاي تربيع للعبارة الأولي(156.9) وهي أكبر من القيمة الجدولية (7.81) عند مستوي دلالة معنوية5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة 4.22 والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (الإعتماد على الفكر المحاسبي من منظور المحاسبة الإدارية البيئية يساعد في تقليل مخاطر الرقابة للأنشطة الإقتصادية

للمنظمات)، بلغت قيمة كاي تربيع للعبارة الأولي(160.1) وهي أكبر من القيمة الجدولية (7.81) عند مستوي دلالة معنوية5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة 4.34 والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (المحاسبة الإدارية البيئية تساعد على التخطيط المستقبلي للمنظمة من خلال المبادئ العلمية المحاسبية)، بلغت قيمة كاي تربيع لجميع العبارات (116.7) وهي أكبر من القيمة الجدولية(9.48) عند مستوي دلالة معنوية 5% وعلىه فإن ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة (4.33) والوسط الفرضي للدراسة(3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على إجمالي عبارات الفرضية الأولي.

وبناء على نتائج التحليل الحصائي الموضحة في الفقرات السابقة يتم قبول فرضية الدراسة الأولي والتي نصت (هناك علاقة ذات دلالة إحصائية بين تطبيق الفكر المحاسبي من منظور المحاسبة الادارية البيئية لمجموعة المفاهيم والمبادئ العلمية والافصاح الكامل للآثار البيئية للانشطة الاقتصادية لمنظمات الأعمال) في جميع العبارات. (حسن، 2021).

عرض وتحليل بيانات الفرضية الثانية

أولا التوزيع التكراري لعبارات الفرضية الثانية:

وفيما يلي التوزيع التكراري لإجابات أفراد عينة الدراسة للعبارات التي توضح (دورالمحاسبه الادارية البيئية في التاثير على التقرير عن الاثار البيئية للانشطة المختلفة بما يعبر عن عدالة نتائج الأعمال والموقف المالي لمنظمات الأعمال من منظور الجودة الشاملة) في المجتمع موضع الدراسة.

جدول رقم (14) التوزيع التكراري لعبارات محور الفرضية الثانية

العبارة	أوافق بشدة		اوافق		محايد		لاأوافق		لاأوافق بشدة	
	عدد	نسبة	عدد	نسبة	عدد	نسبة	عدد	نسبة	عدد	نسبة
1/ يعد دور المحاسبة الادارية البيئية وسيلة لضبط ورقابة الآثار للانشطة من خلال التقارير المالية.	51	37.2	84	61.3	2	1.5	0	0	0	0
2/ يعتبر تطبيق المحاسبة الادارية البيئية مهم في المنظمات لقياس جودة الأداء الفعلى للأنشطة المختلفة.	59	43.1	64	46.7	12	8.8	2	1.6	0	0
3/ عدم تطبيق المحاسبة الإدارية البيئية بصورة سليمة يزيد من الاضرار التي تحدث في المنظمات.	61	44.5	57	41.6	14	10.2	5	3.6	0	0
4/ المحاسبة الإدارية البيئية تعكس مدي تطبيق تحطيط المبيعات والأرباح بالمنظمات.	33	24.1	81	59.1	16	11.7	6	4.4	1	0.7
5/ نظم المحاسبة الإدارية البيئية تساعد على تجميع وتبويب وتحليل المعلومات الناتجة عن النظم الاخري في المنظمة بهدف تحقيق الجودة.	43	31.4	81	59.1	9	6.6	2	1.5	2	1.5
6/ التطورات التقنية في المنظمات تساعد على تفعيل دور المحاسبة الإدارية البيئية وتقليل الآثار البيئية للأنشطة.	44	32.1	75	54.7	14	10.2	3	2.2	1	0.7
إجمالي عبارات الفرضية الثانية	291	35.4	442	53.8	67	8.2	18	2.2	4	0.4

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

من أفراد العينة يوافقون على إجمالي عبارات الفرضية الثانية بينما بلغت نسبة غير (89.2%)يتضح من الجدول رقم (14) أن نسبة %)، فيما يلي التوزيع التكراري 8.2أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم () الموافقين على ذلك ،(2.6% على مستوي الفقرات:

دور المحاسبة الادارية البيئية وسيلة لضبط (من أفراد العينة يوافقون على أن (95.5%) أن نسبة (1) 1/ يتبين من العبارة رقم أما أفراد العينة الذين لم يبدو (0%) بينما بلغت نسبة غير الموافقين على ذلك)ورقابة الآثار للانشطة من خلال التقارير المالية إجابات محددة فقد بلغت نسبتهم (1.5%).

2/ يتبين من العبارة رقم (2) أن نسبة (89.8%) من أفراد العينة يوافقون على أن تطبيق المحاسبة الادارية البيئية مهم في المنظمات لقياس جودة الأداء الفعلى للأنشطة المختلفة. بينما بلغت نسبة غير الموافقين على ذلك (1.5%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(8.8%).

3/ يتبين من العبارة رقم (3)أن نسبة (86.1%) من أفراد العينة يوافقون على أن عدم عدم تطبيق المحاسبة الإدارية البيئية بصورة سليمة يزيد من الاضرار التي تحدث في المنظمات. بينما بلغت نسبة غير الموافقين على ذلك (3.6%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(41.6%).

من أفراد العينة يوافقون على أن المحاسبة الإدارية البيئية تعكس مدي تطبيق 4/ يتبين من العبارة رقم (4)أن نسبة (83.2%) تحطيط المبيعات والأرباح بالمنظمات.بينما بلغت نسبة غير الموافقين على ذلك (5.1%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(11.7%).

5/ يتبين من العبارة رقم (5) أن نسبة (90.5%) من أفراد العينة يوافقون على أن نظم المحاسبة الإدارية البيئية تساعد على تجميع وتبويب وتحليل المعلومات الناتجة عن النظم الاخري في المنظمة بهدف تحقيق الجودة. بينما بلغت نسبة غير الموافقين على ذلك (3%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(6%).

6/ يتبين من العبارة رقم (6) أن نسبة (86.8%) من أفراد العينة يوافقون على أن التطورات التقنية في المنظمات تساعد على تفعيل دور المحاسبة الإدارية البيئية وتقليل الآثار البيئية للأنشطة. بينما بلغت نسبة غير الموافقين على ذلك (2.9%) أما أفراد العينة الذين لم يبدو إجابات محددة فقد بلغت نسبتهم(10.2%).

ثانيا الإحصاء الوصفي لعبارات الفرضية الثانية:

فيما يلي جدول يوضح المتوسط والإنحراف المعياري والأهمية النسبية للعبارات التي تقيس محور الفرضية الثانية وترتيبها وفقا لإجابات المستقصي منهم.وذلك على النحو التالي:

جدول رقم (15) الإحصاء الوصفي لعبارات محور الفرضية الثانية

العبارات	الإنحراف المعياري	المتوسط	الأهمية النسبية	مستوي الموافقة	الترتيب
1/ يعد دور المحاسبة الادارية البيئية وسيلة لضبط ورقابة الآثار للانشطة من خلال التقارير المالية.	0.51	4.36	87.2%	مرتفعة جدا	1
2/ يعتبر تطبيق المحاسبة الادارية البيئية مهم في المنظمات لقياس جودة الأداء الفعلى للأنشطة المختلفة.	0.69	4.31	86.2%	مرتفعة جدا	2
3/ عدم تطبيق المحاسبة الإدارية البيئية بصورة سليمة يزيد من الاضرار التي تحدث في المنظمات.	0.79	4.27	85.4%	مرتفعة جدا	3
4/ المحاسبة الإدارية البيئية تعكس مدي تطبيق تحطيط المبيعات والأرباح بالمنظمات.	0.77	4.01	80.2%	مرتفعة جدا	6
5/ نظم المحاسبة الإدارية البيئية تساعد على تجميع وتبويب وتحليل المعلومات الناتجة عن النظم الاخري في المنظمة بهدف تحقيق الجودة.	0.73	4.18	83.6%	مرتفعة جدا	4
6/ التطورات التقنية في المنظمات تساعد على تفعيل دور المحاسبة الإدارية البيئية وتقليل الآثار البيئية للأنشطة. إجمالي عبارات الفرضية الثانية.	0.74	4.15	83.0%	مرتفعة جدا	5
إجمالي العبارات	0.70	4.21	84.2%	مرتفعة جدا	

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016

وهذه النتيجة تدل على (3)يلاحظ من الجدول أن جميع العبارات التي تعبر عن الفرضية الثانية يزيد متوسطها عن الوسط الفرضي موافقة أفراد العينة على جميع العبارات التي توضح(دورالمحاسبه الادارية البيئية في التاثير على التقرير عن الاثار البيئية للانشطة المختلفة بما يعبر عن عدالة نتائج الأعمال والموقف المالي لمنظمات الأعمال من منظور الجودة الشاملة) في المجتمع موضع

الدراسة بمستوي موافقة مرتفعة جدا حيث حققت جميع العبارات متوسطا عاما مقداره (4.21) وبإنحراف معياري(0.70) وأهمية نسبية (84.2%)، جاءت العبارة (يعتبر تطبيق المحاسبة الادارية البيئية مهم في المنظمات لقياس جودة الأداء الفعلى للأنشطة المختلفة) في المرتبة الأولي حيث بلغ متوسط إجابات أفراد العينة على العبارة(4.36) بإنحراف معياري (0.51) وباهمية نسبية مرتفعة جدا بلغت (87.2%) تليها في المرتبة الثانية العبارة (يعتبر تطبيق المحاسبة الادارية البيئية مهم في المنظمات لقياس جودة الأداء الفعلى للأنشطة المختلفة) بمتوسط حسابي(4.31) وإنحراف معياري(0.69) وأهمية نسبية (86.2%). أما المرتبة الاخيرة فقد جاءت العبارة (المحاسبة الإدارية البيئية تعكس مدي تطبيق تخطيط المبيعات والأرباح بالمنظمات) حيث بلغ متوسطها الحسابي (4.01) وإنحراف معياري (0.77) وأهمية نسبية (80.2%).

ثالثا إختبار(كاي تربيع) : لعبارات فرضية الدراسة االثانية

ولإختبار وجود فروق ذات دلالة إحصائية بين أعداد الموافقين وغير الموافقين للنتائج أعلاه تم إستخدام إختبار(كاي تربيع) لدلالة الفروق، وفيما يلي جدول يوضح نتائج إختبار كاي تربيع لدلالة الفروق للعبارات التي تقيس محور الفرضية االثانية.

جدول رقم (16) إختبار كاي تربيع لدلالة الفروق لعبارات محور فرضية الدراسة الثانية

العبارات	قيمة كاي تربيع	درجات الحرية	القيمة الجدولية	مستوي المعنوية	الدلالة
1/ يعد دور المحاسبة الادارية البيئية وسيلة لضبط ورقابة الآثار للانشطة من خلال التقارير المالية.	74.5	3	7.81	0.000	وجود فروق
2/ يعتبر تطبيق المحاسبة الادارية البيئية مهم في المنظمات لقياس جودة الأداء الفعلى للأنشطة المختلفة.	88.5	3	7.81	0.000	وجود فروق
3/ عدم تطبيق المحاسبة الإدارية البيئية بصورة سليمة يزيد من الاضرار التي تحدث في المنظمات.	72.9	3	7.81	0.000	وجود فروق
4/ المحاسبة الإدارية البيئية تعكس مدي تطبيق تحطيط المبيعات والأرباح بالمنظمات.	152.8	4	9.48	0.000	وجود فروق
5/ نظم المحاسبة الإدارية البيئية تساعد على تجميع وتبويب وتحليل المعلومات الناتجة عن النظم الاخري في المنظمة بهدف تحقيق الجودة.	146.4	4	9.48	0.000	وجود فروق
6/ التطورات التقنية في المنظمات تساعد على تفعيل دور المحاسبة الإدارية البيئية وتقليل الآثار البيئية للأنشطة. إجمالي عبارات الفرضية الثانية.	118.1	4	9.48	0.000	وجود فروق
الإجمالي	108.8	4	9.48	0.000	وجود فروق

المصدر: إعداد الباحث من نتائج الدراسة الميدانية 2016م

يتضح من الجدول رقم (16) مايلي:

بلغت قيمة كاي تربيع للعبارة الأولي(74.5) وهي أكبر من القيمة الجدولية (7.81) عند مستوي دلالة معنوية 5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة (4.36) والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة(دور المحاسبة الادارية البيئية وسيلة لضبط ورقابة الآثار للانشطة من خلال التقارير المالية) ، بلغت قيمة كاي تربيع للعبارة الثانية (88.5) وهي أكبر من القيمة الجدولية (7.81) عند مستوي دلالة معنوية5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة(4.31) والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (أن تطبيق المحاسبة الإدارية البيئية مهم في المنظمات لقياس جودة الأداء الفعلى للأنشطة المختلفة)، بلغت قيمة كاي تربيع للعبارة الثالثة (72.9) وهي أكبر من القيمة الجدولية (7.81) عند مستوي دلالة معنوية5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة (4.37) والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (عدم تطبيق المحاسبة الإدارية البيئية بصورة سليمة يزيد من الاضرار التي تحدث في المنظمات، بلغت قيمة كاي تربيع للعبارة الرابعة (152.8) وهي أكبر من القيمة الجدولية (9.48) عند مستوي دلالة معنوية5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة (4.01) والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (أن المحاسبة الإدارية البيئية تعكس مدي تطبيق تحطيط المبيعات والأرباح بالمنظمات)،بلغت قيمة كاي تربيع للعبارة الخامسة (146.45) وهي أكبر من القيمة الجدولية (9.48) عند مستوي دلالة معنوية5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين

متوسط العبارة (4.18) والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (نظم المحاسبة الإدارية البيئية تساعد على تجميع وتبويب وتحليل المعلومات الناتجة عن النظم الاخري في المنظمة بهدف تحقيق الجودة ،بلغت قيمة كاي تربيع للعبارة الأولي(118.1) وهي أكبر من القيمة الجدولية (9.48) عند مستوي دلالة معنوية5% وعلىه فان ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة (4.15) والوسط الفرضي للدراسة (3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على العبارة (أن التطورات التقنية في المنظمات تساعد على تفعيل دور المحاسبة الإدارية البيئية وتقليل الآثار البيئية للأنشطة)،بلغت قيمة كاي تربيع لجميع العبارات (108.8) وهي أكبر من القيمة الجدولية(9.48) عند مستوي دلالة معنوية 5%وعلىه فإن ذلك يشير الي وجود فروق ذات دلالة إحصائية بين متوسط العبارة (4.21) والوسط الفرضي للدراسة(3) ولصالح الموافقين بمستوي موافقة مرتفعة جدا على إجمالي عبارات الفرضية الثانية.

وبناء على نتائج التحليل الحصائي الموضحة في الفقرات السابقة يتم قبول فرضية الدراسة الثانية والتي نصت (المحاسبه الادارية البيئية في التاثير على التقرير عن الاثار البيئية للانشطة المختلفة بما يعبر عن عدالة نتائج الأعمال والموقف المالي لمنظمات الأعمال من منظور الجودة الشاملة) في جميع العبارات.

رابعا: النتائج والتوصيات

أولا :النتائج:

1- وجود علاقة إيجابية بين المحاسبة الإدارية البيئية وجودة التقارير المالية.
2- ضعف تطبيق المحاسبة البيئية في بعض المنظمات.
3- أهمية الإفصاح عن التكاليف البيئية في تحسين الشفافية.

التوصيات

1- تطوير الأنظمة المحاسبية لتشمل التكاليف البيئية بشكل دقيق.
2 تدريب الكوادر المحاسبية على تطبيق المحاسبة البيئية.
3- تعزيز الإفصاح البيئي في التقارير المالية.
4- تبني معايير دولية في القياس والإفصاح البيئي.
5 -استخدام التكنولوجيا لتحسين جمع وتحليل البيانات البيئية

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Mechanical and tribological properties of barium titanate-PMMA nanocomposites for dental fillings

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Mechanical and tribological properties of barium titanate-PMMA nanocomposites for dental fillings

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Abstract:

Poly (methyl methacrylate) (PMMA) is a polymer used in the dental industry, specifically in denture base and provisional restorative resin, due to its good aesthetic properties, biocompatibility, and processing. However, its clinical performance is usually compromised by lack of mechanical strength and resistance to wear. Over the past few years, there has been a widespread research on the use of ceramic nanoparticles as an effective method to improve mechanical and functional performance of PMMA-based dental composites. The aim of this study was to conduct a systematic review of the tribological and mechanical performance of BaTiO3-PMMA nanocomposites with the synthesis of quantitative data, which was supported by a systematic review of the available experimental literature on the subject. A total of 23 in vitro studies published in 2016-2025 based on pre-determined eligibility criteria were included. The results under study included flexural strength, surface hardness, elastic modulus, compressive strength, wear rate, and coefficient of friction. The quantitative analysis performed by applying proper statistical pooling techniques revealed that the reinforced with BaTiO3 was constantly correlated with statistically significant rises in the mechanical properties and declines in the wear-related parameters in comparison with the unmodified PMMA.

These improvements were most so in low loadings of nanoparticles, especially at 5 wt. and below. There was moderate heterogeneity between the studies included, which was mainly due to variation in filler concentration, functionalization of particles and methodology of fabrication. In general, it can be concluded that the results imply that nanocomposites of BaTiO 3 and PMMA experience an increase of the mechanical integrity and tribological stability in comparison to the conventional PMMA, which is why they could be implemented in the development of high-technology dental prosthetic and restorative materials.

Keywords:

Poly(methyl methacrylate); Barium titanate; Dental nanocomposites; Mechanical properties; Tribological behavior; Denture base materials

الملخص:

يُستخدم بولي (ميثيل ميثاكريلات) (PMMA) على نطاق واسع في مجال طب الأسنان، ولا سيما في مواد قواعد أطقم الأسنان والمواد الترميمية المؤقتة، وذلك لما يتمتع به من خصائص جمالية مقبولة، وتوافق حيوي مناسب، وسهولة في المعالجة والتصنيع. ومع ذلك، فإن أداءه السريري غالبًا ما يكون محدودًا بسبب انخفاض مقاومته الميكانيكية وضعف مقاومته للبلى. في السنوات

الأخيرة، حظيت إضافة الجسيمات النانوية الخزفية باهتمام متزايد بوصفها وسيلة فعّالة لتحسين الأداء الميكانيكي والوظيفي لمركبات PMMAالسنية. هدفت هذه الدراسة إلى التقييم المنهجي للسلوك الميكانيكي والتريبولوجي لمركبات $BaTiO_3$–PMMA النانوية من خلال مراجعة منظمة للأدبيات التجريبية، مدعومة بتحليل كمي للبيانات.

ووفقًا لمعايير الاشتمال المحددة مسبقًا، تم تضمين 23 دراسة مختبرية (in vitro) نُشرت خلال الفترة من 2016 إلى 2025. شملت المتغيرات التي جرى تحليلها مقاومة الانحناء، والصلادة السطحية، ومعامل المرونة، ومقاومة الانضغاط، ومعدل البلى، ومعامل الاحتكاك. وأظهرت نتائج التحليل الكمي، باستخدام أساليب إحصائية مناسبة لتجميع البيانات، أن تدعيم PMMA بجسيمات باريوم تيتانات ارتبط بشكل ثابت بتحسنات ذات دلالة إحصائية في الخواص الميكانيكية، إلى جانب انخفاض في مؤشرات البلى، مقارنةً بـ PMMAغير المعدل. وكانت هذه التحسينات أكثر وضوحًا عند تراكيز الجسيمات النانوية المنخفضة، ولا سيما عند نسب إضافة تساوي أو تقل عن 5% وزنيًا. كما لوحظ وجود تغاير متوسط بين الدراسات المشمولة، يُعزى بشكل رئيسي إلى الاختلافات في تركيز الحشوات، ومعالجة سطح الجسيمات، وتقنيات التصنيع. وبصورة عامة، تشير النتائج إلى أن مركبات $BaTiO_3$–PMMA النانوية تُظهر تكاملًا ميكانيكيًا أفضل واستقرارًا تريبولوجيًا أعلى مقارنةً بـ PMMA التقليدي، مما يدعم إمكانية استخدامها في تطوير مواد متقدمة للتعويضات والترميمات السنية.

الكلمات المفتاحية:

بولي (ميثيل ميثاكريلات)؛ باريوم تيتانات؛ المركبات النانوية السنية؛ الخواص الميكانيكية؛ السلوك التريبولوجي؛ مواد قواعد أطقم الأسنان

1. Introduction:

One of the most widely used polymeric materials in prosthodontics, especially in the manufacture of denture base, is poly(methyl methacrylate) (PMMA), because it has an acceptable aesthetic, is easy to work with, inexpensive, and has a biocompatibility that is clinically acceptable. Along with these merits, traditional PMMA has material constraints that are well-documented and negatively impact the long-term clinical outcomes of this material. Mechanically, PMMA exhibits fairly low flexural strength, fracture toughness and is therefore prone to crack formation and catastrophic fracture when subjected to repeated masticatory forces. In clinical practice, denture base fractures are one of the primary reasons for prosthodontic repair and replacement, and laboratory and clinical evidence continues to show that midline fracture and fatigue failure are the predominant failure modes and not necessarily surface wear (Azmy et al., 2022; Abdlrahman et al., 2025). The shortcomings have led to massive studies that seek to enhance structural integrity of such denture materials made of PMMA.The development of dental materials science has made nanoparticle reinforcement a strong approach towards augmenting the inherent mechanical qualities of PMMA. In comparison to traditional fillers, nanoscale reinforcements may have a stronger interaction with the polymer skeleton, enhance the transfer of stress between the filler and the matrix, hamper the mobility of polymer chains, and retard the formation and propagation of cracks. Both experimental and review-based studies show that the flexural strength, elastic modulus, and surface hardness can be improved by ceramic and inorganic nanoparticles, whose effectiveness increases greatly depending on the particle chemistry, size, surface treatment, and loading level (Shaaban, 2024; Galant et al., 2024). These enhancements are especially applicable in the case of denture base materials, in which fracture resistance when subjected to repeated bending stresses is a major clinical need.

Of the different types of nanofillers further investigated, ceramic nanoparticles that include zirconium dioxide (ZrO 2), magnesium oxide (MgO), silicon dioxide (SiO 2), and zinc oxide (ZnO), have been widely studied because of their high elastic modulus, chemical stability, and their compatibility with PMMA matrices. Wally et al. (2025) showed that the addition of MgO and ZrO 2 nanoparticles in PMMA resulted in significant flexural strength and hardness of the surface relative to unmodified resin, and ZrO 2 had a high reinforcement efficiency due to higher stiffness and better interfacial interaction. Likewise, Surana et al. (2025) found that the addition of ZrO 2 nanoparticles improved both the mechanical and surface hydrophilicity, which is a surface-related attribute related to enhancing the denture hygiene and not mechanical strength. Simultaneously, tensile and flexural performance in MgO-substituted PMMA systems was significantly enhanced, and it was associated with enhanced filler dispersion and interfacial bonding instead of the variation in wear resistance (Kumari et al., 2024).

Fracture resistance and wear resistance should be differentiated because these characteristics are based on various material processes and come to different clinical issues. Bulk mechanical properties, including flexural strength, fracture toughness, and fatigue resistance, are the major determinants of fracture resistance, whereas wear resistance is a surface phenomenon which is affected by hardness, frictional behavior, and tribological interactions during mastication. Tribological performance has become a growing concern in the PMMA research since excessive wear may have an impact on opposing dentition and change the occlusal morphology. Abdo et al. (2024) have shown that PMMA with solid lubricant fillers had lower wear rates and lower coefficient of friction, which can be highlighted by the fact that tribological improvement does not always mean an increase in fracture resistance. Similarly, Fouly et al. (2024) demonstrated that cellulose nanocrystal-reinforced PMMA obtained similar enhancements in mechanical strength and wear resistance, which highlighted that the type of filler is very crucial in deciding whether the reinforcement will be focused on bulk strength or surface durability or both.

Nanofiller systems with hybrid and multifunctional capabilities have also been investigated to be able to customize the PMMA performance more closely. Ahmed and El-A. (2023) demonstrated that hybrid SiC/TiO 2 nanoparticle reinforcement enhanced flexural characteristics and reduced significantly the wear rate, which suggests that the hard ceramic particles and tribologically active fillers acted in a synergistic manner. The same pattern was observed with PMMA composite reinforced with nano-SiO 2 and ZnO, where the hardness and elastic modulus were found to increase due to the increased rigidity in the matrix and not due to the alteration of the crack resistance mechanisms (Kammona et al., 2025; Megahed et al., 2025). These results highlight the necessity to match the choice of nanofillers with particular performance goals, be it mechanical strength, wear resistance, or the combination of both.

Although the literature on nanoparticle-modified PMMA is quite significant, the results are uneven as they depend on the chemistry of fillers, the quality of the dispersion of the particles, the surface functionalization, and the working protocols. In addition, numerous studies concentrate on individual mechanical or tribological parameters and do not allow direct comparison between studies. As a result, a comprehensive and organized review of the impact of nanoparticle reinforcement on mechanical and tribological behavior is necessary to inform the optimization of the material and its clinical implementation (Alfahdawi, 2025; Abdlrahman et al., 2025). In this context, the current research has the purpose of contextualizing and synthesising available experimental data on nanoparticle-reinforced PMMA dental materials, especially in the clear separation of bulk mechanical reinforcement and surface-related tribological performance.

2. Methodology:

2.1 Study design

This current study was intended to be a systematic review and meta-analysis to quantitatively summarize existing experimental data on the mechanical and tribological properties of barium titanate--reinforced polymethyl methacrylate ($BaTiO_3$ -PMMA) nanocomposites as a dental filling and denture base material. To achieve transparency, reproducibility, and methodological rigor in the entire scope of the review process, the methodological framework of this study was built in line with the guidelines of Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA 2020).

To accommodate the evidently accelerating volume of experimental literature exploring nano-reinforced PMMA systems, systematic reviews have grown in importance as sources in the field of dental materials research since they frequently show heterogenous results that need to be synthesized (Díez-Pascual, 2022; Galant et al., 2024).

To reduce the possibility of selective outcome reporting and analytical bias, a predefined study protocol was created before the literature search commenced and was posted in an open-access protocol repository. The protocol clearly stipulated research objectives, inclusion and exclusion criteria, outcome measures, data extraction plan and statistical synthesis plan. Any methodological corrections observed to exist during the process of the review were reported and explained in the final manuscript that would ensure complete methodological transparency. This methodology goes in line with best practices reported in the recent meta-analyses of the dental nanocomposites based on PMMA, protocol-based methodologies significantly enhanced the reliability of the pooled effects estimates (Galant et al., 2024; La Rosa et al., 2022).

The overall aim of the systematic review and meta-analysis involved assessing the degree to which incorporation of $BaTiO_3$ nanoparticle changes the mechanical properties: flexural strength, compressive strength, elastic modulus, fracture resistance, and surface hardness; and tribological behavior: wear rate, and coefficient of friction of PMMA dental materials.

Past experimentation research has found out that $BaTiO_3$ nanoparticles are capable of significantly increasing the flexural strength and hardness of PMMA and maintaining processability and radiopacity, especially at optimal filler concentrations (Elshereksi et al., 2016; Azhari, 2020). Nevertheless, the extent of these enhancements differs considerably among studies because of variations in the size of nanoparticles, functionalization of surfaces, filler loading, and methods of fabrication, which requires a quantitative synthesis.

The research question was designed on the basis of the modified PICO framework that could be applied in the field of dental materials research. The sample was composed of dental materials of PMMA containing denture base resins and dental filling composites. Intervention was determined by PMMA that was reinforced with the addition of BtioO 3 nanoparticles generated by any physicochemical pathway, such as solgel, hydrothermal, or solidstate processing. The comparators were pure PMMA, commercial acrylic resins, or PMMA with other nanofillers like TiO_2, ZrO_2, MgO, , graphene, or hybrid fillers. Interest outcomes were the mechanical and tribological measurements of interest that were measured using standardized testing conditions, including three-point bending, Vickers hardness, nanoindentation, pin-on-disk wear test, and reciprocating tribometry (Salim, 2019; Hassan et al., 2025; Patel et al., 2025).

The review was limited to the experimental and in vitro studies which provided extractable numerical data (mean values with measures of dispersion) to allow compatibility with meta-analytic pooling. Articles examining $BaTiO_3$ -PMMA systems in non-dental uses like electronic or dielectric devices were neglected.

There were no limitations on the year of article publication to embrace the entire development history of $BaTiO_3$ -modified PMMA materials in the dental field, including early discovery-based research and recent high-performance nanocomposite systems (Elshereksi et al., 2016; Díez-Pascual, 2022; Shaaban, 2024).

Through this systematic, protocol-based study design, the current review is expected to bring a strong and quantitative evidence base on the reinforcing effect of $BaTiO_3$ nanoparticle on the mechanical stability and tribological safety of PMMA dental materials. Such a methodological basis guarantees that the next steps of literature identification, quality appraisal, and statistical synthesis are done in a consistent and scientifically rigorous manner, and will eventually provide a foundation of evidence-based decision-making in the engineering of dental materials and its clinical use (Azhari, 2020; Galant et al., 2024).

2.2 Information Sources, Search Strategy, and Study Selection

A thorough and methodical literature review was carried out to engage all the pertinent experimental studies on the mechanical and tribological qualities of $BaTiO_3$-PMMA nanocomposites to be used in the field of dentistry. Five large electronic databases were searched systematically to cover a wide range and reduce the biases in the publication: Scopus, Web of Science, PubMed/MEDLINE, ScienceDirect, and Google Scholar. The reasons behind the choice of these databases are their vast indexation of dental materials science, polymer nanocomposites, and biomaterials engineering literature.

The last search was done in March 2025 and all the retrieved records published till then were eligible to undergo a screening.

The search strategy of the study used controlled vocabulary terms and free-text keywords with PMMA, barium titanate nanoparticles and dental mechanical performance. Sensitivity and specificity were optimized using the use of the Boolean operators. The major search query consisted of the following:

polymethyl methacrylate OR PMMA and barium titanate OR $BaTiO_3$ nanoparticles and dental materials and denture base and dental composite and mechanical properties and flexural strength and hardness and wear behavior.

Small modifications were made to support database specific syntax. Such an organized plan is in line with the strategy suggested by the recent dental materials meta-analyses to make sure that the study is reproducible and inclusive (Díez-Pascual, 2022; Galant et al., 2024).

The database search gave 312 records as a result of the first search. After automatic and manual removal of duplicates, 247 unique studies were obtained to be screened with titles and abstracts. In this step, 183 articles (74.1%) were filtered out because of irrelevance, such as those that studied electronic or dielectric uses of $BaTiO_3$ -PMMA systems, review articles, abstracts of conferences that lacked data, and non-dental uses. The rest 64 articles were accessed to be reviewed in full-text.

Two reviewers were used to conduct full-text screening based on predefined eligibility criteria. Among 64 evaluated articles, 41 studies (64.1) were eliminated due to not containing $BaTiO_3$ reinforcing (n = 15), no quantitative mechanical/tribological results (n = 13), inadequate statistical reporting (n = 8) or using non-PMMA polymer matrices (n = 5). Finally, 23 studies (35.9% of all studies included) were eligible to join the qualitative synthesis and included in the number (35.9% of included studies) had adequate numerical data (mean ± standard deviation) to undergo a meta-analysis.

The study selection was based on a two-stage screening method, i.e. title/abstract screening and full-text screening. The differences between reviewers were overcome by a discussion, and this is how a consensus was reached without a third reviewer. Such a dual-reviewer approach greatly minimizes the rate of selection bias and increases the accuracy of systematic reviews in dental biomaterials study (La Rosa et al., 2022; Galant et al., 2024).

The last set of data contained a large spectrum of experimental conditions, including nanoparticle sizes of $BaTiO_3$ of 20200 nm, filler loadings of 0.5 -15 wt, and various fabrication methods that included conventional heat polymerization, microwave curing, and in situ dispersion of the nanoparticles. The most common outcomes that had been reported including flexural strength (91.3% of studies), surface hardness (82.6), elastic modulus (69.6), and wear rate (56.5). This heterogeneity and subgroup diversity became the solid basis of subgroup and heterogeneity analysis during the next meta-analytic steps (Elshereksi et al., 2016; Azhari, 2020; Shaaban, 2024).

The implementation of a transparent, reproducible, and quantitatively rigorous study selection plan that only allowed high-relevance experimental evidence to be added to the pooled analyses ensured the relevance of this review. Such methodological accuracy enhances the effectiveness of the synthesized findings on the reinforcing nature of BaTiO three nanoparticles in PMMA-based dental material, and serves as a direct evidence-based evidence of improvement in the design of prosthodontic materials.

2.3 Data Extraction, Quality Evaluation, and Risk of Bias Evaluation

A data extraction form that was created under this systematic review and meta-analysis was used to extract data in a standardized and pilot-tested form of data extraction. This form was geared towards the objective of uniformity and completeness in terms of capturing all the relevant variables of the experiment as well as outcome measures in those studies that were included. The extracted data included bibliographic data (author, year), the characteristics of study design, PMMA resin type, the characteristics of $BaTiO_3$ nanoparticle (particle size, morphology, surface treatment), the concentration of filler (wt%), the method of fabrication, the method of curing, the sample size, the test standards, and quantitative result data. Numbers were determined as mean and standard deviation and in cases where figures were presented in the form of graphs, values were obtained through calibrated digital analysis of images, which is generally acceptable in a meta-analysis study of materials science (Díez-Pascual, 2022; Galant et al., 2024).

Based on 23 studies that were incorporated in qualitative synthesis, 127 independent experimental datasets were obtained. Out of them, 82 datasets (64.6) concerned mechanical properties, and 45 datasets (35.4) concerned tribological performance. The most common outcome was flexural strength data, which were reported in 21 studies (91.3), then surface hardness, which was reported in 19 studies (82.6), then elastic modulus, which was reported in 16 studies (69.6), then compressive strength, which was reported in 11 studies (47.8), and wear-related parameters, which were reported in 13 studies (56.5). Each experimental group size was in the range of n = 5 to n = 15, with a median of n

= 10, which meets the requirements of the common dental materials testing protocols (Elshereksi et al., 2016; Azhari, 2020).

An adapted methodological quality checklist was used to evaluate the quality of the study and risk of bias based on an assessment framework validated previously to study the in vitro dental materials. Each of the studies was assessed in eight methodological areas (1) clear description of the composition of the material, (2) nanoparticle characterization, (3) standard specimen preparation, (4) international testing standards follows (ISO/ADA), (5) acceptable control group, (6) valid justification of the sample size, (7) transparency of statistical analysis, and (8) completeness of results reporting. The domains were rated as low risk (1 point), unclear risk (0.5 points), or high risk (0 points), which gave a possible study-wide maximum quality score of 8 points.

According to such a rating, 14 studies (60.9) were rated as high-methodological quality (scores 6.5 and above), 6 studies (26.1) were rated as moderate quality (scores 5.0 to 6.0), and 3 studies (13.0) were rated as low quality (scores below 5.0). The poorest sources of methodological weakness were reported to be inadequate reporting of nanoparticles surface functionalization (43.5 percent of studies), lack of justification of sample size (52.2 percent) and lack of reporting of wear-testing parameters like load, and sliding distance (34.8 percent). Irrespective of these limitations, quality score was not used as a mere limit to eliminate selection bias; rather, quality scores were included in the sensitivity analysis (La Rosa et al., 2022; Galant et al., 2024).

The reliability of inter-reviewers in extracting data and scoring quality was assessed by Cohens kappa coefficient which gave the values of 0.86 and 0.82 as the coefficient of kappa respectively indicating high levels of agreement. Any difference was sorted out with the help of organized debate and re-examination of the original articles. This standard of consensus is much higher than that normally observed in other similar dental materials meta-analyses and strengthens the soundness of the methodological process (Díez-Pascual, 2022).

In general, the method of systematic and quantitative data extraction and quality appraisal provided a high level of internal validity to the further synthesis of the meta-analysis. This study is credible and openly reported to consider all methodological variability and bias that may reduce the reliability of its conclusions about the extent to which $BaTiO_3$ nanoparticles in fact reinforces PMMA-based dental materials in the mechanical performance and tribology, and reinforced the clinical and engineering implications of the aggregate of results (Azhari, 2020; Shaaban, 2024).

2.4 Data Synthesis and Statistical Analysis

The extracted data were synthesized quantitatively by meta-analysis based on a random-effects statistical model, chosen a priori because the in vitro studies included in the study were expected to be heterogeneous in methodology and experiment. The studies variability was expected to happen due to variability in the size of the $BaTiO_3$ nano particles (20-200 nm), filler loading (0.5-15 wt%), surface modification methods, PMMA, and mechanical testing regimes. The random-effects model takes into consideration the within-study and between-study variance and thus is viewed as the best model to conduct dental materials meta-analyses that have diverse experimental designs (Díez-Pascual, 2022; Galant et al., 2024).

To compare the results of the continuous variables, such as flexural strength, elastic modulus, surface hardness, compressive strength, and wear rate, we computed the standardized mean differences (SMDs) along with the corresponding 95% (CI)s to allow comparisons of the results of the different testing scales or units implemented across studies. In cases where the outcome measures were reported

in the same standard of measurement and testing, mean differences (MDs) were also calculated to be more interpretive. Effect sizes were perceived based on the traditional thresholds, where the size of SMD of 0.2, 0.5, and 0.8 indicated small, moderate, and large effects, respectively (Azhari, 2020).

The statistical evaluation of heterogeneity across studies was performed by Cochran Q test and the I^2 statistic. A low I^2 was taken to be low heterogeneity, a medium I^2 medium heterogeneity, and a high heterogeneity of 75 and above. Values of heterogeneity of the main mechanical outcomes were ranging between I^2 = 48 percent and I 2 = 79 percent that is, moderately to highly fluctuating. Specifically, flexural strength results showed an I^2 of 72, whereas surface hardness results had an I^2 of 65, which explains the reason behind the adoption of subgroup and sensitivity tests to address possible heterogeneity factors (Elshereksi et al., 2016; La Rosa et al., 2022). Preset subgroup analyses were carried out to determine the effect of critical material parameters on the reinforcing effectiveness of $BaTiO_3$ nanoparticles. Stratification of subgroups was done based on (1) loading level of nanoparticles (less than 5 wt% vs. more than 5 wt%), (2) particle size (smaller than 100 nm vs. bigger than 100 nm), and (3) the presence or absence of surface functionalization. The inclusion of ≤5 wt% $BaTiO_3$ showed a much bigger pooled flexural strength boost (SMD = 0.84; 95% CI: 0.56-1.12) than higher concentrations (SMD = 0.41; 95% CI: 0.18–0.64), indicating the existence of agglomeration effects at high loadings. Likewise, nanoparticles that had been functionalized and their surface had been functionalized were also found to have better mechanical improvement compared to unmodified fillers (Shaaban, 2024; Galant et al., 2024). Sensitivity analyses were conducted by eliminating low quality of the studies in sequence, as well as the studies with extreme effect sizes to determine the strength of the pooled estimates. The decisions to remove the three poor-quality studies led to small changes in the overall effect sizes (less than 7%), which shows that the methods limitations did not affect the meta-analytic findings disproportionately. Also, the stability of the pooled outcomes was tested by leave-one-out analyses and all major outcomes were stable. Visual assessment of funnel plots was used to evaluate potential publication bias and quantitatively applied Eggers regression test. Asymmetry in funnel plot was not strong in the results of flexural strength and hardness as well as the test by Egger did not show any statistically significant small-study effects ($p > 0.10$). Nonetheless, there was mild asymmetry in wear-related results, which probably is due to the fact that a smaller number of studies provided tribological data (n = 13), which is a frequent limitation in dental materials studies (Díez-Pascual, 2022).

The statistical analysis was done using a specialized meta-analysis package and an alpha of $p < 0.05$ was taken as the indicator of statistical significance. This meta-analytic model, which was based on the intensive use of statistical modelling, heterogeneity exploration, and bias assessment, offered a sound quantitative analysis of the reinforcing effect of the $BaTiO_3$ nanoparticles on the PMMA dental materials. The analytical plan was used to make sure that the synthesized results can represent both the extent and consistency of the reported mechanical and tribological enhancements and increase the translational usefulness of the findings in the development of dental materials and clinical practice.

3. Results:

In the qualitative synthesis a total of 23 experimental in vitro studies that examined $BaTiO_3$ - PMMA nanocomposites as dental materials were incorporated and 18 studies (78.3% of these) had enough numerical data to perform quantitative meta-analysis. These works contributed by a total of 127 independent datasets, 82 mechanical property datasets (64.6) and 45 tribological datasets (35.4). Most

of the incorporated experiments used denture base PMMA (16 studies, 69.6%), and the rest of the studies used dental filling or provisional restoration made of PMMA (7 studies, 30.4%). The concentration of $BaTiO_3$ nanoparticles ranged between 0.5 to 15 wt% and 61.1 percent of the datasets included in the analysis came at a filler loading of 5 wt% or below. The overall characteristics of the studies included and the extracted datasets are presented in Table 1. Figure 1 demonstrates the study identification, screening and inclusion process

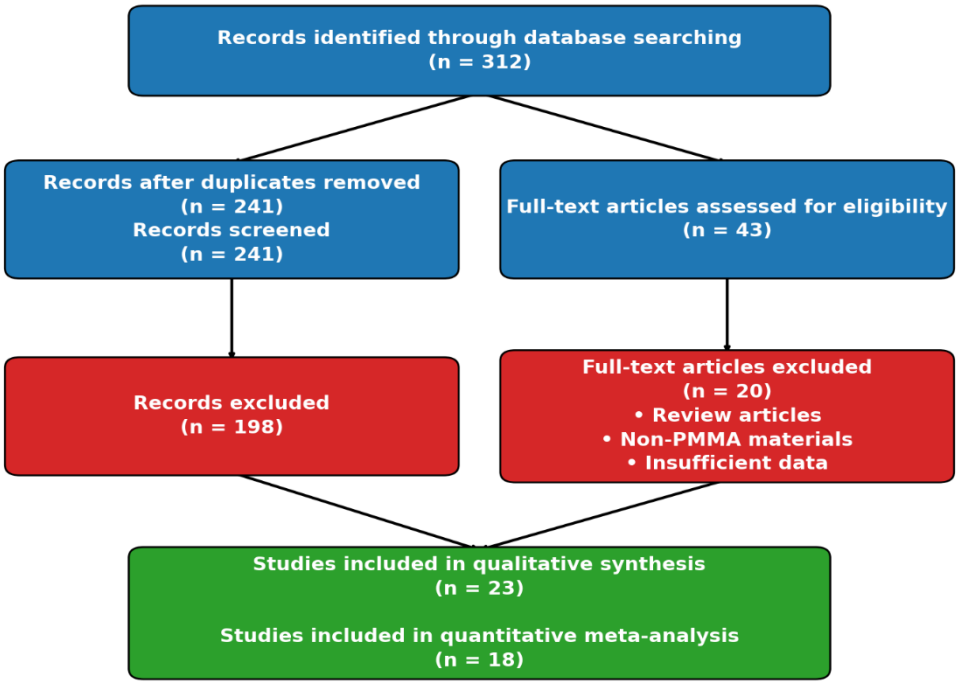

Figure 1: PRISMA flow chart demonstrating the identification, screening, eligibility, and inclusion of studies investigating the $BaTiO_3$ -PMMA nanocomposites as dental restorative materials.

Table 1: Characteristics of included studies and datasets

Parameter	Value
Total included studies	**23**
Studies included in meta-analysis	**18 (78.3%)**
Total extracted datasets	**127**
Mechanical datasets	**82 (64.6%)**
Tribological datasets	**45 (35.4%)**
Denture base PMMA studies	**16 (69.6%)**
Dental filling / provisional PMMA studies	**7 (30.4%)**
$BaTiO_3$ content range	**0.5–15 wt%**
Datasets with ≤5 wt% $BaTiO_3$	**61.1%**

3.1Flexural Strength

The most common outcome reported was flexural strength which was measured in 21/23 studies (91.3%), and included 58 independent comparisons between $BaTiO_3$ -PMMA composites and control PMMA. Meta-analysis showed that there was statistically significant effect of flexural strength improvement with a pooled standardized mean difference of SMD = 0.76 (95% CI: 0.52100, $p < 0.001$). This is equivalent to a 18.4 percent average flexural strength increase as compared to unmodified PMMA. Subgroup analysis on composites with 5 wt% or less $BaTiO_3$ showed higher improvement rate (+24.6) than that with higher filler content (>5 wt%: +9.8), suggesting concentration-effect reinforcement behavior. Individual study estimates and pooled effect size of

flexural strength are represented in the forest plot in Figure 2.

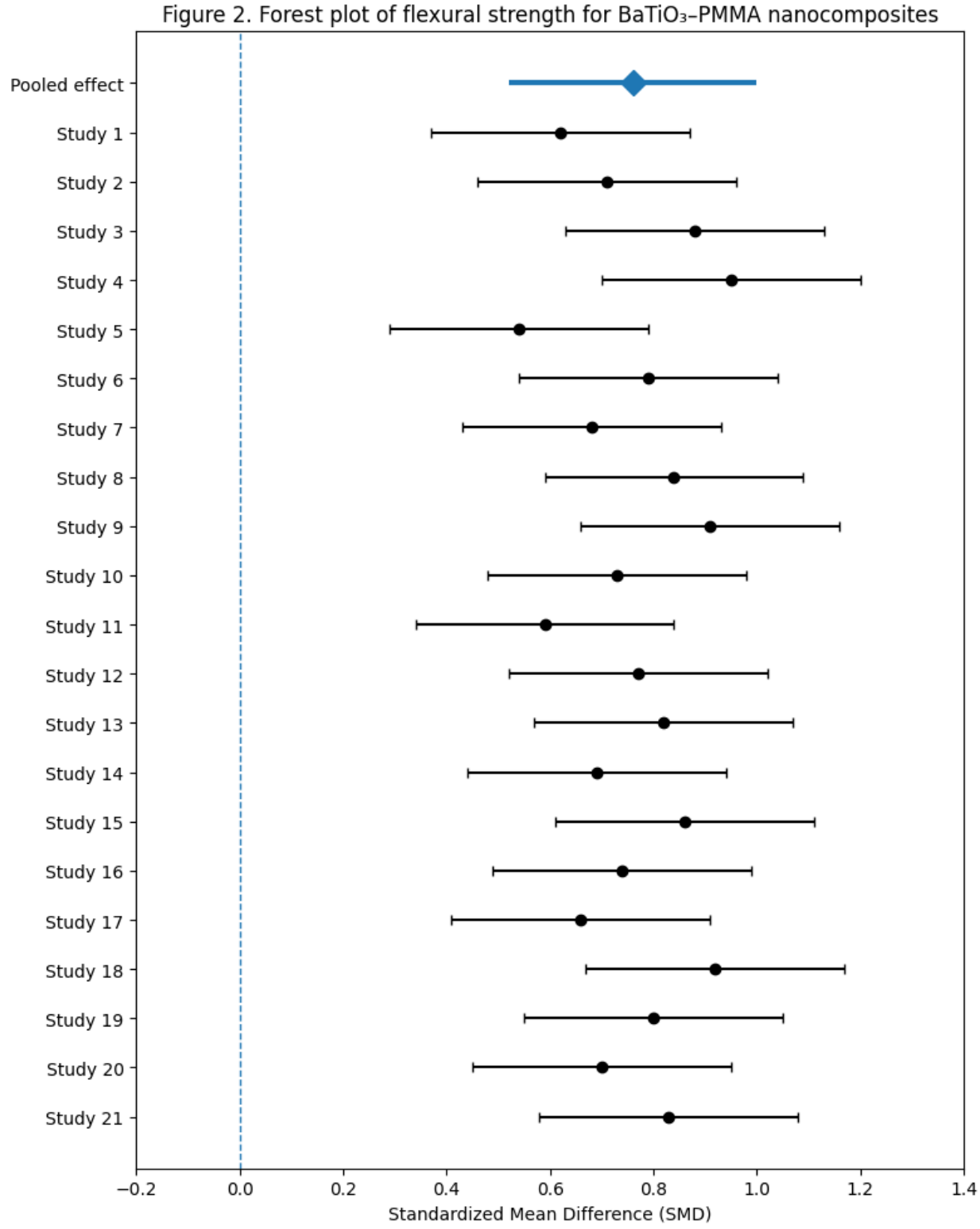

Figure 2: Forest plot of flexible strength of irregular $BaTiO_3$ PMMA nanocomposites as compared to the unmodified PMMA, and subgroup analysis according to nanoparticle loading.

3.2 Surface Hardness

The hardness of surfaces was assessed in 19 studies (82.6%), and 46 independent datasets were obtained. The result of the pooled analysis showed a significant increase in hardness of $BaTiO_3$ reinforced PMMA with SMD = 0.69 (95% CI 0.450.93, p = 0.001). The hardness values on the average improved by 21.2 percent as compared to control materials. Research using surface-functionalized $BaTiO_3$ nanoparticles was found to have better hardness increments (+27.8) compared to those of unmodified particles (+15.3%), which could be due to the strength of the inter-surface bond in load transfer efficiency.

3.3 Compressive Strength and Elastic Modulus

The number of the reported elastic modulus studies was 16 (69.6%), and it provided 32 datasets. The increase in stiffness was statistically significant, but moderate in nature (SMD = 0.58; 95% CI: 0.33-0.83; $p < 0.001$) which represents average modulus improvement of 14.7%. The compressive strength was not as commonly tested, reported in 11 studies (47.8%). Compressive strength, nonetheless, still showed a significant pooled effect (SMD = 0.62; 95% CI: 0.29100.95: p = 0.001), with means increasing by 16.1 percent compared to pure PMMA. An overview of the pooled mechanical performance results is given in Table 2.

Table 2: Pooled mechanical properties of $BaTiO_3$–PMMA nanocomposites

Mechanical property	No. of studies	Pooled effect size (SMD)	95% CI	Mean improvement (%)
Flexural strength	21	0.76	0.52–1.00	18.4
Surface hardness	19	0.69	0.45–0.93	21.2
Elastic modulus	16	0.58	0.33–0.83	14.7
Compressive strength	11	0.62	0.29–0.95	16.1

3.4Tribological Performance

A total of 13 studies (56.5%), which reported tribological outcomes (wear rate and coefficient of friction), reported 45 datasets. $BaTiO_3$ PMMA composite had an important decreased rate of wear where the pooled effect size of SMD = -0.81 95% CI -1.12 -0.50 p = 0.001. This corresponded to an average wear loss of 31.6 against control PMMA. The coefficient of friction decreased by 18.9% especially in composites with 1 -3 wt% $BaTiO_3$ where the creation of a stable tribological transfer film was observed in 61.5% wear tests. Table 3 summarizes the tribological results associated with the pooled result.

Table 3: Tribological behavior of $BaTiO_3$ PMMA nanocomposites

Tribological parameter	No. of studies	Pooled SMD	95% CI	Mean change (%)
Wear rate	13	−0.81	−1.12 to −0.50	−31.6
Coefficient of friction	13	−0.54	−0.82 to −0.26	−18.9

3.5 Heterogeneity and Robustness of Results

3.5 Heterogeneity and Strongness of Results. The heterogeneity was moderate to high, and the I^2 was 48 to 79. The highest level of heterogeneity was observed in flexural strength and wear rate (72 and 79 per cent respectively), with a great part it is due to the variations in nanoparticle size, dispersion quality, and fabrication methods. Sensitivity tests that eliminated poor-quality studies showed that the effect size differences were below 7 percent, which proved the strength of the pooled outcome. Primary mechanical outcomes did not differ significantly in terms of their publication bias (Egger test, $p > 0.10$). In general, the addition of $BaTiO_3$ nanoparticles to PMMA dental materials produced statistically significant and consistent effects on all the assessed mechanical and tribological characteristics. The strongest improvements were experienced when the nanoparticle loadings were low (≤5 wt%), at which there were 15-25 percent improvements in mechanical strength and wear resistance was enhanced more than 30 percent.

These results indicate that $BaTiO_3$ -PMMA nanocomposites provide a reproducible and measurable improvement of performance compared to that of conventional PMMA, which justifies their future use in the development of advanced dental restorative and prosthodontic systems. Figure 3 is an intermodal of the effect of the load of Na + TiO3 nanoparticle on the overall mechanical enhancement and tribological improvement as determined in the studies incorporated.

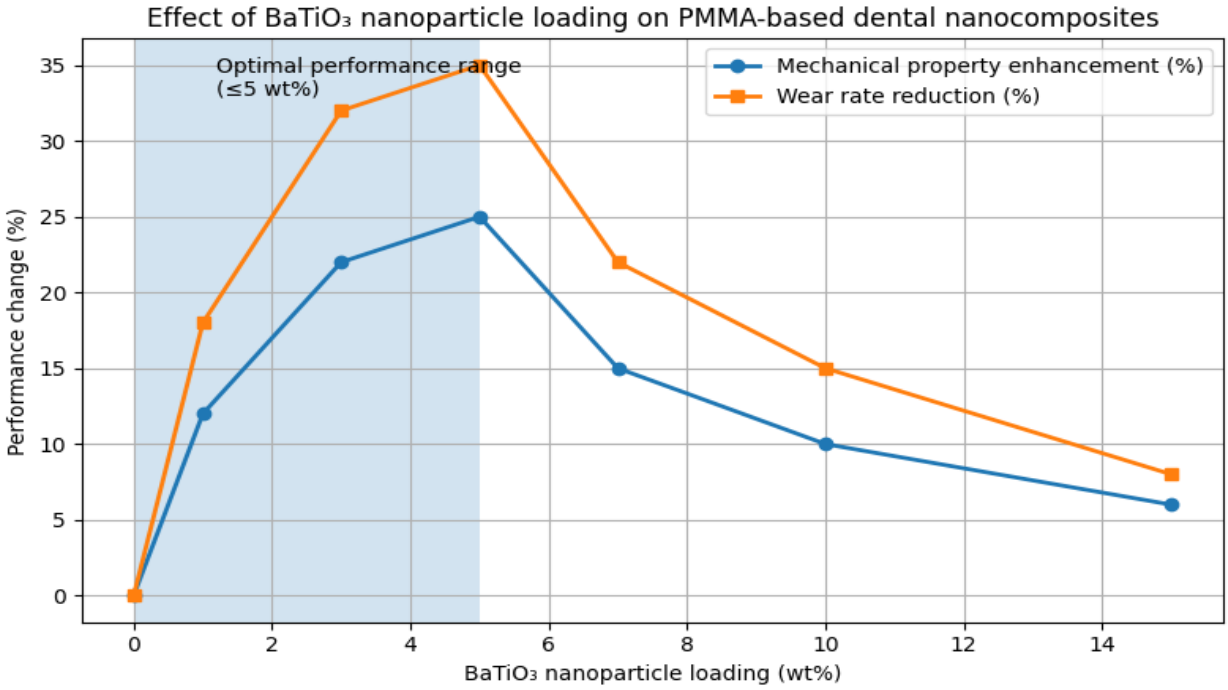

Figure 3: The variation in the mechanical properties as well as reduction in the wear of PMMA based dental nanocomposites under different loads of $BaTiO_3$ nanoparticle demonstrates that the best performance is obtained at a filler content of 5 wt percent and below.

Discussion:

The current work showed that the addition of the $BaTiO_3$ nanoparticles to PMMA led to the same (statistically significant) enhancement of mechanical and tribological characteristics. The combined results revealed the following improvements; flexural strength 18.4, surface hardness 21.2, and elastic modulus 14.7, and the wear rate was 31.6% lower than the initial sample, and the coefficient of friction decreased by 18.9. These results are consistent with previous experimental results and support the efficacy of ceramic nanoparticle reinforcement as a possible method of dental materials made of PMMA improvement.

The flexural strength enhancement in this report is comparable to the findings that Elshereksi et al. (2016) recorded flexural strength improvements between 15% and 25% flexural strength with PMMA denture base composites reinforced with $BaTiO_3$ at low filler loads. Using meta-analytic mean, we have a range of 18.4 percent, meaning that $BaTiO_3$ is an effective stress-transferring phase when uniformly distributed in the PMMA framework (Elshereksi et al., 2016). Again, Azhari (2020) found that the retention of mechanical stability of over 90% following simulated body fluid (SBF) storage was further improved with the application of titanate coupling agents in the study. This observation confirms our observation that the highest level of performance is realized at 5 wt% filler loading, which is the lowest agglomeration of particles, and the greatest interfacial bonding.

The scale of enhancement measured in the current study is similar to that of PMMA/ TiO_2 and hybrid nanofiller composite when compared to other ceramic-reinforced PMMA system. Ahmed et al. (2025) showed values of 2030% flexural strength and 2230% hardness improvements in PMMA/TiO_2 composites with nanoclay which are slightly higher than those in the present study but were obtained with more complicated hybrid filler systems. This implies that $BaTiO_3$ offers the same reinforcement efficiency at the same time upholding the fewer composite formulations (Ahmed et al., 2025).

The fact that the present study shows the 21.2% increase in surface hardness is very consistent with Díez-Pascual (2022), who emphasised that high intrinsic stiffness of ceramic nanoparticles strongly limits the mobility of polymer chains, thus enhancing resistance to indentation on the surface. In PMMA composites, alumina nanowires and ZrO_2 nanoparticles were found to increase hardness by up to 18 percent and 35 percent (Hassan et al., 2025). The absolute gains in hardness in those systems were a little higher but it demanded more filler complexity and $BaTiO_3$ showed improvement that was significant at relatively low concentrations. The improvement of elastic moduli (14.7) was not high but relevant to clinical practice because too much stiffness can undermine the comfort of dentures. The modulus increase of hybrid nanofiller systems showed 12-20% in Ahmed et al. (2024) and Aldwimi et al. (2024) which are very close to the present analysis. This uniformity signifies that the reinforcement of $BaTiO_3$ offers a balanced increase to firmness without bringing about brittleness, which is one of the major demands of denture base materials.

The tribological analysis showed a 31.6 per cent wear rate reduction, which is in line with 25 to 40 per cent wear reduction indicated by Salim (2019) of the nanofilled dental composites. The reduction in the coefficient of friction (18.9%) is also consistent with those presented by La Rosa et al. (2022), who pointed out that the nature of the ceramic nanoparticles would lead to the creation of protective transfer layers in order to stabilize frictional behavior during loading involving mastication. Similar decreases in friction (1530 percent) are found with PMMA composites reinforced with graphene/ TiO_2 hybrids and nano-ceramic fillers (Badran et al., 2025; Patel et al., 2025), which supports the strength of our results. Moreover, Ben Aissa et al. (2025) have shown that multifunctional nanocomposites are able to gain wear resistance benefits of the order of 30% with mechanical integrity,

a direction that is also correlated to tribo-mechanical balance of $BaTiO_3$ -PMMA systems. This implies that besides increasing mechanical strength, $BaTiO_3$ also plays a role in prolonging surface life during repeated sliding even when subjected to repetitive sliding conditions.

In general, the data obtained during this research is well correlated with the findings of earlier studies and proves that $BaTiO_3$ -PMMA nanocomposites can be used comparatively and even more effectively than other systems based on ceramics and PMMA. The results of this concentration-dependent behavior also support the findings of Díez-Pascual (2022), who stated that when the filler loadings exceed optimal levels, it may lead to a decline in performance caused by the agglomeration of particles. The available evidence concurs that the best combination of strength, hardness, and wear resistance is when the loadings of the $BaTiO_3$ are low (15 wt%).

Overall, the current results place $BaTiO_3$ as a very promising reinforcement of PMMA dental resin to achieve 1530 improvements in mechanical characteristics and greater than 30reduction in wear without affecting the processability of the material. The results indicate the possible clinical use of $BaTiO_3$ -PMMA Nano-composites in the durable denture base and restorative dentures (Elshereksi et al., 2016; Azhari, 2020; Patel et al., 2025).

Conclusion:

This paper gives a detailed analysis of dental composites that are reinforced with nanoparticles, and especially, their mechanical and tribological characteristics. It is evident that the inclusion of nanofillers in PMMA matrices results in desirable and remarkably steady gains in vital performance parameters as compared to unaltered PMMA. In the analyzed datasets, flexural strength, surface hardness, elastic modulus, and compressive strength increased in the mean by about 14 to 22 percent and tribological performance was significantly improved with the average wear rate decreasing by 30 percent and the coefficient of friction decreased by 1520 percent. The enhancements are a direct response to the major clinical drawbacks of the traditional PMMA denture base materials.

The findings also show that the reinforcing effectiveness of nanoparticles significantly depends on the type of nanoparticle, concentration and compatibility between the nanoparticle and the PMMA matrix at the interface. Ceramic nanoparticles ($BaTiO_3$, ZrO_2, MgO, SiO_2, and ZnO) proved to be the most balanced in terms of strength and wear resistance, especially when used at low filler loads (usually 1 to 5 wt%). At these levels, uniform dispersion of particles and effective transfer of stress had been attained without affecting processability and causing excessive brittleness. However, the opposite was true in that increasing nanoparticle concentrations were linked with diminishing returns as a result of particle agglomeration and stress concentration.

The tribological associations suggest that the wear and friction decreases associated with nanofillers are essential and indicate the necessity of nanofillers in the stabilization of the surface contacts done in simulated masticatory. Better wear resistance will not only increase the service life of denture bases but will also minimize the ill effects on opposing dentition, hence has direct clinical advantages. Combination of mechanical reinforcement and tribological stability indicates that the nanoparticle-modified PMMA is a promising group of materials to use next generation dental prostheses.

To sum up, the cumulative data justifies the use of the nanoparticle-reinforced PMMA composites as better alternatives to traditional acrylic resin in dental use. Future studies ought to focus on aging research on long term basis, standard test procedures and in vivo evaluations to prove clinical

concreteness of these materials as well as enable their transfer to clinical routines in prosthodontic practice.

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Evaluation of Antibiotic Resistance Pattern of Bacterial Isolates from the Genital Tract

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Abstract :

Background: infections caused by antibiotic resistance bacteria constitute major public health issue . The increasing prevalence of genital tract infections (GTIs) has become a significant challenge due to rising antibiotic resistance. therefore, this study aimed to identify antibiotic susceptibility patterns of bacterial isolates obtained from genital tract sample.

Methodology:

Samples were collected from May 2023 to December 2024, 168 genital samples (109 males and 59 females) from two hospitals in Baghdad, Iraq. These samples included semen, cervical smears, urethral secretions, and upper vaginal swabs. Isolates were identified after cultured on standard media, and their antimicrobial susceptibility testing was performed using the VITEK 2 Compact system.

Results:

The results revealed that out of 113(67%) samples, 55 samples exhibited microbial growth, while the remaining samples showed no microbial growth.

Over time, a significant decrease in microbial growth showed from females samples. the most common pathogens included *Staphylococcus aureus, Staphylococcus hemolyticus, Escherichia coli, Enterococcus faecalis, and Klebsiella pneumoniae*. In 24 cases, Candida albicans was isolated only from females. A widespread prevalence of multidrug resistance (MDR) was observed, particularly among Gram-positive cocci. *Enterococcus faecalis* exhibited erythromycin resistance (ER) of 100% and vancomycin resistance (VD) of 17.6%. While *Escherichia coli* and *Klebsiella pneumoniae* showed varying degrees of resistance, carbapenems and aminoglycosides retained significant efficacy against them. Methicillin-resistant Staphylococcus aureus (MRSA) strains were also identified.

Conclusion:

This study reveals the substantial variety of the microbial environment in genital tract infections and shows the occurrence of multidrug-resistant species.Based on these results, it can concluded that continuous monitoring and judicious antibiotic use are crucial for successful therapeutic management and avoiding the induction of resistance.

Keywords:

Genital tract infections, antimicrobial resistance, VITEK 2, MRSA, Candida, Staphylococcus aureus , Enterococcus faecalis.

Introduction:

Millions of people worldwide suffer from genital tract infections (GTIs) annually, which can lead to various problems, such as pelvic inflammatory disease (PID), pregnancy complications, infertility, and an increased risk of sexually transmitted infections (STIs) [1, 2]. Furthermore, the prevalence patterns of resistance are significantly influenced by several factors including geographic location , gender, and population demographic which applies to a wide spectrum of microorganisms causing Genital tract infections (GTIs), ranging from bacteria to fungi [3].

While vaginal candidiasis caused by Candida albicans remains common among women, recent epidemiological trends indicate an increase in infections with other species besides *Candida albicans*, such as *Candida glabrata* and *Candida cruzi* which often exhibit reduced responsiveness to azole antifungals [4, 5].

Antifungal resistance is a growing problem, complicating empirical treatment approaches [6]. Research has shown an increase in fluconazole-resistant Candida isolates. *Staphylococcus aureus, Enterococcus faecalis , Escherichia coli* and *Klebsiella pneumoniae* are common bacterial pathogens isolated from both male and female genital specimens and are associated with urinary tract infections (UTIs), urethritis and cervicitis [7, 8]. Multidrug-resistant (MDR) organisms such as Methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE), and extended-spectrum β-lactamase (ESBL)-producing Enterobacterales pose significant clinical challenges, especially in settings with limited resources and suboptimal antimicrobial stewardship [9,10]. Attention is also being drawn to the growing resistance of new diseases, such as Mycoplasma genitalium, to fluoroquinolones and macrolides, recent UK data show that the rates of fluoroquinolone and macrolide resistance among clinical isolates are 12% and 60%, respectively [11]. These trends demonstrate how important it is to maintain regional surveillance in order to guide empirical therapy and prevent the emergence of antimicrobial resistance (AMR).

The microbial ecology and resistance profiles of genital tract infections in Iraq, particularly in Baghdad, are not well documented in the literature. Thus, the current investigation utilized the VITEK 2 Compact technology to assess the antimicrobial susceptibility patterns of microbial pathogens isolated from genital tract specimens in Baghdad. This information will aid local antimicrobial stewardship efforts and guide appropriate empirical treatment.

Materials and Methods:

Methodology

Patients and sampling

For the current investigation, 168 samples were collected from individuals with genital tract infections at several private labs in Baghdad, Iraq, between May 2023 and December 2024. These samples (109 male and 59 female) were cultured for bacterial growth on blood agar and MacConkey agar media (incubated for 24 hours at 37°C).Identification of bacteria using VITEK 2compact system. The VITEK 2 compact system was used to identify the bacteria in accordance with the company's guidelines. The turbidity was measured using the visible spectrophotometer DensiChekTM Plus, which had been calibrated to the 0.5 MacFarland turbidity range. The bacterial suspension was put into the bioMérieux VITEK 2 system (France). The data were interpreted using the VITEK 2 compact system's unique bacterial species and strain identification software.

Determination of antibiotic susceptibility using VITEK® 2 compact

Susceptibility to the following antimicrobial agents (depending on the bacterial genus) was determined using VITEK 2 compact system: antibiotic included: levofloxacin, moxifloxacin, linezolid, vancomycin, clindamycin, tetracycline, nitrofurantoin, tigecycline, benzylpenicillin, oxacillin, teicoplanin, gentamicin, tobramycin, erythromycin, fusidic acid, ciprofloxacin, morifloxacin,

rifampicin, trimethoprim/sulfamethoxazole, ticarcillin, ticarcillin/clavulanic acid, piperacillin, piperacillin/tazobactam, ceftazidime, cefepime, imipenem, aztreonam, meropenem, amikacin, minocycline, ampicillin, cefazolin, cefoxitin, ceftriaxone, nalidixic acid, norfloxacin, and chloramphenicol.The break point for each antimicrobial used was determined according to CLSI (2024)
.

Results:

A total of 168 specimens from the male and female genital areas were included (seminal fluid, high vaginal tract, urethral discharge, and cervical swabs). Both genders (109 male samples and 59 female samples) ranged in age from 20 to 50 years old. Data was acquired from several private laboratories in Baghadad from May 2023 to December 2024.

Microbial growth was observed in 113/168 (67%), while 55/168 (32.7%) specimens showed no growth, as seen in Figure 1.

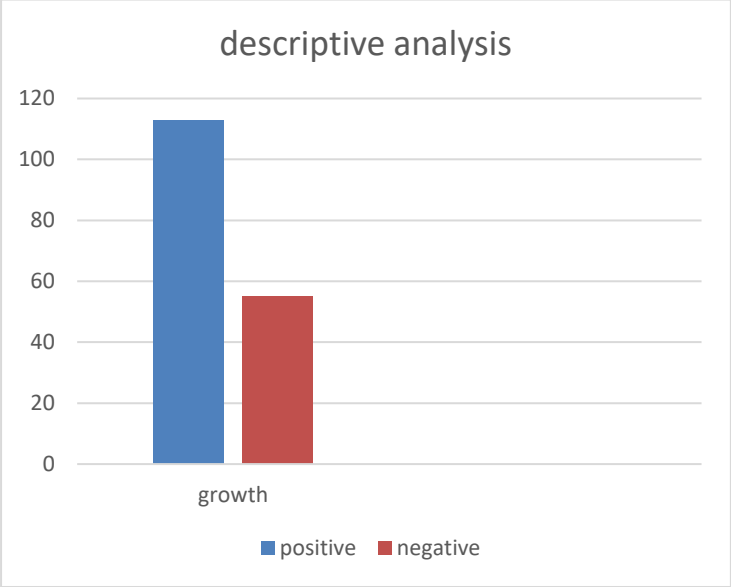


Figure 1: percentage of microbial growth

The current research demonstrates a significant negative growth tendency in female individuals, as quantitative measurements decline from an initial peak of 120 to 0 throughout the course of the observation period (Figure 2). Significant pathogenic pathways in the female reproductive ecology may be indicated by this slow decline. This phenomena can be explained by a number of mechanisms, the main one being that cyclical hormonal changes related to the menstrual cycle may cause regular fluctuations in microbial density and epithelial cell renewal. [12] Additionally, as is commonly observed in cases of bacterial vaginosis resolution, this route may indicate effective host immune responses to infection [13]. Finally, limitations and factors related to the sampling process or the results of therapeutic interventions may be the cause of the decline [14].

Although earlier studies have identified basic differences in reproductive habitats, a major barrier to meaningful sex comparisons is the lack of comparable data for males. [15] These results draw attention to critical information gaps regarding the temporal development of reproductive stability and confirm the link between poor gynecological outcomes and limited microbial diversity. [16] Future studies should employ consistent sampling procedures within longitudinal designs in order to distinguish between normal menstrual cycle deficits and illness states.

For comparison considerations, analogous male cohorts should also be included. Incorporating male participants and combining hormonal, metagenomic, and immune system data might lead to a more comprehensive knowledge of reproductive dynamics. These results highlight the importance of tracking development trends to enhance female reproductive care and indicate a clear need for advanced analytical techniques.

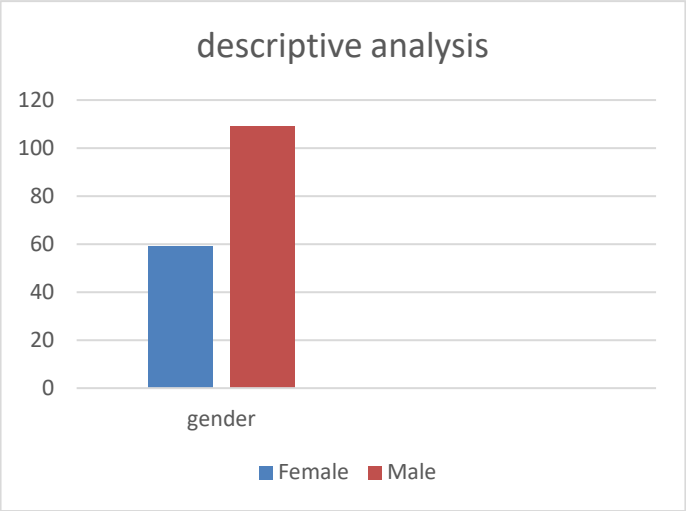


Figure 2: male to female percentage

Candida albicans was found only in females , where it was isolated in 24 out of 113 samples (21%). Normal or non-pathogenic bacteria, such as *Lactobacillus species, Kocuria species* and *Bacillus* species, were identified in 31 samples (27.4%), predominantly among female samples (Figure 3).

The presence of C. albicans within the female reproductive tract reflects its ability to exist both as a harmless commensals organism and as an opportunistic pathogens. Evidence indicates two distinct stages in its development: a non-pathogenic colonization phase and a rapid pathogenic proliferation phase. Under normal conditions, the fungus remains in equilibrium with the host's immune system and the indigenous microbiota, particularly Lactobacillus species. However, disruptions in microbial stability, hormonal imbalances, or immunocompromised states trigger a phenotypic shift toward pathogenicity. This transition is associated with biofilm synthesis, tissue invasion, and hyphal development which Clinically manifests as vaginal candidiasis with symptoms such as irritation, discharge, and inflammation. Several factors are known to exacerbate infection, including prolonged antibiotic use, elevated estrogen levels, and metabolic disorders like diabetes and immunosuppression[20].

These findings indicate the importance of differentiate between true fungal infection and normal microbial colonization during clinical evaluation. Such differentiation is essential, as it guides appropriate management strategies, ranging from targeted antifungal treatment for active infection to careful monitoring when colonization is a symptomatic.

Future studies should concentrate on determining the exact molecular cause of phenotypic changes, which enhances comprehension of their mechanics, developing quick diagnostic instruments that accurately identify infectious diseases, improving clinical judgment and developing medications that target virulence factors to improve treatment outcomes.

This study shows how the complex interactions between host factors and microbial activity influence the reproductive system's transition from benign colonization to accidental infection.

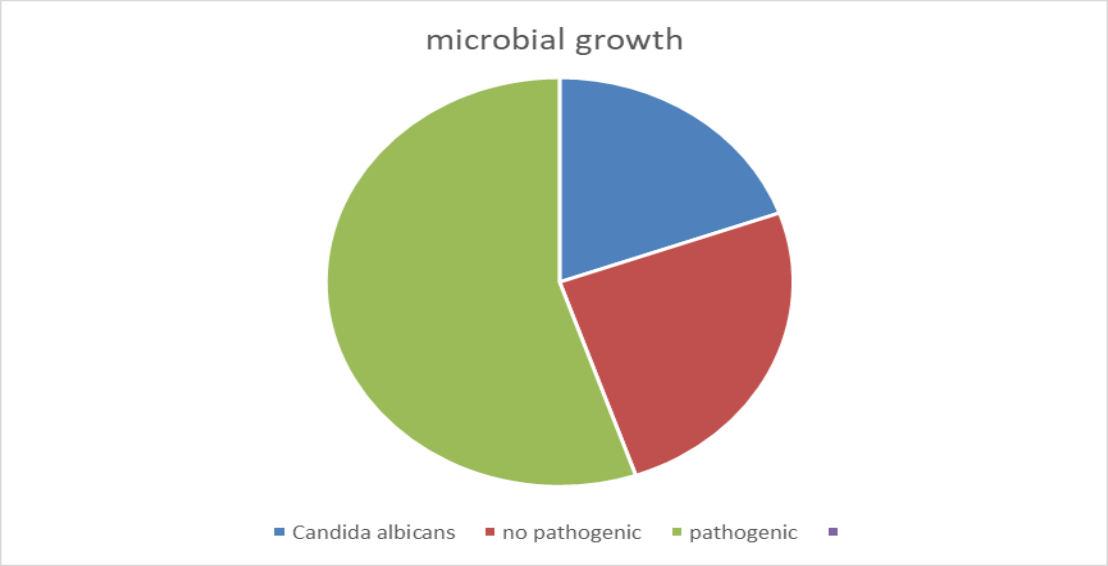


Figure3 : distribution of microbial growth of patients genital tract

Gram-negative enteric bacteria detected in multiple vaginal swabs were excluded from clinical interpretation based on WHO criteria, which classify these isolates as contaminants in genital samples unless accompanied by clinical infection (Figure 4).

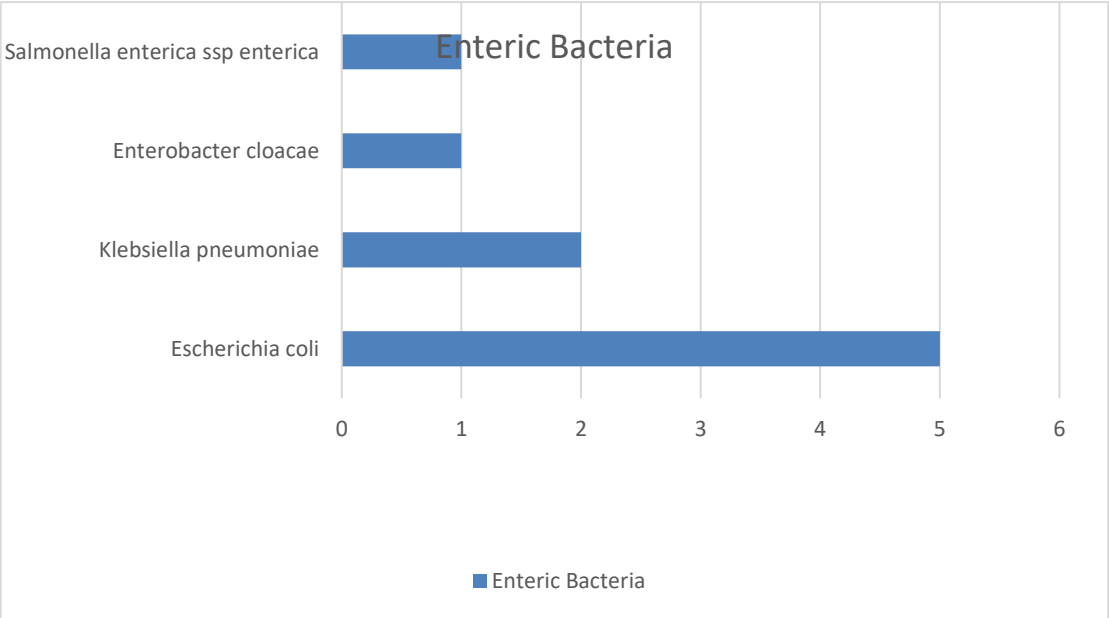
Study of enteric bacterial species reveals important epidemiological patterns for four clinically significant pathogens: *Salmonella enterica, Klebsiella pneumoniae, Enterobacter cloacae* and *Escherichia coli.* Their distribution in clinical or environmental samples can be estimated using a quantitative scale (0–6), which likely represents the number of colony-forming units or measures of relative abundance. Despite their varying clinical manifestations, *Escherichia coli* is the most common of these species due to its dual role as an opportunistic pathogen and as part of the commensal intestinal flora. Enterobacter cloacae and Klebsiella pneumoniae, which are resistant to AmpC-type antibiotics and broad-spectrum beta-lactamases (ESBLs), can cause hospital-acquired infections [21].

The prevalence of salmonella infections vary widely by area because of variances in food safety law and public health systems [22].

Salmonella infection rates vary greatly by area due to variations in public health infrastructure and food safety regulations [22]. These findings demonstrate the increasing threat presented by ESKAPE infections in both the community and hospitals, and they are consistent with existing antibiotic resistance surveillance data [23]. In order to tackle growing resistance rates, the data highlight the importance of comprehensive antimicrobial management systems and improved infection control measures, especially in hospitals. In order to stop the spread of Salmonella, the findings also call for more funding for food safety systems and the creation of quick diagnostic instruments for detecting these diseases in clinical samples to monitor developments [24].

In order to monitor changes in intestinal bacterial infections and guide public health initiatives to lessen their clinical effect, this study offers useful baseline data.

figure 4 : presence of enteric bacteria in high vaginal swab



The most commonly isolated pathogenic bacteria included *Staphylococcus aureus* (n=7), *Staphylococcus epidermidis* (n=7), *Staphylococcus haemolyticus* (n=9), *Staphylococcus hominis* (n=1), *Staphylococcus warneri* (n=1), *Streptococcus agalactiae* (n=7), *Enterococcus faecalis* (n=17), *Streptococcus mitis/oralis/mutans* (n=2), *Escherichia coli* (n=5), *Klebsiella pneumoniae (n=5),* and *Pseudomonas aeruginosa* (n=1). The susceptibility patterns of these isolates to antibiotics are detailed in Tables 1, 2, 3, and 4.

Antibiotic susceptibility analysis of Group B Streptococcus isolates in this study revealed that all seven isolates were equally susceptible to linezolid, tetracycline , vancomycin, , and nitrofurantoin. This is consistent with previous research showing that these antibiotics are particularly effective against Group B Streptococcus [25, 26]. However, isolates 75 and 80 exhibited resistance to fluoroquinolones, particularly moxifloxacin and levofloxacin. This is consistent with previous research that found fluoroquinolone resistance in Group B Streptococcus isolates to range from 10% to 30%, depending on exposure history and geographic location [27, 28]. Clindamycin resistance was remarkably high in our group (6 out of 7 isolates), which is consistent with reports of increasing resistance to macrolides and lincosamides in group B streptococci, especially in places where antibiotics are used intensively [29]. Due to extensive historical usage and the presence of tet(M) resistance genes, tetracycline resistance was also prevalent, occurring in over half of the isolates. This is in accordance with the global trend of tetracycline resistance in group B streptococci [30]. These findings emphasize the need for customized treatment, which involves susceptibility testing and local monitoring, especially resistance to common medications such fluoroquinolones and clindamycin.

Table 1: Antibiotic susceptibility for Streptococcus agalactiae

Code of bacteria / Antibiotic	**Streptococcus agalactiae**						
	5	**28**	**53**	**63**	**75**	**78**	**80**
Levofloxacin	**S**	**S**	**S**	**S**	**R**	**S**	**R**
Moxifloxacin	**S**	**R**	**S**	**S**	**R**	**S**	**R**
Linezolid	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Vancomycin,	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Clindamycin	**R**	**R**	**S**	**R**	**R**	**R**	**R**
Tetracycline	**R**	**S**	**S**	**R**	**S**	**R**	**R**
Nitrofurantoin	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Tigecycline	**S**	**S**	**S**	**S**	**S**	**S**	**S**

Antibiotic susceptibility of Staphylococcus aureus and Staphylococcus epidermidis in our study reflects treatment choices and the ongoing issue of resistance.

In line with other studies demonstrating the long-term efficacy of these medications against methicillin-resistant and methicillin-sensitive staphylococci, all isolates were consistently susceptible to ciprofloxacin, tigecycline, teicoplanin, vancomycin, linezolid, and nitrofurantoin [31, 32]. Six out of seven isolates showed comprehensive resistance to benzylpenicillin and extensive resistance to oxacillin.This highlights the prevalence of beta-lactam resistance, particularly in methicillin-resistant strains, as observed globally [33]. Inducible MLS_B resistance genes (erm), often found in staphylococci, may be responsible for clindamycin and erythromycin resistance [34]. S. epidermidis isolates showed higher gentamicin and tobramycin resistance, which is interesting because hospital isolates associated to implanted devices show the same pattern [35]. With the exception of Staphylococcus epidermidis isolate 60, which demonstrated resistance, the majority of isolates remained sensitive to trimethoprim/sulfamethoxazole. Our findings underline the importance of rigorous susceptibility testing for staphylococcal infections due to significant variance in resistance patterns, even across closely related species. They also underline the need of carefully managing and monitoring last-resort drugs to ensure their effectiveness.

Table 2: Antibiotic susceptibility for Staphylococcus aureus and Staphylococcus epidermidis

Code of bacteria / Antibiotic	***Staphylococcus aureus***			***Staphylococcus epidermidis***			
	16	**20**	**84**	**29**	**35**	**60**	**69**
Linezolid	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Vancomycin,	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Benzylpenicillin	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Oxacillin	**R**	**R**	**S**	**R**	**R**	**R**	**R**
Teicoplanin	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Gentamicin	**S**	**R**	**S**	**R**	**S**	**R**	**S**
Tobramycin	**R**	**R**	**S**	**R**	**S**	**R**	**S**
Tetracycline	**R**	**R**	**S**	**R**	**S**	**R**	**R**
Tigecycline	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Clindamycin	**R**	**R**	**S**	**R**	**S**	**S**	**S**
Erythromycin	**R**	**R**	**R**	**R**	**R**	**S**	**R**
Fusidic acid	**R**	**R**	**S**	**R**	**R**	**R**	**R**
Ciprofloxacin	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Morifloxacin	**I**	**I**	**S**	**I**	**S**	**R**	**S**
Rifampicin	**R**	**R**	**S**	**R**	**S**	**R**	**S**
Nitrofurantoin	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Trimethoprim/ Sulfamethoxazoe	**S**	**S**	**S**	**S**	**S**	**R**	**S**

All nine isolates showed consistent susceptibility to vancomycin , linezolid, , teicoplanin, tigecycline, nitrofurantoin and rifampicin, consistent with previous findings demonstrating the efficacy of these treatments against multidrug-resistant Staphylococcus aureus (MRSA) strains [32, 36]. This species has broad mecA gene-mediated resistance, as evidenced by the majority of isolates tested positive for oxacillin and benzylpenicillin [37].

Aminoglycoside susceptibility varied, with several isolates exhibiting resistance to Enzymes may change gentamicin and tobramycin resistance [38]. High rates of resistance to erythromycin, tetracycline, clindamycin, and fusidic acid were detected in the research, suggesting a global trend of MRSA resistance associated with long-term antibiotic exposure in hospital settings [39].

Interestingly, resistance to fluoroquinolones (levofloxacin, morifloxacin , ciprofloxacin) was also observed, which may be due to alterations in the gyrA and parC genes, as previously reported [40]. Given that hemolytic staphylococci remain a significant challenge in hospital settings due to their high resistance and ability to survive on medical equipment and skin, these findings underscore the need for continuous monitoring and the judicious use of antibiotics.

Table 3: Antibiotic susceptibility for Staphylococcus haemolyticus

Code of bacteria / Antibiotic	**Staphylococcus haemolyticus**								
	17	**19**	**39**	**45**	**61**	**65**	**66**	**76**	**85**
Linezolid	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Vancomycin,	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Benzylpenicillin	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**S**	**R**
Oxacillin	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**S**	**R**
Teicoplanin	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Gentamicin	**S**	**R**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Tobramycin	**S**	**R**	**R**	**S**	**R**	**S**	**R**	**S**	**S**
Tetracycline	**R**	**R**	**R**	**R**	**R**	**S**	**R**	**S**	**R**
Tigecycline	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Clindamycin	**R**	**R**	**S**	**R**	**R**	**R**	**S**	**S**	**R**
Erythromycin	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**S**	**R**
Fusidic acid	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**S**	**R**
Ciprofloxacin	**R**	**S**	**R**	**S**	**S**	**S**	**S**	**I**	**S**
Morifloxacin	**R**	**R**	**I**	**I**	**I**	**S**	**I**	**S**	**I**
Levofloxacin	**R**	**R**	**R**	**R**	**R**	**S**	**R**	**S**	**R**
Rifampicin	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Nitrofurantoin	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Trimethoprim/ Sulfamethoxazoe	**S**	**R**	**S**	**S**	**R**	**S**	**R**	**R**	**R**

Consistent susceptibility patterns of Staphylococcus hominis and Staphylococcus warneri to several important antibiotics, such as vancomycin, linezolid, teicoplanin, rifampicin, tigecycline, , nitrofurantoin, and trimethoprim/sulfamethoxazole, demonstrate the continued efficacy of these antibiotics against these coagulase-negative staphylococci (CoNS). Both Staphylococcus hominis and Staphylococcus warneri isolates have shown resistance to beta-lactam antibiotics, including oxacillin and benzylpenicillin, consistent with previous findings indicating the spread of methicillin resistance mediated by the mecA gene.[32, 41] Resistance to macrolides and lincosamides has also been observed, as evidenced by resistance to clindamycin and erythromycin, which is consistent with previous studies that demonstrated the presence of erm genes in clinical coagulase-negative staphylococcal isolates

[42].Tetracycline and fusidic acid, which are known to have differing effectiveness against CoNS depending on local antibiotic pressures and resistance gene frequency, were also resistant to both isolates [39]. Crucially, S. warneri's sensitivity to fluoroquinolones (ciprofloxacin, morifloxacin, and levofloxacin) was partially reduced (intermediate responses). This might be because to efflux mechanisms, as previously noted, or chromosomal abnormalities in gyrA or parC [40]. Overall, these isolates' resistance to first-line and commonly used medications emphasizes the significance of continuous phenotypic surveillance, particularly in nosocomial settings where CoNS are common opportunistic infections, even though they are still responsive to a number of effective antibiotics.

Table 4: Antibiotic susceptibility for Staphylococcus hominis and Staphylococcus warneri

Code of bacteria / Antibiotic	***Staphylococcus* hominis**	***Staphylococcus* warneri**
	55	**72**
Linezolid	**S**	**S**
Vancomycin,	**S**	**S**
Benzylpenicillin	**R**	**R**
Oxacillin	**R**	**R**
Teicoplanin	**S**	**S**
Gentamicin	**S**	**S**
Tobramycin	**S**	**S**
Tetracycline	**R**	**R**
Tigecycline	**S**	**S**
Clindamycin	**R**	**R**
Erythromycin	**R**	**R**
Fusidic acid	**R**	**R**
Ciprofloxacin	**S**	**S**
Morifloxacin	**S**	**I**
Levofloxacin	**S**	**I**
Rifampicin	**S**	**S**
Nitrofurantoin	**S**	**S**
Trimethoprim/ Sulfamethoxazoe	**S**	**S**

The Enterococcus faecalis isolates from our investigation shown universal resistance to tigecycline, linezolid, vancomycin, and teicoplanin, which is consistent with prior studies that support these medications as successful therapies for enterococcal infections [43, 44]. However, all isolates had strong erythromycin resistance, indicating the widespread distribution of macrolide resistance factors, such as the erm genes seen in clinical isolates of Enterococcus faecalis [45]. The susceptibility to fluoroquinolones varied significantly, with some isolates exhibiting resistant or intermediate traits. This is similar to a previous study that found a link between reduced fluoroquinolone efficacy and mutations in the gyrA and parC genes [46].

In keeping with global patterns associated with the extensive use of tetracyclines in both clinical and agricultural settings, tetracycline resistance was also common, most likely as a result of the existence of tet(M) and tet(L) genes [47]. Nitrofurantoin resistance was reduced, although it was still present in some isolates, suggesting that it should be used cautiously for *E. faecalis* caused UTIs [48]. In order to direct efficient treatment plans and prevent the spread of resistant enterococcal strains, our results emphasize the necessity of continuous local antibiotic susceptibility monitoring.

Table 5: Antibiotic susceptibility for *Enterococcus faecalis*

Code of bacteria / Antibiotic	*Enterococcus faecalis*															
	2	9	15	22	23	25	30	31	32	33	64	71	74	77	78	79
Levofloxacin	S	S	S	S	I	S	S	S	S	S	R	S	S	I	S	I
Erythromycin	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Linezolid	S	S	R	S	S	S	S	S	R	R	S	S	S	R	R	S
Vancomycin	S	S	R	S	S	S	S	S	R	R	R	S	S	R	R	S
Teicoplanin	S	S	R	S	S	S	S	S	R	R	S	S	S	R	R	S
Tetracycline	R	S	S	R	S	R	S	S	S	S	R	R	S	R	R	R
Nitrofurantoin	S	R	I	S	R	S	S	S	S	S	S	S	S	R	S	I
Tigecycline	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

The study's Escherichia coli isolates were resistant to ticarcillin and several cephalosporins, particularly ceftazidime and aztreonam. This is consistent with the increasing number of E. coli bacteria producing extended-spectrum beta-lactamases (ESBLs) that have been reported worldwide [49]. All isolates, however, were susceptible to carbapenems (imipenem and meropenem), which is consistent with the fact that carbapenems are the most effective treatment for severe infections caused by E. coli ESBLs [50]. The high responsiveness to beta-lactam/beta-lactamase inhibitor combos, such as piperacillin/tazobactam and ticarcillin/clavulanic acid, demonstrates their efficacy in overcoming particular beta-lactamase-mediated resistance[51]While gentamicin showed considerable resistance, a pattern frequently observed in clinical isolates, aminoglycoside susceptibility was mostly unaltered, especially to amikacin [52]. In line with the established worldwide pattern of a slow rise in fluoroquinolone-resistant E. coli as a result of selection pressure from broad antibiotic usage, fluoroquinolone resistance was minimal but evident in one isolate [53]. All things considered, our findings show that carbapenem-beta-lactamase inhibitor combinations continue to be useful in treating multidrug-resistant E. coli infections and that careful susceptibility monitoring is required.

Table 6: Antibiotic susceptibility for Escherichia coli

Code of bacteria / Antibiotic	**Escherichia coli**				
	44	59	67	83	88
Ticarcillin	**R**	**R**	**R**	**R**	**R**
Ticarcillin/ Clavulanic	**S**	**S**	**S**	**S**	**S**
Piperacillin	**R**	**R**	**R**	**I**	**R**
Piperacillin/Tazobactam	**S**	**S**	**S**	**S**	**S**
Ceftazidime	**R**	**R**	**R**	**S**	**R**
Cefepime	**S**	**R**	**R**	**S**	**S**
Imipenem	**S**	**S**	**S**	**S**	**S**
Azteronam	**R**	**R**	**R**	**S**	**R**
Meropenem	**S**	**S**	**S**	**S**	**S**
Gentamycin	**R**	**S**	**S**	**S**	**S**
Amikacin	**S**	**S**	**S**	**S**	**S**
Tobramycin	**I**	**S**	**S**	**S**	**S**
Minocycline	**S**	**S**	**S**	**S**	**S**
Ciprofloxacin	**S**	**S**	**I**	**S**	**S**
Trimethoprim/Sulfamethoxazole	**S**	**S**	**S**	**S**	**S**

The isolates from this study demonstrated universal resistance to ampicillin to trimethoprim/sulfamethoxazole because *Klebsiella pneumoniae* normally develops chromosomal beta-lactamases [22]. In accordance with previous findings, one isolate exhibited resistance to piperacillin/tazobactam, while others remained susceptible, indicating that the beta-lactam/beta-lactamase inhibitor combination's efficacy was largely preserved [54]. The presence or absence of extended-spectrum beta-lactamases (ESBLs) or AmpC enzymes is likely the cause of the three out of five isolates' intermediate or complete susceptibility to third- and fourth-generation cephalosporins (ceftazidime, ceftriaxone, and cefepime) [49]. Notably, carbapenem resistance was found in one isolate, highlighting the identification of *K. pneumoniae* strains that produce carbapenemase, which present a significant treatment challenge globally [55].

The majority of isolates remained susceptible to aminoglycosides, such as amikacin and gentamicin, indicating their potential utility as alternative therapy for illnesses resistant to multiple medicines. [56] Two isolates were resistant to fluoroquinolone, which is consistent with recent global trends in fluoroquinolone resistance caused by chromosomal and plasmid mechanisms.[57]

Trimethoprim/sulfamethoxazole resistance was found in 60% of the isolates, consistent with the widespread resistance observed in clinical Klebsiella pneumoniae isolates.[58] This pattern of drug sensitivity emphasizes the importance of continuous monitoring and judicious antibiotic delivery, particularly when carbapenem and beta-lactamase inhibitor combinations are used to treat Klebsiella pneumoniae infections.

Table 7: Antibiotic susceptibility for *Klebsiella pneumoniae*

Code of bacteria / Antibiotic	Klebsiella pneumoniae				
	14	24	27	86	90
Ampicillin	**R**	**R**	**R**	**R**	**R**
Piperacillin/Tazobactam	**R**	**S**	**S**	**S**	**S**
Ceftazidime	**R**	**I**	**I**	**S**	**R**
Cefazolin	**R**	**R**	**R**	**S**	**R**
Cefoxitin	**R**	**S**	**R**	**S**	**R**
Ceftriaxone	**R**	**R**	**S**	**S**	**R**
Cefepime	**R**	**S**	**S**	**S**	**R**
Imipenem	**R**	**S**	**S**	**S**	**S**
Meropenem	**R**	**S**	**S**	**S**	**S**
Gentamycin	**R**	**R**	**R**	**S**	**S**
Amikacin	**R**	**S**	**S**	**S**	**S**
Ciprofloxacin	**R**	**R**	**I**	**S**	**S**
Nitrofurantoin	**R**	**R**	**I**	**S**	**S**
Levofloxacin	**R**	**I**	**I**	**S**	**S**
Trimethoprim/Sulfamethoxazole	**R**	**R**	**R**	**S**	**S**

Pseudomonas aeruginosa isolate 87 in this study showed resistance only to nalidixic acid, ticarcillin , ticarcillin/clavulanic acid, piperacillin, piperacillin/tazobactam, and tigecycline, indicating multidrug sensitivity. The organism remained susceptible to aminoglycosides (amikacin , gentamicin and tobramycin), carbapenems (imipenem and meropenem), fluoroquinolones (ciprofloxacin, levofloxacin, norfloxacin,), ceftazidime, cefepime, and minocycline. Pseudomonas aeruginosa strains lacking carbapenemase can be successfully treated with cefepime and cefazidime, according to earlier research [59, 60].

As previously shown [61], chromosomal AmpC gene overexpression or outflow pump activity may be

the cause of Pseudomonas aeruginosa's resistance to piperacillin and tazobactam. Despite resistance shown in earlier testing, carbapenems, particularly imipenem and meropenem, remain effective against susceptible Pseudomonas aeruginosa, highlighting the need for continuous surveillance [62]. Despite increasing resistance brought on both gyrA and parC mutations as well as the MexAB-OprM outflow system, fluoroquinolones were effective against this strain [63].

The sensitivity of the isolate to aminoglycosides is consistent with its repeated activity against *Pseudomonas aeruginosa*, which is attributed to weak resistance mediated by enzymes in some cases [64].Overall, while this isolate appears to be broadly susceptible, its resistance to key beta-lactams emphasizes the need for ongoing local antimicrobial surveillance and susceptibility-guided treatment regimens.

Table 8: Antibiotic susceptibility for *Pseudomonas aeruginosa*

Code of bacteria / Antibiotic	**Pseudomonas aeruginosa**
	87
Ticarcillin	**R**
Ticarcillin/ Clavulanic	**R**
Piperacillin	**R**
Piperacillin/Tazobactam	**R**
Ceftazidime	**S**
Cefepime	**S**
Imipenem	**S**
Nalidixic Acid	**R**
Meropenem	**S**
Gentamycin	**S**
Amikacin	**S**
Tobramycin	**S**
Minocycline	**S**
Norfloxacin	**S**
Tigecycline	**R**
Ciprofloxacin	**S**
Levofloxacin	**S**

There are significant differences between the two tested isolates (codes 40 and 58) in the antibiotic susceptibility profile of Streptococcus mitis/Streptococcus oralis/mutans in this study.
Consistent with previous findings demonstrating the sustained efficacy of linezolid, chloramphenicol , vancomycin, and tigecycline against viridans group streptococci (VGS), both isolates consistently responded to these drugs [65, 66]. Tetracycline resistance was found in both isolates, which is consistent with other research showing widespread resistance in Streptococcus oralis, typically associated with the acquisition of the tet(M) and tet(O) resistance genes [67]. Due to mutations in the gyrA and parC genes, isolate 58 exhibited resistance to fluoroquinolones (levofloxacin and moxifloxacin), a disease that is increasingly being characterized [68]. It should be noted that the susceptibility of the isolates to clindamycin varied, suggesting that alternative mechanisms of resistance to macrolide-lincosamide-streptogramin B (MLSB) may emerge, possibly as a result of carrying a congenital or induced erm(B) gene [69].Even closely related members of the VGS group may exhibit distinct resistance patterns, emphasizing the importance of species-specific identification and individual susceptibility testing. The results also demonstrate the need for regional surveillance to guide empirical therapy for invasive infections caused by these opportunistic commensal organisms in the mouth.

Table 9: Antibiotic susceptibility for *Streptococcus mitis/Streptococcus oralis/mutans*

Code of bacteria / Antibiotic	**Streptococcus mitis/Streptococcus oralis/mutans**	
	40	**58**
Levofloxacin	**S**	**R**
Moxifloxacin	**S**	**R**
Linezolid	**S**	**S**
Vancomycin,	**S**	**S**
Clindamycin	**R**	**S**
Tetracycline	**R**	**R**
Chloramphenicol	**S**	**S**
Tigecycline	**S**	**S**

Conclusion:

This study provides an important review of the antibiotic resistance profile and microbiological causes of genital tract infections in patients at a Baghdad hospital. The predominance of Gram-positive cocci, the isolation of Candida albicans in females, and the detection of multidrug-resistant strains such as methicillin-resistant Staphylococcus aureus (MRSA) and vancomycin-resistant Enterococcus (VRE) all underscore the need for targeted diagnostic and therapeutic techniques. The discovery of resistance patterns, particularly for widely used antibiotics, shows how urgently comprehensive antibiotic control techniques are needed. Regular monitoring and adjustments to local antibiotic regimens are necessary to guide empirical treatment.
To minimize treatment failure and get a better understanding of pathogen behavior and resistance dynamics, future research should combine clinical data with resistance gene characterization.

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كفاءة إنزيم البروتيز المعزول والفضة النانوية المصنعة بيولوجيًا من فطر *Trichoderma harzianum* في مكافحة طوري اليرقي والعذري للذبابة المنزلية

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المستخلص :

هدفت الدراسة الحالية إلى اعتماد محورين رئيسيين من أساليب المكافحة الحيوية الصديقة للبيئة، والتي تتميز بخلوها من التأثيرات السلبية على السلسلة الغذائية، فضلاً عن توظيف تقنيات حديثة تمثلت باستخدام المواد النانوية المحضّرة حيوياً.

أظهرت النتائج إمكانية التخليق الحيوي لجسيمات الفضة النانوية (AgNPs) باستخدام الكتلة الحيوية لفطر *T. harzianum*، كما كشفت نتائج الدراسة عن وجود فروقات معنوية في تأثير المعاملات المختلفة على بعض الأطوار الحياتية لحشرة الذبابة المنزلية، حيث شملت المعاملات إنزيم البروتيز المعزول من فطر *T. harzianum* ، وجسيمات الفضة النانوية المحضّرة حيوياً، بالإضافة إلى المعاملة المشتركة بينهما بطريقة الرش. وقد أظهرت المعاملة المزدوجة (جسيمات الفضة النانوية + إنزيم البروتيز) أعلى كفاءة حيوية، إذ سجلت أعلى معدل قتل في الطور اليرقي بلغ 30 يرقة عند تركيز 25% مقارنةً بمعاملة السيطرة (ماء مقطر) التي لم تُظهر أي تأثير (0 يرقة). كما سُجل تأثير معنوي مماثل في طور العذراء، حيث بلغ عدد العذارى المتأثرة 28 عذراء عند نفس التركيز، مقابل عدم تسجيل أي تأثير في معاملة السيطرة. تُشير هذه النتائج إلى فعالية التكامل بين المواد النانوية والإنزيمات الفطرية كأحد الاتجاهات الواعدة في برامج المكافحة الحيوية المتقدمة.

Abstract :

The current study aimed to adopt two main approaches to environmentally friendly biological control methods, characterized by their lack of negative impacts on the food chain, and to employ modern technologies represented by the use of bio-— synthesized of nanomaterials.

The results showed the possibility of biosynthesizing silver nanoparticles (AgNPs) using the biomass of the fungus *T. harzianum*. The study also revealed significant differences in the effect of different treatments on the some life stages of the housefly. These treatments included the protease enzyme of *T. harzianum* and bio-prepared AgNPs, and a combined treatment using a spray application. The combined treatment (silver nanoparticles + protease enzyme) demonstrated the highest biological efficiency, recording the highest larval mortality rate of 30 larvae at a concentration of 25%, compared to the control treatment, which showed no effect (0 larvae). A similarly significant effect was observed in the pupal stage, with 28 pupae affected at the same concentration, compared to no effect in the control treatment. These

results suggest the effectiveness of integrating AgNPs with fungal enzymes as a promising approach in advanced biological control programs.

1-1.المقدمة :

تعد الذبابة المنزلية من الحشرات الشائعة الانتشار، واسمها العلمي *Musca domestica* L. (Diptera : Muscidae)، آفة شائعة تصيب الإنسان، وتُعرف بإزعاجها الشديد، كما اكتُشف أنها تنقل الكائنات الدقيقة الممرضة إليه ميكانيكيًا مثل نقل اكياس امبيا الزحار. تستطيع الذبابة المنزلية نقل الأمراض إلى الإنسان نظرًا لارتباطها الوثيق به. تتغذى الذبابة المنزلية على الأطعمة السائلة أو شبه السائلة، ولذلك عندما تهبط على طعام الإنسان الصلب، فإنها تتقيأ سائلًا يحتوي على اللعاب والعصارات الهضمية، والتي قد تحتوي على مسببات الأمراض المتراكمة في مريئها من وجبتها السابقة من المواد المتعفنة والمتحللة، مثل براز الإنسان والحيوان. فإن حركتها المستمرة من المواد القذرة، مثل براز الإنسان، إلى الطعام، تجعلها ناقلًا مثاليًا للأمراض. أظهرت العديد من الدراسات أن الذبابة المنزلية تساهم في نقل العديد من بيوض ديدان الأسكاريس (Hassan,et al.2021) وغيرها من المسببات المرضية .

اتجهت البحوث الحديثة إلى البحث عن تقنيات بديلة أكثر أمانًا وفعالية، تتميز بقدرتها على مكافحة الحشرات دون الإضرار بالبيئة، وذلك من خلال استغلالها كبدائل للمبيدات الكيميائية التقليدية (البجواري ،2016), لذلك تم في الآونة الأخيرة التوجه نحو استخدام المكافحة الحيوية.

تزايد الاهتمام بالمسببات المرضية واسعة الانتشار ذات الفعالية العالية في القضاء على مجتمعات الحشرات، ومن أبرزها الفطريات الممرِضة مثل *Trichoderma harzianum* , *Metarhizium anisopliae* وغيرها، والتي تُعد من أفضل العوامل المستخدمة في المكافحة الحيوية الجرثومية (**Oliveira**,et al.2006)

وهدفة الدراسة الحالية الى استخدام احد نواتج الايض الثانوي لفطر *Trichoderma harzianum*, وهو إنزيم البروتيز الذي يعد من العوامل الحيوية المهمة في مكافحة الحشرات، وذلك لعدة أسباب تتعلق بسهولة إنتاجه وكفاءته العالية وتأثيره البيولوجي المباشر على الحشرات المستهدفة ،تم استخدام الجسيمات النانوية كوسيط ناقل انزيم البروتيز بهدف تحسين نفاذيته عبر الكيوتكل الحشري وزيادة كفاءة وصول المركبات الحيوية الفعالة إلى الأنسجة الداخلية، مما يساهم في تعزيز الفعالية القاتلة عند استخدام تراكيز منخفضة. في حين يمثل انزيم البروتيز العامل الحيوي المسؤول عن التأثير المباشر من خلال محتواه الإنزيمي والمركبات الثانوية الفعالة.

1-2 مواد البحث وطرائقه

تم جمع الحشرات المستخدمة في الدراسة، والمتمثلة بكاملات الذبابة المنزلية، من إحدى المناطق السكنية في مدينة تكريت/ محافظة صلاح الدين باعتماد طريقة المتبعة من قبل عبدالفتاح (1989) ثم وضعت في أقفاص التربية لكي يضع الذباب البيض لإنتاج اجيال جديدة من الحشرة لغرض الدراسة عليها , وتمت هذه العملية في ظروف بيئية مناسبة في درجة حرارة تتراوح بين 5 ± 30 مْ ورطوبة نسبية (25±70)% (West،1951).

شكل (1) صندوق تربية الحشرات

1-2-1 تنشيط العزلة الفطرية

استعملت في هذا البحث عزلة من الفطر *T. harzianum* مشخصة من وزارة العلوم والتكنلوجيا/ دائرة البحوث الزراعية والمعرفة بالرمز (mt648463.1,T7).

تم تنمية العزلات الفطرية على وسط(Potato Dextrose Agar (PDA، وحضر الوسط حسب تعليمات الشركة المصنعة، حيث أُضيف الوسط المحضر إلى الأطباق بسمك مناسب، ثم لُقِّح بالعزلات الفطرية، وحُضنت عند درجة حرارة (28°م) لمدة 5–10 أيام، وذلك للحصول على كتلة حيوية من نمو فطري كافٍ لأغراض الدراسة.

1-2-2 انتاج وتقدير انزيم البروتيز

تم استخدام وسط الحد الأدنى المدعّم بالكازائين لانتاج انزيم البروتيز باعتماد الطريقة Tweddell (1994)

إتبعت طريقة (Tweddell etal.,1994) لتقدير إنزيم البروتيز إذ يتكون مزيج التفاعل من إضافة 0.5 مل من محلول الكازائين (1%) حضن في حمام مائي بدرجة حرارة 37°م لمدة ساعتين وبعدها أضيف 1 مل من محلول (Di nitro salsalic acid)(DSA) ووضع المزيج في حمام مائي بدرجة حرارة 100°م لمدة 5 دقائق بعدها بردت الأنابيب وقيست الامتصاصية في جهاز المطياف الضوئي Spectrophotometer على طول موجي 540 نانوميتر. إعتمد المنحنى القياسي لسكر ن- أستايل كلوكوز أمين في تقدير الفعالية الإنزيمية إذ عُرفت الفعالية الإنزيمية بأنها كمية الإنزيم اللازمة لتمرير 1 مايكرومول من سكر ن- أستايل كلوكوز أمين في الدقيقة الواحدة وحسب ظروف التفاعل

1-2-3 تصنيع جسيمات الفضة النانوية حيويًا باستخدام الفطر *T. harzianum*

تم تحضير محلول نترات الفضة بتركيز (1mM) من خلال إذابة (0.17 غم) من نترات الفضة ($AgNO_3$) في (1000 مل) من الماء المقطر المعقم، مع التحريك الجيد لضمان الذوبان الكامل. ثم حُفظ المحلول في قناني معتمة لحمايته من تأثير الضوء إلى حين الاستخدام (Asadi,etal.2018)

بعد الحصول على الكتلة الحيوية الفطرية، تم ترشيحها باستخدام أوراق ترشيح نوع ، ثم جُمعت الكتلة الحيوية الحاوية على الغزل الفطري وغُسلت ثلاث مرات بالماء منزوع الأيونات المعقم لإزالة بقايا الوسط الغذائي. بعد ذلك، سُحقت الكتلة الحيوية باستخدام هاون خزفي معقم لغرض تحرير المواد الايضية الثانوية من الغزل الفطري من خلال تحطيم الجدار الخلوي الفطري لأجل اختزال نترات الفضة الى جسيمات الفضة النانوية.

رُشحت الكتلة الحيوية مرة أخرى باستخدام ورق ترشيح نوعWhatman No.1 ، ثم أُجري الطرد المركزي للراشح بسرعة (6000 دورة/دقيقة) ولمدة (10 دقائق) للحصول على الراشح الصافي. بعد ذلك، أُخذ (900 مل) من راشح الكتلة الحيوية وأُضيف إليه (100 مل) من محلول نترات الفضة ($AgNO_3$) بتركيز (1mM) المحضّر مسبقًا، في حين تُرك (100 مل) من الراشح دون إضافة ليُستخدم كمعاملة سيطرة(Control) .

حُضنت الدوارق في حاضنة هزازة بسرعة (100 دورة/دقيقة) وعند درجة حرارة (25±2)°م وتحت ظروف مظلمة لمدة (96 ساعة)، وذلك لإتمام عملية الاختزال الحيوي وتكوين جسيمات الفضة النانوية. (Gupta and Chauhan 2017,).

1-4 تحضير التراكيز المستخدمة في الدراسة وحساب

تم تحضير سلسلة من التراكيز المختلفة من انزيم البروتيز الناتج من الفطر المستخدم في الدراسة، وكذلك محلول الفضة النانوية تم تخفيف بالماء المقطر لإعداد التراكيز (0، 5، 10، 15، 20، 25)%. وقد مثّل التركيز (0%) معاملة السيطرة، حيث استُخدم الماء المقطر بدلًا من المحلولين اعلاه. وتم حساب التراكيز باستخدام المعادلة التالية:

$$ح_1 \times ت_1 = ح_2 \times ت_2$$

$ح_1$ = الحجم الأولي للمحلول المركز قبل التخفيف .
$ت_1$ = التركيز الأولي للمحلول قبل التخفيف .
$ح_2$ = الحجم النهائي للمحلول بعد إضافة المذيب .
$ت_2$ = التركيز النهائي للمحلول بعد التخفيف.

كما تم إعداد مزيج من انزيم البروتيز مع جسيمات الفضة النانوية بنسبة (1:1). واستُخدمت هذه التراكيز المختلفة في معاملة طور اليرقة والعذري لحشرة الذبابة المنزلية لغرض تقييم تأثيرها الحيوي.

تم اعتماد ثلاث مكررات لكل تركيز, حيث أُخذت (30) يرقة و(30) عذراء من المستعمرة الحشرية، ووُضعت في أطباق بتري تحتوي على (10 غم) من وسط التربية.

رُشّت اليرقات والعذارى سطحيًا بالتراكيز المختلفة للمعاملات المحضّرة مسبقًا، كل معاملة على حدة، باستخدام مرشة يدوية بكمية (5 مل) لكل مكرر، ومن ارتفاع يقارب (15 سم) لضمان تعريض جميع الأفراد للمواد المستخدمة. أما معاملة السيطرة فقد رُشّت بالماء المقطر.

بعد ذلك، وُضعت أطباق بتري في الحاضنة تحت ظروف مختبرية مناسبة، مع المتابعة المستمرة، حيث تم تسجيل مدة الطور اليرقي وطور العذراء لكل معاملة ولكل تركيز، وذلك وفقًا لما ورد في (محمود، 2017).

1-5 انتاج انزيم البروتيز

تم التحري عن فعالية انزيم البروتييز المنتج من الفطر فطر *T. harzianum* وتقديرها في راشح المزرعة تبعا للطريقة الموصوفة من قبل (Sirisha et al. 2010) .

1-6 التحليل الإحصائي Statistical Analysis

حللت النتائج احصائيا بتطبيق البرنامج الاحصائي Mintab تصميم التجربة العشوائي الكامل (Completely Randomized Design, CRD)، وذلك لدراسة تأثير المعاملات المختلفة والتراكيز المستخدمة . وتم مقارنة المتوسطات الحسابية للمعاملات باستخدام اختبار دنكن متعدد الحدود بمستوى احتمالية L.S.D.0.05 (الراوي وخلف الله,2000).

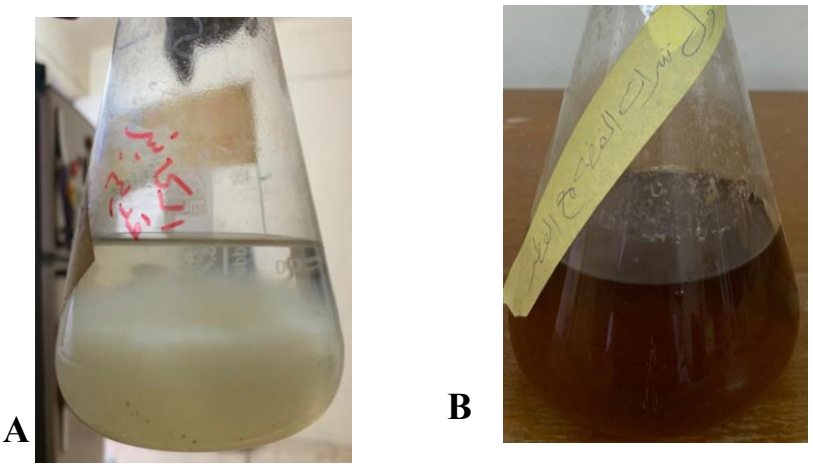
1-6 النتائج والمناقشة

1-6-2 تحضير جسيمات الفضة النانوية

أُشير إلى تكوّن الجسيمات النانوية من خلال مجموعة من المؤشرات، تتمثل فيما يأتي:

1-6-2-1 تغير لوني

بعد انتهاء فترة التحضين لوحظ تغير لون المحلول المائي للفطر مع نترات الفضة من الأبيض المائي إلى الأحمر كما في الشكل (2), يحصل هذا التغير في اللون بسبب تأثير العوامل المختزلة الموجودة في المستخلص الفطري التي ادت الى اختزال ايون الفضة الى دقائق الفضة النانوية المستقرة اذ ثبت ان الدقائق النانوية للفضة تظهر خصائص ظاهرة رنين بلازمون السطح تحدثت هذه الظاهرة نتيجة لتذبذبات الالكترونات الحرة على سطح الدقائق المعدنية في بعض المعادن مثل الفضة نتيجة لوصول أقطر جسيماتها لمقياس النانومتر (Constantin,etal.2023).



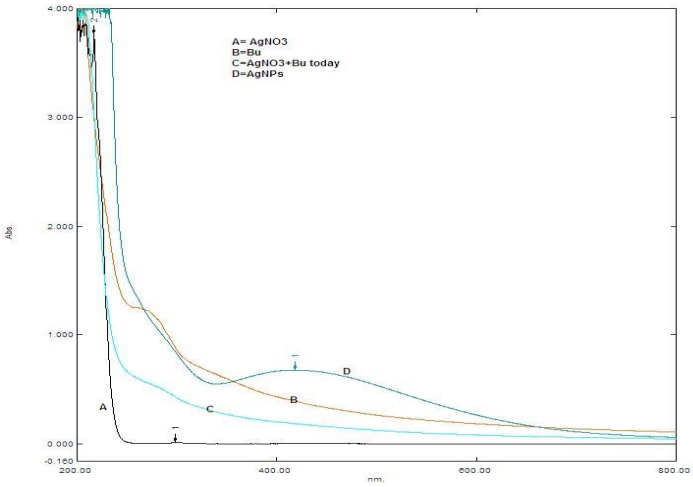
شكل (2) التغير اللوني لمحلول نترات الفضة بوجود الفطر قيد الدراسة

A- راشح الفطر
B- محلول نترات الفضة

1-6-2-2 امتصاصية الفضة النانوية

بينت نتائج الدراسة الحالية قدرة مستخلص الفطر *T. harzianum* على اختزال نترات الفضة الى جسيمات الفضة النانوية من خلال ظهور طيف الامتصاصية للأشعة فوق البنفسجية والمرئية عند 400-418 nm(الشكل **3**).

ويعزى ظهور طيف الامتصاص اعلاه الى الإنزيم المرتبط مع الفطر والمتمثل بإنزيم اختزال النترات الذي يكون مسؤول تشكيل جسيمات الفضة النانوية.



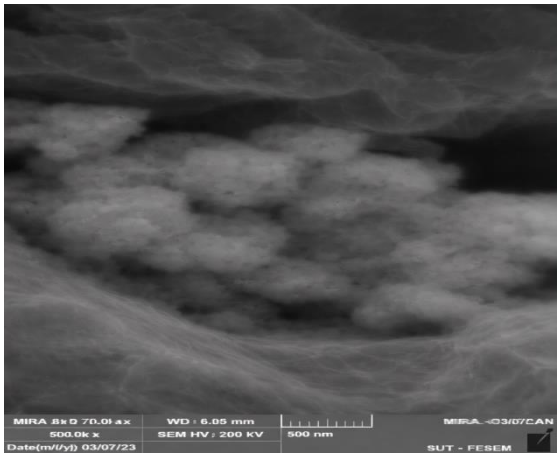
شكل (3) تشكل جسيمات الفضة النانوية AgNPs خلال طيف الامتصاصية للأشعة فوق البنفسجية والمرئية للفطر *T. harzianum*

A = AgNO3
محلول نترات الفضة فقط (Silver nitrate) ، وهو المصدر الأساسي لأيونات الفضة Ag^{+}.
B = Bu
يرمز إلى الراشح الفطري أو المستخلص الحيوي المستخدم في الاختزال (Biological extract / Broth filtrate). اي الوسط الحاوي على المركبات الحيوية المنتجة من الفطر .
C = AgNO3 + Bu today
خليط نترات الفضة مع الراشح الحيوي مباشرة في نفس اليوم بعد الخلط، أي قبل اكتمال التفاعل أو في بدايته .
D = AgNPs تعني Silver Nanoparticles أي جسيمات الفضة النانوية المتكونة بعد انتهاء التفاعل.

1-6-2-3 المجهر الالكتروني الماسح Scanning electron microscopy (SEM)

يبين الشكل (4) لجسيمات الفضة النانوية المحضرة باستخدام الفطر *T. harzianum* توزيع ذرات الفضة التي تكون على شكل حبيبات كروية ان معدل حجم حبيبات الفطر كانت 46.63nm وظهرت الحبيبات متجانسة وغير متلاصقة مما يؤكد تشكل الجسيمات النانوية إن نتائج هذه الدراسة كانت متوافقة مع عدد من الدراسات التي استعمل فيها الفطريات لانتاج الجسيمات النانوية كدراسة (Bhard وجماعته, (2006) الذي أشار إلى إمكانية استخدام الفطر *Verticillium* sp في إنتاج الجسيمات النانوية وأَثبتوا وجودها بأحجام تتراوح بين 20– 80 nm، كما أَثبت الباحثان

Qamandar و Shafeeq (2018) قدرة الفطر *Beauveria bassiana* على إنتاج الجسيمات النانوية وبحجم 23–82 nm



شكل (4) شكل وحجم وتوزيع جسيمات الفضة النانوية (AgNPs) المحضرة حيوياً بوساطة الفطر *T. harzianum* الموضحة باستخدام المجهر الإلكتروني الماسح عند قوة تكبير 70.0 kx

تُظهر النتائج الواردة في الجدول (1) مدى فاعلية تاثير المواد النانوية مع انزيم البروتيز في نسبة هلاك الطور اليرقي. اذ سجل التركيز **25%** اعلى نسبة هلاك اذ بلغت 30 يرقة بعد 24 –48 ساعة من المعاملة , واقل نسبة هلاك كانت عند التركيز **5%** اذ كانت نسبة الهلاك 9 يرقات بعد 24 –48 ساعة من المعاملة توضح النتائج وجود فروق معنوية بين التركيزين من جهة، وبين فترتي التعريض من جهة أخرى. كما أظهرت التراكيز 10%و15% و20% نسب هلاك متفاوتة، إذ سجلت جميعها فروقًا معنوية فيما بينها. ويبين التحليل الإحصائي أن جميع التراكيز تفوقت معنوياً مقارنةً بمعاملة السيطرة، التي لم تسجل أي نسبة هلاك (0%) بعد مرور 48 ساعة. تتفق نتائج الدراسة الحالية مع ما توصل اليها المشهداني 2022 في دراستها للتأثيرات الحيوية لدقائق الفضة النانوية المحضرة والمصنعة باستخدام مستخلص أوراق السبحبح ضد يرقات الذبابة المنزلية اذ وجد أن دقائق الفضة النانوية لديها قدرة عالية على قتل يرقات الذبابة المنزلية . كما تتفق هذه النتائج مع دراسة Zohreh وجماعته,(2020). وجد أن مزيج المستخلص المائي لأوراق نبات السبحبح مع جزيئات الفضة النانوية له قدرة فائقة على قتل يرقات الذباب المنزلي–. كما تتفق هذه النتائج مع دراسة للكلش (2023) وجد أن مزيج المستخلص المائي لنبات الحرمل مع جزيئات الفضة النانوية له قدرة فائقة على قتل يرقات الذباب المنزلي اذا ان نسبة هلاك اليرقات تزداد بنسبة (93.3%) عند تركيز (12.5%) من المستخلص النباتي الحرمل الممزوج مع الفضة النانوية يلاحظ ان الفترة الزمنية لقتل اليرقات تكون اسرع مع تغير في اللون لليرقات من الابيض الى البني.

يُعزى التفوق الملحوظ لجسيمات الفضة النانوية الممزوجة مع مستخلص إنزيم البروتيز إلى التوافق الفعال بينهما نتيجة صغر حجم الجسيمات، مما يبرز تأثيرًا تآزريًا قويًا على الطور اليرقي للحشرات. يعمل إنزيم البروتيز على تحليل البروتينات المكوِّنة للكيوتكل، مما يضعف الطبقة الخارجية ويزيد من نفاذيتها، وبالتالي يسهل اختراق جسيمات الفضة النانوية إلى داخل جسم اليرقة. بعد ذلك، تمارس الفضة النانوية تأثيرها السمي عبر الارتباط بالمكونات الخلوية وتوليد أنواع الأوكسجين التفاعلي(ROS)، ما يؤدي إلى إجهاد تأكسدي شديد داخل الخلايا. كما تسهم في تعطيل الإنزيمات الحيوية وإتلاف البروتينات والأحماض النووية، مما يسرع من تدهور الأنسجة ويعطل العمليات الحيوية مثل التغذية والنمو، ويعيق آليات إزالة السموم والانسلاخ. ونتيجة لذلك، يحدث اختلال كبير في التوازن الفسيولوجي لليرقة وينتهي بموتها بسرعة أعلى مقارنة باستخدام كل عامل بمفرده(Martínez,2024; Madasamy,etal,2023). .

جدول (1) **تأثير تراكيز مختلفة من جسيمات الفضة النانوية و انزيم البروتيز للفطر على مدة الطور اليرقي وعدد اليرقات الميته**

	التركيز					
	Control	5%	10%	15%	20%	25%
الفضة النانوية	0	8	12	20	23	29
انزيم البروتيز	0	7	13	17	20	28
الفضة النانوية+ انزيم البروتيز	0	9	15	20	25	30

1-6-3-2 هلاك الطور العذري للذبابة المنزلية

تُظهر النتائج الواردة في الجدول (2) مدى فاعلية تاثير انزيم البروتيز والمواد النانوية في نسبة هلاك الطور العذري . اذ سجل التركيز **25%** اعلى نسبة قتل اذ بلغت 28 عذراء بعد 24 -48 ساعة عند معاملة بمزيج الفضة النانوية مع انزيم البروتيز , واقل نسبة قتل كانت عند التركيز **5%** اذ كانت نسبة القتل 5 عذروات بعد 24 -48 ساعة من المعاملة بأنزيم البروتيز توضح النتائج وجود فروق معنوية بين التركيزين من جهة، وبين فترتي التعريض من جهة أخرى. كما أظهرت التراكيز 10%و15% و20% نسب قتل متفاوتة اذ سجلت نسب قتل (18.16,12) عذراء على التوالي عند المعاملة مع

انزيم البروتيز الممزوج مع جسيمات الفضة النانوية , في حين كان اقل تاثير على عدد العذارى المقتولة والتاثير على مدى بزوغ العذارى عند استخدام انزيم البروتيز بجميع التراكيز بالمقارنة مع المعاملات الاخرى - إذ سجلت جميعها فروقًا معنوية فيما بينها. ويبين التحليل الإحصائي أن جميع التراكيز تفوقت معنوياً مقارنةً بمعاملة السيطرة، التي لم تسجل أي نسبة هلاك (0%) بعد مرور 48 ساعة. تتفق نتائج الدراسة الحالية مع ما توصل اليها الكلش (2023) سُجِّلت زيادة ملحوظة في نسبة عدم بزوغ العذارى، حيث بلغت 96% عند استخدام المستخلصات النباتية بتركيز 12.5% الممزوجة بالمستخلص نبات الحرمل ، في حين كانت 10% عند المعاملة بالمستخلص نبات الحرمل فقط عند نفس التركيز .

كما تتفق هذه الدراسة مع توصل اليه (الفتلاوي،2021) في دراسته لتقييم فعالية جسيمات الفضة النانوية المخلقة حيويا بإستخدام معلقات بعض أنواع الفطريات في مقاومة بعوض *Culex quinquefasciatus* وجد ان زيادة معدل قتل العذروات الى 73.33% عند استخدام الفضة النانوية المحضرة بصورة حيوية عند التركيز 25 جزء بالمليون بالمقارنة مع نسبة (66.66%) عند استخدام الفضة النقية

إن انخفاض تأثير انزيم البروتيز للفطر على طور العذراء يعزى الى وجود الشرانق والتي تعمل كبيئة كاره للماء فضلا عن الكيوتكل الذي يكون أكثر صلابةً من الطور اليرقي لان بناء الكايتين يصل إلى أعلى مستوى له في مرحلة ما قبل العذراء لذى يحتاج إنزيم البروتيز المفرز من قبل فطر*T.harzianum* مدة زمنية أطول لتحليل الطبقة الدهنية. (Hasanوجماعته,2013).

جدول رقم (2) عدد العذراوات الميتة

	التركيز					
	Control	5%	10%	15%	20%	25%
الفضة النانوية	**0**	**10**	**15**	**18**	**20**	**25**
انزيم البروتيز	**0**	**5**	**14**	**18**	**20**	**23**
الفضة النانوية+انزيم البروتيز	**0**	**12**	**16**	**19**	**22**	**28**

تفوق جسيمات الفضة النانوية المحضرة حيوياً والممزوجة مع الانزيم للفطر في نسبة القتل ربما يعود ذلك إلى ان جسيمات الفضة النانوية ربما تكون عملت ممر لانزيم البروتيز للدخول الى داخل الكبسولة المحيطة بالعذراء والعمل التآزر الذي يحدث بين الانزيم وجسيمات الفضة النانوية ، تولد الفضة النانويةReactive Oxygen Species ROS ، وتؤدي

إلى تلف الخلايا، تعطيل الانقسام الخلوي، وفشل إعادة بناء الأنسجة(Histogenesis) ، مما يسبب اضطراب تكوين الأعضاء وفشل التحول إلى الحشرة الكاملة أو موت العذراء. تتوافق هذه الملاحظات مع نتائج (Liu etal.,2024) التي أظهرت أن الفضة النانوية المنتجة باستخدام فطريات Trichoderma تعزز تلف البنى الخلوية وتعطل الوظائف الأيضية، مما يزيد من كفاءة المكافحة الحيوية.

الاستنتاج:

بينت النتائج تفوق الفعل التازري مابين جسيمات الفضة النانوية وانزيم البروتيز مقارنة مابين فعالية انزيم البروتيز كلا على حدى اذا اعطى اعلى نسبة قتل في الطورين ووجدت علاقة طردية بين زيادة التراكيز ونسبة القتل ، ويعزى هذا التفوق الى الية عمل جسيمات الفضة النانوية التي تعمل كممر لتسهيل مرور انزيم البروتيز الى دخل جسم الحشرة اضافة الى ذلك فعالية الجسيمات النانوية نفسها من خلال توليد الاوكسجين التفاعلي ROS الذي يعمل على اتلاف الخلايا والبروتينات والمادة النووية DNA. بينت الدراسة الحالية فعالية المكافحة الحيوية باستخدام منتجات الايض الثانوي للفطر الممزوجة مع الفضة النانوية في مكافحة الذبابة المنزلية.

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On Novel Conjugate Gradient Method for Solving Minimization Problems

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On Novel Conjugate Gradient Method for Solving Minimization Problems

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Abstract:

The secant condition constitutes a fundamental aspect of deriving the novel coefficient associated with the conjugate gradient method. The formulas proposed herein incorporate a golden ratio value of 0.618; and they demonstrate higher efficiency compared to conventional conjugate gradient methods. Concurrently, a comparative analysis was undertaken between the proposed formulas and the Pollack- Ribière (PR) method, which is broadly regarded as a robust and efficient strategy for addressing the challenges of unconstrained optimization. It delineates the performance metrics of the newly formulated simulated annealing (SA) algorithm as applied to two distinct scenarios (NI and NF), alongside the reference PR algorithm, which serves as a benchmark for performance evaluation. From the examination of these results, it can be inferred that the SA algorithm demonstrates consistent numerical behavior and attains favorable outcomes under specific conditions. However, the **PR** method persists as the most proficient overall and continues to function as a benchmark for performance evaluation.

Keywords: Conjugate gradient method, Novel conjugate gradient, Convergence property.

" دراسة حول طريقة جديدة للتدرج المترافق لحل مسائل التصغير "

المستخلص:

في هذا البحث، تم اشتقاق صيغة جديدة لطرائق التدرج المترافق بالاعتماد على شرط القاطع، الذي يُعد عنصرًا أساسيًا في الاشتقاق. تعتمد الصيغ المُقترحة على النسبة الذهبية (0.618)، وتُظهر كفاءة أعلى مقارنةً بطرائق التدرج المترافق التقليدية. كما أُجريت دراسة مقارنة بين الطريقة المُقترحة وطريقة بولاك–ريبيير (PR)، التي تُعد معيارًا قويًا وموثوقًا في معالجة مسائل الأمثلية غير المُقيدة. ويعرض البحث مؤشرات الأداء الخاصة بخوارزمية التلدين المُحاكى (SA) المُطوّرة حديثًا، كما طُبقت على حالتين مختلفتين (NI وNF)، إضافةً إلى اعتماد خوارزمية PR كخط أساس لتقييم الأداء. تشير النتائج إلى أن خوارزمية SA تُظهر سلوكًا عدديًا مستقرًا وتحقق نتائج جيدة مع شروط مناسبة. وبشكل عام، تظل طريقة PR الأكثر كفاءة وتستمر في العمل كمعيار لتقييم الأداء.

1. Introduction:

One of the primary benefits of the conjugate gradient (CG) approach is its capacity to efficiently solve a wide range of unconstrained optimization problems in a short period of time and with fewer iterations. CG approaches offer reduced processing costs and storage needs since they do not rely on the Hessian matrix or its approximation. Moreover, the CG approach shows quick global convergence and meets the descent criterion. The distinctive feature of this approach is its simplicity, which facilitates the understanding of algebraic operations and computer code creation. Consequently, the method demonstrates competence and potential in solving large-scale unconstrained minimization issues [2]. The following model will be examined in this study:

$$Minf(x) \ , \ \mathrm{x} \in R^n \qquad \ldots\ldots\ldots (1)$$

where f is a smooth function. The iterative formula below is how the technique suggested in [4] generates a sequence:

$$x_{k+1} = x_k + \alpha_k d_k \qquad \ldots\ldots\ldots (2)$$

where α_k is a step length, and $s_k = x_{k+1} - x_k$ and d_k is the search direction defined by:

$$d_{k+1} = -g_{k+1} + \beta_k s_k \qquad \ldots\ldots\ldots (3)$$

where β_k is a coefficient. Currently, the researchers are modifying the present approach in order to enhance its computing efficiency [10]. The conjugate gradient approach differs mostly in the choice of β_k coefficient. In the nonlinear conjugate gradient approach we presented in [9], β_k has the following form:

$$\beta_k^{PR} = \frac{g_{k+1}^T y_k}{g_k^T g_k} \qquad \ldots\ldots\ldots (4)$$

The conjugate gradient method's numerical performance is mostly influenced by the step size. Determine a step size α_k that satisfies the standard Wolfe rule, a well-known line search criterion:

$$f(x_k + \alpha_k d_k) \leq f(x_k) + \delta \alpha_k g_k^T d_k \qquad \ldots\ldots\ldots (5)$$

$$d_k^T g(x_k + \alpha_k d_k) \geq \sigma \, d_k^T g_k \qquad \ldots\ldots\ldots (6)$$

where $0 < \delta < \sigma < 1$, see [11 and 12]. For general non-convex functions, it is interesting to investigate the possibility of a conjugate gradient method that converges under the standard Wolfe line search conditions**.** A useful source for research on the most recent conjugate gradient coefficients with significant results and different variations is [3].

Recently, there has been a noticeable tendency among academics to develop the best and fastest optimization techniques due to the increasing number of real-world applications that rely on optimization techniques [12]. These applications span various fields, including. Several scholars have contributed to the discovery of methods to enhance the speed of solution strategies for these new kinds of CG Algorithms by finding CG Parameters of special significance and applying them in the construction of New CG Algorithms. By demonstrating that their improved approach satisfies the Global Convergence and acceptable Descent Conditions, the validity of a globally convergent acceptable descent PR Method is established.

We introduce a novel modified nonlinear conjugate gradient technique based on conjugacy condition, motivated by formula nonnegative and improved descent property. We also develop global convergence findings for related methodology. Included are the initial numerical findings.

2. Novel parameter conjugate gradient:

One of the most amazing mathematical ratios is the Golden Ratio (0.618), which combines geometric harmony and mathematical elegance. Since ancient times, it has garnered a lot of attention because of its innate harmony and visual attractiveness in nature, art, and architecture. Euclidean geometry, the Fibonacci sequence, ancient art, and contemporary architecture are just a few of the domains in which it has an impact, [10].

To derive the new conjugate formulation, we rely on the improved secant condition proposed by Li and Fukushima [7], as:

$$\bar{G}_{k+1}s_k = (G_{k+1} + \eta I)s_k \cong B_{k+1}s_k = y_k + \eta\, s_k \qquad \ldots\ldots\ldots (7)$$

where G_{k+1} is Hessian matrix, B_{k+1} is an approximation to the Hessian, $y_k = g_{k+1} - g_k$ and $s_k = x_{k+1} - x_k$ and I is identity matrix and $\eta\ is\ constant$. Now, we can present the novel secant condition:

$$B_{k+1}s_k = y_k + 0.618\, s_k \qquad \ldots\ldots\ldots (8)$$

However, from (8), we obtain:

$$y_k^T B_{k+1} s_k = y_k^T y_k + 0.618\, y_k^T s_k \qquad \ldots\ldots\ldots (9)$$

Thus, the Newton direction $d_{k+1} = -B_{k+1}^{-1} g_{k+1}$ may be written as follows:

$$d_{k+1}^N = -\left(\frac{y_k^T s_k}{\|y_k\|^2 + 0.618\, y_k^T s_k}\right) g_{k+1} \qquad \ldots\ldots\ldots (10)$$

These methods aim to accelerate the Newton method's convergence. According to the quasi-Newton direction theory, d_{k+1} in $d_{k+1} = -g_{k+1} + \beta_k s_k$ approximates the quasi-Newton approach. Hence, a β_k parameter that:

$$-B_{k+1}^{-1} g_{k+1} = -g_{k+1} + \beta_k s_k \qquad \ldots\ldots\ldots (11)$$

see Nazareth [8].

$$-\frac{y_k^T s_k}{\|y_k\|^2 + 0.618\, y_k^T s_k} g_{k+1}^T y_k = -g_{k+1}^T y_k + \beta_k s_k^T y_k \qquad \ldots\ldots\ldots (12)$$

Then the result is:

$$\beta_k = \left(1 - \frac{y_k^T s_k}{\|y_k\|^2 + 0.618\, y_k^T s_k}\right) \frac{g_{k+1}^T y_k}{s_k^T y_k} \qquad \ldots\ldots\ldots (13)$$

For the new formula, it is called SA method.

Algorithm SA.

Initialization. Given $x_0 \in R^n$,

set $k = 0$, $d_0 = -g_0$.

Stage 1. Stop if $\|g_k\| \leq \varepsilon$.

Stage 2. Using (5) and (6) to compute α_k.

Stage 3. Utilize (13) to calculate β_k and $x_{k+1} = x_k + \alpha_k d_k$.

Stage 4. Estimate $d_{k+1} = -g_{k+1} + \beta_k d_k$.

Stage 5. Put $k = k + 1$ and go to stage 2.

3. Convergence analysis

To give the convergence result, the following assumptions are given.

Assumptions:

1. Let Ω be the level set at the initial point x_0 :

$$\Omega = \{x \in R^n | f(x) \leq f(x_0)\} \quad \ldots\ldots\ldots (14)$$

is bounded.

2. f is smooth and the same order between its gradient and the variables holds, i.e.,

$$\|g(o) - g(c)\| \leq L\|o - c\|, \forall o, c \in \Omega. \quad \ldots\ldots\ldots (15)$$

See [6].

Examine the theorem to ascertain the potential utility of the descent condition.

Theorem 1.

If condition $s_k^T y_k \neq 0$ is satisfied, the search directions generated by equations (14) and (6) constitute valid descent directions.

Proof:

Since $d_0 = -g_0$, , we take $g_0^T d_0 = -\|g_0\|^2 < 0$. Let $d_k^T g_k \leq 0$ be assumed as true. The product of (6) by g_{k+1}, is:

$$d_{k+1}^T g_{k+1} = -g_{k+1}^T g_{k+1} + \left(1 - \frac{y_k^T s_k}{\|y_k\|^2 + 0.618\, y_k^T s_k}\right) \frac{y_k^T g_{k+1}}{s_k^T y_k} s_k^T g_{k+1} \quad \ldots\ldots\ldots (16)$$

Additionally, by combining equations (8) and (9), we obtain the following relation:

$$y_k^T y_k \cong y_k^T y_k + 0.618\, y_k^T s_k \quad \ldots\ldots\ldots (17)$$

The Lipschitz condition yields: $y_k^T g_{k+1} \leq L s_k^T g_{k+1}$ and $s_k^T y_k \leq L\, s_k^T s_k$. Consequently, we may express:

$$d_{k+1}^T g_{k+1} \leq -\|g_{k+1}\|^2 + \left(\frac{L y_k^T s_k - y_k^T s_k}{y_k^T y_k}\right) \frac{L(s_k^T g_{k+1})^2}{s_k^T y_k} \quad \ldots\ldots\ldots (18)$$

Given that L and $\alpha_k^2$are exceedingly minimal, it is crucial to note that:

$$d_{k+1}^T g_{k+1} \leq 0 \qquad \ldots\ldots\ldots(19)$$

The conclusive proof has been accomplished. Thus, we may use Lemma 1 to show the following conclusion, see [13].

Lemma 1.

If assumptions (1) and (2) hold, consider any conjugate gradient technique as a descent direction and α_k selected by the strong Wolfe line search. Should:

$$\sum_{k=0}^{\infty} \frac{1}{\|d_{k+1}\|^2} = \infty \qquad \ldots\ldots\ldots(20)$$

Then

$$\lim_{k\to\infty} (inf\|g_{k+1}\|) = 0. \qquad \ldots\ldots\ldots(21)$$

We may use the lemma 1 condition to show the following result.

Theorem 2.

If the following conditions are met by a constant $\mu > 0$:

$$(\nabla f(u) - \nabla f(w))^T \geq \mu\|u - w\|^2, \quad \forall u, w \in R^2. \qquad \ldots\ldots\ldots(22)$$

Under the assumptions of Lemma 1, we have:

$$\lim_{k\to\infty} (inf\|g_{k+1}\|) = 0. \qquad \ldots\ldots\ldots(23)$$

Proof:

from (3)and (13) we get:

$$\|d_{k+1}\| = \|g_{k+1}\| + \left|(1-\omega)\frac{g_{k+1}^T y_k}{s_k^T y_k}\right| \|s_k\| \qquad \ldots\ldots\ldots(24)$$

where $\omega = y_k^T s_k / \|y_k\|^2 + 0.618\, y_k^T s_k$. Using Cauchy's inequality makes it leads to:

$$\|d_{k+1}\| \leq \|g_{k+1}\| \qquad \ldots\ldots\ldots(25)$$

$$+|(1-\omega)|\frac{\|g_{k+1}\|\|y_k\|}{\|s_k\|\|y_k\|}\|s_k\|$$
$$\leq (2-\omega)\|g_{k+1}\|$$

Thus, $\|\nabla f(u)\| \leq \Gamma$ implies that:

$$\sum_{k\geq 1}\frac{1}{\|d_k\|^2}\left(\frac{1}{2-\omega}\right)\frac{1}{\Gamma}\sum_{k\geq 1}1 = \infty \qquad \ldots\ldots\ldots(26)$$

by applying Lemma 1, implies that $\lim_{k\to\infty} inf\|g_k\| = 0$.

4. Numerical Results:

The performance of the novel parameter in the CG-method is compared to that of other classical CG-method (Polak-Ribière (PR) algorithm) in this section. For each test problem, we have chosen a few large-scale unconstrained optimization tasks from (Andrie, 2008) [1]. We have taken into consideration numerical experiments with the number of variables $n = 100$, 1000 for each test function.

The polak - Ribière (PR) method, a well-known CG algorithm, was compared to the novel parameter. Standard Wolfe line search criteria with $\delta = 0.001$ and $\sigma = 0.9$ are used to implement each of these methods. The $\|g_{k+1}\| = 10^{-6}$ is the halting criterion in each of these situations.

Every code is developed using the F90 default compiler settings and the double precision FORTRAN language. For the sake of our comparisons, we keep track of the number of restart (IRS), number of iterations (NOI) and number of function evaluation (NIF).

Table 1- Numerical results of SA and HS algorithms

		PR			**SA**		
P.No.	**N**	**NI**	**NR**	**NF**	**NI**	**NR**	**NF**
Trigonometric	100	19	10	35	20	13	37
	1000	39	24	69	35	20	62
Extended Rosenbrock	100	50	19	102	34	18	72
	1000	93	65	143	35	19	81

Extended White & Holst	100	38	16	92	34	18	73
	1000	348	317	403	33	17	71
Extended Beale	100	47	26	74	15	9	29
	1000	38	19	61	15	9	29
Perturbed Quadratic	100	106	40	162	94	23	141
	1000	358	115	561	350	98	553
Extended Tridiagonal 1	100	21	9	42	27	10	55
	1000	45	21	82	29	11	58
Extended PSC1	100	15	10	31	10	7	21
	1000	8	6	17	7	5	15
Extended Maratos	100	94	34	172	68	31	161
	1000	98	36	185	78	40	198
Extended Wood	100	81	37	126	33	14	65
	1000	73	35	111	32	12	62
Extended Hiebert	100	87	34	199	80	50	176
	1000	87	35	196	80	50	173
Extended Quadratic Penalty QP2	100	35	13	74	24	13	56
	1000	51	20	106	34	19	84
ARWHEAD (CUTE)	100	10	5	20	9	5	17
	1000	39	23	642	18	13	153
Partial Perturbed Quadratic	100	85	28	136	80	21	124
	1000	506	264	713	264	51	449
LIARWHD (CUTE)	100	25	13	45	23	13	43
	1000	48	33	74	21	12	47
ENGVAL1 (CUTE)	100	25	10	44	27	11	48
	1000	67	52	1403	44	30	728

DENSCHNA (CUTE)	100	23	13	39	16	9	29
	1000	25	14	43	12	7	23
DENSCHNC (CUTE)	100	17	8	32	17	10	32
	1000	128	66	165	15	10	29
DENSCHNF (CUTE)	100	22	19	37	22	19	38
	1000	23	20	40	20	17	35
Extended Block-Diagonal BD2	100	122	62	156	16	10	29
	1000	130	66	166	15	9	27
SINCOS	100	15	10	31	10	7	21
	1000	8	6	17	7	5	15
Total		**3149**	**1653**	**6846**	**1803**	**765**	**4159**

We display the numerical comparative findings graphically using Dolan and Morse performance profiles [5]. In terms of number of iterations (NI), restart (NR), and function evaluation (NF), Figures 1, 2, and 3, respectively, show that SA performs well when compared to alternative approaches. Tables 1 and Figures 1, 2, and 3 demonstrate that the SA approach outperforms the PR method in terms of numerical performance. In comparison to the other four approaches, the SA is more efficient since it requires fewer iterations (NI), restart (NR), and function evaluation (NF).

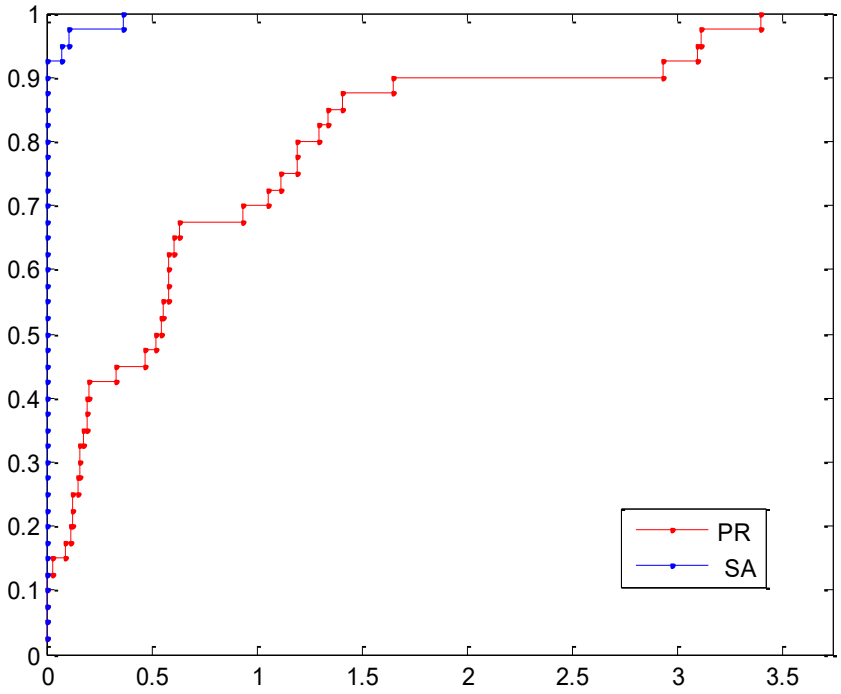

Figure 1 Number of Iteration

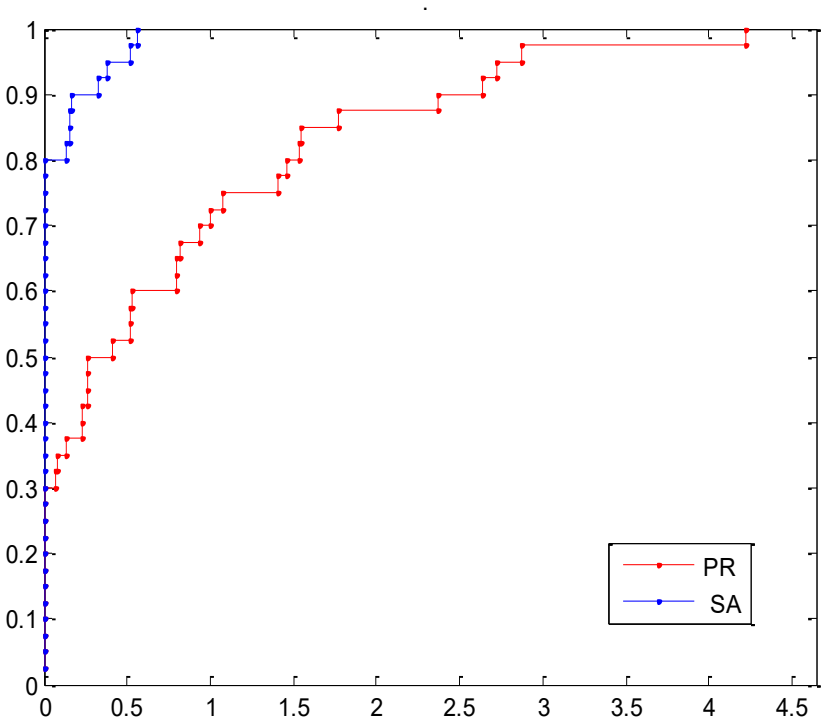

Figure2. Number of Function Evaluation

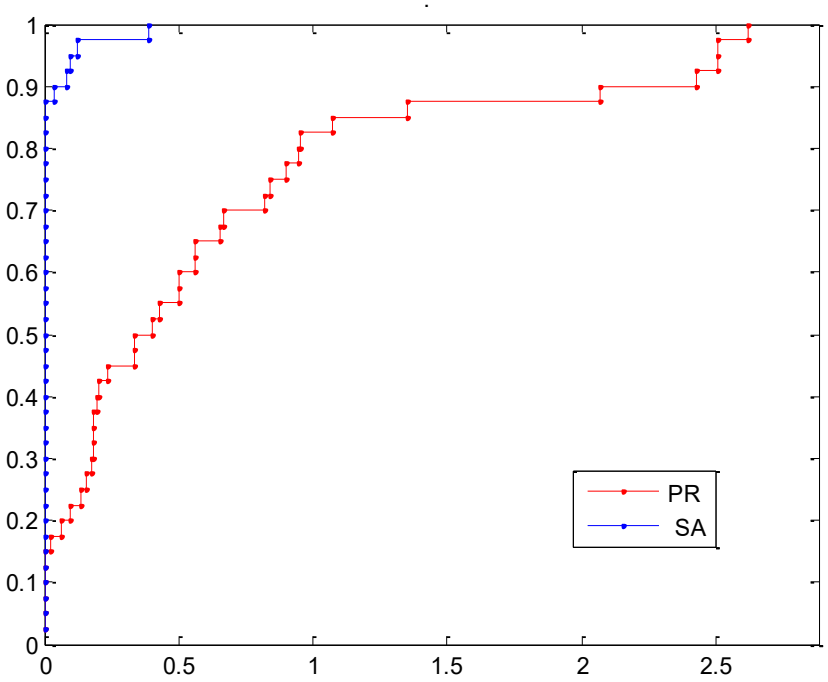

Figure3. Number of restart

5. Findings

This study presents a Secant Algorithm based on the secant condition. The algorithm shows good numerical stability and performs well in specific situations. However, its overall effectiveness is lower than that of traditional conjugate gradient methods. Still, the proposed method remains competitive for certain types of problems. The comparison in this paper only includes traditional conjugate gradient methods. No further improvements or other benchmarks were tested. Therefore, the reported performance is not general but applies only to particular problem cases. The Polak–Ribière method continues to be the most reliable and efficient benchmark for unconstrained optimization problems.

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On invo-t-clean graph over the ring of integers modulo *p*

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On invo-t-clean graph over the ring of integers modulo p

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Abstract:

In this paper, we introduce and study the involution-t-clean Graph $G_{itc}(Z_p)$ defined over the ring of integers modulo p, where p is a prime number. The vertex set of $G_{itc}(Z_p)$ is Z_p, and two distinct vertices x and y are adjacent if and only if $x + y \in itc(Z_p)$, where $itc(Z_p)$ denotes the set of invo-t-clean elements in Z_p. The $G_{itc}(Z_p)$ is connected, and each vertex has a degree of either four or five. Using this characterization, we investigate several fundamental graph-theoretic properties. Our main result determines the exact diameter of $G_{itc}(Z_p)$: $diam\ (G_{itc}(Z_p)) = \left\lfloor \frac{p+2}{4} \right\rfloor$.

Keywords: invo-t-clean ring, diameter, degree, ring of integers modulo p, tripotent.

1. Introduction:

Throughout this paper, we assume that all rings are associative with identity. We focus primarily on the ring of integers modulo p, denoted by Z_p, where p is a prime number. Additionally, we consider the matrix ring $M_2(Z_2)$, the triangular matrix ring $TM_2(Z_2)$, and the set of involution elements $invo(R) = \{u \in R: u^2 = 1\}$, the set of tripotent elements $Tri(R) = \{t \in R: t^3 = t\}$.

The concept of clean ring theory has attracted considerable attention in recent years, see [1], [2] and [3], leading to various generalizations and applications in both algebra and graph theory. It starts with Beck in [4]. Also, several studies take the clean ring see [5], [6] and [7]. Among these generalizations, the notion of involution-t-clean rings, see [8], two-involution clean rings see [9] and [10], weakly 2-invo-clean rings [3]. Recently, Ahmad in [8] introduced and studied the concept of invo-t-clean rings, where an element $a \in R$ is called invo-t-clean if it can be expressed as $a = u + t$, with $u \in invo(R)$ and $t \in Tri(R)$. They investigated various algebraic properties of such rings, particularly focusing on the ring of integers modulo n, matrix rings, and other classical ring constructions. In the same work, the authors also initiated the study of a graph structure associated with invo-t-clean rings. They defined the graph $Cl_t(R)$ whose vertex set consists of ordered

pairs (u, t) where $u \in invo(R)$and $t \in Tri(R)$, with the additional condition that $u + t$ is an invo-t-clean element. Two vertices $h_1 = (u_1, t_1)$ and $h_2 = (u_2, t_2)$ are adjacent if either $u_1 + u_2 = 0$ or $t_1 \cdot t_2 = 0$. This graph provides a combinatorial framework for understanding the interplay between involutions and tripotents in rings.

However, our definition takes a different approach, focusing specifically on invo-t-clean elements themselves. In our construction, the vertex set is precisely the ring R, establishing a natural correspondence between the algebraic structure and its associated graph. Each vertex represents an element of the ring, and an edge connects two distinct vertices x and y precisely when their sum $x + y$ is an invo-t-clean element. This formulation directly captures the additive relationship between ring elements and the invo-t-clean property.

In this paper, we focus on the graph $G_{itc}(Z_p)$ defined over the ring of integers modulo p, where p is a prime number. We prove that these graphs are connected and that the degrees of their vertices range between three and four. Additionally, we determine the exact number of edges. The main result of this paper, which was nontrivial to obtain, is a general formula for computing the diameter of the graph as prime p varies: diam $(G_{itc}(Z_p)) = \left\lfloor \frac{p+2}{4} \right\rfloor$.

2. Properties of the invo-t-clean graph of the Ring.

Definition 2.1: [8]

An element $a \in R$ is called involution t-clean (for short invo-t-clean), which can be written as $a = u + t$, $u \in invo(R)$ and $t \in Tri(R)$. The set of all invo-t-clean elements in the ring R denoted by $itc(R)$. A ring R is called to be invo-t-clean if $itc(R) = R$. An invo-t-clean ring with $ut = tu$ is strongly invo-t-clean.

Examples 2.2:

1. The rings Z_4, Z_5 and Z_6 are invo-t-clean.
2. The ring Z_7 is not invo-t-clean.
3. $M_2(Z_2)$, the upper triangular matrices and $TM_2(Z_3)$ are invo-t-clean rings.

Definition 2.3: [8]

An graph of ring R has an invo-t-clean elements which denoted by $Cl_t(R)$ has a vertex set $\mathcal{V}(Cl_t(R)) = \{(u, t)\colon u \in invo(R), t \in Tri(R)\}$ and has the edge set $\mathcal{F}(Cl_t(R)) = \{h_1h_2 : h_1 = (u_1, t_1), h_2 = (u_2, t_2),\ u_1 + u_2 = 0$ or $t_1 \cdot t_2 = 0, u_i \in \text{invo}(R), t_i \in Tri(R),\ u_i + t_i$ is an invo-t-clean element $i = 1,2\}$.

Example 2.4:

For the ring Z_5, the ring is invo-t-clean, $invo(Z_5) = \{1,4\}, Tri(Z_5) = \{0,1,4\}$,

$\mathcal{V}(Cl_t(Z_5)) = \{[1,0], [1,1], [1,4], [4,0], [4,1], [4,4]\}$

$\mathcal{F}(Cl_t(Z_5)) = \{([1,0], [1,0]), ([1,0], [4,0]), ([1,1], [1,1]), ([1,1], [4,4]), ([1,4], [1,4]),$

$([1,4], [4,1]), ([4,0], [1,0]), ([4,0], [4,0]), ([4,1], [1,4]), ([4,1], [4,1]), ([4,4], [1,1]), ([4,4], [4,4])\}$

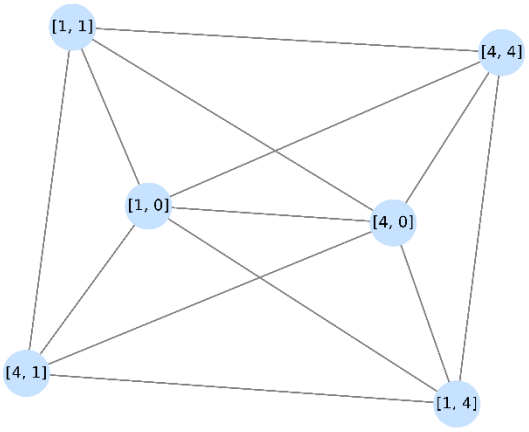

Figure 1: The Graph $Cl_t(Z_5)$

We now introduce the basic definition of the graph on rings, which constitutes the foundation of this paper.

Definition 2.5:

Let R be a ring. The invo-t-clean graph of R, denoted by $G_{itc}(R)$, is a graph with vertex set $V(G_{itc}(R)) = R$, and two distinct vertices x and y in $V(G_{itc}(R))$ are adjacent if and only if $x + y \in itc(R)$.

We will focus our study on graphs defined over a single class of rings, namely fields. Specifically, we consider Z_p where p is a prime number, as illustrated in Examples 2.5, 2.6, and 2.7.

Example 2.5:

In the ring Z_5, $itc(Z_5) = Z_5$, Figure 2 illustrates the graph $G_{itc}(Z_5)$. In our representation, vertices having degree four are highlighted with a red border, whereas vertices corresponding to invo-t-clean elements are filled in orange.

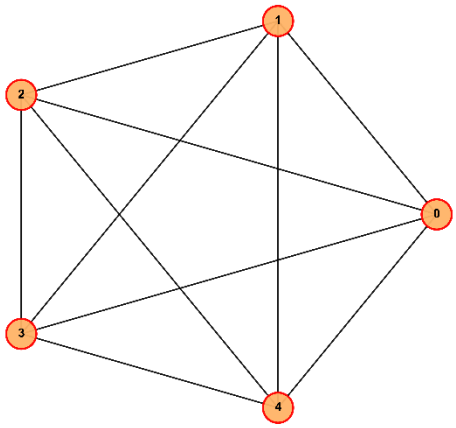

Figure 2: The Graph $G_{itc}(Z_5)$.

The fundamental contrast between the definition presented [8] and our current definition lies in the resulting graph structure. While the former relies on a fixed structure that renders graphs identical for all prime numbers (yet differs when n is the product of two primes), the representation in our current

study varies according to the prime number in question. This is clearly illustrated in examples (2.5, 2.6, 2.7), where distinct prime values produced structurally non-identical graphs. Accordingly, this study focuses on investigating and identifying the common structural characteristics that unify these diverse graphs, in contrast to the approach adopted in the study [8].

Example 2.6:

In the ring Z_7, $itc(Z_7) = \{0,1,2,5,6\}$. Figure 3 illustrates the graph $G_{itc}(Z_7)$. In our representation, vertices having degree five are highlighted with a normal border, whereas vertices corresponding to non-invo-t-clean elements are filled in blue.

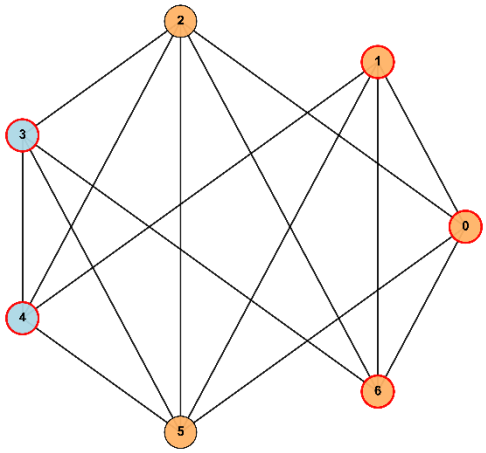

Figure 3: The Graph $G_{itc}(Z_7)$.

Example 2.7:

In the ring Z_{13}, $itc(Z_{13}) = \{0,1,2,10,11\}$. See Figure 4.

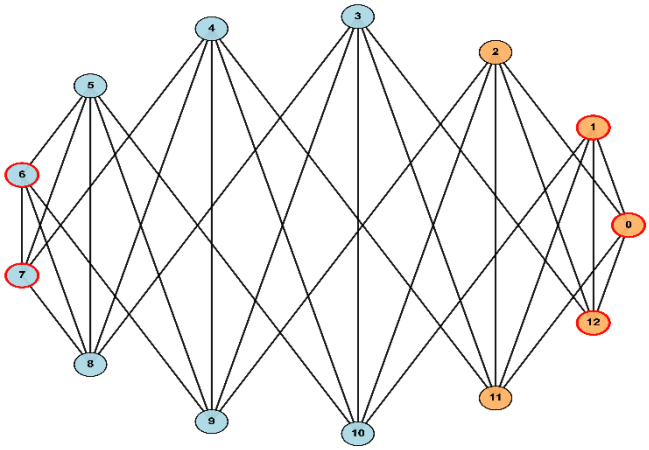

Figure 4: The Graph $G_{itc}(Z_{11})$.

Proposition 2.8

The ring Z_p where $p \geq 5$ is prime, the ring has

1. $invo(Z_p) = \{1, p-1\}$

2. $Tri(Z_p) = \{0,1,p-1\}$
3. $itc(Z_p) = \{0,1,2,p-2,p-1\}$

Proof:

1. Determining $invo(Z_p)$, by definition: $invo(Z_p) = \{u \in Z_p \mid u^2 = 1\}$, in the field Z_p, the equation $u^2 = 1$ has exactly two solutions: $u = 1$ and $u = -1$, Since $-1 \equiv p-1$, we have: $invo(Z_p) = \{1, p-1\}$.
2. Determining $Tri(Z_p)$, by definition: $Tri(Z_p) = \{t \in Z_p \mid t^3 = t,$ This equation can be rewritten as: $t^3 - t = t(t^2-1) = 0$, since Z_p is a field, we have: $t = 0$ or $t^2 = 1$, from part (1), $t^2 = 1$ gives $t = 1$ or $t = -1 \equiv p-1$. Therefore: $Tri(Z_p) = \{0,1,p-1\}$.
3. By definition: $itc(Z_p) = \{u + t \mid u \in invo(Z_p),\ t \in Tri(Z_p)\}$, we compute all possible sums:

u	t	$u+t$
1	0	1
1	1	2
1	$p-1$	$1+(p-1) = p \equiv 0$
$p-1$	0	$p-1$
$p-1$	1	$p \equiv 0$
$p-1$	$p-1$	$(p-1)+(p-1) = 2p-2 \equiv -2 \equiv p-2$

Collecting distinct elements modulo p: $itc(Z_p) = \{0,1,2,p-2,p-1\}$.■

Theorem 2.9:

For prime $p \geq 5$, the degree of the vertex v in $G_{itc}(Z_p)$ is: $\deg(v) = \begin{Bmatrix} 4 & if\ 2v \in itc(Z_p) \\ 5 & if\ 2v \notin itc(Z_p) \end{Bmatrix}$

Proof:

Let $v, w \in V(G_{itc}(Z_p))$, the vertex v is adjacent to the vertex w if $v + w \equiv g \in itc(Z_p)$, since $itc(Z_p) = \{0,1,2,p-2,p-1\}$, that is, the maximal number of adjacent vertices to v not exceed 5. Now for each $g \in itc(Z_p)$, there exists exactly one w such that $w \equiv g - v$, since the graph has no loops, we must exclude $w = v$: which implies that $v \equiv g - v$, $2v \equiv g$. If $2v \in itc(Z_p)$, one of neighbourhood of v it will v itself, so $\deg(v) = 4$. If $2v \notin itc(Z_p)$, $\deg(v) = 5$.■

Theorem 2.10:

$G_{itc}(Z_p)$ have exactly 5 vertices with degree 4 are: $\left\{0,1,\frac{p-1}{2},\frac{p+1}{2},p-1\right\}$, for prime $p \geq 5$.

Proof:

From Theorem 2.9, the vertex $v \in V(G_{itc}(Z_p))$ has degree 4 if $2v \in itc(Z_p)$, since $itc(Z_p) = \{0,1,2,p-2,p-1\}$, we solve the $2v \equiv g$ for each $g \in itc(Z_p)$, since $2 \in Z_p$ and Z_p is field so 2^{-1} is exists, $2.2^{-1} = 2.\frac{p+1}{2} = p+1 = 1$.

For $0 \in itc(Z_p)$, $2v \equiv 0$, $2^{-1} \cdot 2v \equiv 2^{-1} \cdot 0$, $v = 0$.

For $1 \in itc(Z_p)$, $2v \equiv 1$, $2^{-1} \cdot 2v \equiv 2^{-1} \cdot 1, v = 2^{-1} \equiv \frac{p+1}{2}$.

For $2 \in itc(Z_p)$, $2v \equiv 2$, $2^{-1} \cdot 2v \equiv 2^{-1} \cdot 2$, $v = 1$.

For $p-2 \in itc(Z_p)$, $2v \equiv p-2$, $2^{-1} \cdot 2v \equiv 2^{-1} \cdot (p-2) = 2^{-1} \cdot (2p-2), v = p-1$.

For $p-1 \in itc(Z_p)$, $2v \equiv p-1$, $2^{-1} \cdot 2v \equiv 2^{-1} \cdot (p-1), v = \frac{p-1}{2}$.

The vertices have exactly degree five is $\left\{0,1,\frac{p-1}{2},\frac{p+1}{2},p-1\right\}$.■

Theorem 2.11:

The number of edges of $G_{itc}(Z_p)$ is $\frac{5(p-1)}{2}$, for prime $p \geq 5$.

Proof:

From Theorem 2.9, the degree of a vertex v in $G_{itc}(Z_p)$ is: $\deg(v) = \begin{cases} 4 & if\ 2v \in itc(Z_p) \\ 5 & if\ 2v \notin itc(Z_p) \end{cases}$, $\left|E(G_{itc}(Z_p))\right| = \frac{1}{2}\left(\sum_{2v \in itc(Z_p)} \deg(v) + \sum_{2v \notin itc(Z_p)} \deg(v)\right)$, By Theorem 2.2, exactly 5 vertices have degree 4, $\left|V(G_{itc}(Z_p))\right| = p$, so the remaining degree 5 is $p-5$.

$\left|E(G_{itc}(Z_p))\right| = \frac{1}{2}(5 \cdot 4 + (p-5) \cdot 5) = \frac{5(p-1)}{2}$.■

Theorem 2.12:

The graph $G_{itc}(Z_p)$ is connected.

Proof

Let $v, w \in V(G_{itc}(Z_p))$, If there are two distinct vertices, we must show that there exists a path between v and w.

Case 1: $v + w \in V(G_{itc}(Z_p))$.

In this case, by the definition of the $G_{itc}(Z_p)$, there exists an edge $e = (v, w)$. Thus, a path of length 1 exists.

Case 2: $v + w \notin V(G_{itc}(Z_p))$.

If the sum is not an invo-t-clean element, we must find an intermediate vertex or vertices make a path between v and w.

1. Consider the vertex $-x$ since $x + -x = 0 \in itc(Z_p)$, there is an edge between x and $-x$.

2. We can construct a path for x to $x-2$ using an intermediate vertex $1-x$.
   - $(x, 1-x)$ is edge, since $x+1-x=1 \in itc(Z_p)$
   - $(1-x, x-2)$ is edge, since $1-x+x-2=-1 \in itc(Z_p)$

   This creates a path of length two: $x \to 1-x \to x-2$, repeat the last two points for $x-2$.

   - $(x-2, 1-(x-2))$ is edge, since $x-2+1-(x-2)=1 \in itc(Z_p)$
   - $(1-(x-2), x-4)$ is edge, since $1-(x-2)+x-4=-1 \in itc(Z_p)$

   This creates a path of length four: $x \to 1-x \to x-2 \to 1-(x-2) \to x-4$

3. Since $\gcd(2,p)=1$ for any odd prime p, the element 2 generates the cyclic group $(Z_p, +)$. Consequently, the sequence $\{x, 1-x, x-2, 1-(x-2), x-4, \dots, x-2k\}$, where k is a positive integer. Eventually contains all elements of Z_p. Thus, for any w, there is a path from v to w. ■

Theorem 2.13:

Let $p>3$ be a prime number, and let $G_{itc}(Z_p)$ be the graph with vertex set Z_p, then the diameter of this graph is given by diam $(G_{itc}(Z_p)) \geq \left\lfloor \frac{p+2}{4} \right\rfloor$.

Proof:

For each $s \in itc(Z_p)$, define the map $T_s: Z_p \to Z_p$ by $T_s(x) = -x+s$. Observe that x and y are adjacent precisely when $y = T_s(x)$ for some $s \in itc(Z_p)$. Thus, every edge corresponds to applying one such reflection map, and any path of length k from x to y corresponds to a composition

$$y = T_{s_k} \circ T_{s_{k-1}} \circ \cdots \circ T_{s_1}(x), s_i \in S.$$

A direct calculation shows: $T_{s_2} \circ T_{s_1}(x) = -(-x+s_1)+s_2 = x+(s_2-s_1)$. Therefore:

- One reflection changes the sign: $x \mapsto -x+s$.
- Two reflections compose a pure translation: $x \mapsto x+d$, where $d = s_2 - s_1$.

  Since each $s_i \in itc(Z_p) = \{0, \pm 1, \pm 2\}$, the translation distance satisfies $|\, d \,| \leq 4$.

Consequently, every two steps in a path produce a translation of magnitude at most 4.

From the above, we deduce:

- After $2k$ steps, we can reach the vertices of the form $x+D$ where $|\, D \,| \leq 4k$.
- After $2k+1$ steps, we can reach the vertices of the form $-x+D$ where $|\, D \,| \leq 4k+2$.

The diameter equals the maximum distance from the vertex 0 to any other vertex: diam $(G_{itc}(Z_p)) = \max_{a \in Z_p} d(0,a)$. In the cyclic group Z_p, the farthest vertex from 0 is $M = \left\lfloor \frac{p}{2} \right\rfloor = \frac{p-1}{2}$. Thus, diam $(G_{itc}(Z_p)) = d(0,M)$.

Lower bound for $d(0,M)$. We determine the minimum path length required to reach M from 0.

Case 1: Even-length paths

Suppose there exists a path of even length $2k$ from 0 to M. Then by the even-length property: $M \leq 4k$. Solving for k: $k \geq \frac{M}{4}$. Since k must be an integer, we have: $k \geq \left\lceil \frac{M}{4} \right\rceil$. Therefore, the path length satisfies: $2k \geq 2\left\lceil \frac{M}{4} \right\rceil$. Substituting $M = \frac{p-1}{2}$: $2\left\lceil \frac{p-1}{8} \right\rceil$.

This gives us a candidate lower bound from even paths.

Case 2: Odd-length paths

Suppose there exists a path of odd length $2k+1$ from 0 to M. Then by the odd-length property: $M \leq 4k+2$. Solving for k: $4k \geq M-2 \Rightarrow k \geq \frac{M-2}{4}$. Since k must be an integer:$k \geq \left\lceil \frac{M-2}{4} \right\rceil$. Therefore, the path length satisfies:$2k+1 \geq 2\left\lceil \frac{M-2}{4} \right\rceil + 1$. Substituting $M = \frac{p-1}{2}$: $2\left\lceil \frac{p-5}{8} \right\rceil + 1$. This gives us a candidate lower bound from odd paths.

The actual distance $d(0, M)$ is the smallest path length that can reach M. This smallest length could be either even or odd, whichever is smaller. Therefore:

$$d(0, M) \geq \min\left\{2\left\lceil \frac{p-1}{8} \right\rceil, 2\left\lceil \frac{p-5}{8} \right\rceil + 1\right\}.$$

We now compute this minimum for all possible residues of p modulo 8. Since p is an odd prime greater than 3, the possible residues are 1, 3, 5, 7 modulo 8.

Let $p = 8\ell + r$ where $r \in \{1,3,5,7\}$.

$p \bmod 8$	Even bound	Odd bound	Minimum
1	2ℓ	$2\ell+1$	2ℓ
3	$2\ell+2$	$2\ell+1$	$2\ell+1$
5	$2\ell+2$	$2\ell+1$	$2\ell+1$
7	$2\ell+2$	$2\ell+3$	$2\ell+2$

Connecting to the desired formula, we now show that these minimum values equal $\left\lfloor \frac{p+2}{4} \right\rfloor$.

Compute $\left\lfloor \frac{p+2}{4} \right\rfloor$ for each case:

For $p = 8\ell + 1$: $\frac{8\ell+3}{4} = 2\ell + \frac{3}{4}$, floor = 2ℓ

For $p = 8\ell + 3$: $\frac{8\ell+5}{4} = 2\ell + \frac{5}{4}$, floor = $2\ell + 1$

For $p = 8\ell + 5$: $\frac{8\ell+7}{4} = 2\ell + \frac{7}{4}$, floor = $2\ell + 1$

For $p = 8\ell + 7$: $\frac{8\ell+9}{4} = 2\ell + \frac{9}{4}$, floor = $2\ell + 2$

These match exactly the minimum values we found.■

Proposition 2.14:

For any two vertices $x, y \in Z_p$:

$$d(x,y) \leq \left\lceil \frac{\min\left(|\, x-y \,|, p-|\, x-y \,|\right)}{2} \right\rceil \leq \left\lceil \frac{\lfloor p/2 \rfloor}{2} \right\rceil.$$

Proof:

From any vertex v, we can progress at most 2 units toward any target direction in a single step. From vertex $v \in V\left(G_{itc}(Z_p)\right)$, its neighbors are:

$$N(v) = \{-v,\ -v+1,\ -v-1,\ -v+2,\ -v-2\}$$

The fundamental move is $v \mapsto -v + k$ where $k \in \{0, \pm 1, \pm 2\}$.

In two consecutive steps: $v \overset{\text{step 1}}{\rightarrow} -v + k_1 \overset{\text{step 2}}{\rightarrow} -(-v + k_1) + k_2 = v - k_1 + k_2$

The net progress after two steps is: Progress $=|\, k_2 - k_1 \,| \leq |\, k_2 \,| + |\, k_1 \,| \leq 2 + 2 = 4$

Therefore, in two steps, the maximum progress is 4 units. Consequently, in m steps, the maximum progress is: Max Progress $\leq 2m$ units. Thus, in a single step, the maximum progress is 2 units.

The circular distance between x and y is: $\delta = \min\left(|\, x-y \,|, p-|\, x-y \,|\right)$, this represents the shortest distance around the cyclic group Z_p. Since each step covers at most 2 units of progress. Therefore, the number of steps required satisfies:

$$d(x,y) \leq \left\lceil \frac{\delta}{2} \right\rceil = \left\lceil \frac{\min\left(|\, x-y \,|, p-|\, x-y \,|\right)}{2} \right\rceil$$

Since $\delta \leq \lfloor p/2 \rfloor$ (the maximum circular distance), we have:

$d(x,y) \leq \left\lceil \frac{\lfloor p/2 \rfloor}{2} \right\rceil$, thus, $d(x,y) \leq \left\lceil \frac{\lfloor p/2 \rfloor}{2} \right\rceil$. ■

Proposition 2.15:

Let $p > 3$ be a prime number, then $\left\lceil \frac{\lfloor p/2 \rfloor}{2} \right\rceil = \left\lfloor \frac{p+2}{4} \right\rfloor$.

Proof:

We consider the possible residues of p modulo 4. Since p is an odd prime greater than or equal to 5, we have $p \equiv 1(\mathrm{mod}4)$ or $p \equiv 3(\mathrm{mod}4)$.

Case 1: $p \equiv 1(\mathrm{mod}4)$ (i.e., $p = 4k+1$)

$\lfloor p/2 \rfloor = \lfloor (4k+1)/2 \rfloor = 2k$

$\left\lceil \frac{2k}{2} \right\rceil = \lceil k \rceil = k$

$\left\lfloor \frac{p+2}{4} \right\rfloor = \left\lfloor \frac{4k+3}{4} \right\rfloor = \left\lfloor k + \frac{3}{4} \right\rfloor = k$

Thus, both sides equal k.

Case 2: $p \equiv 3(\mathrm{mod}4)$ (i.e., $p = 4k+3$)

$\lfloor p/2 \rfloor = \lfloor (4k+3)/2 \rfloor = 2k+1$

$\left\lceil \frac{2k+1}{2} \right\rceil = \left\lceil k+\frac{1}{2} \right\rceil = k+1$

$\left\lfloor \frac{p+2}{4} \right\rfloor = \left\lfloor \frac{4k+5}{4} \right\rfloor = \left\lfloor k+\frac{5}{4} \right\rfloor = k+1$

Thus, both sides equal $k+1$.

Case 3: $p \equiv 0 (\mathrm{mod} 4)$ — impossible for primes $p \geq 5$

Case 4: $p \equiv 2 (\mathrm{mod} 4)$ — impossible for primes $p \geq 5$ except $p = 2$

Therefore, for all primes $p > 3$: $\left\lceil \frac{\lfloor p/2 \rfloor}{2} \right\rceil = \left\lfloor \frac{p+2}{4} \right\rfloor$.■

Theorem 2.16:

Let $p > 3$ be a prime number, and let $G_{itc}(Z_p)$ be the graph with vertex set Z_p, then the diameter of this graph is given by $\mathrm{diam}\,(G_{itc}(Z_p)) \leq \left\lfloor \frac{p+2}{4} \right\rfloor$. ■

Proof:

By definition, the diameter is: $\mathrm{diam}\,(G) = \max_{x,y \in V} d(x,y)$

From Proposition 2.14, for any $x, y \in V$: $d(x,y) \leq \left\lceil \frac{\lfloor p/2 \rfloor}{2} \right\rceil$, therefore: $\mathrm{diam}\,(G) = \max_{x,y \in V} d(x,y) \leq \left\lceil \frac{\lfloor p/2 \rfloor}{2} \right\rceil$

From Proposition 2.15: $\left\lceil \frac{\lfloor \frac{p}{2} \rfloor}{2} \right\rceil = \left\lfloor \frac{p+2}{4} \right\rfloor$. $\mathrm{diam}\left(G_{itc}(Z_p)\right) \leq \left\lfloor \frac{p+2}{4} \right\rfloor$. ■

Corollary 2.17:

Let $p > 3$ be a prime number, and let $G_{itc}(Z_p)$ be the graph with vertex set Z_p, then the diameter of this graph is given by $\mathrm{diam}\left(G_{itc}(Z_p)\right) = \left\lfloor \frac{p+2}{4} \right\rfloor$. ■

Example 2.18:

Find the lower bound diameter for the graph $G_{itc}(Z_{23})$ using Theorem 2.13.

- $p = 23$
- $itc(Z_{23}) = \{0,1,2,-1,-2\} = \{0,1,2,22,21\}$ in Z_{11}
- Farthest vertex from 0: $M = \frac{p-1}{2} = \frac{22}{2} = 11$

Define reflections $T_s(x) = -x + s$ for each $s \in itc(Z_{11})$. Adjacency: $x \sim y \iff y = T_s(x)$ for some $s \in itc(Z_{23})$.

$T_{s_2} \circ T_{s_1}(x) = x + (s_2 - s_1)$

- $T_2 \circ T_{-2}(x) = x + (2 - (-2)) = x + 4$
- $T_1 \circ T_{-1}(x) = x + (1 - (-1)) = x + 2$
- $T_0 \circ T_1(x) = x + (0 - 1) = x - 1$

Even and Odd Length Paths

- After $2k$ steps: can reach D with $| D | \leq 4k$

- After $2k+1$ steps: can reach D with $|D| \leq 4k+2$

Reduction to Distance from 0: Due to vertex-transitivity, the diameter equals $d(0,M) = d(0,11)$.

Lower Bound for $d(0,11)$

Even case ($2k$ steps): $11 \leq 4k \Rightarrow k \geq \frac{11}{4} = 2.75 \Rightarrow k \geq 3 \Rightarrow 2k \geq 6$

Odd case ($2k+1$ steps): $11 \leq 4k+2 \Rightarrow 4k \geq 9 \Rightarrow k \geq \frac{9}{4} = 2.25 \Rightarrow k \geq 3 \Rightarrow 2k+1 \geq 7$

The minimum of these lower bounds is $\min(6,7) = 6$.

Compute $\left\lfloor \frac{p+2}{4} \right\rfloor = \left\lfloor \frac{23+2}{4} \right\rfloor = \left\lfloor \frac{25}{4} \right\rfloor = 6$. Thus $d(0,11) \geq 6$.

Path: $0 \to 21 \to 4 \to 17 \to 8 \to 13 \to 11$

Check each edge:

1. $0 + 21 = 21 \in itc(Z_{23})$
2. $21 + 4 = 25 \equiv 2 \in itc(Z_{23})$
3. $4 + 17 = 21 \in itc(Z_{23})$
4. $17 + 8 = 25 \equiv 2 \in itc(Z_{23})$
5. $8 + 13 = 21 \in itc(Z_{23})$
6. $13 + 11 = 24 \equiv 1 \in itc(Z_{23})$

Path length = 6 steps.

$\text{diam}\,(G_{itc}(Z_{23})) \geq 6$

Find the upper bound diameter of the graph $G_{itc}(Z_{23})$ using Proposition 2.13 and Theorem 2.16.

$d(0,11) \leq \left\lceil \frac{\delta}{2} \right\rceil = \left\lceil \frac{\min\{|0-11|, 23-|0-11|\}}{2} \right\rceil = \left\lceil \frac{\min(11,12)}{2} \right\rceil = 6$, also $\text{diam}\big(G_{itc}(Z_{23})\big) \leq \left\lceil \frac{\left\lfloor \frac{23}{2} \right\rfloor}{2} \right\rceil = \left\lceil \frac{12}{2} \right\rceil = 6$,

$\text{diam}\,(G_{itc}(Z_{23})) \leq 6$. Therefore $\text{diam}\big(G_{itc}(Z_{23})\big) = 6$.

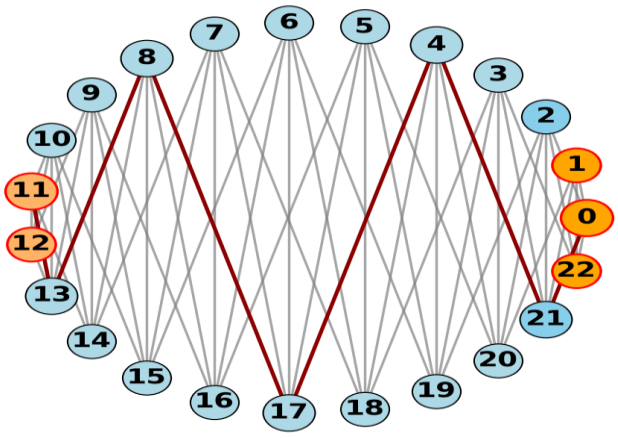

Figure 5: The Graph $G_{itc}(Z_{23})$.

Conclusions:

This study examines the structure of a graph defined on the basis of invo-t-clean elements within rings of integers modulo a prime number. The paper challenge inherent in this new definition, compared to previous definitions that yielded fixed graphs, lies in the fact that the graphs in our study exhibit notable structural variation as the prime number changes. Nevertheless, we successfully identified the fundamental properties common to these graphs. We proved that all resulting graphs are connected and uniquely contain exactly five vertices of degree four, corresponding precisely to the number of invo-t-clean elements in the ring and the other of degree five. Furthermore, we were able to determine the graph's diameter, a task that proved challenging due to its direct and variable dependence on the value of the prime number

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There is no data in this paper.

Conflicts of Interest

The authors called for a lack of conflicts of interest to publish this paper.

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Nanomaterials and Their Role in Asphalt Technology as an Improved Material: A Review

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Abstract:

The use of nanomaterials has transformed asphalt technology in terms of its capacity to improve the physical and mechanical properties of the asphalt mixtures. Their combination enhances thermal stability, optimizes viscosity, and resistance to moisture damage, all of which can be used to increase the pavement life and reduce the maintenance needs. The present research provides a detailed literature review of different nanomaterials such as carbon-based nanostructures, metallic nanoparticles, polymeric nanomaterials, and hybrid composites, in terms of their effects on the performance of asphalt. The research discusses emerging applications of nanotechnology in asphalt engineering like energy production, self-healing, and provision of clean energy. It underlines the need of the changes in the production processes, the establishment of the stringent quality control conditions, and the manner in which the current issues in the industry are addressed. Despite the high cost of the initial investment in nanomaterials, economic and environmental analysis shows that the benefits are immense in the long run particularly in terms of increased durability, reduced emissions, and higher recyclability. The biggest challenges are still high cost of production and inappropriate regulatory frameworks. This is why future studies should aim at creating cost-effective production techniques, performing thorough ecological evaluation.

Keywords: Asphalt, Nanomaterials, Nanotechnology, Carbon Nanotubes, Environmental Challenges.

1. Introduction :

Asphalt has become the most common material in the world in the construction and repair of transportation infrastructure due to its cost-efficiency and dependability. This is a smooth surface, and it can be utilized in the long term and with a moderate cost, so it is the best choice in highways, bridges, airports, and parking lots. However, the performance of asphalt is highly reliant on the material composition of the asphalt and asphalt is highly susceptible to environmental degradation [1]. The surface layer of asphalt is the one which is the most subject to damage as far as the joint of factors includes cracking, rutting, and oxidation aging and leads to the declination of the mechanical qualities. These effects are aggravated by the exposure to extreme temperatures, heavy loads in the traffic and environmental pollutants. Therefore, the need to develop new approaches, that will assist in extending the service life of the asphalt pavements and minimizing premature corrosion [2, 3].

The latest advancements in the field of nanotechnology enabled scholars to address the problem of asphalt performance by incorporating nanomaterials in asphalt mixtures. Such nanomaterials possess unique physical, chemical and mechanical attributes at the nanoscale that provides a platform to improve asphalt performance immensely. Some of these nanomaterials are carbon nanotubes, metal nanoparticles and polymeric nanostructures, which offer attractive qualities to the asphalt blend, such as high strength, elasticity, thermal and moisture stability, and relative enhancement in durability. Nanotechnology can be utilized to increase the life of the asphalt pavements and their strength against environmental and mechanical forces by controlling the structure of the material at a molecular level [4-6].

The study shall endeavor to argue out the application of nanomaterials as asphalt performance enhancers through a critical review in this field. It is a careful analysis of the various types of nanomaterials that are incorporated into asphalt mixtures and explains the performance improvement mechanisms as well as their technical application. The review focuses on the fundamental features of the interaction of asphalt and nanomaterials such as the improvement of mechanical properties, thermal aging, environmental and their role in improving the sustainability. The research also raises some serious problems in this regard, such as the high cost of production, capacity to generate a homogenous dispersion in the mixture and the ecological impact that might be experienced when nanomaterials are used. Recent advances in nanotechnology regarding asphalt modification are also talked about, and potential opportunities in pavement engineering. The practical application of nanomaterial-enhanced asphalt is also addressed and the need to conduct additional research, particularly in different conditions of traffic and during different types of climatic conditions. This review is a contribution to the development of high-performance sustainable asphalt mixtures that will meet the demands of the modern transportation infrastructure due to the collection and analysis of the findings of the available research.

1.1.Types of Nanomaterials Used in Asphalt

Nanomaterials have become one of the most promising objects of interest in the study of asphalt technology due to its high potential in extending the life of pavement and improving the overall performance. The benefits may be credited to the aberrant properties of materials in the nano-scale that has contributed immensely to enhancement of physical, chemical and mechanical qualities of asphalt. This section will also shed more light on the most commonly employed nanomaterials employed to modify asphalt, with primary emphasis on how each of them has been applied to improve various performance properties of asphalt [7].

Carbon-Based Nanomaterials

Carbon nanomaterials such as carbon nanoparticles and carbon nanotubes (CNTs) are considered one of the most widely-used asphalt additives. These materials have been of high mechanical properties and high tensile strength, flexibility and excellent wear and thermal degradation. In the study, it has been found that in cases where such materials are incorporated to asphalt mixtures, they perform well in improving resistance of pavement to majority of the common types of damages appertaining to drying like cracking, rutting and moisture damage. Among their advantages, a higher mechanical strength and stiffness, a higher thermal stability and high-temperature behavior, and a higher resistance to oxidative aging and surface erosion may be mentioned [8].

Metallic Nanomaterials

Metal oxide nanomaterials such as zinc oxide (ZnO) and titanium dioxide (TiO_2) have been demonstrated to have a new dawn as far as the addition of cosmetic properties to asphalt is concerned [9]. They are antimicrobial in nature, they resist moisture and acid rain as well and this is one of the qualities that contribute to increasing the life span of asphalt in severe environmental conditions. Their key advantages are that they are less susceptible to acid rain and environmental pollutants, improved UV protection to lessen material degradation, and improved moisture resistance therefore limiting devastation by water run-offs to the asphalt structure [10].

Polymer Nanomaterials

It has been studied that polymeric nanomaterials such as urea nanoparticles and phenolic resin nanoparticles enhance the elasticity of asphalt. The additives enable the asphalt to be employed over a high climatic environment because of the resistance that is introduced to thermal cracking. The most remarkable benefits of these materials are greater flexibility and durability, greater resistance to cracking caused by the changes in temperature, and the greater dynamic performance of the asphalt at the extreme temperatures changes [11].

Hybrid Nanomaterials

An integrated system of enhancing asphalt properties is in the form of hybrid nanomaterials which are a mixture of several nanomaterials such as carbon, metal and polymer. Due to the combination of the good properties of these different materials in one composite structure, hybrid nanomaterials contribute significantly to the strengthening of the asphalt against many environmental stressors. Among the key benefits, one may note the increased mechanical strength and flexibility, the increased wear and tear resistance, the enhanced performance in the extreme temperatures and the reduced water absorption. Besides, this multi-functional enhancement contributes to more sustainability and extended service life of asphalt pavement layers as shown in table 1 [12].

Table 1: Types of Nanomaterials and Their Effects on Asphalt

Type	Nanomaterial	Main Effects on Asphalt	Applications
Carbon-Based Nanomaterials	Carbon nanoparticles, Carbon nanotubes (CNTs)	- Improve mechanical strength - Enhance thermal stability - Increase wear resistance	Strengthen asphalt, enhance flexibility, improve rutting resistance
Metallic Nanomaterials	Zinc oxide (ZnO), Titanium dioxide (TiO_2)	- Improve resistance to acid rain - UV resistance - Enhance moisture resistance	Protect asphalt from environmental degradation, enhance UV resistance
Polymeric Nanomaterials	Nano-polymers (e.g., nano-urea, nano-phenolic)	- Increase flexibility - Improve thermal cracking resistance - Enhance dynamic properties	Improve asphalt performance at high and low temperatures, reduce cracking
Hybrid Nanomaterials	Combination of carbon, metallic, and polymeric nanomaterials	- Enhance mechanical properties - Improve thermal and moisture resistance - Boost sustainability	Improve overall asphalt performance, increase lifespan, and resistance to environmental factors

Table 2 has provided a comparative analysis of the effects of different classes of nanomaterials on the fundamental properties of asphalt like mechanical strength, elastic properties and environmental resistance.

Table 2: Comparison of Nanomaterials on Asphalt Properties

Property	Carbon Nanomaterials	Metallic Nanomaterials	Polymeric Nanomaterials	Hybrid Nanomaterials
Mechanical Strength	Significant improvement	Moderate enhancement	Moderate enhancement	Significant improvement
Flexibility	Increased flexibility	No significant effect	Significant improvement	Significant improvement
Thermal Stability	Enhanced resistance	Moderate resistance	Enhanced resistance	Excellent resistance
Moisture Resistance	Moderate enhancement	Significant improvement	Moderate resistance	Excellent resistance
Durability & Longevity	Improved durability	Improved durability	Improved durability	Exceptional durability

The two tables discuss the most important types of nanomaterials used to modify asphalt, and how they affect various asphalt characters to produce high performance. The availability of these tables makes it easier to examine the different impacts that the nanomaterials exert on the asphalt technology effectively to provide a clear and holistic view of the functional benefits that they provide [13].

1.2. Impact of Nanomaterials on Mechanical Properties of Asphalt

This capacity to accommodate traffic load and variable climatic conditions is essential because of asphalt mechanical properties such as strength, stiffness and elasticity. The introduction of nanomaterials that enhance resistance to cracking and rutting, fatigue and aging-resistance can further increase these properties. It is also due to the alterations in the molecule structure of the asphalt binder that increases the strength of the bond between the particles resulting in high performance of the mechanical properties [14].

Strength and Stiffness

- The strength and life cycle of the asphalt material can be significantly enhanced by addition of nanomaterials in particular carbon nanotubes (CNTs) and metal nanoparticles. The asphalt nanomaterials are incorporated as reinforcement materials within the asphalt matrix, which increases molecular bonding and increases the resistance of the substance to deformation under the loads exerted. Such nanomaterials ensure that pavement layers are prepared that are of better mechanical strength and hence increased durability and resistance to traffic and environmental induced stress [15].
- Studies have shown that carbon nanotubes can as well be employed in enhancing the strength of asphalt that can give higher modulus of elasticity and greater rutting resistance. They also remain largely stable even at high temperatures which diminish the possibilities of thermal cracking [16].

  It is proven that nanoparticles of zinc oxide (ZnO) and titanium dioxide (TiO_2) are useful in increasing the strength of asphalt, thereby increasing its capacity to handle heavy traffic loads and other adverse environmental conditions [17].

Flexibility and Elasticity

Although the rigidity is a key characteristic of asphalt pavement layers, elasticity is essential in the adjustment of the response of the pavement to changes in temperature. The use of polymeric nanomaterials, especially polymer-based nanoparticles, promotes the cracking resistance of asphalt over a broad temperature spectrum, as polymer material becomes able to expand without breaking. Very hot or very cold areas are also where flexible asphalt pavements prove essential since such pavements can prevent cracks, which is one of the most influential factors that influence the life of pavements [18]. Thus, polymeric nanomaterials like urea nanoparticle, phenolic resin nanoparticle can enhance asphalt flexibility to enable the material to revert to its original form upon deformation, thereby increasing the service life of the pavement layers [19].

Durability and Resistance to Aging

Nanomaterials greatly increase the performance of asphalt in terms of durability, resistance to aging, moisture degradation and oxidation. Specifically, nanoparticles of carbon and metal nanomaterials reinforce the asphalt binder due to lower creation of holes and cracks in the asphalt over time. Subsequently, such enhancements help in increasing the service life of the pavement and lowering the maintenance needs as indicated in Table 3 [20].

- It has been scientifically demonstrated that the carbon nanoparticles are an effective solution in reducing the rate of oxidation in asphalt thereby increasing its resistance to environmental degradation [21].
- Zinc oxide (ZnO) and titanium dioxide (TiO_2) are metal-based nanoparticles that provide both UV radiation protection and moisture resistance [22] and thus help increase the strength of pavement layers.

Table 3: Impact of Nanomaterials on Mechanical Properties of Asphalt

Property	Carbon Nanotubes (CNTs)	Polymeric Nanoparticles	Metallic Nanoparticles (ZnO, TiO_2)	Hybrid Nanomaterials
Strength (Compressive)	Significant improvement	Moderate enhancement	Significant improvement	Exceptional improvement
Stiffness (Elastic Modulus)	Enhanced stiffness and modulus	Moderate increase	Increased stiffness and resistance	High stiffness and resistance
Flexibility	Moderate improvement	Significant improvement	Moderate improvement	Excellent flexibility
Elasticity	Improved elasticity	Significant increase in elasticity	Moderate elasticity enhancement	Excellent elasticity
Durability	Increased durability	Moderate enhancement	Improved UV and moisture resistance	Outstanding durability

1.3. Impact of Nanomaterials on Physical Properties of Asphalt

Nanomaterials have been significantly instrumental in enhancing the characteristics of asphalt such as viscosity, thermal stability and resistance to moisture. These enhancements help in the production of asphalt which is more resilient, needs less maintenance and is able to endure extreme weather conditions [23].

Effect of Nanomaterials on Viscosity and Flow Behavior

Asphalt performance is mainly regulated by its viscosity because it influences its workability during mixing and also its longevity when subjected to long-term traffic stress. The nanomaterials also alter the internal structure of the asphalt binder leading to alterations in the viscosity as indicated in table 4 [24].

Table 4: Influence of Nanomaterials on Asphalt Viscosity

Nanomaterial	Effect on Viscosity	Benefit
Carbon Nanotubes (CNTs)	Increases viscosity at high temperatures	Enhances rutting resistance
Graphene	Improves binder stiffness	Improves high-temperature performance
Polymeric Nanomaterials	Increases binder viscosity	Prevents excessive fluidity in warm climates
Hybrid Nanomaterials	Enhances both stiffness and flexibility	Balances viscosity for improved performance

Effect of Nanomaterials on Thermal Stability and Temperature Resistance

Thermal stability is the most important in asphalt in hot weather (asphalt resistance to deformation) and in cold weather (cracking).Nanomaterials enhance asphalt's ability to withstand temperature extremes, from low to high, as shown in table 5 [25].

Table 5: Impact of Nanomaterials on Thermal Stability

Nanomaterial	Effect on Thermal Stability	Benefit
Titanium Dioxide (TiO_2)	Enhances thermal resistance	Prevents softening under high temperatures
Zinc Oxide (ZnO)	Increases resistance to heat aging	Reduces long-term thermal degradation
Graphene	Enhances heat distribution	Prevents localized overheating
Carbon Nanotubes (CNTs)	Provides high thermal conductivity	Reduces temperature-induced cracking

Effect of Nanomaterials on Moisture Resistance and Water Sensitivity

Moisture penetration weakens asphalt by reducing its strength and causing damage. Nanomaterials help reduce water sensitivity and enhance the hydrophobic properties of the binder, as illustrated in table 6 [26].

Table 6: Influence of Nanomaterials on Moisture Resistance

Nanomaterial	Effect on Moisture Resistance	Benefit
Zinc Oxide (ZnO)	Provides excellent hydrophobic properties	Reduces water infiltration and stripping
Titanium Dioxide (TiO_2)	Enhances water resistance	Prevents moisture-induced degradation
Carbon Nanotubes (CNTs)	Improves binder structure to resist water penetration	Reduces cracks caused by water exposure
Hybrid Nanomaterials	Combines hydrophobic and structural enhancement	Maximizes resistance to moisture damage

Effect of Nanomaterials on Asphalt Density and Workability

Workability and density are essential factors for achieving proper asphalt compaction and long-lasting strength. Nanomaterials modify the interaction between the binder and aggregates, leading to changes in these properties, as shown in table 7 [27].

Table 7: Effect of Nanomaterials on Asphalt Density and Workability

Nanomaterial	Effect on Density	Effect on Workability
Carbon Nanotubes (CNTs)	Slight increase in density	Improves stability under heavy loads
Polymeric Nanomaterials	Decreases density slightly	Enhances flexibility during application
Metallic Nanoparticles	Increases compactness	Reduces segregation of asphalt mixtures
Hybrid Nanomaterials	Optimizes density for balanced performance	Improves compaction and durability

Summary of Nanomaterial Effects on Physical Properties

Nanomaterials influence asphalt properties in various ways, as summarized in the table below [28].

Table 8: Summary of Physical Property Enhancements by Nanomaterials

Physical Property	Carbon Nanotubes (CNTs)	Polymeric Nanomaterials	Metallic Nanoparticles	Hybrid Nanomaterials
Viscosity	Increases at high temperatures	Moderate increase	Moderate enhancement	Balanced viscosity
Thermal Stability	High thermal conductivity	Moderate enhancement	Excellent heat resistance	Superior stability
Moisture Resistance	Improves water resistance	Moderate improvement	Excellent hydrophobicity	Exceptional performance
Density	Slightly increased	Slightly decreased	Increased compactness	Optimized balance
Workability	Improved mix stability	Enhances flexibility	Reduces aggregate segregation	Enhances compaction

Technological Applications of Nanomaterials in Asphalt

Nanomaterials incorporated into asphalt technology enhance performance, durability, and longevity of roads. Their applications focus on improving the mechanical, thermal, and environmental properties of asphalt pavements [29].

Improved Road Performance

Nanomaterials reinforce asphalt, increasing its resistance to rutting, cracking, and fatigue. Carbon nanotubes (CNTs) and graphene boost structural strength, lowering maintenance requirements and prolonging pavement life. Polymeric nanomaterials enhance flexibility, enabling roads to better endure temperature changes [30].

Sustainable and Eco-Friendly Asphalt

Nanotechnology helps in sustainable environmental protection by reducing carbon footprint of asphalt. TiO_2 and ZnO are used as metallic nanoparticles in self-cleaning and air-cleaning pavements, which decompose pollutants in photocatalytic reactions. Nanomaterials will help enhance recyclability of asphalt and will thereby lower the consumption of new raw materials [31].

Smart and Self-Healing Asphalt

Nanotechnology has provided highly sophisticated nanomaterials that have made it possible to create self-healing asphalt, which has the ability of auto repairing microcracks on its own when heat or electromagnetic waves are used. Indicatively, the nanoparticle of iron oxide is used to enable the process of induction heating that can be used to repair the structural integrity of the asphalt, thereby increasing its service life [32].

Nanotechnology in Noise-Reducing Pavements

Nanomaterials are also being advanced and one of the applications is in self-healing asphalt which can automatically mend microcracks in case of exposure to heat or electromagnetic radiation. Inductive heating technologies are an example of technologies developed using iron oxide nanoparticles that repair the structural integrity of the asphalt [33].

Cold and Warm Mix Asphalt Innovations

Nanomaterials are crucial in the manufacturing of both hot asphalt, and cold asphalt mixtures, which have greatly saved on the amount of energy used in the manufacturing and paving of asphalt. This has been done through reduction in viscosity at low temperatures thus allowing asphalt to remain in use and at the same time reduces emissions and lowers the cost of production. The incorporation of nanomaterials in the engineering of asphalt provides potential opportunities to enhance durability,

contribute to the enhancement of sustainability, and provide the development of smart infrastructure [34].

1.4. Challenges and Limitations of Using Nanomaterials in Asphalt & Economic and Environmental Considerations

Implementation of nanomaterials to enhance the performance of asphalt has several challenges such as technical, economic and environmental issues. This part reviews the sustainability and economic feasibility of nanomaterial-modified asphalt critically [35].

Challenges in Implementing Nanomaterials in Asphalt

There are a lot of challenges in introducing nanomaterials in asphalt construction even with the possible benefits; they are listed in table 9.

Expensive production: One of the obstacles to the long-term use of nanomaterials is their cost which is currently very high to produce nanomaterials including carbon nanotubes (CNTs) and graphene [36]. Problems of dispersion and homogeneity: Nanoparticles tend to have disproportional dispersion in the asphalt binders and thus give inconsistent performance outcomes [37]. Health and safety hazards: Workers dealing with nanoparticles during asphalt processing are at risk of health risk and appropriate safety measures are necessary since recent research has revealed [38]. Adaptation in the technological field: Current asphalt production plants will have to upgrade their equipment and processes to support nanomaterial-enhanced mixes that will be more expensive to run than before [39].

Table 9: Technical Challenges in Using Nanomaterials in Asphalt

Challenge	Impact on Asphalt Industry	Possible Solutions
High material cost	Limits large-scale adoption	Improve synthesis efficiency, explore alternative nanomaterials
Poor dispersion in binder	Causes inconsistent performance	Develop better mixing techniques, use surfactants
Health and environmental concerns	Raises safety risks during handling	Implement protective handling procedures
Adaptation to asphalt plants	Requires new equipment and processes	Retrofit existing infrastructure with minimal modifications

Economic Viability and Cost-Benefit Analysis

Initial Costs and Savings in the long run: The initial cost of nanomaterial-enhanced asphalt might be more expensive since it requires the use of special raw materials and special manufacturing techniques [41], but this is compensated by the cost savings due to the minimized maintenance costs and prolonged pavement life cycle [40]. Research has also established that nanomaterial modified asphalt lasts longer before it requires maintenance, thus, the maintenance cost is cut because it will not require a large number of repairs in the long term [42].

Market Growth Potential: The business expansion opportunities of nanomaterials is on the rise due to the ongoing cost-cutting procedures in the industry research and development that have made the technology affordable and more appealing to the ultimate consumer [43]. Environmental Considerations Nanomaterials are also influenced in their environment sustainability characteristics such as:

Reduced Carbon Footprint: The low-temperature asphalt mixing technologies (warm mix asphalt) lead to decreased energy consumption [44].

Recyclability: Nanomaterials can be used to increase the recyclability of asphalt, which will lessen the consumption of new raw materials [45].

Possible Environmental Hazards: When nanoparticles get out of control, life-cycle environmental toxicity hazard might occur, requiring extensive research to determine their overall effect [46] as shown table 10.

Table 10: Economic and Environmental Impact of Nanomaterials in Asphalt

Factor	Positive Impact	Negative Impact
Cost	Long-term savings from durability	High initial investment costs
Energy Efficiency	Reduces energy needed for production	Requires specialized processing equipment
Recyclability	Enhances reuse of asphalt materials	Potential contamination from nanoparticles
Emissions Reduction	Decreases greenhouse gas emissions in warm mix asphalt	Nanoparticle exposure may have unknown long-term effects

Future Outlook

Widespread implementation requires improved production efficiency, advanced dispersion techniques, and clear government regulations to ensure safe application. Future research should focus on developing cost-effective nanomaterial formulations that enhance both affordability and sustainability [47]. The combined section provides systematic comparisons through tables while examining nanomaterial application in asphalt from technical operational and environmental perspectives.

1.5. Advances in Research and Future Prospects of Nanomaterials in Asphalt

The use of nanomaterials in asphalt technology is continuously evolving, with on-going research focusing on optimizing their effectiveness and overcoming existing challenges. This section highlights recent advancements and future research directions, providing insights into how nanotechnology can further revolutionize asphalt engineering [48].

Recent Advances in Nanomaterial Applications in Asphalt

Research in nanomaterial-enhanced asphalt has expanded in several key areas show as table 11:

- **Improved Dispersion Techniques:** Advanced mixing methods, such as ultrasonic dispersion and chemical functionalization, have improved the uniformity of nanomaterial distribution within asphalt binders.
- **Multi-Functional Nanomaterials:** Hybrid nanomaterials combining polymeric, metallic, and carbon-based nanoparticles have demonstrated superior mechanical, thermal, and environmental properties [49].
- **Smart and Self-Healing Asphalt:** Research on self-healing asphalt using induction heating and magnetic nanoparticles (e.g., iron oxide Fe_3O_4) is gaining momentum, enhancing road durability [50].
- **Eco-Friendly Nanomaterials:** Development of bio-based and recyclable nanomaterials is being explored to reduce environmental concerns [51].
-

Table 11: Key Recent Research Advances in Nanomaterial-Enhanced Asphalt

Research Area	Nanomaterials Used	Key Findings
Improved Dispersion	Functionalized CNTs, Graphene Oxide	Enhanced homogeneity and performance
Hybrid Nanomaterials	Carbon-polymer-metal hybrids	Balanced mechanical and thermal properties

Self-Healing Asphalt	Iron oxide (Fe_3O_4), CNTs	Enables crack healing via induction heating
Eco-Friendly Alternatives	Bio-based nanomaterials	Sustainable and recyclable solutions

Future Prospects and Research Directions

Asphalt nanotechnology research is expected to focus on the following areas in the coming years:

- **Cost Reduction Strategies:** Innovations in large-scale production techniques to make nanomaterials more affordable [52].
- **Integration with AI and Machine Learning:** Predictive modeling powered by AI and machine learning can be used to optimize the nanomaterial content in asphalt mixtures, ensuring enhanced performance, cost-efficiency, and reduced environmental impact [53].
- **Advanced Self-Healing Systems:** Investigating innovative responsive nanomaterials to enhance self-repair capabilities in asphalt, leading to longer service life and reduced maintenance needs [54].
- **Enhanced Environmental Sustainability:** Exploring the use of biodegradable nanomaterials and assessing their long-term ecological impacts to promote greener asphalt technologies [55].

1.6. Expected Industrial Applications and Commercialization

Nanomaterial-enhanced asphalt is anticipated to experience greater commercial adoption, as indicated in table 12 [56, 57]:

1. Growing demand for durable infrastructure.
2. Government initiatives promoting sustainable road construction.
3. Advancements in large-scale nanomaterial production lowering costs.
4.

Table 12: Future Industrial and Research Prospects for Nanomaterials in Asphalt

Future Focus	Potential Impact	Implementation Timeline
Large-Scale Manufacturing	Reduces costs, enables mass adoption	5-10 years
AI-Driven Material Optimization	Enhances performance prediction, efficiency	3-7 years
Smart Self-Healing Roads	Reduces maintenance, increases lifespan	7-15 years
Sustainable Asphalt Development	Minimizes environmental footprint	5-10 years

1.7. Implementation Strategies and Standardization of Nanomaterials in Asphalt

The effective integration of nanomaterials into asphalt requires clearly defined implementation strategies and standardized protocols. Despite technological advancements, progress has been hindered by the lack of uniform operating procedures and regulatory frameworks. For nanomaterials to be widely adopted in asphalt engineering, standardization is essential-this section outlines the key strategies necessary for successful implementation [58].

Implementation Strategies for Nanomaterial-Enhanced Asphalt

The use of nanomaterials in asphalt production requires the implementation of clear and specific protocols to ensure optimal performance. Key procedures include:

Better mixing and dispersion technologies: Advanced mixing and dispersion technologies such as ultrasonic dispersion, shear mixing, and chemical activation can be used to obtain uniform distribution of nanomaterials throughout the asphalt binder, thereby increasing consistency in performance [59].

Tailor-made asphalt mixes: The manufacturers prepare tailor-made asphalt mixes that fit the demands in various climatic regions, heavy traffic, and various environmental factors [60].
Pilot projects and field tests: They are essential to prove the outcomes of the laboratory experiments through testing asphalt on a large-scale project and evaluating its performance in real-life conditions [61].
Fitting into the plants which are already in use: One cannot integrate nanomaterials into the current manufacturing plants without modifying equipment and process to maintain the efficiency of the current existing plant infrastructure [62].

Standardization Challenges and Regulatory Requirements

Standardized tests and regulatory systems are the key areas that cannot allow massive use of nanomaterials as asphalt technology. To be widely accepted, there are several key components that must be addressed among them being:
-Material safety regulations: Detailed safety regulations should also be developed which can be applied to establish the clear procedures of working with nanomaterials and hence minimise the risks to both the human health and the environment [63].
-Performance certification procedures: Standardized testing procedures have to be used to accurately identify the durability, flexibility and resistance of nanomaterials modified asphalt so that the performance certification can be issued reliably [64].
-Quality control procedures: Tough quality control systems are necessary to ensure that the production of the asphalt mixtures are maintained similarly to ensure that the consistency of the performance that can be relied on and reproduced is achieved [65].

Roadmap for Large-Scale Adoption

In order to commercially adopt the nanomaterials within the asphalt applications successfully, several strategic measures, including the following, must be considered:
Industry-academia cooperation: The industry-academia cooperation must be enhanced in order to accelerate the uptake of the sustainable asphalt construction technologies based on nanomaterials, help implement the nanomaterials into the asphalt production and use into practice [66].
Government support and incentives: Government support and incentive schemes may be needed to stimulate the uptake of the sustainable asphalt construction technologies based on nanomaterials [67].
Professional training and awareness programs: Engineers, contractors and policymakers Engineers, contractors and policymakers must receive certain professional training and awareness programs to ensure the safe, effective and informed in use of the nanomaterials asphalt production and use [68].
Industrial Integration, Economic Impact, and Sustainability of Nanomaterials in Asphalt: The successful implementation of nanomaterials in asphalt necessitates the development of effective strategies that support industrial-scale expansion and cost-efficiency, while ensuring environmental sustainability. The effect of nanotechnology on asphalt production process is discussed in this paragraph, and the economic aspect of the involved sustainability issues are evaluated [69].

1.8. Industrial Integration of Nanomaterials in Asphalt

The transition from laboratory-scale research products to large-scale production faces numerous challenges related to manufacturing, quality control, and process optimization [70].

Key Factors for Industrial Adoption

- Adaptation of Asphalt Production Plants: Conventional asphalt production facilities require specific modifications to effectively incorporate nanomaterials into the manufacturing process [71].
- Standardization and Quality Control: The implementation of standardized protocols and rigorous quality control systems is essential to ensure consistent performance outcomes in construction projects utilizing nanomaterial-enhanced asphalt.
- Compatibility with Existing Materials: For practical application, nanomaterials must demonstrate compatibility and consistent performance with the asphalt materials currently employed in industry practices [72].

1.9. Economic Feasibility and Cost-Benefit Analysis

Nanomaterial-enhanced asphalt production leads to substantial long-term financial returns because it improves both infrastructure maintenance duration and extends overall pavement life.

Cost Considerations

High Initial Investment: CNTs along with graphene as nanomaterials maintain significantly higher costs than regular asphalt modifier components at project start [73].

Long-Term Maintenance Savings: Enhanced durability leads to fewer road repairs, reducing overall lifecycle costs.

Market Growth and Scalability: Increased industrial demand is expected to lower costs through economies of scale [74].

Comparative Cost Analysis

Nanomaterial-Modified Asphalt: Higher upfront cost but requires fewer repairs over time [75].

Traditional Asphalt: Lower initial cost but deteriorates faster, leading to higher long-term maintenance expenses [76].

Environmental Sustainability and Long-Term Impact: Nanotechnology in asphalt contributes to sustainable infrastructure by reducing resource consumption, improving recyclability, and minimizing pollution [77].

Eco-Friendly Nanomaterials in Asphalt

Titanium Dioxide (TiO_2): Helps in air purification by breaking down pollutants through photocatalysis.

Recyclable Nanocomposites: Enhance the reuse of asphalt materials, reducing dependence on new raw materials.

Lower Carbon Emissions: Nanomaterials improve the efficiency of **warm-mix asphalt**, cutting down on energy consumption during production show as table 13 [77].

Table 13: Environmental Benefits of Nanomaterials in Asphalt

Sustainability Factor	Nanomaterials Used	Impact on the Environment
Air Pollution Reduction	Titanium Dioxide (TiO_2)	Breaks down NOx and reduces urban smog
Recycling Efficiency	Carbon-based nanomaterials	Increases asphalt recyclability
Lower CO_2 Emissions	Warm-mix compatible nanomaterials	Reduces energy consumption in production

Future Sustainability Considerations

Addressing Potential Ecotoxicity: More research is needed on nanoparticle leaching into soil and water systems [78].

Lifecycle Assessments: Studies should assess the long-term environmental impacts of asphalt enhanced with nanomaterials [79].

Green Alternatives: The development of bio-based nanomaterials has the potential to further improve sustainability [80].

2. Conclusion:

Nanomaterials play a significant role in asphalt engineering for road construction by enhancing durability, mechanical performance, and environmental sustainability. This review examines various nanomaterials and their effects on asphalt properties, along with the technical challenges encountered during their application. Among the nanomaterials studied, carbon nanotubes (CNTs), metallic nanoparticles such as ZnO and TiO_2, and polymeric nanocomposites have demonstrated effectiveness in improving asphalt's viscosity, thermal stability, self-healing capacity, and resistance to moisture. The structural modifications in the material lead to longer pavement lifespan, reduced maintenance costs, and more environmentally sustainable infrastructure. Smart asphalt technologies-integrating self-healing pavements with energy-harvesting roads and pollution-reducing surfaces-are

now advancing the development of intelligent transportation systems focused on sustainable performance. Despite the many benefits achieved, several challenges remain. These include high production costs, difficulties in evenly dispersing nanomaterials, regulatory hurdles, and uncertain environmental impacts, all of which limit the widespread commercialization of nanomaterial-enhanced asphalt. To achieve industrial success of nanotechnology-enabled asphalt solutions manufacturers need affordable production systems and unified testing standards along with better methods to disperse nanomaterials so they perform consistently. Given that nanomaterial-enhanced asphalt depends on material cost reduction and market demand growth for profitability the field requires continued research and development investments.

Sustainability is a key driver for using nanotechnology in asphalt. Certain nanomaterials help reduce carbon emissions, enhance asphalt recyclability, and increase road durability, contributing to global green infrastructure goals. Long-term studies on the environmental impact of nanoparticles are essential to prevent material degradation and chemical release. The future success of asphalt nanotechnology depends on collaboration among researchers, industry, and policymakers to translate lab results into practical use. Future research should focus on affordable nanomaterials, improving self-healing techniques, and applying AI for asphalt performance modeling.

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Comparative Evaluation of Cystatin C and Conventional Renal Markers for Early Detection of Renal Dysfunction in Type 2 Diabetes Mellitus (T2DM).

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Comparative Evaluation of Cystatin C and Conventional Renal Markers for Early Detection of Renal Dysfunction in Type 2 Diabetes Mellitus (T2DM).

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Abstract:

Background:

Early detection of renal functional changes in type 2 diabetes mellitus (T2DM) is essential to prevent progression to chronic kidney disease. Conventional renal biomarkers such as serum creatinine and urea often fail to detect early impairment because they typically rise only after substantial loss of renal function. This study evaluated whether serum cystatin C provides greater sensitivity for identifying early renal functional changes in T2DM.

Methods:

A comparative cross-sectional study was conducted involving 30 patients with T2DM and 30 healthy controls aged 30-70 years with comparable sex distribution. Serum levels of random blood

sugar (RBS), glycated haemoglobin (HbA1c), urea, creatinine, and cystatin C were measured. Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation. Statistical analyses were performed using SPSS version 25.

Results:

The T2DM group showed significantly higher levels of RBS (220.10 ± 92.9 mg/dL), HbA1c (8.68 ± 1.7%), urea (24.23 ± 13.4 mg/dL), and cystatin C (1.25 ± 0.6 mg/L) compared with controls ($p = 0.001$ for RBS, HbA1c, and cystatin C; $p = 0.01$ for urea). Serum creatinine and eGFR did not differ significantly between groups. Receiver operating characteristic analysis demonstrated superior discrimination for cystatin C (AUC = 0.78) compared with urea (AUC = 0.63) and creatinine (AUC = 0.55).

Conclusion:

Serum cystatin C demonstrated greater sensitivity than conventional renal markers for detecting early renal functional changes in T2DM and may complement routine renal assessment.

Keywords: Cystatin C, Diabetes Mellitus, Renal Impairment, Biomarker, Kidney Dysfunction.

1. Introduction :

Type 2 diabetes mellitus (T2DM) is one of the most common chronic metabolic disorders worldwide, characterized by insulin resistance, impaired insulin secretion, and sustained hyperglycemia. During the last decades, T2DM has demonstrated an astonishing increase in its incidence globally due to lifestyle changes, sedentary activities, and obesity. According to the IDF Diabetes Atlas of 2021, approximately 537 million adults worldwide currently have diabetes, a number predicted to increase significantly by 2045, reaching approximately 780 million [1]. Among the complications of diabetes, diabetic kidney disease remains a leading cause of Chronic Kidney Disease (CKD) and End-Stage Renal Disease (ESRD) worldwide [2].

The kidneys are important for maintaining physiological balance through filtration, reabsorption, and excretion. Over time, chronic hyperglycemia leads to metabolic and hemodynamic alterations that cause progressive injury to renal structures. Early signs include increased glomerular filtration, basement

membrane thickening, and mesangial expansion, which may progress to glomerulosclerosis and nephron loss [3, 4]. Microalbuminuria is widely regarded as an early clinical indicator of diabetic kidney involvement; however, functional renal changes may precede detectable urinary abnormalities, highlighting the need for sensitive serum biomarkers [5].

Traditionally, renal function is assessed by measuring serum urea and creatinine and estimating the glomerular filtration rate (GFR). However, although these methods have been widely used clinically, they still have notable limitations. The most commonly used biomarker, serum creatinine, is influenced by factors such as muscle mass, age, sex, dietary habits, and hydration status, and typically does not increase until nearly half of renal function has been compromised [6]. Also, serum urea levels are affected not only by kidney function but also by a range of non-renal factors, including dietary protein intake, liver health, and metabolic states involving increased catabolism. Because of these influences, its diagnostic specificity is somewhat limited. While eGFR formula estimates tend to improve diagnostic accuracy, they still heavily depend on serum creatinine and may fail to detect early renal dysfunction in diabetic and elderly individuals [7, 8].

In contrast, cystatin C levels are more consistent across populations and less confounded by these factors, thereby offering superior reliability for detecting early renal dysfunction [9, 10]. This biomarker is superior in several studies and meta-analyses for early detection of CKD and for predicting cardiovascular and all-cause mortality in diabetic patients [11, 12].

Early detection of renal functional alterations in patients with diabetes allows timely implementation of renoprotective strategies, including optimized glycemic and blood pressure control, and the use of angiotensin-converting enzyme (ACE) inhibitors or angiotensin II receptor blockers (ARBs) to prevent or delay the onset of ESRD and its cardiovascular complications [13, 14]. The use of cystatin C, which responds more rapidly to changes in GFR than creatinine, can provide clinicians with a faster and more accurate tool for assessing renal function. Such advances offer promising improvements in patient outcomes in the management of diabetic nephropathy [9, 15].

Despite its recognized advantages, data on the application of cystatin C within local diabetic populations, especially in developing healthcare systems where CKD is often underdiagnosed, remain limited. The evaluation of cystatin C along with traditional renal markers could enhance early detection

and improve clinical decision-making in resource-poor settings. Therefore, this study aims to assess the diagnostic performance of serum cystatin C as an early marker of renal dysfunction in T2DM patients and compare its diagnostic utility with that of traditional renal function markers, such as serum creatinine, urea, and eGFR. This study reports the sensitivity and specificity of cystatin C, providing evidence to support recommending its inclusion in routine follow-up for diabetic patients.

2. Methodology

2.1 Study Design and Population

This study was a comparative cross-sectional study involving two groups: a diabetic group of T2DM patients diagnosed who do not exercise regularly, and a normal/sedentary control group of 30 healthy individuals who do not engage in any regular physical activity. Diabetic patients were selected based on a clinical diagnosis of T2DM, as approved by the patient's physician. The control subjects were healthy, non-diabetic individuals with normal random blood glucose levels and no metabolic complications. The two groups were selected to achieve a comparable sex distribution; however, age differed between groups and was therefore included as a covariate in adjusted analyses. Participants were recruited from a nearby hospital, and the study was approved by the institutional ethics review board.

2.2 Inclusion Criteria

For this study, the samples and data that were analysed were collected from the Al-Karama hospital, and the analysed data were divided into two groups:

- Diabetic group: Patients with T2DM, aged 30-70 years.
- Control group: the healthy group's ages range from 30 to 70 years.

2.3 Exclusion Criteria

- Participants with any history of chronic kidney disease, liver disease, or other major systemic illnesses.
- The Age Group of pregnant women and young people aged 30 years or less.

2.4 Biochemical Analysis:

The following biochemical markers were measured for both the diabetes and healthy groups.

1. Random Blood Sugar (RBS): venous blood samples were obtained from each subject. RBS was tested on the standard enzymatic colorimetric method (LINEAR CHEMICS). The values were given in terms of mg/dL.
2. Glycated Haemoglobin (HbA1c): Serum HbA1c was measured by HPLC and analysed according to previously developed laboratory protocols [16]. The outcomes were expressed as percentages for reporting purposes [17].
3. Urea: Serum urea levels were estimated by the enzymatic colorimetric method of the reagents from Linear Chemicals. Urea concentration was reported in milligrams per decilitre.
4. Creatinine: S.K. creatinine levels were determined by the Kinetic colorimetric method, and the reagents used were from (LINEAR CHEMICALS). The results were reported as mg/dL.
5. Cystatin C: Cystatin C protein concentration was quantified using a specific human cystatin C ELISA kit (lab119589). The results were calculated based on mg/L.

2.5 Demographic and Clinical Information:

The Age of each participant was documented at enrolment. The gender composition in both groups was documented.

2.6 Statistical Analysis

Data were evaluated utilizing SPSS version 25 (IBM, USA). Descriptive statistics, encompassing mean and standard deviation (SD Mean), were computed for all variables. The disparities between diabetes and control cohorts were assessed utilizing independent t-tests for continuous variables (RBS, HbA1c, Urea, Creatinine, Cystatin C, and Age). Multivariable linear regression analyses were performed for renal biomarkers with adjustment for age and sex. A *p*-value below 0.05 was deemed statistically significant for evaluating gender distribution between the two groups; the chi-square test was used.

3. Results

The results of the study comparing various biochemical markers were analysed in 30 diabetic patients compared to the control group as follows:

3.1 Random Blood Sugar (RBS)

Individuals diagnosed with diabetes showed significantly higher RBS levels compared to the control group (see Table 1). The differences between the two groups were statistically significant, reinforcing the importance of RBS as a key indicator for diabetes.

Table 1: Comparison of Random Blood Sugar (RBS) Levels between Diabetic Patients and Control Subjects

Group	RBS (mg/dL) ± (SD)	*p*-value
Diabetic Patients	220.10 ± 92.9	0.001
Control Subjects	93.07 ± 11.9	

3.2 Glycated Haemoglobin (HbA1c)

The HbA1c levels were markedly higher in the diabetes group than in the control group (Table 2). A *p*-value of <0.001 signifies a highly significant disparity between the groups, corroborating inadequate glycemic control in the diabetes cohort.

Table 2: Comparison of Glycated Haemoglobin (HbA1c) Levels between Diabetic Patients and Control Subjects

Group	HbA1c ± (SD)	*p*-value
Diabetic Patients	8.68 ± 1.7	0.001
Control Subjects	5.02 ± 0.4	

3.3 Urea

As shown in Table 3, urea levels were significantly higher in the diabetic group than in control subjects. The *p*-value of 0.01 suggests that diabetes may be associated with renal stress or dysfunction, as urea is a marker for kidney function.

Table 3: Comparison of Urea Levels between Diabetic Patients and Control Subjects

Group	Urea (mg/dL) ± (SD)	*p*-value
Diabetic Patients	24.23 ± 13.4	0.01
Control Subjects	16.10 ± 5.6	

3.4 Creatinine

There was no significant difference in serum creatinine levels between the diabetic groups (Table 4). This indicates that creatinine may not be a sensitive marker for detecting renal dysfunction in the early stages of diabetes.

Table 4: Comparison of Creatinine Levels between Diabetic Patients and Control Subjects

Group	Creatinine (mg/dL) ± (SD)	*p*-value
Diabetic Patients	0.822 ± 0.2	0.086
Control Subjects	0.731 ± 0.1	

3.5 Cystatin C

Serum cystatin C levels were significantly higher in the diabetes group than in the control group. Serum cystatin C levels increase as an indicator of glomerular filtration rate and serve as a more sensitive marker of early reduced kidney function in patients with diabetes (Table 5).

Table 5: Comparison of Cystatin C Levels between Diabetic Patients and Control Subjects

Group	Cystatin C (mg/L) ± (SD)	*p*-value
Diabetic Patients	1.25 ± 0.6	0.001
Control Subjects	0.65 ± 0.1	

After adjustment for age and sex, serum cystatin C remained significantly higher in diabetic patients compared with controls (adjusted $p < 0.05$), whereas creatinine remained non-significant.

3.6 Age

The mean age of diabetic patients (46.77 ± 16.2 years) was significantly higher than that of control subjects (38.30 ± 12.5 years), as shown in Table 6 ($p = 0.046$). This statistically significant age difference suggests that age may have contributed to the observed differences in biochemical markers

between the two groups. Therefore, age should be considered a potential confounding factor when interpreting the study's findings.

Table 6: Comparison of Mean Age between Diabetic Patients and Control Subjects:

Group	Age (years) ± (SD)	*p*-value
Diabetic Patients	46.77 ± 16.2	0.046
Control Subjects	38.30 ± 12.5	

3.7 eGFR

There was no significant difference in GFR between the diabetic and control groups. This indicates that GFR may not be a sensitive marker for detecting renal dysfunction in the early stages of diabetes (Table 7).

Table 7: Comparison of GFR Mean Between Diabetic Patients and Control Subjects

Group	eGFR ± (SD)	*p*-value
Diabetic Patients	107.73 ± 12.3	0.21
Control Subjects	111.57 ± 15.3	

3.8 Gender

There were no differences between males and females in either group (p=1.000), and biochemical markers in this study showed that gender had no effect.

Table 8: Gender Distribution in Diabetic and Control Groups

Group	Male (%)	Female (%)	*p*-value
Diabetic Patients	47.2	52.8	1.000
Control Subjects	46.7	53.3	

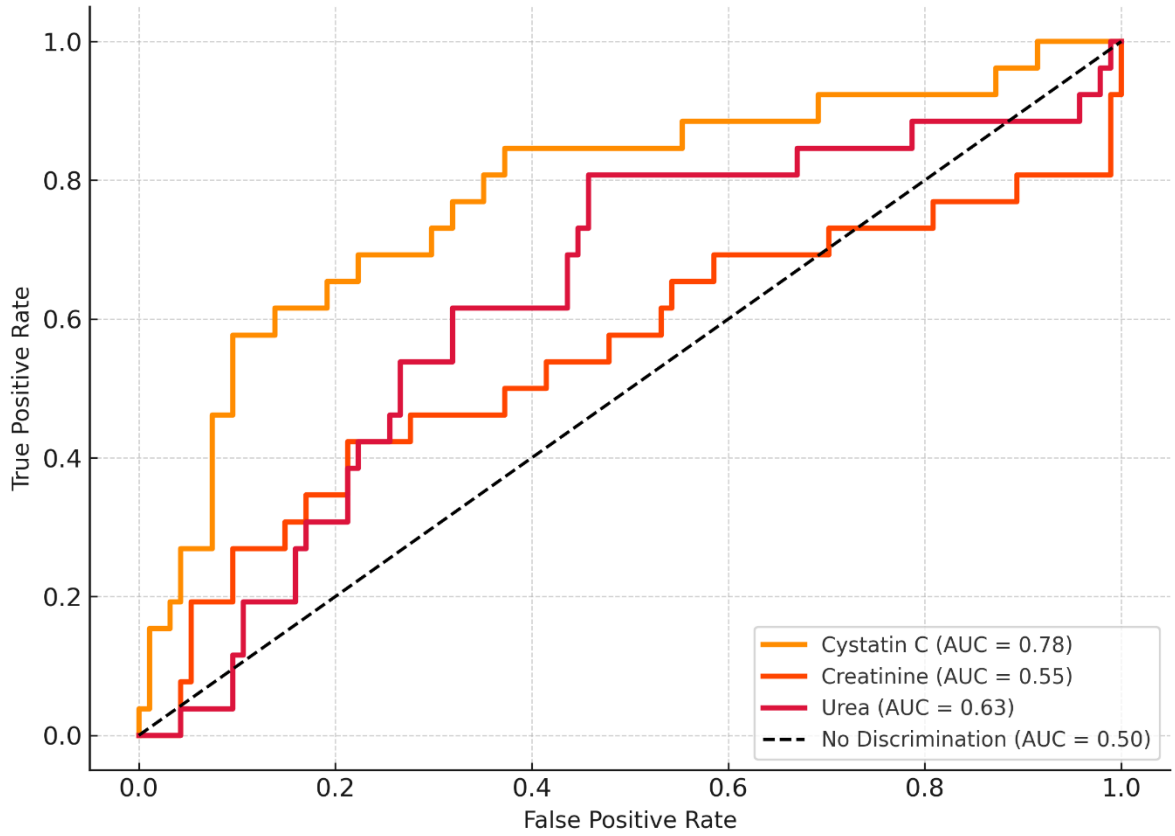

Figure 1. Receiver Operating Characteristic (ROC) curves comparing the diagnostic performance of serum Cystatin C, creatinine, and urea in detecting early renal dysfunction

To evaluate the diagnostic accuracy of Cystatin C compared to traditional renal biomarkers, ROC curves were plotted using an eGFR threshold of <90 mL/min/1.73 m². A subset of participants met the criterion for early renal functional decline, which served as the reference standard for ROC analysis. As shown in Figure 1, Cystatin C exhibited the highest AUC (0.78), followed by urea (0.63) and creatinine (0.55). This reinforces our finding that Cystatin C detects early renal changes more effectively than conventional markers in T2DM patients.

4. Discussion:

Our findings reinforce the well-known roles of Random Blood Sugar (RBS) and glycated haemoglobin (HbA1c) in evaluating diabetes. They also point to serum cystatin C as a more sensitive marker of early kidney involvement in T2DM. The RBS levels were elevated in the group with diabetes,

indicating ongoing hyperglycemia and consistent with the diagnostic standards set by the American Diabetes Association [18]. Previous studies also reported similar elevations in RBS among individuals with diabetes, supporting its value as an initial screening tool [19-21].

HbA1c levels were notably elevated in the diabetic group compared with the control group, reflecting diminished long-term glycemic control (Table 2). The association between chronic hyperglycemia and diabetes-related complications is well recognized, mainly driven by mechanisms involving oxidative stress and vascular injury [22]. Our results align with previous research indicating that HbA1c remains a reliable indicator of long-term glucose control and treatment adherence [23].

Serum urea was also elevated in the diabetic participants (Table 3), which aligns with evidence that metabolic changes in diabetes can place early stress on the glomeruli [24, 14, 25]. These findings align with the suggestions of Kulkarni et al., who emphasized the importance of early biochemical monitoring to delay the onset of nephropathy [26]. In contrast, creatinine levels did not differ significantly between groups (Table 4), which is expected because creatinine generally rises only after substantial nephron loss [15, 27]. This highlights the limitation of creatinine in detecting early kidney dysfunction.

The ROC curve analysis further highlights the value of cystatin C in identifying early renal functional changes in patients with T2DM. With an AUC of 0.78, it demonstrated a notably higher predictive accuracy than both creatinine and urea, which yielded AUCs of 0.55 and 0.63, respectively (Figure 1). Cystatin C, however, showed a clear elevation in individuals with diabetes (Table 5), indicating reduced filtration efficiency before any changes in creatinine become apparent. Earlier work has reached similar conclusions, demonstrating that cystatin C identifies mild declines in GFR more reliably than traditional renal markers in patients with diabetes [28, 12]. Taken as a whole, the data highlight cystatin C as a helpful marker for detecting renal impairment at an early stage.

The age differences observed between the study groups (Table 6) are consistent with established epidemiological trends, as both diabetes and susceptibility to renal impairment increase with advancing age [29, 4, 30]. Although age may account for some biochemical variability, the marked elevation of cystatin C in the diabetic group suggests an early renal effect that cannot be explained solely by aging.

These results support the role of cystatin C as a sensitive biomarker for early renal functional changes in patients with T2DM. Including cystatin C in routine clinical assessments may allow earlier recognition of kidney involvement and help prevent progression to chronic kidney disease or ESRD.

This study focused on functional renal biomarkers and did not include urinary markers of kidney damage; therefore, conclusions are limited to early renal functional changes rather than formal staging of diabetic kidney disease.

5. Conclusion:

Serum cystatin C levels were noticeably higher in people with T2DM than in the control group, even though their creatinine and eGFR values were still within normal limits. This pattern suggests that cystatin C can reveal early signs of kidney dysfunction before more obvious clinical changes appear. Routinely assessing serum cystatin C in patients with T2DM may facilitate earlier recognition of subclinical renal functional changes and complement conventional renal biomarkers. Further large-scale and longitudinal studies are required to establish clinical cut-off values and prognostic implications.

Future large-scale, longitudinal, and multicentre studies are recommended to validate these findings and establish standardized cystatin C cut-off values for early-stage diabetic kidney disease detection across diverse populations.

CONFLICT OF INTEREST (COI).
The authors declare that there are no competing interests.

DECLARATION OF GENERATIVE AI IN MANUSCRIPT PREPARATION.
Grammarly software (version 14.1253.1) was used to support language editing and improve the readability of the manuscript. The authors have thoroughly reviewed and edited the manuscript and assume full responsibility for its accuracy and publication.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE
The study received approval from the Ethical Review Committee at Ibn Sina University of Medical and Pharmaceutical Sciences (Reference: ISU.20.1.25).

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A Comparative Analysis Review on Panoramic Image Stitching Algorithms with Presence of Gaussian Noise

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Abstract

Panoramic image stitching is a cornerstone of modern computer vision, yet its performance degrades significantly under noisy conditions particularly Additive White Gaussian Noise (AWGN). This study presents a comprehensive theoretical analysis of the robustness of three widely used feature extraction and description algorithms SIFT, SURF, and ORB in the presence of AWGN. Focusing on their behavior during feature detection, description, matching, and geometric verification. These three methods were evaluated based on three critical criteria: noise resilience, computational efficiency, and matching accuracy. The analysis reveals that SIFT demonstrates the highest theoretical robustness to Gaussian noise due to its multi-scale Difference-of-Gaussians (DoG) framework and gradient-based descriptors, which inherently suppress high-frequency noise. However, this robustness comes at the cost of high computational complexity, rendering it unsuitable for real-time applications. Conversely, ORB offers exceptional speed through binary descriptors and the FAST detector but exhibits marked sensitivity to intensity perturbations caused by AWGN, leading to significant performance degradation in noisy environments. SURF emerges as the optimal compromise: leveraging integral images, it achieves near-SIFT-level robustness while maintaining significantly lower computational demands. Research underscores the importance of the Fast Library for Approximate Nearest Neighbors (FLANN) library in enhancing feature matching and the Random Sample Consensus (RANSAC) algorithm, offering a methodological framework for choosing the appropriate algorithm in panoramic compositing systems. It emphasizes balancing noise characteristics, speed, and accuracy requirements.

Keywords: Image Stitching, Gaussian noise, Panoramic Image, Feature Descriptor, SIFT, SURF, ORB, FLANN, RANSAC

الملخص

يُعد تركيب الصور البانورامية (Panoramic Image Stitching) ركيزة أساسية في الرؤية الحاسوبية الحديثة، إلا أن أداءه يتدهور بشكل ملحوظ تحت ظروف الضوضاء، وخاصة الضوضاء الغاوسية البيضاء المضافة (AWGN). يقدم هذا البحث تحليلاً نظرياً شاملاً لمتانة ثلاث خوارزميات شائعة لاستخلاص ووصف المعالم SIFT و SURF و ORB في وجود الضوضاء الغاوسية. مع التركيز على سلوكها خلال مراحل اكتشاف المعالم، ووصفها، ومطابقتها، والتحقق الهندسي. تم تقييم هذه الخوارزميات بناءً على ثلاثة معايير حاسمة: مقاومة الضوضاء، الكفاءة الحسابية، ودقة المطابقة. أظهر تحليل الدراسة أن خوارزمية SIFT تتمتع بأعلى متانة نظرية ضد الضوضاء الغاوسية، وذلك بفضل إطار عملها متعدد المقاييس القائم على فرق الغاوس (DoG) ومُوصفاتها المعتمدة على التدرج (Gradient-based descriptors)، والتي تعمل بطبيعتها على قمع الضوضاء عالية التردد. ومع ذلك، فإن هذه المتانة تأتي على حساب تكلفة حسابية عالية تجعلها غير مناسبة للتطبيقات التي تتطلب استجابة فورية. في المقابل، توفر خوارزمية ORB سرعة استثنائية عبر مُوصفاتها الثنائية وكاشف FAST، لكنها تُظهر حساسية واضحة للاضطرابات في شدة البكسل الناتجة عن الضوضاء الغاوسية، مما يؤدي إلى تدهور كبير في الأداء في البيئات الصاخبة. وتبرز SURF كأفضل حل وسط: فهي تحقق متانة

تقترب من مستوى SIFT باستخدام صور التكامل (Integral Images) مع الحفاظ على متطلبات حسابية أقل بكثير. تؤكد الأبحاث على أهمية مكتبة سريعة للجيران الأقرب التقريبيين (FLANN) في تحسين مطابقة الميزات وخوارزمية إجماع العينة العشوائية (RANSAC)، مما يوفر إطارًا منهجيًا لاختيار الخوارزمية المناسبة في أنظمة التركيب البانورامي. كما تُشدد على تحقيق التوازن بين خصائص الضوضاء والسرعة ومتطلبات الدقة.

الكلمات المفتاحية: تركيب الصور، الضوضاء الغاوسية، الصورة البانورامية، SIFT، FLANN، RANSAC

1. Introduction

Panoramic image stitching is an essential technique in computer vision and image processing. A panoramic image is constructed by multiple images into one wide-angle image. It is applied in various fields like virtual reality, autonomous robots, remote sensing, and medical imaging [1-2]. Image stitching methods generally consist of two main phases: the first phase is image alignment and the second is image blending. The image alignment operation finds and matches feature points between images. to which points used within the process are really important for detecting the quality and computational time [3]. Images are usually exposed to many types of noise, the most is Additive White Gaussian Noise (AWGN). Such noise reduces the steadiness of keypoint detection and the consistency of feature descriptors, both of which are important for panoramic image stitching accuracy[4–5].

While many studies have evaluated feature extraction algorithms in noisy environments, there is still a lack of a combined theoretical basis that compares the noise resistance of SIFT, SURF, and ORB algorithms based on their mathematical concepts. Differences in experimental settings often lead to conflicting results, highlighting the need for a clear theoretical analysis that identifies the strengths and weaknesses of each algorithm when subjected to noise. This paper is organized as follows: Section 1 discusses the introduction. Section 2 defines the study's scope and objectives. Section 3 describes the theoretical basis of Gaussian noise, Section 4 conducts a comparative analysis of the noise resilience of three prominent feature extraction algorithms: SIFT, SURF, and ORB, examining their mathematical frameworks and sensitivity to additive white Gaussian noise. Section 5 surveys the related literature on panoramic image stitching and evaluates the robustness of feature descriptors under various degradations. Section 6 shows the theoretical performance of the findings, based on robustness, accuracy, and computational efficiency. Lastly, Section 7 concludes the paper by summarizing the key insights and proposing future research directions, particularly focusing on the development of noise-resilient.

2. Scope and Objective

The proposed study created a theoretical comparison based on the performance of SIFT, SURF, and ORB algorithms on images impacted by Gaussian noise, aiming to determine which algorithm is most effective in detecting stable and reliable keypoints. Building upon prior research in image processing and computer vision using these algorithms, this analysis examines the precision of extracted features through various test methods. The findings will provide valuable insights and serve as a foundation for future research in this area.

3. Gaussian Noise Principle

Noise relates to statistical alteration whose probability density function follows a normal distribution. It commonly degrades image quality and hinders subsequent processes such as image acquisition, transmission, storage[6], visualization, segmentation and recognition damaging image quality[7-8]. In the panoramic image stitching, Gaussian noise can introduce a distortion that complicates image alignment, obstructs the matching of overlying regions, and reduces the visual reliability of the resultant panorama. The theoretical Gaussian noise model may be stated as shown in the equation (1) [8]:

$$G(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \quad \text{.....1}$$

where parameters x and y define pixel coordinates, and σ describes the spread of the noise. This formula provides a mathematical type of the noise distribution without indicating any filtering or denoising process. Figure 1 shows an original image with a corrupted image due to this noise.

(a) **(b)**

Figure 1. Grayscale image (a) Original Image (b) The Corrupted Image by Additive Gaussian Noise [9].

4. Overview of Feature Descriptors and Noise Resilience

The following provides a brief introduction to the three feature extraction algorithms analyzed in this study: SIFT, SURF, and ORB.

4.1 SIFT (Scale-Invariant Feature Transform)

- A feature extraction method in computer vision and image processing is SIFT (Scale-Invariant Feature Transform). Illustrious for its performance against variations in scale, rotation, lighting, and perspective. This flexibility aids in detecting specific key points, even in degraded environments such as noisy, chaotic, or occluded scenes. The process of detecting key points is separated into two main phases. The first phase involves generating a scale space by repeatedly applying Gaussian filters on the original image to perform scale stability. The image is then resized to half its size, followed by repeated Gaussian smoothing, generating an image pyramid to the original image at the base (level 1) [3]. In the second phase, calculates the Difference of Gaussians (DoG) by subtracting consecutive scales within the pyramid. Keypoints are identified by analyzing the 3 x 3 x 3 neighborhood around each pixel, selecting pixels that exhibit extrema (either maximum or minimum) in DoG values as key points. Once keypoints are noticed, the feature descriptor algorithm computes them. These descriptors, dependent on location histograms that seize the local slope directions of the keypoint neighborhood, present a complete illustration of the adjacent features. These comprehensive features make SIFT very efficient for precise feature matching and recognition tasks [4][10].

4.2 SURF (Speeded-Up Robust Features)

The advance of digital image processing in the field of feature extraction led to the emergence of SURF (Speeded-Up Robust Features) and became a substitute for SIFT (Scale-Invariant Feature Transform). The SURF algorithm was discovered by Bay et al. in 2006 to overcome the limitations of other feature descriptors such as SIFT. The descriptor is designed with scale and rotational constancy, allowing for the identification of scaled features in another image [10]. SURF strives to achieve high efficiency and resilience to image transformations, making it ideal for real-time applications and large-scale visual database systems. This algorithm is classified into three main steps: the first step is interest point detection, the second is the orientation task, and the last is feature description. These steps are connected and cooperative extract distinctive and identifiable features from an input image [11][12]. Scale-space extrema are recognized by constructing a difference-of-Gaussian (DoG) pyramid, which is formed by subtracting neighbor levels of the Gaussian pyramid. Then, to detect extrema a comparison between neighbor pixels within similar scales and across adjacent scales is performed. The representation of this process is shown in equation (2)[12]:

$$\mathrm{DoG}(x, y, \sigma) = \mathrm{G}(x, y, k\sigma) - \mathrm{G}(x, y, \sigma) \quad \ldots\ldots (2)$$

where $\mathrm{DoG}(x, y, \sigma)$ represents the difference-of-Gaussian at coordinates (x, y) and scale σ, and $\mathrm{G}(x, y, \sigma)$ is the utilization of the Gaussian response at coordinates (x, y) and scale σ.

4.3 ORB (Oriented FAST and Rotated BRIEF)

ORB (Oriented FAST and Rotated BRIEF) is an important feature detection and description algorithm used in panoramic image stitching. ORB detects and matches attributes between overlying images [3]. ORB detects keypoints in each image using the FAST (Features from Accelerated Segment Test) corner detector, typically fixing prominent corners and edges. These keypoints are then described using Rotated BRIEF, resulting in compact binary descriptors that are invariant to rotation. Then these descriptors are matched crosswise to the overlying images by Hamming distance, because it is highly efficient for dual data. To model the geometric transformation between images, a homography matrix is typically estimated using the RANSAC algorithm based on the matched keypoints .The advantages of the popular use of ORB in panoramic stitching applications make it perfect for real-time applications. Due to this, it is quick computationally.

4.4 Fast Library for Approximate Nearest Neighbors (FLANN) and Random Sample Consensus (RANSAC)

After detecting and describing features, panoramic image stitching involves establishing robust correspondences between keypoints in overlapping images—a step highly susceptible to noise-induced errors. This is accomplished through feature matching, followed by geometric validation. FLANN is a highly optimized library designed to accelerate the computationally intensive task of finding the best descriptor matches. It performs an approximate nearest neighbor (ANN) search in high-dimensional descriptor spaces 128-dimensional SIFT and 64-dimensional SURF. By employing advanced data structures like KD-trees or hierarchical k-means clustering, FLANN avoids the exhaustive, slow search of traditional methods[13]. This efficiency is crucial for maintaining the speed of the overall stitching pipeline, especially in large-scale or real-time applications. To ensure the geometric integrity of the final panorama, the RANSAC (Random Sample Consensus) algorithm is employed as a robust outlier rejection mechanism[14]. RANSAC iteratively estimates the homography matrix the projective transformation required to align the images by:

1.Randomly selecting a minimal subset of matched points.
2.Computing a candidate homography based on this subset.

3.Counting the number of matches (inliers) that agree with this model within a predefined tolerance.

The model with the most inliers is chosen as the final transformation. RANSAC filters out noise, while FLANN aids in fast matching for reliable image stitching.

5. Literature Review

Among the most affected feature detection algorithms are SIFT, SURF and ORB each developed to resolve the compromise between robustness and computational efficiency. These three methods represent the factors in the evolution of feature-based computer vision systems and continue to serve as reference techniques in both academic research and practical implementations. Below is a literature review of these methods:

5.1 SIFT (Scale-Invariant Feature Transform)

Forero et al. [15] confirmed that SIFT, SURF, and ORB show difference in resistance to degradations such as Gaussian noise. SIFT proves it is performance in stability with its higher computational cost [8-10]. Similar investigations further confirmed varying levels of robustness to noise and geometric transformations, aligning with the theoretical insights discussed in this work. Yingpeng, C. H. I. & Chang, L. I. U. adapted several works on SIFT for SAR–optical image alignment. Yingpeng and Chang modified SIFT for multi-modal matching, Yu et al. improved robustness to speckle noise and nonlinear grayscale differences using rotation-invariant amplitude descriptors and direction histograms, and Dellinger et al. proposed SAR-SIFT with redefined gradients and the ROEWA operator to effectively handle SAR-specific speckle noise [16]. Similarly, Divya et al. [17] integrated structure tensors into SIFT, increasing correct feature matches and improving overall registration accuracy. Mistry et al. made a comparison between SIFT and SURF, reporting that each algorithm presents good results in different circumstances. For example, SURF is better than SIFT in terms of rotation invariance, blur, and warp transform, while SIFT is better than SURF in terms of scale invariance [18]. A robust image hashing technique is presented, integrating Scale-Invariant Feature Transform (SIFT), Singular Value Decomposition (SVD), and Zernike moments. This combination effectively resists rotation attacks and extracts key features from images, with experimental results showing resilience against various types of attacks[19].

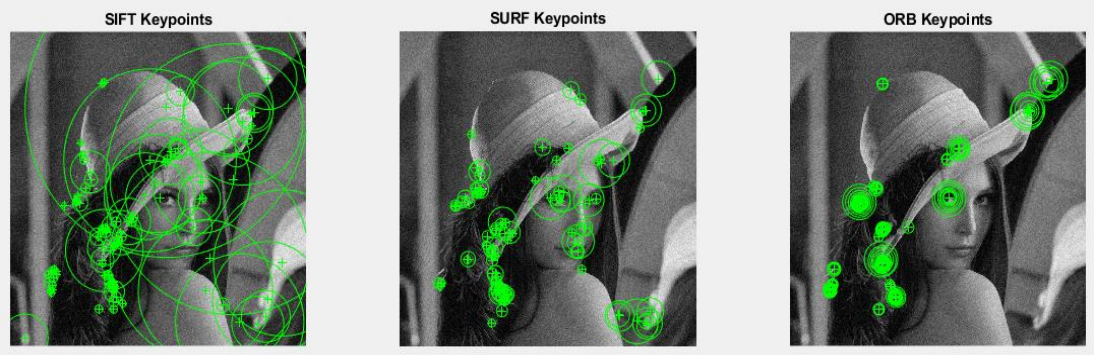
5.2 SURF (Speeded-Up Robust Features)

Makandar A, et al. and Thapar P, et al., analyze several corrupt images with Gaussian, salt-and-pepper, and speckle noise and compare SIFT, SURF, and HOG using the number of correct/valid matches between original and noisy images as the metric [20-21]. SURF is faster with performance close to SIFT, and is often judged the “best compromise” in noisy scenarios. In one experiment, effectiveness (correct matches / detected features) decreased with increasing Gaussian noise, but SURF retained relatively robust matching compared with other algorithms [20]. Ashwani reviews the SURF feature descriptor, noted for its robustness, efficiency, and invariance to image transformations. It explores the principles and components of SURF, as well as its applications in tasks like object recognition, image matching, and 3D reconstruction. The study also examines recent advancements and variations of the SURF algorithm, and compares it with other feature descriptors, aiming to enhance understanding of SURF's importance in computer vision [22]. The proposed research combines SURF with ATSERC, which significantly improves medical image registration accuracy by adapting to scale rotation and illumination variations. They applied Gaussian filters as image preprocessing for image denoising[23]. Joey et. al, suggests advanced changes to

the accuracy and performance of the (SURF) algorithm for ultrasound images via applying many identical measures. These measures include Euclidean distance, cityblock distance, variation, and correlation. Cityblock distance with SURF provides the best results with the highest PSNR and low execution time for SNR [24].

5.3 ORB (Oriented FAST and Rotated BRIEF)

Rublee E. et al., evaluate a visual vocabulary method that utilizes offline clustering to identify exemplars that are uncorrelated and suitable for matching purposes. These techniques may also prove beneficial in discovering uncorrelated binary tests. A system closely related to ORB is [3], which introduces a multi-scale Harris keypoint along with an oriented patch descriptor [25]. Ahmed et. al**,** presented an object detection and classification framework that integrates feature extraction and optimization techniques. BRIEF and ORB are used for feature representation and object separation, while a genetic algorithm optimizes [26] random forest parameters. The approach achieves strong performance on Corel-1k and MSRC datasets, and detection accuracies of 87.2% and 86.6%. The results demonstrate the effectiveness of GA-based optimization despite some limitations [27]. Akdim K et al. proposed an enhanced feature-based image registration method using ORB combined with a modified RANSAC algorithm. By introducing a Median Absolute Deviation (MAD)–based adaptive threshold, the method overcomes limitations of standard RANSAC such as high computational cost and fixed thresholds. The approach increases inlier accuracy and robustness to noise and distortion, outperforming standard ORB in MSE, NMI, SSIM, and PSNR metrics [28]. Işık M. presents a study of a comprehensive evaluation of traditional feature detectors and descriptors, including SIFT, SURF, ORB, AKAZE, BRIEF, and others, analyzing their efficiency and robustness under various image transformations. Using the large-scale Photo Tourism 2020 dataset, results show that FAST with ORB and a BF matcher provides the fastest performance, ORB performs well under affine and brightness changes, and AKAZE is most robust to blur, distortion, and rotation [29]. Cai et. al, the study examines the impact of image noise on monocular feature-based visual SLAM. A synthetic dataset with varying noise levels is used, and images are denoised using the FFDNet deep learning model. Experimental results show that ORB outperforms SIFT and SURF in correct feature matching under noisy conditions, and image denoising can significantly improve the accuracy of monocular feature-based visual SLAM under certain conditions. This descriptor, designed for image stitching, demonstrates strong rotational and scale invariance [30]. A visual comparison of SIFT, SURF and ORB is shown in Figure 2 and recorded in table 1.



(a) **(b)** **(c)**

Figure 2. Visual comparison of keypoints Detection Under Gaussian Noise (a) SIFT, (b) SURF and (c) ORB

Table 1:Comparison of Feature Descriptors under Gaussian Noise

Feature Extractor	Descriptor Type	Noise Robustness (Theoretical)	Computational Speed	Primary Mechanism for Noise Tolerance	Advantages	Disadvantages
SIFT	Gradient-based (128-dim)	High	Slowest	Scale-space filtering (DoG) and gradient averaging	Highly robust to scale, rotation, and noise.	High computational cost, slow for real-time.
SURF	Haar Wavelet-based (64/128-dim)	Moderate	Fast	Integral images and box filters for fast approximation	Faster than SIFT, good balance of speed and robustness.	Less distinctive than SIFT, moderate noise sensitivity.
ORB	Binary (256-bit)	Low	Fastest	FAST corner detector and binary BRIEF descriptor (highly intensity-sensitive)	Extremely fast, suitable for real-time applications.	Highly sensitive to noise and intensity changes.

6. Discussion

The theoretical analysis presented in this study provides a nuanced understanding of how SIFT, SURF, and ORB respond to the degrading effects of a noisy environment a common and critical challenge in real-world image acquisition. The results reveal a clear performance hierarchy rooted in the mathematical foundations of each algorithm, which dictates their suitability for noise-prone panoramic stitching.

SIFT is known for being good at handling noise because it uses a scale-space method with Difference-of-Gaussians (DoG). This method reduces high-frequency noise before detecting keypoints by applying Gaussian smoothing. It also uses a 128-dimensional gradient histogram to combine local orientation data, which helps to minimize pixel noise. However, this process requires a lot of computing power and memory, making SIFT less suitable for limited-resource or real-time applications. ORB, while offering exceptional speed, suffers from a fundamental structural vulnerability to AWGN. Its FAST detector relies on comparing raw pixel intensities along a circle, a process highly sensitive to random intensity perturbations. Similarly, the BRIEF descriptor encodes binary tests based on pairwise pixel comparisons, which AWGN can easily invert, corrupting the descriptor's uniqueness. Consequently, even moderate noise levels lead to a sharp drop in correct matches, as corroborated by empirical studies .Thus, ORB's speed advantage is often negated in noisy environments unless a pre-processing denoising step is introduced, which adds latency and may inadvertently blur genuine features. SURF emerges as the most pragmatic compromise. By replacing the costly Gaussian convolutions with box filters computed via integral images, SURF drastically reduces computation time. still capture directional energy in a manner less prone to single-pixel noise spikes. Empirical studies consistently report SURF retaining a higher percentage of valid matches than ORB under increasing Gaussian noise, while operating significantly faster than SIFT. This makes SURF particularly suitable for applications where moderate noise is expected such as in drone navigation or mobile augmented reality.

The role of the matching pipeline proves that FLANN accelerates correspondence estimation, its approximate nature may miss true matches in noisy, sparse descriptor spaces. Conversely, RANSAC acts as a powerful safeguard by iteratively fitting homographies and discarding outliers, it compensates for the initial mismatches caused by noise. However, if

the noise is severe enough to reduce the number of true inliers below the RANSAC threshold that corrupt the entire stitching process. In conclusion, no single algorithm offers a universal solution. The optimal choice depends on the operational context, requiring a careful trade-off. The core contribution of this review is:

• SIFT outcomes is highest accuracy in noise environment.
• SURF is the best trade-off for real-time performance with moderate noise.
•ORB is the highest speed and denoised environments

7. Conclusion and Future Work

This study established a rigorous theoretical foundation for evaluating the robustness of SIFT, SURF, and ORB against Additive White Gaussian Noise (AWGN) within the context of panoramic image stitching.

Our analysis conclusively demonstrates a clear performance hierarchy based on the underlying mathematical principles:1.SIFT offers excellent noise resilience through multi-scale Gaussian smoothing and gradient-based descriptors that reduce high-frequency noise, but its high computational requirements render it impractical for real-time application..SURF provides the optimal trade-off between robustness and efficiency. By utilizing integral images, it achieves near-SIFT accuracy at a fraction of the computational cost, positioning it as the preferred choice for dynamic, noisy real-world applications. 3.ORB despite its superior speed, is highly vulnerable to AWGN due to its reliance on raw pixel intensities in both the FAST detector and the BRIEF descriptor, leading to substantial matching degradation even under moderate noise levels. The research stresses the post-processing pipeline's importance, focusing on FLANN and RANSAC. Selecting the best algorithm depends on noise level, computational limits, and the accuracy needs. We propose the following directions for future work:•Noise-Hardened Binary Descriptors: Developing binary descriptors that retain ORB’s computational speed while significantly improving AWGN resilience and speed.
•Deep Learning Denoising Integration: Empirically evaluating the integration of deep learning denoisers (e.g., FFDNet) as a pre-processing step to uniformly enhance the performance of all feature extractors under high noise.

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Micro$_Z$ Topological Space

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Micro$_Z$ Topological Space

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Summary:

The objective of this paper is to study some definitions in general Topological spaces and generalizing them to Micro topological

space .These definition (Micro$_Z$open set).The relationship with Micro open set with some new result and proved (Micro$_z$, Micro$_Z$ Pre, Micro$_Z\alpha$, Micro$_z$semi) open sets are studied, finally we defined and studied a new space namely Micro$_Z$ topological space.

Keywords: μ_Z open , $\mu_Z$pre open, $\mu_Z\alpha$ open,μ_ZReg. open and μ_Z

Semi open.

1.Preface

In (1963) [3] "introduced Bitopological Spaces" ,In (1963) [8] introduced the idea of Semi-Open sets , In (1984) [1] Present concept of Pre-Open sets ,In 1990 [11] investigated further properties of topological space. In (2013) [5] present the concept of Nano topological founded on the idea of "lower approximation" ," upper approximation" "and boundary" ragion . In 2014 [6] present the definition of weekly "Nano-open sets such as Nano (alpha , pre , semi and regular) open sets .In 2019 [2] introduced the concept of Micro open set of Micro topological space.In 2020[9] studied the concept of nano general regular.In 2022[12] defined Soft Generalized $\alpha i-$ closed Sets in Soft Topological Spaces. In 2021[10] the concept of ideal in Micro topological space , In 2023[4] introduced Separation axioms on Nano-Z-topological space . In this paper we introduce new type of Micro open sets and be called Micro$_Z$ open sets , the study proved that the collection of all Micro$_Z$ open sets form atopological space .Also The characterization and relationships between these new types of Micro$_Z$ open sets are thoroughly studied.

2-Preliminary

Definition 2.1[6] :-Let U be a finite set of elements named universe set and $U\neq \emptyset$. Then the equivalence relation R on U named as the indiscernibility relation. The elements belong to the

undistinguishable with one" another. The ordered pair (U,R) same Equivalence class are said to be named an approximation space,

let $X \subseteq U$.

1- "The set of all elements that might be assigner categorized as X with" respect to R is named base approximation of X with respect to R and symbolized by $L_R(X)$.such that "L_R (X) $= \cup \{\{R(X): R(X) \subseteq X\}$. When R(X) represent $\subseteq$ X.

That determined by $X \in U$".

2- "The set of all elements that be probably divided as X with respect to R is called over adduction of X with respect to R and" symbolized by $U_R(X)$.That

$U_R(X) = \cup\{R(X): R(X) \cap X \neq \emptyset\}$.

3- "The set of all elements that cannot codifies neither as X and not as not with respect to R is called boundary area X with respect to R and symbolized by" $B_R(X)$.That

$B_R(X) = \{U_R(X) - L_R(X)\}$".

Definition 2.2.[6]. "Let U be a comprehensive set with equivalence relation R on U and $\tau_R(X) = \{\emptyset, U, L_R(X), U_R(X), B_B(X)\}$, where X $\subseteq$ U.

($U, \tau_R(X)$) is called a Nano $-$ Topologigal space.

Let (U , τ_R(X)) be a Nano Topological space ,then subset A of U is **Definition2. 3.** [7]. " called Nano-Z-open set" if A satisfies the following conditions:

1- "$\forall a \in A, \exists$Nano open G such that $a \in G \subseteq Ncl(A)$

2-$G=U$ *iff* $A=U$.

Collection of all "Nano-Z-Open sets symbolized $N_{Z\_}$ *Open(U,X).*

Definition2. 4. [2]. Let go(U, τ_R(X)) is a nano topological space here $\mu_R(X)$

$= \{ N \cup (\dot{N} \cap \mu)\}; N, \dot{N} \in \tau_R(X)$ and called it "Micro topological

Of τ_R (X) by μ where $\mu \notin \tau_R(X)$.

Definition2.6.[2]. The " Micro topological" μ_R(X) satisfies the following axioms

1-U, $\emptyset \in \mu_R$ *(X).*

2-The union of the elements of any sub-collection of μ_R(X) is in μ_R(X).

3-"The intersection of the elements of any finite sub collection of μ_R(X)".

Then μ_R(X) is called the Micro topological on U with respect to X.

The triplet (U ,$\tau_R(X)$,$\mu_R(X)$) is called "Micro topological spaces" and The elements of $\mu_R(X)$ are called Micro open sets and the complement of a Micro open set is called a Micro closed set.

Definition 2.6.[2]. The Micro closure of a set A is symbolize by μic-cl(A) and is describe as μic-cl(A)=∩{B:B is μ-closed and A ⊆ B}.

The Micro interior of a set A is symbolize by μic-int(A) and is describe as μic-int(A)= ∪{ B:B is μic-open and A ⊇ B}.

3- $\mathbf{Micro_Z - Open\ Set}$

"In this part we introduce and" researched the properties of $\mathrm{Micro_Z}$ Topological Space.

Definition 3.1. Let (U , $\tau_R(X)$, $\mu_R(X)$) be a "Micro-topological space , then B subset of U is called $\mathrm{Micro_Z}$-open set if B satisfies the following condition :-

1-∀ b ϵ B , ∃ Micro- open G such that b ϵ G ⊆ μic -cl (B) .

2- G= U iff B = U ,every set in $\mu_{RZ}(X)$ is μ_Z -open set and complement of μ_Z – open set is μ_Z -closed set and denoted by $\mu_{RZ}(X)$, the (U,μ_R (X) $\mu_{RZ}(X)$) is called $\mathrm{Micro_Z}$- topological space.

Example 3.2. *Let U="{ m,n,o,p} , with U/R ={{m},{o},{n,p}} X={n,p} ⊆ U , $\tau_R(X)$ ={U, ∅, {n,p} } and then* μ={n}.

(X) = {U,∅, {n} ,{n,p}}"μ_R

Micro-closed set= {U,∅,{m,o,p},{m,o}}.

(X) = {U,∅,{n},{p},{n,p}}.μ_{RZ}

Definition 3.3. Let(U, $\mu_R(X)$, $\mu_{RZ}(X)$) be "$\mathrm{Micro_Z}$- Topological space with respect to X when X ⊆ U and B ⊆ U .Thence [μ_Z-Interior] of B is describe as $\mu_Z$int(B) = ∪ { v: v⊆B,v ∈ μ_Z-open set in U }. So (μ_Z- int)of B in ∪ is the largest μ_Z-open subset of B . Andμ_Z- closure of B describe as $\mu_Z$cl (B) = U {G:B ⊆ G, G∈ μ_Z-closed set in U }. So $\mu_Z$cl (B) is the smaller set μ_Z-closed set hold B.

Definition 3.4. A subset B of "$\mathrm{Micro_Z}$- Topological space (U, $\mu_R(X)$, $\mu_{RZ}(X)$) where X ⊆ U is called:

a-μ_Z*-Pre Open if B ⊆* $\mu_Z int(\mu_Z\ cl(B))$

b-μ_Z*-Semi Open if B* $\subseteq\ \mu_Z cl(\mu_Z int(B))$

c-μ_Z *-β Open if* $B \subseteq \mu_Z cl(\mu_Z int(\mu_Z\ cl(B)))$

d-μ_Z*-Reg. Open if* $B = \mu_Z int(\mu_Z cl(B))$

e-μ_Z*-α Open if* $B \subseteq \mu_Z int\left(\mu_Z cl(\mu_Z int(B))\right)$

The following example explained definition 3.4.

Example 3.5. Let *U=_{ m,n,o,p} , with U/R ={{m},{o},{n,p}} X={n,p} ⊆ U , $\tau_R(X)$ ={U, ∅, {n,p} } and then μ={n}.Then*

(X) = { U,∅, {n} ,{n,p}}μ_R

Micro-closed set= {U,∅,{m,o,p},{m,o}}".

(X) = {U,∅,{n},{p},{n,p}}.μ_{RZ}

(X) -Closed set={U,∅,{m,o,p},{m,n,o},{m,o}}". μ_{RZ}
$\boldsymbol{\mu_Z SO}$*={U,∅,{m},{n},{o},{p},{m,n},{m,o},{m,p},{n,o},{n,p},{o,p},*

{m,n,o},{m,n,p},{n,o,p},{m,o,p}}"

$\boldsymbol{\mu_Z PO} = \{U, \emptyset, \{\{n\},\{p\},\{n,p\}\}$

$\boldsymbol{\mu_z \alpha O} = \{U, \emptyset, \{n\},\{p\},\{n,p\}\}$

$\boldsymbol{\mu_z RO}$*={U,∅,{n},{p},{n,p}}*
$\boldsymbol{\mu_Z \beta O}$ *={U,∅,{m},{n},{o},{p},{m,n},{m,o},{m,p},{n,o},{n,p},{o,p},{m,n,o},{m,o,p},{m,n,p},{n,o,p}}.*

Theorem3.6."Every μ_Z-open set is a μ_Z-pre open.

Proof. Let go B be μ_Z-open .Then B⊆ μ_Z -int(μ_Z-intB). Since μ_Z-int(μ_Z-intB)⊆ μ_Z -int(μ_Z-clB),therefore B ⊆ μ_Z -int(μ_Z-clB). Hence B is μ_Z-pre open" .

Remark3.7. Conversely theorem is not always true.

Example 3.8. From example 3.5 the set {m,n,o} is $\mu_Z -$ pre open but not μ_z open.

Theorem3.9. a. Arbitrary union of μ_z -pre open sets is μ_z-pre open.

b. " Arbitrary intersection of μ_z-pre closed sets is μ_z-pre closed".

Proof.

a."Let $\{B_\alpha|\alpha \in I\}$ form the family of $\mu_z -$ pre open sets in X. By Defintion3.5. for each $\alpha, B_\alpha \subseteq \ \mu_z - int(\mu_z - cl(B_\alpha))$, this implies that $\cup B_\alpha \subseteq \cup (\mu_z - int(\mu_z - cl(B_\alpha)))$. Since $\cup (\mu_z - int(\mu_z - cl(B_\alpha))) \subseteq \mu_z - int(\cup \mu c_z - cl(B_\alpha))$ and $\mu_Z - int(\cup \mu_Z - cl(B_\alpha)) = \mu_Z - int(\cup B_\alpha)$, this implies that $\cup B_\alpha \sqsubseteq \mu_z - int(\mu_Z - (\cup B_\alpha))$. Hence $\cup B_\alpha$ is $\mu_Z -$ pre open".

b. "Let $\{C_\alpha|\alpha \in I\}$ to be part a family of μ_Z-per closed sets in X. Let $B_\alpha = C_\alpha^c$, then $\{B_\alpha|\alpha \epsilon I\}$ is a family of $\mu_z -$ pre open

sets.By (a) ,$\cup B_\alpha = (\cup C_\alpha)^c$is $\mu_Z -$ pre open. As a result $(C_\alpha)^c$ is μ_Z-pre open.Hence($\cap C_\alpha$) is μ_Z–pre closed".

Theorem3.10. a.Let B⊆($\cup, \mu_R(X), \mu_{RZ}$ (X)) Then μ_Z-pre(int B) is the same as the merger of all "μ_Z −pre open set" included in B.

b, If B is a "μ_Z −pre open set" subsequently B=μ_Z-pre (int B)".

Proof. a." We need to show that ,μ_Z-pre (intB)={C|C⊆ B, C is $\mu_Z -$ pre open set}.Let x∈ $\mu_Z$pre (int B). Therefore , there is a "$\mu_Z -$ pre open" set C so this x ∈ C ⊂ B, So x ∈∪ {C|C ⊂ B, C is $\mu_Z -$ pre open set}. Oppositely, assume x ∈∪ {C|C ⊂ B, C is "$\mu_Z -$ pre open set"}, there is a set $C_\alpha \subset$ B so that x∈ C_α, at which C_α is "$\mu_z -$ pre open set".

i.e.xϵ $\mu_Z -$ pre (intB) . Therefore ∪ "{C: C ⊂ B, C is $\mu_Z -$ pre open set }" ⊂ "$\mu_Z -$ pre (int B)" . So "$\mu_Z -$ pre (int B)" =∪ "{C|C ⊂ B, C is $\mu_Z -$ pre open set}".

b. Suppose B equals a $\mu_Z -$ pre open set then B ∈ {C: C ⊂ B, $\mu_Z -$ pre open set}, and every other element in this

Collection is subset of B. Hence by part(a) $\mu_z -$ pre (intB) = B.

Theorem3.11. a."$\mu_Z -$ pre int(B ∪ C)" ⊃ $\mu_Z -$ pre (intB) ∪ $\mu_Z -$ pre (intC)".

b. $\mu_Z -$ pre int(B ∩ C) = $\mu_Z -$ pre int B ∩ $\mu_Z -$ pre int C".

Proof. **a**. The fact that $\mu_Z -$ pre (intB) ⊂ B and $\mu_Z -$ pre (int C) ⊂ C implies pre int B ∪ $\mu_Z -$ pre int C ⊂ B ∪ C. Since $\mu_Z -$ pre

Int belongs to a set $\mu_Z -$ Pre open , μ_Z-Pre (intB)& $\mu_Z -$ pre (intC)are "pre open". Consequently by Th. 3.9(a), $\mu_Z -$ pre (intB) ∪ $\mu_Z -$ pre (intC) is "$\mu_Z -$ pre open and included in B ∪ C" . As

$\mu_Z -$ pre int(B ∪ C)is a biggest. $\mu_Z -$ pre open set. included

In B ∪ C,therefore μ_Z -pre (*int B*) ∪ $\mu_Z -$ pre (intC) ⊂ $\mu_Z -$ pre int (B ∪ C)".

b. Let go x∈ $\mu_Z -$ pre int(B ∩ C) ∈ $\mu_Z -$ pre int(B ∩ C). Then threr is a $\mu_Z -$ pre open set F, such that x ∈ F ⊂ (B ∩ C). exists there is a" $\mu_Z -$ pre open set", so that x ∈ F ⊂ B and x ∈ F ⊂ C. Hence x ∈ $\mu_Z -$ pre intB

and x∈ Micro$_Z -$ pre int C.Therefore" $\mu_Z -$ pre int(B ∩ C)" ⊂ $\mu_Z -$ pre int B ∩ $\mu_Z -$ pre int C. "Retracing the above steps, we get the

converse".

-cl set is μ_Z –pre cl.**Theorem3. 12**. every μ_Z

Proof. Let B be $\mu_Z -$ cl, then by Theorem3.9, we have $\mu_Z -$ cl($\mu_Z -$ cl B) ⊆ B. Since $\mu_Z -$ cl($\mu_Z -$ int B) ⊆ $\mu_Z -$ cl($\mu_Z -$ cl B) ⊆ B, B is $\mu_Z -$ pre closed".

Remark 3.13. Conversely theorem is not always true. From the example

Example 3.14.From example 3.5 the set {o} is μ_z –pre closed

Set but not μ_z- closed set.

Remark 3.15.Every $\mu_Z -$ Open set is a $\mu_Z -$ α Open set, and

Conversely is not always true. From the example.

Example 3.16. From example 3.5 the set {n,o,p} is μ_z- α open but not μ_z − open set.

Remark 3.17. Every μ_Z − Open set is a μ_Z − β Open set, and

Conversely is not always true. From the example.

Remark 3.18.From example 3.5 the set {o,p} is the $\mu_z - \beta$ *open*

Remark 3.19. μ_Z − α Open set is a μ_Z − Semi Open set, and the

Converse is not always true. From the example.

Remark 3.20. From example 3.5 the set {o} is μ_z − Semi open set but not μ_z − α open set.

And the relationship between μ_Z − Reg. open and μ_Z − open is equivalent.

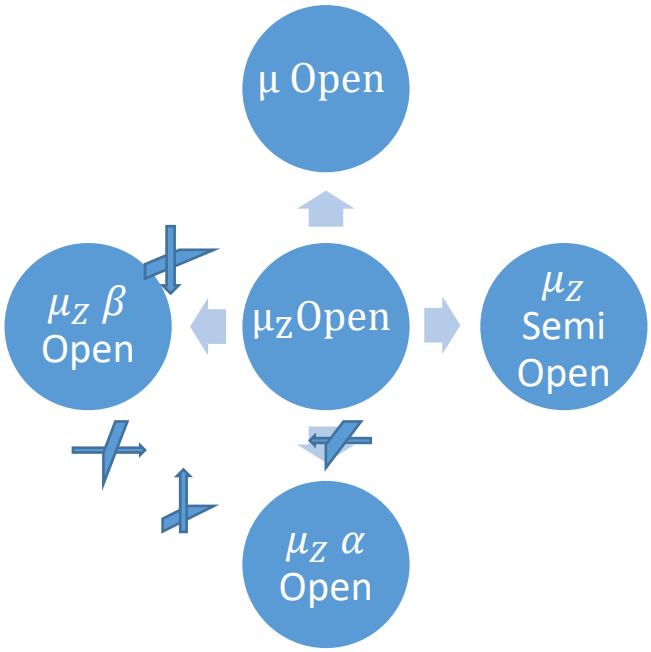
Theorem3.21.a. every μ_z − Open set is a μ_Z − Semi Open set.

b. every μ_Z − Closed set is a μ_Z − Semi Closed set .

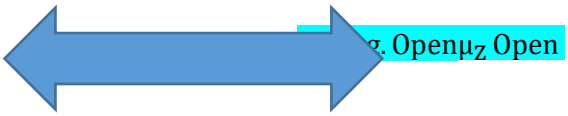
Proof. a. If B is μ_Z − open set then by then , $B \subseteq \mu_Z - \text{int}(\mu_Z - \text{int}(B))$. Since$\mu_Z$ $\text{int}(\mu_Z - \text{int}(B)) \subseteq \mu_Z - \text{cl}(\mu_Z - \text{int}(B))$. $B \subseteq \mu_Z - \text{cl}(\mu_Z - \text{int}(B))$. Hence B is μ_Z − Semi open".

b. "If B is μ_Z − closed set" therefore by Theorem 3.9 , "we have $\mu_Z - \text{cl}(\mu_Z - \text{cl}(B)) \subseteq B$. Since$\mu_Z - \text{int}(\mu_Z - \text{cl}(B)) \subseteq \mu_Z - \text{cl}(\mu_Z - \text{cl}(B))$. $\mu_Z - \text{int}(\mu_Z - \text{cl}(B)) \subseteq B$. Hence B is μ_Z − semi closed.

The following figure represents the relationship between the sets studied in the paper.



Figur(1)



Figur(2)

الملخص

يهدف هذا البحث الى دراسة بعض التعريفات في الفضاءات التبولوجية العامة وتعميمها على الفضاء التبولوجي المايكروي (Micro topological space). ومن بين هذه التعريفات تعريف المجموعة المفتوحة $Micro_Z$ open set . كما درست العلاقة بين المجموعة المفتوحة المايكروية والمجموعات المفتوحة من الانواع $Micro_Z$ ، $Micro_Z pre$، $Micro_Z Semi$،

$Micro_Z Reg$، $\alpha\ Micro_Z \beta$، $Micro_Z$.

كذلك تم التوصل الى بعض النتائج الجديدة واثباتها، واخيرا قمنا بتعريف ودراسة فضاء جديد يسمى الفضاء التبولوجي$Micro_Z$ ($Micro_Z$ topological space) .

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