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NAAC ACCREDITED



Gossner Academia

(An International Multidisciplinary Journal)

Bi-Annual Journal

Year 2025

Volume : 01 (Jan to June)



www.gcran.org



0651-2331659



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INDEX

Sl. No	Author Name	Title of Research	Page No.
1	Dr. Ajay Kumar, Assistant Professor, faculty of Commerce, Gossner College, Ranchi (Ranchi University, Ranchi) & Dr. Deepak Sharma, Assistant Professor, Faculty of Commerce, Gossner College, Ranchi (Ranchi University, Ranchi)	The Role of Artificial Intelligence in Transforming Financial Services	01 to 09
2	Amos Prashant Topno , Assistant Professor, Department of Zoology, Gossner College, Ranchi	Characterization of Streptococcus pneumoniae D39 protein SPD_1626 in Escherichia coli	10 to 19
3	Dr Aarti Kumari, Faculty English, Gossner College, Ranchi, Jharkhand	RECONCEPTUALIZING THE ROLE OF COMPUTERIZATION IN HIGHER LEARNING: THE NEW NORMAL AND LEARNERS' LIKES	20 to 28
4	Dr. Deepak Sharma, Assistant Professor, Faculty of Commerce, Gossner College, Ranchi (Ranchi University, Ranchi) & Dr. Ajay Kumar, Assistant Professor, faculty of Commerce, Gossner College, Ranchi (Ranchi University, Ranchi)	Sustainable Business Practices: Redefining Corporate Responsibility in the 21st Century	39 to 37
5	Shyam Saurabh, Department of Mathematics, Tata College, Chaibasa, India & Dinesh Prasad, Department of Mathematics, Gossner College, Ranchi	Some Tactical Decomposable Cyclic BIB and RGD Designs	38 to 42
6	डॉ प्रशांत गौरव, सहायक प्राध्यापक, हिंदी विभाग, गोस्सनर महाविद्यालय, रांची।	सांस्कृतिक संगम के प्रहरी : रहीम	43 to 50
7	Sumanta K. Sengupta*, Praween Surin, Mamta Mahima Topno, Smita Singh, Faculty of Science, Gossner College Ranchi	Investigation of electrode metals and supporting electrolytes in the electrochemical polymerization of acrylamide.	51 to 55
8	Sumanta K. Sengupta*, Smita Singh, and Praween Surin, Faculty of Science, Gossner College Ranchi	Postpolymerization of Acrylamide in Aqueous Solution	56 to 59

The Role of Artificial Intelligence in Transforming Financial Services

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Abstract

This research paper explores the transformative role of Artificial Intelligence (AI) in the financial services sector. The **purpose** of the study is to examine how AI technologies are reshaping operations, customer service, risk assessment, fraud detection, and investment strategies within financial institutions. Using **secondary data** from industry reports, journal articles, and case studies, the paper presents a comprehensive overview of recent advancements and applications of AI in finance.

The **findings** reveal that AI has significantly improved decision-making, operational efficiency, and customer personalization while reducing costs and fraud risks. However, challenges such as data privacy, regulatory compliance, and workforce disruption remain.

The **practical implications** suggest that financial institutions must invest in AI capabilities and ethical governance frameworks to stay competitive and responsible. The **originality** of this paper lies in its integrated perspective on how AI is influencing both front-end and back-end financial services through real-world examples and critical analysis.

Keywords: Artificial Intelligence, Financial Services, Risk Management, Customer Experience, FinTech, Automation.

Full Paper

1. Introduction

1.1 Overview of AI and its Relevance
Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are designed to think, learn, and make decisions. In recent years, AI has moved beyond theory to practical applications across various industries. Its ability to process vast amounts of data, identify patterns, and make real-time decisions makes it particularly valuable in sectors that depend on accuracy, speed, and adaptability.

Among these, financial services have emerged as one of the leading adopters of AI, leveraging it to enhance operations, customer service, and risk management.

1.2 Evolution of Financial Services in the Digital Era

The financial industry has undergone significant transformation in the digital age. Traditional banking methods have been replaced by digital platforms, online transactions, and automated services. FinTech companies have disrupted conventional banking with innovative solutions like mobile wallets, robo-advisors, and blockchain-based transactions. This evolution has pushed established institutions to adopt digital technologies to remain competitive. AI plays a key role in this shift, helping institutions deliver smarter, faster, and more secure services.

1.3 Objective and Significance of the Article

This article aims to explore how AI is transforming financial services and redefining the way institutions operate and interact with customers. It highlights the benefits, challenges, and future prospects of AI integration in finance. Understanding these developments is essential for financial professionals, policymakers, and stakeholders navigating the changing landscape.

1.4 Scope and Methodology

The article is based entirely on secondary data, collected from scholarly journals, industry reports, and credible financial publications. It examines various use cases of AI in areas like fraud detection, customer engagement, credit scoring, and asset management. The scope includes both global and Indian financial systems, with a focus on identifying trends, outcomes, and strategic implications of AI-driven change.

2. Understanding Artificial Intelligence in Finance

Artificial Intelligence has emerged as a game-changer in the financial sector, offering new ways to process data, automate decisions, and enhance customer experiences. To understand its growing importance, it is essential to look at the technologies behind AI and how they are applied across different financial services.

2.1 Key AI Technologies: Machine Learning, NLP, Robotic Process Automation

At the core of AI are several technologies that power its capabilities. Machine Learning (ML) allows systems to learn from historical data and improve performance over time without being explicitly programmed. It is widely used in fraud detection, credit scoring, and risk assessment. Natural Language Processing (NLP) helps machines understand and interact in human language, enabling chatbots, virtual assistants, and sentiment analysis in financial markets. Robotic Process Automation (RPA) focuses on automating repetitive tasks such as data entry, compliance checks, and report generation, improving operational efficiency and reducing human error.

2.2 AI vs Traditional IT Systems

Traditional IT systems in finance are rule-based, static, and require constant human intervention for updates and improvements. AI, on the other hand, is dynamic and adaptive. It can learn from new data and adjust its functions accordingly. Unlike traditional systems, AI tools can process unstructured data like emails, voice, and images, making them more flexible and responsive. While traditional systems follow set commands, AI systems can make predictive and prescriptive decisions based on data patterns.

2.3 Applications in Banking, Insurance, Investment, etc.

In banking, AI is used for fraud detection, customer support through chatbots, loan underwriting, and personalized marketing. AI algorithms can analyse customer behaviour to offer tailored financial products. In insurance, AI streamlines claims processing, detects fraudulent claims, and offers dynamic pricing based on customer profiles. In investment and wealth management, AI-driven robo-advisors provide personalized portfolio recommendations, and algorithms are used for high-frequency trading and risk management.

AI is thus not just an enhancement of traditional processes but a complete transformation in how financial services are delivered and experienced. Its ability to analyse large volumes of data and deliver quick, intelligent decisions is reshaping the future of finance.

3. Areas of AI Application in Financial Services

Artificial Intelligence has opened up a wide range of applications in financial services, helping institutions improve efficiency, security, and customer experience. From managing risks to enhancing customer interactions, AI is proving to be a powerful tool across multiple functions.

3.1 Fraud Detection and Risk Management

One of the most important applications of AI in finance is fraud detection. Traditional systems rely on predefined rules, which can miss unusual or new types of fraud. AI, particularly machine learning, can analyse patterns in real-time and detect anomalies that indicate fraudulent activity. It can flag suspicious transactions almost instantly, reducing the risk of financial losses. Similarly, AI enhances risk management by analysing market trends, customer behaviour, and external data to predict potential risks and guide decision-making.

3.2 Algorithmic Trading and Investment Advisory

AI is revolutionizing investment management through algorithmic trading. These algorithms can process vast amounts of market data, identify trends, and execute trades at speeds far beyond human capability. This has made trading more efficient and accurate. In addition, AI-powered robo-advisors are providing automated, low-cost investment advice. By analysing a user's financial situation and goals, these tools recommend customized investment plans, making wealth management more accessible to a wider audience.

3.3 Customer Service: Chatbots and Virtual Assistants

AI is transforming customer service in banking and finance. Chatbots and virtual assistants are now handling customer queries, guiding users through processes, and providing real-time assistance—24/7. These tools use Natural Language Processing (NLP) to understand customer questions and offer appropriate responses. They can handle routine tasks like balance inquiries, transaction histories, or account information, reducing the burden on human agents and speeding up customer service.

3.4 Credit Scoring and Loan Processing

AI is changing the way creditworthiness is assessed. Traditional credit scoring relies mainly on fixed data like income, employment history, and repayment records. AI, however, can analyse alternative data such as transaction history, digital footprint, and even social behaviour to evaluate a borrower's creditworthiness. This makes lending more inclusive, especially for people with little or no formal credit history. Additionally, AI speeds up loan approval processes by automating document verification and risk assessment.

3.5 Personalized Financial Planning

Personalization is becoming a standard expectation among customers, and AI is helping financial institutions meet that demand. AI tools can analyse spending habits, income patterns, and savings behaviour to offer customized financial advice. Whether it's budgeting tips, saving plans, or investment options, AI ensures that recommendations are tailored to each individual's needs and financial goals.

Overall, these applications demonstrate how AI is reshaping financial services from the inside out. By improving accuracy, reducing costs, and enhancing customer satisfaction, AI is not just supporting finance—it is redefining it.

4. Case Studies and Real-World Applications

The impact of Artificial Intelligence in the financial sector is best understood through real-world case studies. Many financial institutions, both in India and globally, have embraced AI to improve service delivery, enhance operational efficiency, and reduce risks. The following examples highlight how AI is being applied in practice.

4.1 Example 1: HDFC Bank Using AI in Customer Service

HDFC Bank, one of India's leading private sector banks, has been a front-runner in integrating AI into its customer service operations. The bank introduced an AI-based chatbot named Eva (Electronic Virtual Assistant) to handle customer queries. Eva can answer thousands of banking-related questions in real-time, covering areas like account details, branch locations, product information, and more. By handling simple and repetitive queries, Eva has helped the bank reduce pressure on call centers and improve response times. It has also ensured 24/7 customer support, which is crucial in today's digital banking era.

4.2 Example 2: JPMorgan Chase Using AI in Document Analysis

Globally, JPMorgan Chase has successfully leveraged AI through its COiN (Contract Intelligence) platform. This AI-powered system reviews legal documents and extracts essential data points with high accuracy. What earlier took legal teams thousands of hours to complete is now done in seconds with the help of AI. COiN helps the bank identify potential risks and ensure compliance, especially in loan agreements and contracts. This has significantly reduced operational costs and improved the speed of internal processes.

4.3 Insights and Outcomes from These Implementations

These case studies reveal several important insights. First, AI significantly enhances efficiency by automating routine tasks, which allows human employees to focus on more complex responsibilities. Second, AI improves accuracy, especially in tasks like data extraction and analysis. Third, AI improves customer satisfaction by ensuring faster, consistent service. However, the success of these implementations depends on proper training, infrastructure, and data management.

In both cases—HDFC Bank and JPMorgan Chase—AI has not replaced human workers but has complemented them, allowing banks to operate more intelligently and responsively. These examples show that with the right strategy, AI can deliver measurable value to financial institutions and their customers.

5. Benefits and Opportunities

Artificial Intelligence is bringing transformative benefits to the financial services industry. As more institutions adopt AI-driven tools and platforms, they are discovering new ways to operate smarter, serve customers better, and remain competitive in a fast-evolving marketplace.

5.1 Increased Efficiency and Cost Reduction

One of the most immediate benefits of AI is improved operational efficiency. AI systems can handle large volumes of transactions, monitor activities in real-time, and perform repetitive tasks without fatigue or error. Processes that once required days can now be completed within minutes. By automating routine tasks like data entry, compliance checks, and report generation, financial institutions can significantly reduce costs while increasing accuracy and speed.

5.2 Enhanced Customer Experience

AI has transformed how banks and financial firms engage with customers. From chatbots offering instant responses to personalized product suggestions based on spending habits, AI enables financial institutions to offer round-the-clock, tailored services. This enhances customer satisfaction and builds trust. Virtual assistants and AI-enabled platforms simplify banking tasks, making financial services more accessible and user-friendly.

5.3 Data-Driven Decision-Making

With access to vast amounts of customer and market data, AI enables more informed decision-making. Advanced analytics help financial institutions predict trends, assess risks, and make proactive decisions. This is especially valuable in areas like investment management, fraud detection, and credit risk assessment, where data insights can directly influence performance and outcomes.

5.4 Competitive Advantage in the Financial Sector

Institutions that invest in AI gain a strategic edge. Whether it's faster loan approvals, better fraud detection, or more engaging customer interactions, AI helps deliver services that meet modern expectations. Early adopters are often better positioned to adapt to market changes and innovate ahead of competitors.

Together, these benefits make AI not just a technological upgrade but a fundamental driver of growth and innovation in financial services.

6. Challenges and Ethical Concerns

While Artificial Intelligence offers immense benefits to the financial services sector, it also brings several challenges and ethical concerns that must be addressed. As institutions integrate AI into their systems, they must do so with responsibility, transparency, and a strong ethical foundation.

6.1 Data Privacy and Cybersecurity

AI systems rely heavily on vast amounts of data to function effectively. This raises concerns about how customer data is collected, stored, and used. Financial institutions must ensure strict data protection measures to prevent unauthorized access and misuse. Additionally, as AI systems become more connected, they can also become targets for cyberattacks, making cybersecurity a top priority.

6.2 Bias in AI Algorithms

AI models are trained on historical data, which may contain biases. If not carefully monitored, these biases can be embedded into algorithms, leading to unfair outcomes in areas like loan approvals or credit scoring. For example, certain demographics may be unintentionally disadvantaged due to biased training data. Ensuring fairness and transparency in AI decision-making is a growing concern.

6.3 Regulatory and Compliance Issues

The regulatory landscape for AI in finance is still evolving. Financial institutions must navigate complex compliance requirements while using AI, especially when making decisions that affect customers' financial health. There is a need for clear guidelines and accountability measures to ensure AI is used ethically and in line with legal standards.

6.4 Employment Displacement Concerns

As AI automates more tasks, concerns about job displacement arise. While AI can enhance productivity, it may also lead to reduced demand for certain roles, particularly in back-office operations. This has raised important questions about workforce reskilling and the future role of humans in finance.

Balancing innovation with ethical responsibility is crucial. As AI continues to shape financial services, addressing these challenges will determine its long-term success and acceptance.

7. Future Prospects and Policy Recommendations

The future of AI in financial services is poised for rapid growth, particularly with its potential integration with other emerging technologies. The combination of AI with blockchain and big data analytics is expected to bring greater transparency, speed, and security to financial operations. While AI can interpret patterns and behaviours, blockchain ensures data integrity, and big data enables deeper insights—together, these technologies can revolutionize how financial decisions are made.

To ensure responsible AI use, there is a growing need for strong AI governance frameworks. These should outline ethical standards, accountability mechanisms, and data protection guidelines that organizations must follow. Clear policies can help prevent misuse and ensure fairness in automated decisions, especially in areas impacting consumers directly, such as credit approvals or fraud alerts.

Moreover, collaboration between fintech companies and regulators will play a crucial role in shaping the future landscape. Open dialogue and shared innovation can help create policies that support innovation without compromising security or ethics. Regulators need to stay informed and agile, while fintechs must remain transparent and compliant.

With the right policies and cooperative efforts, AI can continue to transform financial services while building trust, promoting innovation, and protecting consumers.

8. Conclusion

Artificial Intelligence is reshaping financial services by driving efficiency, enhancing customer experience, and enabling smarter decision-making. Its transformative impact is evident across banking, investment, insurance, and risk management. While AI presents vast opportunities, it also brings challenges such as data privacy, bias, and regulatory uncertainty. A balanced approach that embraces innovation while addressing ethical and operational risks is essential. As the financial industry evolves, AI will continue to play a pivotal role. With responsible use and sound policies, AI can lead the sector toward a more inclusive, efficient, and intelligent financial future.

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Characterization of Streptococcus pneumoniae D39 protein SPD_1626 in Escherichia coli

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ABSTRACT

Streptococcus pneumoniae (pneumococcus) is a Gram-positive, encapsulated pathogen responsible for significant global mortality, particularly in children under five years, causing diseases such as pneumonia, sepsis, meningitis, and otitis media. Its virulence is mediated by various factors, including surface-localized, intracellular, and secreted proteins. Among these, S. pneumoniae produces nucleases that degrade Neutrophil Extracellular Traps (NETs), evading host immunity. One such predicted nuclease is Exodeoxyribonuclease III, encoded by the gene spd_1626. This study aims to clone and express spd_1626 in Escherichia coli to facilitate further characterization of its role in pneumococcal pathogenesis.

Keywords: Streptococcus pneumoniae, virulence factors, Exodeoxyribonuclease III, spd_1626, cloning, expression, Escherichia coli.

Full Paper

INTRODUCTION

Streptococcus pneumoniae (also known as pneumococcus) is a Gram positive, bile soluble, encapsulated, alpha hemolytic, aerotolerant, facultative anaerobic and extracellular pathogen, which grows in pairs or chains. Streptococcus pneumoniae uses quorum sensing to communicate and regulate virulence. It is a major cause of mortality. It causes more deaths in children below five years of age than any other infectious disease. The bacterium is known to cause pneumonia, sepsis, meningitis and otitis media.

Quorum sensing (QS) is a cell-to-cell communication mechanism in bacteria that regulates virulence factor production, biofilm formation, and antibiotic resistance in response to

population density. In pneumonia-causing pathogens like *Streptococcus pneumoniae*, QS systems such as *las/rhl* (Gram-negative) and *com* (Gram-positive) modulate the expression of toxins, proteases, and immune evasion factors. Disrupting QS has emerged as a promising therapeutic strategy, as it can attenuate bacterial pathogenicity without inducing lethal pressure that drives resistance. Recent studies highlight the potential of quorum-sensing inhibitors (QSIs) to reduce virulence and improve antibiotic efficacy in pneumonia treatment.

Pneumococcus has plethora of virulence factors that interact with host cells to cause disease conditions. These virulence factors may be cell surface localized, intracellular or secreted. *S. pneumoniae* is reported to release atleast one nuclease which acts against Neutrophil Extracellular Traps (NETs) by degrading its DNA component. Exodeoxyribonuclease III is predicted to be secreted by pneumococcus. Exodeoxyribonuclease III is encoded by *spd_1626*. The objective of this study is to clone and express *spd_1626* in *Escherichia coli*.

MATERIALS AND METHODS

Polymerase Chain Reaction

Polymerase Chain Reaction (PCR) was performed in a 50 μ L reaction mixture containing 10 ng DNA, 2 μ M primers (Forward Primer- DS_1391:5' CCCCCCGGATCCATGAAACTTATCTCATGGAATATTGA 3' T_m= 66 °C; Reverse Primer- DS_1392, 5' CCCCCCTGCAGTTACAAATCAATTTCCAAGACAATC 3' T_m= 64 °C), 2 μ L Pfu MasterMix, and nuclease-free water. Amplification conditions: initial denaturation (94°C, X min); 25 cycles of 95°C (30 sec), 67°C (30 sec), 72°C (1 sec/kb); final extension (72°C, X min). Products were resolved by 0.8% agarose gel electrophoresis.

Restriction Digestion and Ligation

The DNA fragment(s) and vector were digested with BamHI and PstI in 1x TAE buffer. The insert(s) and vector were ligated at a [3:1] molar ratio using T4 DNA Ligase in 1X ligation buffer overnight at 16°C. The reaction was heat-inactivated at 65°C for 10 min.

Transformation

The ligation products were transformed into chemically competent *E. coli* XL1-Blue cells (transformation efficiency: 7.06×10^6 CFU/ μ g DNA) and plated on LB agar (1.6%) supplemented with ampicillin (100 μ g/mL).

Agarose gel electrophoresis

DNA samples were mixed with 6X loading dye and resolved by electrophoresis on a 0.8% agarose gel prepared in 1X TAE buffer (40 mM Tris-acetate, 1 mM EDTA, pH 8.3). Electrophoresis was conducted at 100 V for 30-45 min alongside a 1 kb DNA ladder as molecular weight standard. Gels were stained with ethidium bromide (0.5 μ g/mL) and DNA bands were visualized under UV transillumination using a gel documentation system.

Protein Expression Analysis

The recombinant plasmid, verified through single and double restriction digestion, was transformed into *E. coli* expression strain SG13009. Transformants were selected on LB agar plates supplemented with ampicillin (100 μ g/mL) and kanamycin (50 μ g/mL). Bacterial cultures were grown at 37°C until reaching an OD600 of 0.5-0.6, followed by induction with 1 mM IPTG for 2 hours at 37°C.

Western blotting

Spd_1626 protein expression was assessed by Western blotting. Briefly, 40 mg cell lysate were subjected to 10% SDS-PAGE and transferred to polyvinylidene fluoride (PVDF) membrane. Membrane was blocked with 3% non-fat skimmed milk for 45 min at room temperature and probed with rat polyclonal anti-spd_1626 antibodies at 4°C for overnight followed by secondary antibody incubation of horsereddish- peroxidase conjugated anti-rat IgG (Jackson ImmunoResearch Laboratories, West Grove, PA) for 2 h at room temperature. Immunoreactive bands were detected by enhanced chemiluminescence (ECL) using immobilon western substrate (Millipore Corporation, Billerica, MA).

RESULTS

PCR amplification of *spd_1626*

The gene encoding *spd_1626* was PCR amplified from genomic DNA of *S. pneumoniae* D39 using following primers.

Forward Primer- DS_1391

5' CCCCCCGGATCCATGAACTTATCTCATGGAATATTGA 3' T_m= 66 °C

Reverse Primer- DS_1392

5' CCCCCCCTGCAGTTACAAATCAATTTCCAAGACAATC 3' T_m= 64 °C

Reaction mixture used for amplifying the gene *spd_1626* is detailed in Table 1.

Component	Volume (μL)	Final Conc.
Water	34.6	
DS_1391 (10μM)	1.2	0.24 μM
DS_1392 (10 μM)	1.2	0.24 μM
Pfu buffer (10X)	10	50X
dNTPs (10 mM)	1	0.2 mM
Pfu Polymerase (2.5 U/μL)	1	0.05 U/μL
D39 genomic DNA (100 ng/μL)	1	2 ng/μL
Total	50	

Table 1. Reaction mixture for PCR amplification of *spd_1626*.

PCR cycle

Touchdown PCR method was used to amplify the gene encoding *spd_1626* using Pfu polymerase. The annealing temperature was decreased by 2°C in every cycle, starting with 67°C for five cycles. This decrease in temperature was done only for five cycles. This method was used to avoid non-specific priming during early cycles. At higher temperature only highly specific primers will bind to its template. The PCR cycling parameters are described in Table 2.

Steps	Temp./Duration	No. of Cycles
Initial denaturation	94 °C/3 min	
Denaturation	94 °C/30 sec	} 5
Annealing	67 (62+5) °C /30 sec	
Extension	72 °C /1min	
Denaturation	94 °C/30 sec	} 25
Annealing	57 (62-5) °C/30 sec	
Extension	72 °C/ 1min	
Final extension	72 °C/ 10min	
Hold	4 °C/ hold	

Table 2. PCR parameters for amplification of spd_1626.

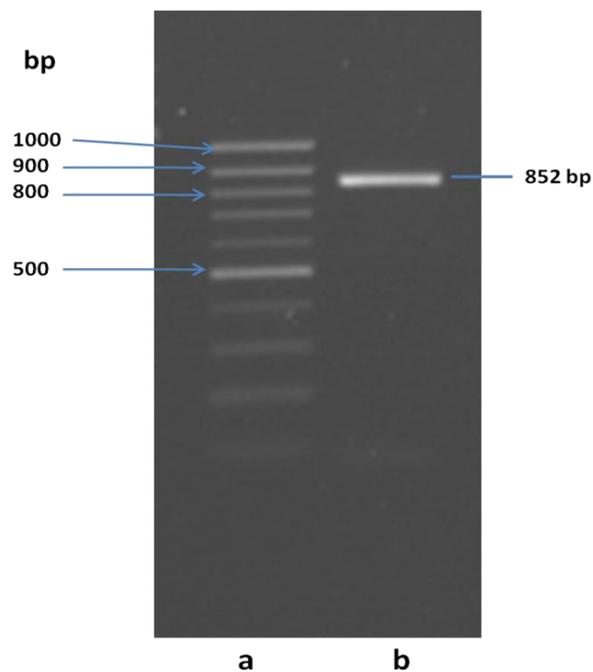


Figure 1. Agarose gel electrophoresis of PCR amplified gene spd_1626. (EtBr stained, 0.8% agarose gel). a. 100 bp DNA ladder, b. PCR amplicon.

After PCR amplification, the amplicon was visualized using agarose gel electrophoresis and the expected amplicon of 852 bp was observed on the gel (Fig. 1).

Ligation of amplified gene

After amplification of *spd_1626*, the amplicon was purified and extracted from the gel using PCR cleanup kit (Real Genomics, Cat no. YDF 100). Purified product and vector pQE30Xa were digested with BamHI and PstI, and restriction digested products were ligated using T4 DNA ligase at 3:1 ratio, 73 ng of PCR amplified product was used against 100 ng of vector.

Transformation

The ligated product or recombinant plasmids were then transformed into the chemically competent *E. coli* XL1-Blue cells and plated on 1.6% LB agar plate containing ampicillin (100 μ L/ml). The prepared competent *E. coli* XL-1 Blue cells had a transformation efficiency of 7.06×10^6 colonies/ μ g of DNA.

Restriction mapping of construct

Transformed colonies were picked from the LB agar plate, and were screened for the presence of recombinant plasmid using plasmid mobility retardation assay and subsequent restriction digestion of plasmid with BamHI and PstI (Fig. 2). In this assay apart from our recombinant plasmids we also got smear at the bottom of agarose gel. This smear may be the RNA contamination; this contamination may arise due to low concentration of RNase used during extraction of plasmids.

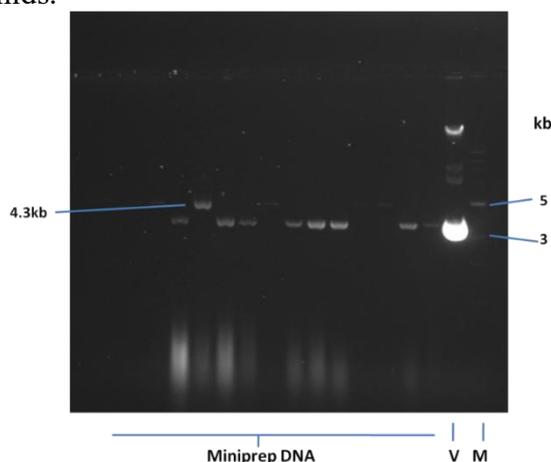


Figure 2. Plasmid mobility shift assay. (EtBr stained, 0.8% agarose) V. vector, M. 1kb DNA ladder.

The recombinant plasmids having correct orientation of the insert were checked using single digestion by HindIII (Fig. 3) and double digestion by EcoRV and NcoI (Fig. 4).

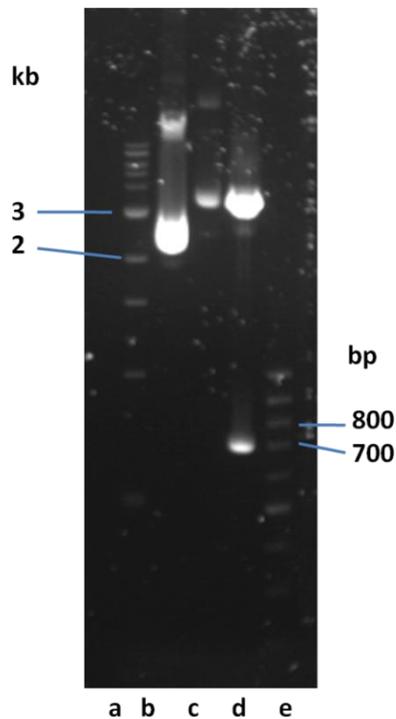


Figure 3. Confirmation of orientation of insert by restriction digestion. (EtBr stained, 0.8% agarose) a. 1kb DNA ladder, b. vector pQE30Xa, c. Construct pQE30Xa+spd_1626, d. HindIII digested construct, e. 100bp DNA ladder.

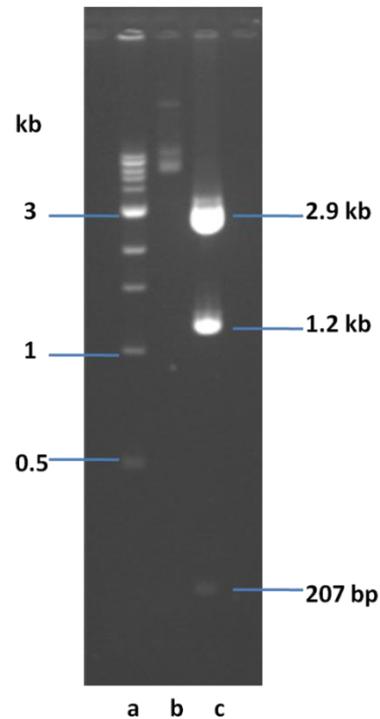


Figure 4. Double digestion of construct. (EtBr stained, 0.8% agarose) a. 1kb DNA ladder, b. uncut vector pQE30Xa+spd_1626, c. Restriction enzyme digestion by EcoRV and NcoI.

Expression of the recombinant SPD_1626

Recombinant plasmid, confirmed by single and double digestion, was transformed into *E. coli* expression strain SG13009 and plated on LB agar plates containing ampicillin (100 µg/ml) and kanamycin (50 µg/ml). Cells were cultured at 37°C till OD reached 0.5-0.6. IPTG (1 mM) induction was given for 2 hr at 37°C and expression profile was observed by SDS-PAGE (Fig. 5); but no significant expression of the desired protein was obtained.

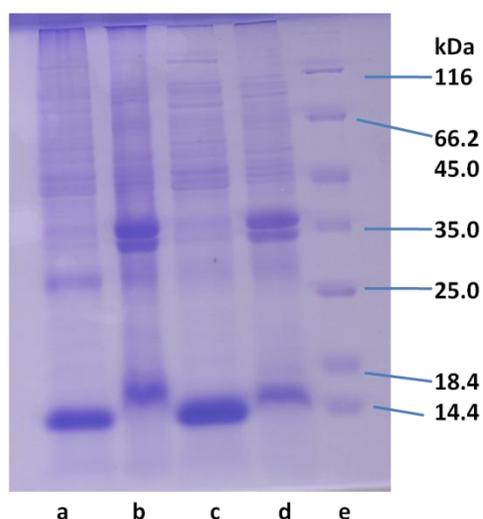


Figure 5. Expression profile of *E. coli* SG13009 having recombinant plasmid. a. uninduced pellet, b. uninduced supernatant, c. induced pellet, d. induced supernatant, e. protein ladder.

Confirmation of expression

As we did not get adequate amount of protein spd_1626 after induction, we tested whether our protein of interest was expressed at all or not. The expressed protein was confirmed using western blot analysis using anti-His antibody) (Fig. 6). The western blot suggests that our protein was expressed in the cell but the concentration was very low.

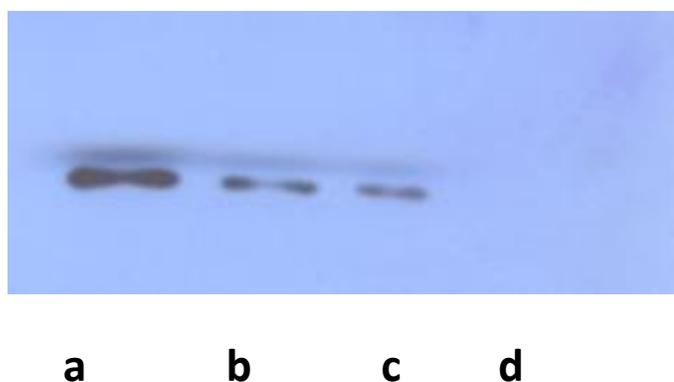


Figure 6. Western blot by anti-His antibody. a&b. IPTG induced, supernatant, c. IPTG induced, pellet, d. uninduced supernatant.

DISCUSSION

A better understanding of pneumococcus biology is essential to combat pneumococcus disease. Characterization of potential secreted virulence may contribute significantly to this purpose. The exodeoxyribonuclease III is one of such protein that may contribute towards escaping from NETs. This protein is encoded by gene *spd_1626*. In this study, we cloned and expressed this gene. We successfully cloned this gene in proper orientation (Fig 2, 3 & 4) and obtained protein in adequate amount.

Since the gene *spd_1626* involves in quorum sensing, therefore deciphering the molecular intricacies of a specific quorum sensing (QS) system is fundamental for the rational design of strategies aimed at modulating downstream bacterial phenotypes. While substantial progress has been achieved in elucidating QS circuitry, the full extent of the regulatory complexity inherent to individual pathways remains inadequately characterized.

The role of Exodeoxyribonuclease III (ExoIII) (encoded by *sp_1626*) in *Streptococcus pneumoniae* underscores its importance in bacterial survival and pathogenesis. As a multifunctional enzyme with 3'→5' exonuclease and AP endonuclease activities, ExoIII is critical for repairing oxidative DNA damage, a common challenge during host infection. Several findings demonstrate that ExoIII-deficient strains exhibit reduced virulence, likely due to impaired resistance to reactive oxygen species (ROS) generated by immune cells. This suggests that ExoIII not only maintains genomic integrity but also enhances pneumococcal fitness in hostile host environments. Targeting ExoIII could thus represent a novel therapeutic strategy, particularly for antibiotic-resistant strains, by sensitizing *S. pneumoniae* to oxidative stress and compromising its pathogenic resilience. Further research should explore small-molecule inhibitors of ExoIII to evaluate their potential as adjunctive therapies.

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RECONCEPTUALIZING THE ROLE OF OMPUTERIZATION IN HIGHER LEARNING: THE NEW NORMAL AND LEARNERS' LIKES

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Abstract

The COVID-19 pandemic forced universities worldwide to rapidly rethink and adapt their approaches to teaching. In response, newly developed technologies, increased use of existing online platforms, and alternative methods for engaging students—both in-person and virtually—have now become part of the "new normal" in higher education.

This research aims to explore two key questions: How do students in higher education perceive the evolving role of technology in the classroom? And, does an overload of technology hinder the potential benefits that blended learning environments can offer?

To investigate these questions, in-depth semi-structured interviews were conducted with eight students from two seminar groups. The findings reveal that students generally hold a positive view of technology in both physical and virtual learning spaces and continue to express interest in its use.

The study offers concrete examples and recommendations to support the effective integration of technology in three critical areas: the learner, the educator, and the technological tools themselves. Ultimately, this research contributes valuable insights to the constructivist approach to learning—particularly in relation to technology use in both current and post-pandemic teaching practices.

The pandemic presented higher education institutions with unprecedented challenges, compelling them to transform traditional course delivery models in a matter of weeks. As a result, technology has become a central element of day-to-day classroom activities. Prior research suggests that digital tools can lead to improved learning outcomes, more effective assessment strategies, and a more efficient way of delivering education to a broad range of learners.

Keywords: Pedagogy, blended learning, constructivism, edutainment, technology

INTRODUCTION

In recent years, the use of technology in higher education has grown significantly. From online courses and digital textbooks to learning management systems (LMS), computerization has transformed how education is delivered and experienced. The COVID-19 pandemic only accelerated this shift; pushing institutions to adopt new digital tools at an unprecedented pace and introducing what many now refer to as the “new normal” in education.

As a result, universities have had to rethink their teaching methods, considering students’ evolving needs, preferences, and the challenges that come with learning in increasingly digital environments.

MAIN FOCUS

This article examines how computerization is reshaping higher education in the post-pandemic era. It explores how technology is changing teaching and learning practices, the challenges and opportunities this shift brings, and how institutions can better align digital learning experiences with students’ needs in a rapidly changing educational landscape.

The Changing Landscape of Higher Education

Traditionally, higher education has centered on face-to-face lectures, printed materials, and physical classrooms. However, technological advancements have steadily disrupted this model. The rise of personal devices, high-speed internet, and cloud-based platforms has made education more accessible, flexible, and interactive than ever before.

Platforms like Coursera, edX, and Khan Academy have opened up learning opportunities to millions, allowing students to learn at their own pace, from anywhere in the world. Similarly, LMS platforms such as Moodle, Blackboard, and Canvas have become essential tools for organizing course content, submitting assignments, managing grades, and fostering communication between educators and learners.

The pandemic dramatically accelerated the shift to digital learning. Almost overnight, institutions had to move courses online. While the transition was challenging, it demonstrated the resilience and adaptability of both teachers and students and underscored the critical role technology now plays in education.

Challenges and Opportunities

While the integration of technology has brought many benefits, it also comes with its own set of challenges.

1. The Digital Divide

One of the biggest concerns is the unequal access to technology. While students in well-resourced environments generally have access to laptops and reliable internet, those in underserved communities often struggle with digital connectivity. Closing this gap is vital to ensuring that all students can benefit from the digital transformation of education.

2. Information Overload and Isolation

The vast amount of online resources can sometimes overwhelm learners. Without proper guidance, students may feel lost or disengaged. Additionally, the lack of in-person interaction in fully online settings can lead to feelings of isolation—especially for those who thrive on social interaction.

3. New Opportunities for Personalized Learning

On the other hand, technology enables more personalized learning experiences. Adaptive learning systems can adjust content and pace based on individual student performance, helping learners better understand challenging concepts.

4. Collaborative Learning

Technology also supports collaborative learning. Online forums, group projects, and virtual classrooms offer new ways for students to connect, share ideas, and learn from each other, regardless of location.

Strategies to Meet Learners' Needs

To make the most of technology in higher education, educators must design digital learning experiences that are student-centered. Here are some key strategies:

Flexibility: Offer varied learning paths, assessment types, and timelines to accommodate different learning styles and personal circumstances.

Engagement: Use multimedia tools—such as videos, quizzes, and simulations—to make learning more interactive and dynamic.

Collaboration: Incorporate opportunities for peer-to-peer interaction, such as group assignments or online discussions, to promote teamwork and a sense of community.

Support Systems: Provide students with access to technical and academic support to help them navigate digital tools and course content effectively.

Timely Feedback: Use digital assessment tools to offer instant, constructive feedback so students can track their progress and stay motivated.

The Evolution of Computerization in Higher Learning

Initially, computers in education were used for basic administrative tasks or supplemental resources. However, with the rise of the internet and powerful software, they've evolved into core components of teaching, learning, research, and communication.

Today, students have access to online lectures, virtual labs, interactive simulations, and more—all available on demand. Educators can create customized learning paths, track student progress, and deliver engaging content that caters to various learning preferences.

The Role of Computerization Today

Computerization now plays several vital roles in modern higher education:

Improving Access and Equity: Digital platforms allow students in remote or underserved areas to participate in higher education.

Enabling Personalized Learning: Through AI and data analytics, platforms can tailor educational experiences to individual needs.

Fostering Collaboration: Students and faculty can work together across time zones and borders using online tools and social platforms.

Encouraging Innovation: Technologies such as virtual reality (VR), simulations, and gamification make learning more immersive and interactive.

Addressing the Challenges

Despite the many advantages, institutions must also confront some key issues:

Bridging the Digital Divide: This includes ensuring all students have access to the necessary hardware, software, and internet connectivity.

Upgrading Infrastructure: Reliable technology infrastructure is essential for delivering consistent and high-quality digital learning experiences.

Rethinking Pedagogy: Teachers need on-going training and support to effectively integrate technology into their teaching in ways that truly enhance learning.

Protecting Data and Privacy: As more learning happens online, safeguarding student data and respecting privacy is critical.

Reconceptualising Computerization in Higher Education

As we move forward, stakeholders—educators, institutions, policymakers, and tech developers—must take a holistic and student-centered approach to digital education. This means:

Promoting Equity and Inclusion: Ensuring all students have the tools they need to succeed, regardless of their socioeconomic background.

Encouraging Innovation in Teaching: Supporting experimentation with new teaching methods and technologies.

Investing in Faculty Development: Helping educators stay current with digital tools and pedagogical strategies.

Embedding Ethics and Digital Literacy: Teaching students how to engage with technology responsibly, critically, and ethically.

Continuously Evaluating Impact: Regularly assessing how digital tools affect learning outcomes and refining approaches accordingly.

The New Normal: Adapting to a Digital Future

The pandemic acted as a catalyst for change, but the shift toward digital education was already underway. The new normal features hybrid learning, flexible course delivery, and an increased reliance on digital tools.

In this environment, students are not just passive recipients of information—they're active participants in their own learning journeys. Flipped classrooms, adaptive learning systems, and collaborative platforms are reshaping what higher education looks like.

CONCLUSION

Computerization is now an essential part of higher education, transforming not just how content is delivered, but how students learn and engage with knowledge. While challenges like digital inequality, information overload, and data privacy remain, the benefits—especially in terms of flexibility, personalization, and access—are profound.

To thrive in the digital age, educators and institutions must reconceptualise the role of technology—not as a replacement for traditional learning, but as a powerful tool that, when used thoughtfully, can enhance and expand the educational experience.

By embracing innovation and prioritizing learners' needs, higher education can become more inclusive, engaging, and effective—preparing students for success in a world that continues to evolve.

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Sustainable Business Practices: Redefining Corporate Responsibility in the 21st Century

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ABSTRACT

This research paper explores the evolving landscape of sustainable business practices and how they are reshaping corporate responsibility in the 21st century. The primary purpose is to understand how businesses are integrating sustainability into their core strategies to meet environmental, social, and governance (ESG) goals. Relying on secondary data from credible reports, journals, and case studies, the paper examines the driving forces behind this shift and highlights practical examples from both Indian and global companies. The findings reveal that companies adopting sustainable practices are not only improving their environmental footprint but also gaining long-term competitive advantage and stakeholder trust. Practical implications include insights for business leaders and policymakers aiming to balance profit with purpose. The paper offers original value by presenting a comprehensive overview of sustainability trends, strategies, and challenges, thus contributing to the growing discourse on responsible business in a rapidly changing world.

Keywords: Sustainable Business, Corporate Responsibility, ESG, Triple Bottom Line, Business Ethics, Green Practices

Full Paper

1. Introduction

Sustainable business practices refer to strategies and actions taken by companies to operate in a manner that is environmentally responsible, socially inclusive, and economically viable. These practices aim to minimize negative impacts on the environment and society while ensuring long-term profitability. From reducing carbon emissions and conserving resources to ensuring fair labor practices and ethical governance, sustainable business practices encompass a wide range of initiatives that align corporate goals with broader societal and environmental needs.

The concept of corporate responsibility has undergone significant transformation over the decades. Initially, businesses were primarily focused on profit-making with little regard for their social or environmental footprint. Over time, growing public awareness, global challenges like climate change, and increased stakeholder expectations led to the emergence of Corporate Social Responsibility (CSR). CSR gradually evolved into a more integrated and strategic approach known today as sustainability in business. This shift marks a transition from reactive to proactive responsibility, where sustainability is embedded into the core business model rather than treated as an add-on.

In the 21st century, sustainable business practices have gained critical importance. With global challenges such as environmental degradation, inequality, and resource scarcity, businesses are expected to take a leading role in driving positive change. Investors, customers, employees, and governments now demand greater transparency, accountability, and purpose-driven leadership from corporations.

The objective of this article is to explore the role of sustainable business practices in redefining corporate responsibility in the modern era. It examines key concepts, strategies, and real-world examples to understand how businesses are adapting and evolving. The scope of the article includes analysis of drivers, benefits, challenges, and the future outlook of sustainability in business. By focusing on secondary data sources, this study aims to provide a holistic understanding of the current trends and their implications for the global business community.

2. Conceptual Framework

The foundation of sustainable business practices rests on a set of guiding principles and frameworks that help organizations operate responsibly while creating long-term value. One of the most widely accepted models is the **Triple Bottom Line (TBL)** approach, which emphasizes that businesses should focus not just on profit, but also on people and the planet. In this model, "People" represents social responsibility, such as fair labour practices and community engagement; "Planet" refers to environmental sustainability, like reducing waste and conserving resources; and "Profit" still remains essential, but it is pursued in a way that supports the other two pillars. The TBL encourages businesses to measure success not only by financial gain but by their overall impact on society and the environment.

Another essential framework is the use of **Environmental, Social, and Governance (ESG)** metrics. These indicators help businesses and investors assess how well a company performs in areas beyond financial statements. Environmental metrics track a company's impact on nature, such as carbon emissions or water use. Social metrics examine how the company treats employees, customers, and communities. Governance looks at internal policies, leadership structure, transparency, and ethical conduct. ESG has become an important benchmark for responsible investing and risk management, guiding decisions in boardrooms and investment firms alike.

The **Sustainable Development Goals (SDGs)** set by the United Nations provide a global roadmap for addressing issues like poverty, climate change, gender equality, and clean energy. Businesses

are increasingly aligning their strategies with these 17 goals, recognizing their role in solving global challenges. Companies that contribute to SDGs not only strengthen their brand image but also open up new markets and innovation opportunities.

From a theoretical perspective, **Stakeholder Theory** plays a crucial role in shaping sustainable business practices. This theory suggests that businesses must consider the interests of all stakeholders — including employees, customers, suppliers, communities, and the environment — not just shareholders. This inclusive approach supports long-term growth and trust. Additionally, various **CSR models** such as Carroll's Pyramid of CSR emphasize economic, legal, ethical, and philanthropic responsibilities, encouraging businesses to go beyond compliance and actively contribute to societal well-being.

Together, these frameworks form the backbone of modern sustainability thinking in business. They provide practical tools and ethical guidance for companies to operate responsibly, stay competitive, and meet the expectations of a changing world.

3. Drivers of Sustainable Business Practices

The rise of sustainable business practices is not a coincidence but a response to several powerful forces that are shaping the modern business environment. Companies today are compelled to adopt sustainability not just for ethical reasons but also to remain competitive and relevant. The key drivers include environmental, regulatory, social, and financial pressures that continue to evolve rapidly.

One of the most urgent and visible drivers is **climate change and environmental concerns**. The growing frequency of extreme weather events, rising global temperatures, and biodiversity loss have made it clear that businesses cannot operate in isolation from the environment. Consumers and communities expect businesses to reduce their carbon footprints, manage waste responsibly, and conserve natural resources. Companies that ignore these issues risk damaging their reputation and losing customer trust, while those that address them are seen as forward-thinking and responsible.

Another significant factor is **regulatory pressures and global policies**. Governments around the world are introducing stricter environmental regulations, such as carbon taxes, emission norms, and sustainability reporting requirements. International agreements like the Paris Climate Accord and national initiatives such as India's push for net-zero emissions are compelling businesses to re-evaluate their operations. Compliance is no longer optional; it's a strategic necessity. Companies that anticipate and adapt to these regulations early can avoid penalties and gain competitive advantages.

Consumer awareness and ethical consumption are also powerful drivers. Today's consumers, especially younger generations, are more informed and conscious of the impact of their purchases. They are willing to support brands that align with their values—whether it's eco-friendly packaging, fair labour practices, or cruelty-free products. This shift in consumer behaviour is

forcing companies to rethink product design, supply chains, and marketing strategies to reflect sustainability.

Finally, **investor and stakeholder expectations** are playing a major role in promoting sustainability. Institutional investors, mutual funds, and venture capitalists are increasingly looking at ESG scores before investing. They view sustainable companies as lower-risk and more resilient in the long term. At the same time, employees, suppliers, and communities expect companies to act responsibly and transparently. Meeting these expectations is no longer just about image—it's about building trust, loyalty, and long-term value.

Together, these drivers are pushing businesses toward a more sustainable and responsible future. Companies that embrace these changes are not only contributing to global goals but are also positioning themselves for sustained growth and success.

4. Strategies for Implementing Sustainability in Business

To become truly sustainable, businesses must integrate environmentally and socially responsible practices into every aspect of their operations. This goes beyond surface-level efforts and requires a strategic and long-term approach. Below are some effective strategies that companies are adopting to implement sustainability in their day-to-day functioning.

One of the most impactful strategies is **Green Supply Chain Management**. This involves designing supply chains in a way that minimizes environmental harm and promotes efficiency. From selecting eco-friendly raw materials to optimizing logistics to reduce carbon emissions, companies are rethinking how their products move from source to consumer. Businesses are also working with suppliers who follow sustainable practices, ensuring that responsibility extends beyond their own operations.

Another vital strategy is **Waste Reduction and Energy Efficiency**. Many companies are investing in technologies and systems that help reduce waste, recycle materials, and use energy more efficiently. For example, factories are switching to energy-efficient machinery, offices are adopting paperless systems, and retail outlets are encouraging reusable bags. Reducing water usage, adopting renewable energy sources like solar or wind, and minimizing packaging materials are other common practices that lead to cost savings and environmental benefits.

Sustainable Product Design and Packaging is also gaining attention. Businesses are now designing products that are durable, repairable, and recyclable. In addition, there is a growing move towards biodegradable and minimal packaging to reduce plastic waste. Some companies are adopting a cradle-to-cradle design philosophy, where the product lifecycle is planned to ensure that materials can be reused or safely returned to the environment at the end of their use.

Corporate Social Responsibility (CSR) Initiatives and Community Engagement form another essential pillar of sustainability. Companies are investing in education, healthcare, and infrastructure in the communities where they operate. Some support local artisans and promote

skill development, while others contribute to environmental conservation efforts. These initiatives build goodwill and strengthen the company's relationship with society, leading to long-term mutual benefit.

Ethical Sourcing and Fair Trade Practices are crucial for businesses that rely on global supply chains. Companies are increasingly ensuring that the materials they source are produced under safe working conditions, with fair wages and no exploitation. Certifications like Fair Trade, Rainforest Alliance, or Forest Stewardship Council (FSC) help consumers identify ethically produced goods. Ethical sourcing not only ensures compliance with global standards but also reflects a company's commitment to human rights and social justice.

Together, these strategies demonstrate that sustainability is not a one-time effort but an ongoing journey. When implemented thoughtfully, these practices lead to better risk management, innovation, and brand loyalty. More importantly, they position businesses as responsible entities that are contributing to a better and more sustainable future.

5. Case Studies of Leading Sustainable Corporations

To understand how sustainable business practices work in the real world, it's helpful to look at companies that have successfully integrated sustainability into their operations. These case studies highlight how businesses from different sectors and regions are setting high standards and inspiring others to follow suit.

Example 1: Tata Group (India)

The Tata Group, one of India's oldest and largest conglomerates, has long been associated with ethical business practices and social responsibility. Sustainability is deeply embedded in its philosophy. Tata Steel has been recognized for its efforts in reducing carbon emissions and managing resources efficiently. Tata Power has made significant investments in renewable energy, while Tata Motors is actively developing electric vehicles. Across its companies, Tata emphasizes employee welfare, community development, and environmental stewardship. Its initiatives in education, healthcare, and rural development through the Tata Trusts further demonstrate its commitment to inclusive growth.

Example 2: Unilever (Global)

Unilever, a global consumer goods giant, is widely regarded as a pioneer in sustainable business. Its "Unilever Sustainable Living Plan" aimed to decouple business growth from environmental impact while increasing positive social influence. Unilever has focused on reducing greenhouse gas emissions, water usage, and waste across its supply chain. The company also supports fair trade, ethical sourcing, and gender equality. Brands like Dove,

Lifebuoy, and Ben & Jerry's promote social messages that align with the company's values. Unilever's transparency in reporting its progress has also helped build trust among stakeholders.

Lessons Learned and Best Practices

From these case studies, several key lessons emerge. First, sustainability must be part of a company's core strategy, not just an add-on. Both Tata and Unilever show that long-term planning, consistent leadership, and a clear vision are essential for meaningful impact. Second, engaging stakeholders—whether employees, communities, or suppliers—is crucial for success. Third, transparency in reporting progress and challenges helps build credibility and public trust. Lastly, innovation plays a central role; whether it's through new technologies or sustainable product design, companies must continuously evolve to meet new challenges.

These examples prove that responsible business practices can go hand in hand with profitability and growth.

6. Challenges and Barriers

While sustainable business practices offer numerous long-term benefits, many companies face significant challenges when trying to implement them. These barriers can slow progress and discourage businesses, especially in traditional or resource-constrained sectors.

One of the most common concerns is cost implications and return on investment (ROI). Transitioning to sustainable operations often requires upfront investments in technology, infrastructure, or certifications. For small and medium enterprises, these costs can seem overwhelming. Additionally, the financial returns from sustainability initiatives may take time to materialize, leading to hesitation among decision-makers focused on short-term gains.

Another major challenge is resistance to change in traditional sectors such as manufacturing, mining, or construction. These industries often rely on legacy systems and practices that are not easily adaptable to sustainable models. Employees and managers accustomed to old ways of working may resist new practices, especially when they involve unfamiliar technologies or workflow disruptions.

Lack of awareness and training also poses a significant barrier. Many businesses, particularly in developing regions, are still unaware of what sustainability entails or how to implement it effectively. Employees need proper

training and guidance to adopt new systems and understand their importance. Without this foundation, even well-intended strategies can fail.

Finally, greenwashing and ethical dilemmas can undermine genuine sustainability efforts. Some companies promote misleading claims about their environmental impact to appear responsible without making real changes. This not only erodes public trust but also creates confusion in the marketplace. Moreover, businesses sometimes face difficult trade-offs between profitability and ethics, such as choosing suppliers who are cheaper but not socially responsible.

Overcoming these challenges requires strong leadership, long-term vision, stakeholder involvement, and consistent education. Only with genuine commitment can businesses navigate these obstacles and truly embrace sustainability as a core part of their identity.

7. Future Outlook and Recommendations

The future of sustainable business practices depends heavily on innovation, supportive policies, and education. Innovation and technology will play a key role in driving change—advancements in renewable energy, digital tools for tracking emissions, and circular economy models will help businesses reduce their environmental impact while improving efficiency. However, innovation alone isn't enough. There is a pressing need for policy support and incentives from governments, such as tax benefits, subsidies, and sustainability-linked loans, to encourage businesses, especially small and medium enterprises, to go green.

Equally important is educating future business leaders. Management education must integrate sustainability, ethics, and environmental responsibility into its core curriculum to prepare students for the challenges ahead. As future decision-makers, they will shape the path businesses take. With the right mix of innovation, support, and leadership, the transition to sustainable business can be both achievable and beneficial for society and the planet.

8. Conclusion

Sustainable business practices are no longer optional—they are essential for long-term success and global well-being. This article has explored the concept of sustainability, its evolution in corporate responsibility, key drivers,

implementation strategies, real-world examples, and the challenges faced. It is clear that climate change, stakeholder expectations, and ethical considerations are pushing businesses to act responsibly.

Reaffirming the importance of sustainability, it must be viewed as a strategic priority, not just a moral obligation. Companies that embed environmental and social responsibility into their core operations are more resilient, trusted, and future-ready.

In redefining corporate responsibility for the 21st century, the focus must shift from short-term profits to long-term value creation for all stakeholders. By embracing innovation, policy support, and education, businesses can become powerful agents of positive change, helping to build a more inclusive, equitable, and sustainable future. The time to act is now—and responsibility must begin at the boardroom.

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Some Tactical Decomposable Cyclic BIB and RGD Designs

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Abstract: Tactical decomposition of some cyclic balanced incomplete block (BIB) and regular group divisible (RGD) designs are given which yields μ –resolvable solutions of these designs.

Keywords: Tactical decomposable design; Resolvability, Balanced incomplete block design; Regular group divisible design; Permutation circulant matrix

MSC: 05B05, 62K10

1. Introduction

Let a $(0, 1)$ – matrix N have a decomposition $N = [N_{ij}]_{\substack{i=1,2,\dots,s \\ j=1,2,\dots,t}}$ where N_{ij} are submatrices of N of suitable sizes. The decomposition is called row tactical if row sum of N_{ij} is r_{ij} and column tactical if the column sum of N_{ij} is k_{ij} and tactical if it is row as well as column tactical. If N is the incidence matrix of a block design $D(v, b, r, k)$, D is called row (column) tactical decomposable. D is called uniform row (column) tactical decomposable if $r_{ij} = \alpha(k_{ij} = \beta) \forall i, j$. If each N_{ij} is an $m \times m$ matrix, D is called square tactical decomposable design, STD (m).

Several methods of constructions of tactical decomposable designs may be found in Bekar *et al.* (1982), Singh and Saurabh (2023), Saurabh (2024a, 2025), among others.

A *balanced incomplete block (BIB) design* or a $2 - (v, k, \lambda)$ design is an arrangement of v elements into $b = \lambda(v^2 - v)/(k^2 - k)$ blocks, each of size $k (< v)$ such that every element is replicated r times and any pair of distinct elements occurs together in λ blocks.

The integers v, b, r, k, λ are called parameters of the BIB design and they satisfy the relations: $bk = vr, r(k - 1) = \lambda(v - 1), v \leq b$ (Fisher's inequality). A BIB design is symmetric (S) if $v = b$. Let N be the $v \times b$ incidence matrix of the design. Then

(i) $NN^T = (r - \lambda)I_v + \lambda J_v$ (ii) $J_{1,v}N = kJ_{1,b}$, where I_v denotes the identity matrix of order v , $J_{v,b}$ denotes the $v \times b$ matrix with all entries 1 and N^T denotes the transpose of N .

Let $v = mn$ elements be arranged in an $m \times n$ array. A *regular group divisible (RGD) design* is an arrangement of the $v = mn$ elements in b blocks each of size k such that:

1. Every element occurs at most once in a block;
2. Every element occurs in r blocks;

3. Every pair of elements, which are in the same row of the $m \times n$ array, occur together in λ_1 blocks whereas remaining pair of elements occur together in λ_2 blocks and
4. $r - \lambda_1 > 0, rk - v\lambda_2 > 0$.

A block design $D(v, b, r, k)$ whose b blocks can be divided into $t = r/\mu$ classes, each of size $\beta = v\mu/k$ and such that in each class of β blocks every element of D is replicated μ times, is called an μ – resolvable design. If $\mu = 1$ then the design is said to be resolvable.

Alternatively, if the incidence matrix N of a block design $D(v, b, r, k)$ may be partitioned in to submatrices as: $N = (N_1|N_2|\dots|N_t)$ where each $N_i(1 \leq i \leq t)$ is a $v \times v\mu/k$ matrix such that each row sum of N_i is μ then the design is μ – resolvable.

A block design $D(v, b, r, k)$ is cyclic if its solution may be obtained by adding the elements of a cyclic group $Z_v = \{0,1,2, \dots, v\} \text{ mod } v$ to the initial blocks of the design.

Example 1: A cyclic solution of the BIB design: $v = b = 7, r = k = 3, \lambda = 1$ can be obtained by developing the initial block $(1, 2, 4)$ under addition modulo 7.

2. Tactical decomposable designs

Tactical decomposition solutions of cyclic BIB and RGD designs are obtained using the following theorem:

Theorem 1 [Saurabh (2024b)]: A block design $D(v, b, r, k)$ has a cyclic solution if and only if its incidence matrix may be partitioned into circulant submatrices of order $v(v|b)$.

Example 2: A cyclic solution of the BIB design (HN42) with parameters: $v = 41, r = 10, k = 5, b = 82, \lambda = 1$ is obtained by developing the initial blocks $[(1, 10, 16, 18, 37); (5, 8, 9, 21, 39)] \text{ (mod } 41)$ [see Hall (1998)]. Then its incidence matrix may be expressed as:

$$N = (\alpha + \alpha^{10} + \alpha^{16} + \alpha^{18} + \alpha^{37} | \alpha^5 + \alpha^8 + \alpha^9 + \alpha^{21} + \alpha^{39}), \quad \text{where } \alpha = \text{circ}(0 \ 1 \ 0 \ \dots \ 0)$$
 is permutation circulant matrix of order 41.

Tactical decomposable solutions of some BIB and RGD designs are given in Tables 1 and 2 respectively using Theorem 1 where R stands for resolvability. HNX and RX numbers are from Hall (1998) and Clatworthy (1973) respectively and $\alpha = \text{circ}(0 \ 1 \ 0 \ \dots \ 0)$ is permutation circulant matrix of order v such that $\alpha^v = I_v$.

Although it is well known that a design $D(v, b, r, k)$ generated by some initial blocks is k – resolvable, here we have obtained such solutions using tactical decomposition. Initial blocks of the following designs may be found in Hall (1998) and Clatworthy (1973).

Table 1: Cyclic BIB designs with $r \leq 15$ and their tactical decompositions using circulant matrices

No.	HNX: (v, b, r, k, λ)	Tactical decomposition	μR
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1	<i>HN9</i> : (13, 26, 6, 3, 1)	$N = (\alpha + \alpha^3 + \alpha^9 \alpha^2 + \alpha^5 + \alpha^6)$	3R
2	<i>HN20</i> : (9, 18, 8, 4, 3)	$N = (\alpha + \alpha^2 + \alpha^4 + I_9 \alpha + \alpha^4 + \alpha^6 + I_9)$	4R
3	<i>HN56</i> : (13, 26, 12, 6, 5)	$N = (N_1 N_2);$ $N_1 = \alpha + \alpha^3 + \alpha^6 + \alpha^7 + \alpha^{11} + I_{13},$ $N_2 = \alpha + \alpha^2 + \alpha^3 + \alpha^7 + \alpha^{11} + I_{13}$	6R
4	<i>HN57</i> : (19, 57, 12, 4, 2)	$N = (N_1 N_2 N_3); N_1 = \alpha + \alpha^3 + \alpha^{12} + I_{19},$ $N_2 = \alpha + \alpha^5 + \alpha^{13} + I_{19},$ $N_3 = \alpha^9 + \alpha^4 + \alpha^6 + I_{19}$	4R
5	<i>HN58</i> : (21, 42, 12, 6, 3)	$N = (N_1 N_2);$ $N_1 = \alpha^2 + \alpha^{10} + \alpha^{15} + \alpha^{19} + \alpha^{20} + I_{21},$ $N_2 = \alpha^3 + \alpha^7 + \alpha^9 + \alpha^{10} + \alpha^{16} + I_{21}$	6R
6	<i>HN60</i> : (25, 100, 12, 3, 1)	$N = (N_1 N_2 N_3 N_4); N_1 = \alpha + \alpha^3 + I_{25};$ $N_2 = \alpha^4 + \alpha^{13} + I_{25}, N_3 = \alpha^5 + \alpha^{11} + I_{25},$ $N_4 = \alpha^7 + \alpha^{17} + I_{25}$	3R
7	<i>HN85</i> : (22, 44, 14, 7, 4)	$N = (N_1 N_2);$ $N_1 = \alpha + \alpha^2 + \alpha^3 + \alpha^{16} + \alpha^7 + \alpha^{13} + \alpha^{21},$ $N_2 = \alpha + \alpha^3 + \alpha^4 + \alpha^5 + \alpha^{11} + \alpha^{16} + \alpha^{20}$	7R
8	<i>HN86</i> : (29, 58, 14, 7, 3)	$N = (N_1 N_2);$ $N_1 = \alpha + \alpha^7 + \alpha^{16} + \alpha^{20} + \alpha^{23} + \alpha^{24} + \alpha^{25},$ $N_2 = \alpha^2 + \alpha^3 + \alpha^{11} + \alpha^{14} + \alpha^{17} + \alpha^{19} + \alpha^{21}$	7R
9	<i>HN92</i> : (11, 55, 15, 3, 3)	$N = (N_1 N_2 N_3 N_4 N_5);$ $N_1 = \alpha + \alpha^3 + I_{11}; N_2 = \alpha + \alpha^5 + I_{11};$ $N_3 = \alpha^2 + \alpha^7 + I_{11}; N_4 = \alpha + \alpha^8 + I_{11};$ $N_5 = \alpha^3 + \alpha^5 + I_{11}$	3R
10	<i>HN93</i> : (13, 39, 15, 5, 5)	$N = (N_1 N_2 N_3); N_1 = \alpha + \alpha^2 + \alpha^4 + \alpha^8 + I_{13},$ $N_2 = \alpha + \alpha^3 + \alpha^6 + \alpha^{12} + I_{13},$ $N_3 = \alpha^2 + \alpha^5 + \alpha^6 + \alpha^{10} + I_{13}$	5R
11	<i>HN94</i> : (16, 80, 15, 3, 2)	$N = (N_1 N_2 N_3 N_4 N_5);$ $N_1 = \alpha + \alpha^3 + I_{16}; N_2 = \alpha^3 + \alpha^8 + I_{16};$ $N_3 = \alpha^2 + \alpha^{12} + I_{16}; N_4 = \alpha + \alpha^7 + I_{16};$ $N_5 = \alpha^4 + \alpha^9 + I_{16}$	3R
12	<i>HN95</i> : (16, 48, 15, 5, 4)	$N = (N_1 N_2 N_3); N_1 = \alpha + \alpha^2 + \alpha^4 + \alpha^7 + I_{16},$ $N_2 = \alpha + \alpha^8 + \alpha^5 + \alpha^{10} + I_{16},$ $N_3 = \alpha + \alpha^3 + \alpha^7 + \alpha^{11} + I_{16}$	5R
13	<i>HN101</i> : (31, 155, 15, 3, 1)	$N = (N_1 N_2 N_3 N_4 N_5);$ $N_1 = \alpha + \alpha^{18} + I_{31}; N_2 = \alpha^2 + \alpha^5 + I_{31};$ $N_3 = \alpha^4 + \alpha^{10} + I_{31}; N_4 = \alpha^{20} + \alpha^8 + I_{31};$ $N_5 = \alpha^9 + \alpha^{16} + I_{31}$	3R
14	<i>HN102</i> : (31, 93, 15, 5, 2)	$N = (N_1 N_2 N_3); N_1 = \alpha + \alpha^2 + \alpha^4 + \alpha^8 + \alpha^{16},$ $N_2 = \alpha^3 + \alpha^6 + \alpha^{12} + \alpha^{17} + \alpha^{24},$ $N_3 = \alpha^5 + \alpha^9 + \alpha^{10} + \alpha^{18} + \alpha^{20}$	5R
15	<i>HN108</i> : (61, 183, 15, 5, 1)	$N = (N_1 N_2 N_3);$ $N_1 = \alpha + \alpha^9 + \alpha^{20} + \alpha^{34} + \alpha^{58},$ $N_2 = \alpha^4 + \alpha^{14} + \alpha^{19} + \alpha^{36} + \alpha^{49},$ $N_3 = \alpha^5 + \alpha^9 + \alpha^{10} + \alpha^{18} + \alpha^{20}$	5R

		$N_3 = \alpha^{13} + \alpha^{15} + \alpha^{16} + \alpha^{22} + \alpha^{56}$	
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Table 2: Cyclic RGD designs with $r \leq 10$ and their tactical decompositions using circulant matrices

No.	RGD: $(v, b, r, k, \lambda_1, \lambda_2, m, n)$	Tactical decomposition	μ R
1	R81: (15, 30, 6, 3, 0, 1, 5, 3)	$N = (N_1 N_2);$ $N_1 = \alpha + \alpha^4 + I_{15}, N_2 = \alpha^2 + \alpha^8 + I_{15}$	3R
2	R83: (15, 45, 9, 3, 2, 1, 3, 5)	$N = (N_1 N_2 N_3); N_1 = \alpha + \alpha^7 + \alpha^{13},$ $N_2 = \alpha + \alpha^4 + \alpha^5, N_3 = \alpha + \alpha^3 + \alpha^8$	3R
3	R86: (16, 32, 6, 3, 0, 1, 4, 4)	$N = (N_1 N_2);$ $N_1 = \alpha + \alpha^2 + \alpha^{11}, N_2 = \alpha + \alpha^3 + \alpha^6$	3R
4	R87: (16, 48, 9, 3, 2, 1, 4, 4)	$N = (N_1 N_2 N_3); N_1 = \alpha + \alpha^5 + \alpha^{13},$ $N_2 = \alpha + \alpha^2 + \alpha^{11}, N_3 = \alpha + \alpha^3 + \alpha^6$	3R
5	R92: (24, 72, 9, 3, 0, 1, 4, 6)	$N = (N_1 N_2 N_3); N_1 = \alpha + \alpha^2 + \alpha^{12},$ $N_2 = \alpha + \alpha^3 + \alpha^8, N_3 = \alpha + \alpha^4 + \alpha^{10}$	3R
6	R105: (9, 18, 8, 4, 6, 2, 3, 3)	$N = (N_1 N_2); N_1 = \alpha + \alpha^2 + \alpha^4 + \alpha^7,$ $N_2 = \alpha + \alpha^2 + \alpha^5 + \alpha^8$	4R
7	R117: (15, 30, 8, 4, 1, 2, 3, 5)	$N = (N_1 N_2); N_1 = \alpha + \alpha^3 + \alpha^{11} + I_{15},$ $N_2 = \alpha + \alpha^5 + \alpha^7 + I_{15}$	4R
8	R146: (12, 24, 10, 5, 8, 2, 3, 4)	$N = (N_1 N_2);$ $N_1 = \alpha + \alpha^2 + \alpha^4 + \alpha^7 + \alpha^{10},$ $N_2 = \alpha + \alpha^3 + \alpha^4 + \alpha^7 + \alpha^{10}$	5R
9	R150: (15, 30, 10, 5, 2, 3, 5, 3)	$N = (N_1 N_2);$ $N_1 = \alpha + \alpha^2 + \alpha^3 + \alpha^5 + \alpha^8,$ $N_2 = \alpha + \alpha^2 + \alpha^5 + \alpha^9 + \alpha^{11}$	5R

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“सांस्कृतिक संगम के प्रहरी : रहीम”

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शोध-सारांश

अकबर के नवरत्नों में एक रहीम, हिंदी काव्य धारा में भी अलग और विलक्षण प्रतिभा के धनी कवि थे। हिंदी में बरवै छंद में रचना करने वाले रहीम पहले कवि थे। साथ ही तुर्की, फारसी, उर्दू, संस्कृत, ब्रजभाषा अवधी पर उनका समान अधिकार था।

भारतीय संस्कृति से उन्हें प्रेम था। उनकी अपनी भाषा फारसी- तुर्की, उर्दू थी। पर तत्कालीन काव्यभाषा ब्रजभाषा और अवधी उन्हें प्रिय थी। रहीम की कविताओं में सांस्कृतिक संगम की झलक मिलती है। दरबारी होते हुए भी सामंती विलास उनकी कविताओं से अनुपस्थित है। उनकी पूरी रचना से गुजर जाइए कहीं राजकीय वैभव के चित्र नहीं मिलेंगे ।

रहीम का हृदय विशाल था। उसमें मानवतावाद था। उनकी रचना में लोक प्रेम है। भक्तियुग में लोक भाषा में काव्य लिखे गए- यह लोक जागरण की भाषिक प्रतिष्ठा है। तुलसी, सूर आदि कवियों की लोक कविता में संस्कृत के शब्दों की बहुलता है। रहीम को पढ़िए। अवधी हो या ब्रजभाषा उसमें अपने फारसी ज्ञान की छुआन तक नहीं है ।

धार्मिक सहिष्णुता और सांस्कृतिक विशालता में भी उनकी रचनाएं हिंदी के गिने चुने कवियों जैसी है निश्चय ही रहीम का कवि हृदय मानवीय रस से परिपूर्ण और अनासक्त तथा अनाविल सौंदर्य दृष्टि से समृद्ध था ।

कूट शब्द— विलक्षण, संस्कृति, मानवतावाद, अनासक्त, अनाविल

भूमिका :-

रहीम हिन्दी साहित्य के इतिहास के पन्नों से बाहर के कवि नहीं हैं बल्कि लोक परम्परा के गाढ़े रंग में नहाये हुए मानव जीवन के अनुभव—सिद्ध कवि हैं। धर्म से मुसलमान और संस्कृति के उदात्त भाव—भूमि पर दोहों में अलख जगाते पूरे—पूरे भारतीय हैं।¹ भारत की संस्कृति उनके हृदय में बसी हुई थी। लेकिन दुर्भाग्य से रहीम कवि—हृदय पाकर भी तलवार के धनी सिपाही की जिन्दगी जीते रहे। अकबर के दरबार के नवरत्नों में एक तथा अनेक युद्धों के विजेता रहीम हिन्दी काव्य—धारा में भी अलग—विलक्षण और विचक्षण थे। तुर्की, फारसी, उर्दू, संस्कृत, ब्रजभाषा अवधी पर उनका समान अधिकार था। दोहा, सोरठा सवैया, बरवै छन्दों पर, जिसमें मध्यकालीन कविताएँ लिखी जा रही थी, रहीम को अधिकार था। अवध के लोक जीवन की मिठास उनके बरवै छन्द में है। हिन्दी में बरवै छन्द में रचना करने वाले रहीम पहले कवि थे। महाकवि तुलसी ने तो बरवै छन्द में इनकी प्रेरणा से ही लिखना आरंभ किया था। रहीम न तो भक्तिकाल में समाते हैं, न रीतिकाल में। उनके नीति और उपदेश के दोहों में उनका निजी जीवनानुभव परिलक्षित होता है। अपने अनुभव सिद्ध सृजन के कारण सर्वसाधारण में तुलसीदास की तरह लोकप्रिय हो गए थे। शुक्ल जी लिखते हैं — ‘रहीम को सांसारिक अनुभवों की मार्मिकता को ग्रहण करने की अद्वितीय क्षमता प्राप्त थी। जीवन की सच्ची परिस्थिति के मार्मिक रूप को ग्रहण करने की क्षमता जिस कवि में होगी, वही जनता का प्यारा कवि होगा।’² जीवन की सच्ची परिस्थिति के मार्मिक अनुभव के विरल—अनन्य कवि थे रहीम। भाषा पर जिस कवि को अधिकार होगा उसकी अनुभव साध्य रचना सूर्य की किरण छूकर हँस पड़ने वाले कमलदल के समान प्रस्फुटित होगी। भाषा ही भाव का वाहक, रचना को सुन्दर बनाने का साधन है। अतः शुक्ल जी आगे लिखते हैं — ‘भाषा पर तुलसी—सा अधिकार हम रहीम का भी पाते हैं। ये ब्रज और अवधी, पश्चिमी और पूर्वी दोनों काव्य—भाषाओं में समान कुशल थे।’³

विषय विश्लेषण :-

रहीम की प्रसिद्धि दोहों के कारण है। संख्या में 284 दोहे प्रामाणिक रूप से प्राप्त हैं। 'नायिकाभेद' की गणना तो रीति में ही होगी। लेकिन रहीम का नायिकाभेद काव्यशास्त्र की परम्परा से अलग है। 'नायिकाभेद' में नायिकाभेद के नाम पर स्त्रियों के सौन्दर्य का वर्णन है। अनेक तरह की सर्वसाधारण स्त्रियाँ नगर शोभा में आयी हैं। कुछ तो कामातुर नारियाँ हैं, लेकिन फोकस सर्वसाधारण नारियों पर है, जिसमें कलाकार नारियाँ हैं, किसान हैं, श्रमिक हैं, शिल्पी हैं। एक सौ उन्नीस ऐसे दोहे हैं, जिसमें पचासों नारियाँ नगर की शोभा बढ़ाती हैं। वे सुन्दरी हैं। कामकाजी हैं। पण्य क्रिया करती हैं। धन्धों में लगी हैं। माल बनाती भी हैं, बेचती भी हैं। इनमें कोई ऐसी नहीं है, जो सामंती मिजाज की है। बनजारिन, कुम्हारिन, कसाइन, लुहारिन, तुरकिन, जोगिन, भाटिन, डोमिन, खटकिन, नटिनी, धोबिन, चमारिनी, ठठेरिनी, दललिन – ऐसी ही सर्वसाधारण स्त्रियाँ हैं।

नगर शोभा में जो सर्वसाधारण स्त्रियाँ आयी हैं, उसका गंभीर अर्थ है। रहीम स्त्रियों की देह सौन्दर्य, उसके अंग-अंग का रीतिकालीन चित्रण नहीं करते, बल्कि उसका एक समाज शास्त्र है। वर्णन तो है उनके अंग-अंग का भी, उनकी चेष्टाओं और हाव-भाव का भी, लेकिन ग्राहक को अपनी अदा से अपने सामान बेचने के लिए। रूप का वर्णन रूप के लिए नहीं है, सोदेश्य है। वे सेल्स वीमेन हैं। इनसे ही नगर की शोभा है। रहीम ने उन्मुक्त सुन्दरियों को बाजार में बिठाकर स्त्रियों के हाव-भाव के साथ एक अर्थशास्त्र रचा है। एक जौहरिन है। वह हँस-हँस कर ग्राहक को मोती माणिक्य बेच रही है। यदि उसका प्रियतम होता तो यह काम उसे नहीं करना पड़ता। प्रियतम की याद में उसकी आँखों से अश्रुविन्दु भी टपक पड़ते हैं। रूप की हाट में, सेल्स वीमेन की भूमिका में अपने अभाव को प्रकट नहीं करना चाहती, पर रहीम उसकी पीड़ा समझते हैं। अतः, उन्होंने कहा है --

रहिमन निजमन की व्यथा मन ही राखो गोय।

सुनि अटिलैहें लोग सब बाँटि न लैहें कोय।¹⁴

रहीम की शृंगार चेतना में कर्म है, सौन्दर्य के साथ कौशल है, अर्थशास्त्र है, समाजशास्त्र है। नायिकाभेद भी है तो अवध की लोक चेतना की मिठास से भरी हुई। इनकी नायिका किसान है। प्रिय

का नैकट्य प्राप्त करने के लिए अपने प्रियतम के साथ खेती करती है। बरसात में उसी खुरपी की सहायता से छतरी बनाती है। हिन्दी में ऐसी शृंगार चेतना जिसमें प्रेम भी है, प्रेमालाप भी है और सबसे बढ़कर कर्म करना, या तो प्रियतम के अभाव में बाजार में माल बेचना या प्रियतम के साथ मिलकर काम करना।

रहीम का स्त्री चित्रण केवल 'रूप' रसिक के विनोद के लिए नहीं है उसका आध्यात्मिक टच भी है। जैसे —

आदिरूप की परम दुति घट-घट रहा समाइ।

लघु मन ते मो मन रसन अस्तुति कही न जाइ।⁵

मन और रसना से नारी के रूप की स्तुति जो घट-घट में है , जो परम दुति है। नारी-रूप को रहीम देह की भूमि से ऊपर उठा देते हैं। स्त्री को इतना स्वतंत्र अस्तित्व देने वाला मध्ययुग का कोई कवि नहीं हुआ है। हाट पर माल बेचने वाली एक चतुर रूप की देवी का हावभाव देखिए—

चतुर चितेरिन चित्र हटै, चरव खंजर के भाइ।

हटै आधौ करि डारई, आधौ मुख दिखराइ।⁶

रहीम में शृंगार भी है, हाव-भाव भी है, नारी का यौवन भी है। एक लौकी बेचने वाली नवयौवना के लिए रहीम कहते हैं —

कुच भांटा गाजर अधर मूरा से भुज पाई।

बैठी लौकी बेचई लेटी खीरा खाई।⁷

सब्जी बेचने वाली काछिनी का शारीरिक सौन्दर्य भी साग-सब्जी जैसा हो गया है। प्रेमीजनों को काछिनी के वक्षस्थल को देखकर बैंगन, होठों को देखकर लाल-लाल गाजर और भुजाओं को देखकर मूली के विचार आते हैं। परन्तु इन बातों से अनभिज्ञ काछिनी लौकी बेच रही है और आराम करते हुए खीरा खा रही है।

नामवर सिंह ने रहीम का मूल्यांकन करते हुए लिखा है कि — 'रहीम में लोक प्रेम है और वह लौकिक भूमि पर हैं, वह लौकिक भूमि उदात्त भाव-भूमि है जिसमें हिन्दू देवी-देवताएँ भी हैं, राम-कृष्ण के प्रति अनुराग भी है, धार्मिक उदारता भी है लेकिन आध्यात्मिकता का कोई गाढ़ा रंग नहीं है इससे हुआ यह कि रहीम की कविताएँ पढ़ते समय सर्वसाधारण जन यह भूल जाते हैं कि वे एक आस्थावान मुसलमान थे। रहीम भाव की ऊच्च भूमि पर पहुँच गए थे, जहाँ एक मुसलमान, मुसलमान होकर भी सिर्फ मुसलमान नहीं रह जाता और न ही हिन्दू, हिन्दू रह जाता है। खास बात यह है कि रहीम की उदात्त भावभूमि इसी लोक के बीच की है। इसे किसी अलौकिक आध्यात्म के आधार की आवश्यकता नहीं है।'⁸

भारतीय संस्कृति में कवि चिंतन का भी महत्त्व है। भारतीय संस्कृति में मुसलमान-हिन्दू की एकता की चिंताधारा मध्यकाल में प्रखर रूप में थी। मध्यकाल में मुसलमान हिन्दी कवियों की प्रतिक्रिया दो रूपों में प्रकट हो रही थी। जायसी, कबीर, दादू, उस्मान इस पक्ष में थे कि दोनों जातियों के लोग एक हो जायें, हिलमिल कर रहें। जबकि दूसरा पक्ष था कि हिन्दू मुसलमान एक दूसरे से अलग रहें। रहीम, रसखान, रसलीन, मुबारक दूसरे पक्ष में थे। रहीम हिन्दू-मुस्लिम एकता का मार्ग फिर भी राष्ट्रीयता का मार्ग मानते थे। दोनों कौमों एक हो नहीं सकती, लेकिन दोनों कौमों में एकता हो सकती है, क्योंकि दोनों ही कौमों का देश एक है। रहीम ने यह दिखा दिया है कि वह अपने धर्म में रहते हुए भी भारतीय थे। यही चाहते थे रहीम कि हिन्दू-मुसलमान अलग रहते हुए भी भारतीय हैं। यही कारण है कि रहीम रामचरित मानस, वाल्मीकि रामायण, हिन्दू देवी-देवता, गंगा-यमुना के प्रति आस्थावान थे। उन्होंने 'खेट कौतुक जातकम' नाम से ज्योतिष में एक ग्रंथ भी लिखा था।

दिनकर ने लिखा है — 'इसमें यह अचरज की बात नहीं कि वह हिन्दू अन्य हिन्दुओं से श्रेष्ठ है जो अपने धर्म के सिवा इस्लाम पर भी श्रद्धा रखता है। और वह मुसलमान भी अन्य मुसलमानों से श्रेष्ठ है जो मजहब के सिवा हिन्दू धर्म का भी सम्मान करता है।'⁹

रहीम मुसलमान होकर भी इसलिए श्रेष्ठ थे कि उन्हें हिन्दू धर्म में भी आस्था थी। हिन्दू धर्म का सम्मान करते थे। हिन्दू संस्कृति उन्हें अच्छी लगती थी। भारतीय संस्कृति से उन्हें प्रेम था। उनकी अपनी भाषा फारसी-तुर्की, उर्दू थी। पर तत्कालीन काव्यशास्त्र ब्रजभाषा और अवधी उन्हें प्रिय

थी। अकबर ने बड़े पैमाने पर संस्कृत ग्रंथों का फारसी में अनुवाद कराया था। भारतीय संस्कृति संगम का नींव डाल रहे थे। वहीं सांस्कृतिक संगम रहीम की कविता में जीवित है। रहीम का सांस्कृतिक संगम उन्हें अकबर के दरबार के नवरत्न बना गया। लेकिन रहीम के कुछ दोहों से ऐसा लगता है कि वे दरबारीपन से मुक्त थे या मुक्त होना चाहते थे। जैसे —

‘आदर घटे नरेश ढिग बसे रहे कछु नाहिं।

जो रहीम कोटिन मिले। घिग जीवन जग मांहि।।’¹⁰

यह भी निजी अनुभव की बात है। राजा के पास रहने से करोड़ों की सम्पत्ति मिल सकती है, रहीम को भी मिली थी। लेकिन मनुष्य का आत्मसम्मान बौना हो जाता है। रहीम दानी थे। अपनी अमीरी के अहंकार को छोड़कर पूरी सहृदयता से दान करते थे। दान करते समय अपनी आँख नीचे रखते थे। उन्हें विश्वास था कि देने वाला तो कोई और है, वह तो निमित्त मात्र हैं। रहीम को बुरे दिन भी देखने पड़े थे। अनेक युद्धों के विजेता रहीम की जागीर चली गई, नजरबन्द होना पड़ा, बेटे का सर कलम करके उनको भेंट तक किया गया। इतने बुरे दिन में भी रहीम की आस्था पराशक्ति से नहीं डिगी। उनके दोहे की धार कुंद नहीं हुई। भारतीयता नहीं टूटी। संस्कृति की पवित्रता से मन मलिन नहीं हुआ। सर्वसाधारण संकट उनकी आँखों से ओझल नहीं हुआ। ऐसे थे रहीम, इतने महान्, इतने ऊँचे, इतने नेक दिल इंसान। अपने दुर्दिन में भी उन्हें राम के दिन याद आते थे। अपने लिए नहीं, आम लोगों के लिए, दुर्दिन के मारे सर्वसाधारण के लिए वह कहते हैं —

‘चित्रकूट में रमि रहे रहिमन अवध नरेश।

जा पर विपदा पड़त है सो आवत यदि देश।।

x x x

जो पुरुषारथ ते कहूं सम्पति मिलत रहीम।

पेट लागि वैराट घर तपत रसोई भीम।।’¹¹

राम, कृष्ण, भृगु हनुमान का संदर्भ उनके दोहों में बहुत है। इन हिन्दू देवताओं से उन्हें शक्ति मिलती थी। उनकी पूरी रचना से गुजर जाइए कहीं राजकीय वैभव के चित्र नहीं मिलेंगे। दरबार के नवरत्न थे। लेकिन सामंती विलास उनके दोहों, कवित्त, सवैए, सोरठा में अनुपस्थित है। दरबार में रहकर दरबारीपन नहीं, साम्राज्यवादी कीचड़ में कमल की तरह खिले हुए, दागरहित, निर्मल सामंती धूल की दुर्गन्ध से अलग, बेलाग बचे हुए। साम्प्रदायिक युग में असाम्प्रदायिक व्यक्तित्व, संसार के अनुभव से रंगे हुए। वह कीचड़ का जल अच्छा है, जिसे पीकर कीड़े जीते हैं। समुद्र के खारे जल को कौन बड़ाई करे, जिसे पिया न जा सके। अर्थात् अमीर, साम्राज्यवाद, सत्ता का नशा, धर्म का नशा, साम्प्रदायिक भाव की अकड़ संसार में फालतू है। वाजिब है एकता का भाव, सांस्कृतिक एकता, असाम्प्रदायिकता, सांसारिक कर्म, हाशिए पर पड़े हुआओं के संकट में खड़े होना, उसके साथ सच्ची सहानुभूति, सहज स्नेह।

‘ज्यों चौरासी लख में मानुष देह

त्योहिं दुर्लभ जग में सहज स्नेह।’

रहीम का हृदय विशाल था। उसमें मानवतावाद था। वह द्रवीभूत होने के लिए कल्पना की उड़ान नहीं भरता था। वह संसार के प्रत्यक्ष व्यवहारों से द्रवीभूत होता था।

रहीम की रचना में लोकप्रेम है। भाषा लोकभाषा है। भक्तियुग में लोकभाषा में काव्य लिखे गए – यह लोक जागरण की भाषिक प्रतिष्ठा है। लेकिन लोकभाषा में कविता है, शब्द संस्कृत के हैं। इससे न तुलसी बचे हैं, न सूर। रहीम को पढ़िए। अवधी हो या ब्रजभाषा उनमें अपने फारसी ज्ञान की छुअन तक नहीं है। लोकभाषा लोक से बनी हुई है, मिठास लिए, उसे फारसी की छाँक देकर श्रेण्य नहीं बनाया गया है।

निष्कर्ष :-

रहीम की कविता जीवन-रस से भरी है। कहीं भी लोकप्रेम अनुपस्थित नहीं है। सांसारिक अनुभव गजब का है। पाप-पुण्य का झमेला नहीं। गृहस्थ-संन्यास का बखेड़ा नहीं। स्त्री की स्वतंत्रता की स्थापना है। काम-धंधे का महत्त्व है। संतत्व का पाखंड यहाँ नहीं है। शक्ति का बाह्याचार नहीं है। जो कुछ भी है, मानवीय है, मनुष्य हिताय है, साम्प्रदायिक एकता है, संस्कृति के ताजे स्वरूप में ढला हुआ भारतीयता है, राष्ट्र-प्रेम है। धार्मिक सहिष्णुता और सांस्कृतिक विशालता में भी उनकी रचनाएँ हिन्दी के गिने चुने कवियों जैसी है। निश्चय ही रहीम का कवि हृदय मानवीय रस से परिपूर्ण और अनासक्त तथा अनाविल सौन्दर्य दृष्टि से समृद्ध था।

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Investigation of electrode metals and supporting electrolytes in the electrochemical polymerization of acrylamide.

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Abstract

The electrochemical polymerization of acrylamide in N, N-dimethyl formamide was carried out using electrode of different metals and with different supporting electrolytes. Maximum polymer yield was obtained when Zn metal was used as an electrode. Similarly, among the different tetra alkylammonium or phosphonium halide used as the supporting electrolyte, the yield was maximum with tetrabutylammoniumhexachloroantimonate. The effects of electrode metals and nature of supporting electrolytes on the polymer yield was investigated.

Keywords: Acrylamide, Electrode metal, Supporting electrolyte, Electrochemical polymerization.

Introduction

Both the electrode material and the supporting electrolyte are critical parameters in electrochemical polymerization. Their careful selection and optimization are essential to control the polymerization process and obtain polymer films with desired properties for specific application. The electrode material significantly affects the electrochemical process through several factors such as electron transfer kinetics[1-2], nucleation and growth of polymer films[3], electrocatalysis[4]. Similarly, supporting electrolyte also plays a vital role in electrochemical polymerization by increasing solution conductivity, facilitating ion transport, doping[5] and affecting the electrochemical double layer[6].

Materials and Experimental

Methods Materials

N,N-dimethylformamide (DMF) was purified by fractional distillation. Acrylamide (AA) and supporting electrolytes were of analytical grade and used without further purification.

Polymerization Method

The electrochemical polymerization of AA in DMF with different supporting electrolytes such as $(\text{CH}_3)_4\text{NCl}$, $(\text{C}_4\text{H}_9)_4\text{NI}$, $(\text{C}_4\text{H}_9)_4\text{NSbCl}_6$ etc. was carried out in an H-type sintered cell using different metal electrode like Pt, Zn, Cu, Al, etc. During electrolysis, the locus of polymerization was in the cathode compartment. The polymerization initially furnishes a homogeneous medium and becomes heterogeneous with the increase of polymer conversion. The polymer yields were determined gravimetrically after precipitation in acetone.

In order to investigate the effect of electrode materials on the polymer yields, the polymerization have been carried out at different metal electrodes and

the results are summarized in the table 1. Under the same experimental conditions, superior polymer yields were obtained at Zn than the Pt electrode. Following polymerization rate sequence is obtained for different metal electrodes

Zn > Fe > Pb > Cu > Al > Pt.

Table 1. Effect of different electrode metals on the polymerization of acrylamide (AA) (2.02 mol. L⁻¹) in the Dimethylformamide (DMF) solution of Tetrabutylammonium iodide (TBAI) (0.271 mol. L⁻¹) at 20mA and 25°C.

Electrode Metal	Polymer Yield (%)	Colour of Catholyte
Zn	70.00	Yellow
Fe	65.50	Yellow
Pb	62.16	Colourless
Cu	60.30	Blue
Al	55.35	Colourless
Pt	52.15	Yellow -orange

The adsorption and catalytic activities of the electrode metals, nature of impurities, hydrogen or oxygen overvoltage, the physical state of the electrode may significantly affect the polymerization process. It is also assumed that the electrode surface of the reactive electrodes may change structure during the electrolysis. The electrode materials may react chemically with AA and cations of the corresponding metals may be discharged. Consequently, negative potential of the cathode would counterpart the dissolution of the metal. The absorption and /or catalytic activity of the electrode may also account for the observed differences in the rates.

Similarly, supporting electrolyte has also a significant role in the electrochemical polymerization. It furnishes the conducting medium for passage of electric current. In many cases, it also provides catalytic species which may be free radical or ionic in nature. It also gives necessary counter ions associated with growing active chains and thus the propagation reaction may be significantly affected by the variation of counter ions. In many cases, supporting electrolyte may also act as a terminating agents[7,8]. Therefore, some supporting electrolytes in regard to their suitability in the electrochemical polymerization of AA had been tested and pertinent results are summarized in Table 2.

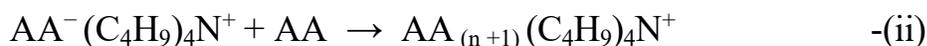
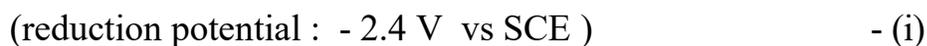
Table 2. Effect of different supporting electrolytes (0.271 mol L⁻¹) on the

polymerization of acrylamide (AA) (2.82 mol L^{-1}) in Dimethylformamide (DMF) at Pt electrodes. Electrolysis time = 120 min; Catholyte vol. = 12.5 mL at $25 \text{ }^\circ\text{C}$.

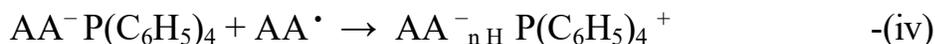
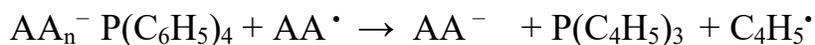
Supporting Electrolyte	Polymer Yield (%)
$(\text{CH}_3)_4\text{NCl}$	42.60
$(\text{C}_4\text{H}_9)_4\text{NI}$	52.15
$(\text{C}_2\text{H}_5)_4\text{NSbCl}_5$	55.50
$(\text{C}_4\text{H}_9)_4\text{NSbCl}_6$	60.30
$(\text{CH}_3)_4\text{NNO}_3$	50.00
$(\text{C}_4\text{H}_9)_4\text{PI}$	35.40

Collins et. al. [9] examined the influence of tetraalkylammonium and tetraarylphosphonium cations on the rate of polymerization in the catholyte. A higher yield with phosphonium salt was obtained in the same electrolysis time even though there was only one-tenth as much as phosphonium salt as the ammonium salt. Contrary to this, in the present work, slightly higher polymer yield was obtained with tetrabutyl salts. On the basis of an intimate ion pair model and the cathodic potentials of the salt, the following propagation mechanism has been advanced.

Propagation with alkylammonium salts



Propagation with phosphonium salts



The reduction of the cation in reaction (iii) results in the formation of polymeric free ion as in reaction (v), which might have been responsible for the observed large increase in the overall rate of the electrochemical polymerization with the aromatic phosphonium salt. No such free ion appears to be generated electrically in the case of alkylquarternary phosphonium cations.

Conclusions

Electrode metals and supporting electrolyte have the active role in electrochemical polymerization. Adsorption and catalytic activities of the electrode metal significantly affect the polymerization process. Similarly, the supporting electrolyte not only makes the solution electrically conducting but it may provide catalytic species for polymerization.

Acknowledgment

The financial support of Gossner College Ranchi to carry out this research is gratefully acknowledged.

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Postpolymerization of Acrylamide in Aqueous Solution

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Abstract

The electrochemical polymerization of acrylamide in aqueous medium was carried out using NH_4NO_3 as a supporting electrolyte. The anolyte became viscous and post polymerization was observed. The effects of impressed current, time of electrolysis and the concentration of monomer on the post polymerization were investigated.

Keywords

Post polymerization, Electrochemical polymerization, Acrylamide.

Full Paper

Introduction

For synthesizing the complex macromolecules, post polymerization offers the most prominent method[1]. Post polymerization allows for the introduction of diverse functionalities which might be challenging or impossible to achieve through direct polymerization of modified monomers[2-4]. Thus, post polymerization may help to increase the versatility and enhance polymer properties in biomedical engineering, gene delivery, water treatment and oil recovery. This paper deals with the electrochemical post-polymerization of acrylamide in its aqueous solution.

Experimental Section

Materials

Acrylamide (AA) and NH_4NO_3 were of analytical grade and used without further purification.

Polymerization Method

The electrochemical polymerization of AA in water with NH_4NO_3 , as a supporting electrolyte was carried out in an H-type sintered cell. The polymer formation did not occur when a solution of AA in water containing NH_4NO_3 was left for 24 h at 25°C . However, when the solution was subjected to electrolysis at 20mA for 2h, polymerization was observed. The locus of polymerization was the anodic compartment and the anolyte became viscous and impressed current decreased with the time of electrolysis, as shown in the figure 1. This might be responsible for the increase of resistance in the polymerizing solution. The remarkable post-polymerization was observed in this electrochemical polymerization of AA i.e., polymer formation continued after the termination of passage of the electric current through the reaction mixture. The post-polymerization of AA mode at different conditions are summarized in Table 1, Table 2 and Table 3.

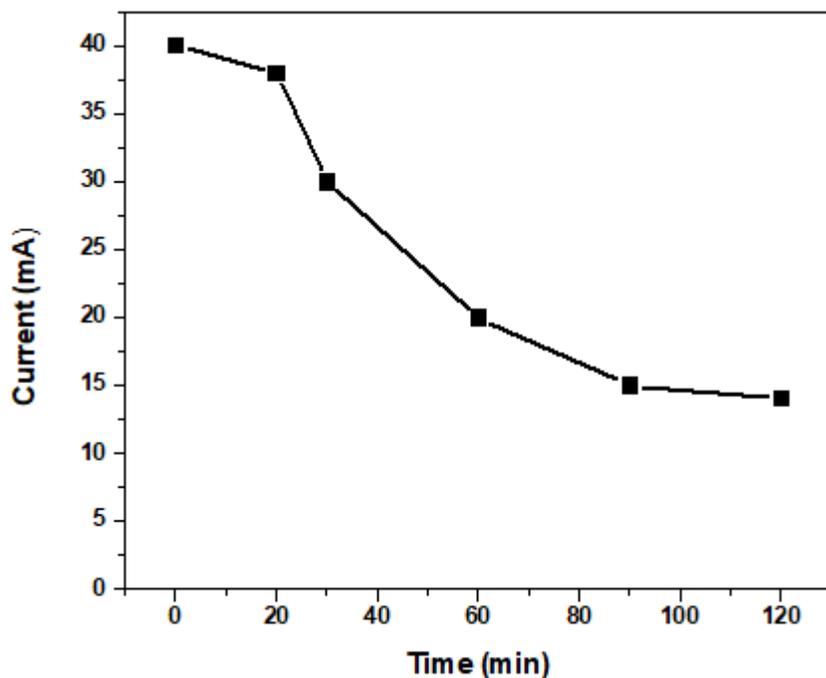


Figure 1. Variation of impressed current with time during the polymerization of AA (6.34 mol L^{-1}) in water at 25°C . Electrode – Pt, Concentration of NH_4NO_3 : 0.30 mol L^{-1} .

Table 1. Effect of current in post-polymerization of Acrylamide (AA) (2.82 mol L^{-1}) in anolyte containing NH_4NO_3 (0.30 mol L^{-1}) in water at $25 \text{ }^\circ\text{C}$. Time of electrolysis = 2h ; Anolyte volume = 12.5 mL.

Current (mA)	Time of post-polymerization (h)	Polymer yield after post-polymerization (%)
10	24	25.0
20	24	34.5
20	36	42.6
40	24	46.3
40	36	Solid gel
50	24	Solid gel
60	24	Solid gel

Table 2. Effect of the time of electrolysis on post-polymerization of Acrylamide (AA) (2.82 mol L^{-1}) in anolyte containing NH_4NO_3 (0.30 mol L^{-1}) in water at $25 \text{ }^\circ\text{C}$. Time of current = 20mA ; Anolyte volume = 12.5 mL.

Time of Electrolysis (h)	Time of post-polymerization (h)	Polymer yield after post-polymerization (%)
1	24	22.8
2	24	34.5
2	36	42.6
3	24	44.0
4	36	48.2
4	24	Solid gel
5	24	Solid gel

Table 3. Effect of Acrylamide (AA) concentrations on post-polymerization of Acrylamide (AA) (2.82 mol L^{-1}) in anolyte containing NH_4NO_3 (0.30 mol L^{-1}) in water at $25 \text{ }^\circ\text{C}$. Time of electrolysis = 2h ; Current = 20mA, Anolyte volume = 12.5 mL.

Monomer Concentration (mol L ⁻¹)	Time of post-polymerization (h)	Polymer yield after post-polymerization (%)
2.82	24	34.5
2.82	36	42.6
4.93	36	Solid gel
6.34	24	Solid gel
7.75	24	Solid gel

Discussions

The post polymerization i.e., continuation even after the termination of the passage of electric current to the reaction mixture is perhaps due to the low termination rate. Such effect has also been reported for the other several systems [5,6]. It is also attributed to the initiating species which got accumulated in the anolyte and continued to cause the polymerization even after the termination of electrolysis.

Acknowledgment

The support of Gossner College Ranchi to carry out this research successfully is gratefully acknowledged.

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