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FROM THE EDITOR-IN-CHIEF'S DESK

Dear Authors, Scholars, and Readers,

It is my distinct honor to introduce Volume 1, Issue 2 (July–September 2026) of the *International Journal of Multidisciplinary Explication and Emerging Research (IJMEER)*. As a quarterly, peer-reviewed, diamond open-access publication, IJMEER serves as a vital global conduit for cutting-edge multidisciplinary scholarship that bridges academic rigor with societal impact.

This second quarterly issue features fifteen original, peer-reviewed research papers contributed by researchers across law, public health, economics, computer science, agriculture, environmental science, chemistry, physics, literature, and social sciences. The breadth of topics published in this issue reflects IJMEER's core mission: encouraging cross-pollination between traditional academic disciplines to address complex contemporary challenges.

In this issue, empirical evaluations of legislative frameworks such as the Prohibition of Child Marriage Act in rural Rajasthan and police preparedness under India's new criminal legislations sit alongside crucial public health investigations into adolescent anaemia in tribal Chhattisgarh. Technical innovations are featured in comparative machine learning for agricultural crop disease detection, while foundational basic science is represented in green nanoparticle synthesis and optical characterisation. Furthermore, empirical inquiries into digital financial literacy, self-help groups, urban water quality, primary educational outcomes, and postcolonial literature enrich this multidisciplinary compendium.

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Dr. Nusrat Ali Hashmi

Editor-in-Chief, IJMEER

Ph.D. in Law | High Court Advocate | Former Principal & Legal Advisor

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Legal Lacunae in India's Whistleblower Protection Act 2014: A Critical Analysis

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Abstract: The Whistleblowers Protection Act, 2014 was enacted with the legislative intent to shield public servants who disclose acts of corruption, misuse of power, or wilful misuse of discretion by government officials. Despite its noble intent, the Act suffers from significant structural and operational deficiencies that render it largely ineffective in practice. This paper undertakes a doctrinal legal analysis of the Act, critically examining its provisions against international standards including the United Nations Convention Against Corruption (UNCAC) and the United Kingdom's Public Interest Disclosure Act (PIDA) 1998. Key lacunae identified include the total exclusion of private sector employees from the Act's protective ambit, the absence of genuine anonymity protection for complainants, inadequate safeguards against retaliation, the ambiguous definition of 'competent authority,' and the non-binding nature of the Central Vigilance Commission's inquiry powers. The study further examines how the proposed Whistleblowers Protection (Amendment) Bill of 2015, which sought to curtail disclosures on national security grounds, was withdrawn in 2019 without a comprehensive replacement, thereby deepening the legislative void. Drawing on Parliamentary Standing Committee reports, CVC annual reports from 2015 to 2022, and documented cases of whistleblower victimisation, the paper argues that India urgently requires a comprehensive legislative overhaul. Recommendations include extending coverage to private entities, establishing an independent national authority, mandating financial compensation, and incorporating strict penal provisions against retaliatory acts.

Keywords: *Whistleblower Protection, Public Interest Disclosure, UNCAC, Legislative Lacunae, Anti-Corruption, Retaliation*

1. Introduction

Whistleblowing — the act of an insider disclosing information about wrongdoing within an organisation to an authority empowered to rectify it — is widely recognised as one of the most effective instruments for detecting and deterring corruption. In the Indian public sector context, the problem of corruption remains acute and pervasive despite various legislative and institutional measures adopted over the past three decades. The Second Administrative Reforms Commission in its Thirteenth Report (2007) observed that the absence of adequate legal protection for whistleblowers had created a culture of silence among public servants who witness maladministration but fear severe professional and personal reprisal.

The Whistleblowers Protection Act, 2014 (WPA 2014) was the legislature's response to growing demands from civil society, the judiciary, and anti-corruption bodies for a comprehensive statutory framework to protect public interest disclosers. The Act was passed in the backdrop of high-profile cases such as the murder of RTI activist Shehla Masood in 2011 and the documented intimidation of senior government employees who reported

financial irregularities in public procurement. The legislation ostensibly created a legal mechanism for complaint-making and provided a degree of protection from victimisation by superior officers.

However, nearly a decade after its enactment, the WPA 2014 has yielded remarkably few successful prosecutions of wrongdoers or effective protections for whistleblowers. Reports of retaliation, arbitrary transfers to remote postings, denial of promotions, and in some cases physical threats against complainants continue to surface with disturbing regularity. Analyses of Central Vigilance Commission data and field documentation by civil society organisations such as Transparency International India suggest that implementation of the Act remains shallow, selective, and largely disconnected from the day-to-day experiences of public servants who wish to report malfeasance.

The legislative framework was further complicated by the introduction of the Whistleblowers Protection (Amendment) Bill, 2015, which proposed to restrict disclosures that allegedly affected national security or sovereignty. Civil society organisations and legal scholars mounted strong opposition, arguing the amendment would effectively gut the Act of its reformative potential. The bill was eventually withdrawn in 2019 without any replacement legislation, leaving the original Act — with all its limitations — as the sole statutory protection for whistleblowers in India. This paper provides a systematic doctrinal critique of those limitations and proposes legislative reform benchmarked against international best practices.

2. Methodology

This study adopts a doctrinal research methodology, relying principally on primary legal sources including the text of the Whistleblowers Protection Act 2014, Parliamentary debates, Standing Committee Reports, CVC annual reports spanning 2015 to 2022, and judicial decisions referencing the Act. The doctrinal method involves systematic analysis, interpretation, and critique of existing legal norms within their textual, contextual, and purposive dimensions, with particular attention to gaps between legislative intent and practical outcome.

Secondary sources include peer-reviewed journal articles from law reviews, policy research reports published by Transparency International India and the Commonwealth Human Rights Initiative (CHRI), and comparative legislative texts from the United Kingdom (PIDA 1998), the United States (Whistleblower Protection Act 1989), and South Africa (Protected Disclosures Act 2000). Comparative legal analysis was employed to benchmark India's framework against established international best practices and to identify structural improvements India can adopt with contextual modifications.

A total of 23 documented cases of alleged whistleblower victimisation, drawn from media archives, CVC annual complaint data, and available court records from 2015 to 2023, were analysed to identify patterns of retaliation and institutional response. No primary field data was collected; the study operates entirely within the domain of desk-based legal research. The paper adopts an evaluative framework derived from the OECD Guidelines for Whistleblower Protection (2012): breadth of coverage, robustness of procedural protections, independence of implementing authority, and adequacy of remedies.

3. Results and Findings

Analysis of WPA 2014 reveals five significant structural lacunae. First, the Act's coverage is confined exclusively to public servants and persons disclosing wrongdoing by public servants. No provision extends protection to employees of private corporations, non-governmental organisations, or multinational companies operating in India. This represents a substantial legislative gap, as the private sector accounts for a rapidly growing share of economic activity and associated institutional misconduct. Large-scale corporate frauds in India's financial sector in recent years have underscored the urgency of private sector coverage.

Second, the Act does not guarantee genuine anonymity to complainants. While Section 4 requires the competent authority to keep the complainant's identity confidential, Section 5(7) permits disclosure if the authority 'considers it necessary.' This phrase is undefined in the statute and provides broad discretionary latitude, effectively rendering the anonymity guarantee illusory in contested or politically sensitive cases. In at least 11 of the 23 cases examined, complainant identity was either disclosed by the authority or independently leaked to the accused department.

Third, the definition of 'competent authority' in Section 2(d) is narrow and incomplete. While the Central Vigilance Commission serves as the competent authority for central government employees, state governments are empowered to designate their own authorities. In several states, no specific authority has been notified, creating an enforcement vacuum. Fourth, the remedial provisions of the Act are inadequate — there is no provision for financial compensation or reinstatement within fixed statutory timelines. Fifth, and critically, prosecutions under Section 16 for retaliation against a whistleblower remain near-zero according to CVC data, constituting a near-total enforcement collapse of the Act's protective machinery.

4. Discussion

The lacunae in WPA 2014 are not merely technical flaws but reflect a deeper policy ambivalence about the desirability of institutionalising whistleblowing within India's administrative culture. The tension between transparency imperatives and security concerns — exemplified by the 2015 Amendment Bill's attempt to bar security-related disclosures — suggests the Indian state has not fully committed to the whistleblower protection paradigm advanced by major international anti-corruption frameworks. A reformed law must navigate this tension without sacrificing the substantive protections that make it effective.

Comparative analysis is instructive. The UK's PIDA 1998, widely regarded as a model legislation, extends protection to workers across all sectors, guarantees compensation through employment tribunals without upper limits in cases of detriment, and places the burden of proof on the employer to justify adverse action. South Africa's Protected Disclosures Act similarly covers private sector employees and provides for reinstatement remedies. India's Act, measured against these benchmarks, fails on multiple dimensions. Ireland's Office of the Protected Disclosures Commission — a fully independent statutory body with prosecutorial powers — illustrates what a robust institutional design might look like for India.

The pattern of documented retaliation analysed in this study suggests that without structural independence of the implementing authority, complainants will continue to face institutional backlash regardless of procedural amendments. Critics argue that expansive whistleblower protection frameworks may be misused for political purposes or to leak genuinely sensitive information. These concerns, while legitimate, should be addressed through calibrated procedural safeguards — such as a good-faith threshold requirement and a rapid first-filter review — rather than through weakening substantive protections, which undermines the law's deterrent value against genuine corruption.

5. Conclusion

India's Whistleblowers Protection Act, 2014 stands as a legislative promise unfulfilled. The Act's narrow scope, procedural infirmities, inadequate remedies, and flawed institutional design collectively undermine its stated objective of protecting those who speak truth to power in the public interest. The withdrawal of the 2015 Amendment Bill without a replacement has deepened rather than resolved the legislative vacuum.

This paper recommends: (i) extending the Act's coverage to private sector employees with appropriate definitional adaptations; (ii) establishing an independent National Whistleblower Protection Authority with

investigative and prosecutorial powers; (iii) mandating financial compensation and safe reinstatement as default remedies within sixty-day statutory timelines; (iv) incorporating strict criminal liability for retaliation with burden-of-proof reversal; and (v) providing ex parte interim protection orders to shield complainants while investigations are pending. Whistleblower protection is not merely an anti-corruption tool — it is a cornerstone of democratic governance. India's commitment to the rule of law demands a comprehensive legislative overhaul aligned with international standards.

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Child Marriage and the Prohibition of Child Marriage Act 2006: Judicial Interpretations and Implementation Gaps in Rural Rajasthan

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Abstract: India continues to witness persistently high rates of child marriage, particularly in rural and tribal areas, despite the enactment of the Prohibition of Child Marriage Act (PCMA) 2006. This paper investigates the legislative architecture of the PCMA 2006, critically analyses conflicting judicial interpretations regarding the legal validity of child marriages — specifically the void versus voidable controversy — and empirically documents implementation gaps in three rural districts of Rajasthan: Tonk, Sawai Madhopur, and Baran. The study draws on analysis of district-level court records, block-level Child Marriage Prohibition Officer (CMPO) reports for the period 2019 to 2023, and structured interactions with gram panchayat functionaries, school teachers, and social workers. Findings reveal that CMPOs across the study districts remain severely understaffed and lack mandatory legal training, that the voidability provision of the 2006 Act incentivises families to solemnise child marriages before filing complaints to delay legal proceedings, and that frontline service providers including Anganwadi workers lack adequate knowledge to invoke available legal remedies. The paper analyses the Supreme Court's landmark judgment in *Independent Thought v. Union of India* (2017) and its limited trickle-down impact on rural compliance. Recommendations include amending the PCMA to declare all child marriages void ab initio, creating a dedicated implementation fund for CMPO capacity-building, and integrating legal literacy on PCMA provisions into ASHA and Anganwadi training curricula.

Keywords: *Child Marriage, PCMA 2006, Judicial Interpretation, CMPO, Rajasthan, Implementation Gap*

1. Introduction

Child marriage — defined under the Prohibition of Child Marriage Act 2006 as a marriage to which either party is below the age of 18 years for girls and 21 years for boys — remains a significant human rights violation and a barrier to gender equity and development in India. According to the National Family Health Survey-5 (NFHS-5, 2019–21), approximately 23.3% of women aged 20–24 in India were married before the age of 18 years, with Rajasthan reporting one of the highest rates at 25.4%, well above the national average despite years of targeted interventions.

The Prohibition of Child Marriage Act, 2006 replaced the earlier Child Marriage Restraint Act, 1929 and sought to create a stronger legal framework by empowering Child Marriage Prohibition Officers (CMPOs), enabling injunctions against impending marriages, and providing for enhanced punishments. However, the 2006 Act conspicuously retained the provision that child marriages, once solemnised, are voidable rather than void — a legislative choice that has generated persistent judicial controversy and has been widely identified as a fundamental weakness of the law.

The Supreme Court's judgment in *Independent Thought v. Union of India* (2017), while primarily addressing the issue of marital rape exceptions, also clarified aspects of the PCMA's interaction with personal law. However, the broader question of whether child marriages should be declared void ab initio — rather than merely voidable at the option of the child — remained unresolved and was subsequently the subject of legislative deliberation following the Supreme Court's directions to Parliament in November 2023 in the Hardev Singh case. The tension between statutory law and personal law in matters of marriage continues to impede effective enforcement of the PCMA in states like Rajasthan.

This study seeks to bridge the gap between the law as enacted and the law as experienced in rural Rajasthan, where social norms, economic compulsions, and institutional failures converge to perpetuate the practice of child marriage. The paper proceeds by presenting the research methodology, analysing key judicial interpretations, documenting empirical implementation gaps, and concluding with targeted reform recommendations.

2. Methodology

This paper employs a mixed-methods approach combining doctrinal legal analysis with field-based empirical observation. The doctrinal analysis encompassed a review of the PCMA 2006 and its provisions, related subordinate legislation, Parliamentary debates, and judicial decisions from the Supreme Court and Rajasthan High Court pertaining to child marriage. Particular attention was paid to cases involving conflict between the PCMA and provisions of personal law statutes including the Muslim Personal Law (Shariat) Application Act, 1937.

The empirical component was conducted across three purposively selected districts in Rajasthan — Tonk, Sawai Madhopur, and Baran — which consistently report above-average rates of child marriage in state government data. District court records (civil and criminal) relating to PCMA cases for the period 2019 to 2023 were accessed with appropriate permissions. Block-level CMPO reports and Women and Child Development department records were obtained through Right to Information applications. Structured interviews were conducted with 18 stakeholders comprising gram panchayat pradhans, school principals, ASHA workers, and civil society volunteers working in the area of child protection.

Ethical clearance was obtained from the institutional review board of Rajkiya Mahavidyalaya, Tonk. All interview participants provided informed consent, and individual identities have been anonymised in this report. Qualitative data was subjected to thematic analysis using an inductive coding framework. Quantitative data from government records was analysed using descriptive statistics. The combined methodology enables triangulation of legal analysis with ground-level implementation realities.

3. Results and Findings

Analysis of CMPO staffing records revealed critical institutional deficiencies. Across the three study districts, only 4 of 18 designated block-level CMPO positions were filled with dedicated personnel; the remaining posts were held by officials with multiple collateral duties who reported spending less than five percent of their working time on child marriage prevention. None of the CMPOs interviewed had received formal legal training on the provisions of the PCMA 2006 or had initiated a pre-marriage injunction proceeding under Section 13 of the Act in the period 2019–2023.

Court records revealed a striking pattern: of 67 registered PCMA cases across the three districts, 61 were complaints filed after the marriage had already been solemnised. Only 6 cases involved pre-marriage injunctions, of which 4 were dismissed at the preliminary stage due to procedural defects in the petition. The voidable rather than void status of child marriages was identified as a key contributing factor: families strategically completed

marriage rituals before approaching the court or before CMPOs could intervene, knowing that a subsequent voidability petition would require the minor herself to file — an action rarely taken in conservative rural settings.

Stakeholder interviews revealed that frontline workers lacked basic awareness of their legal duties. Only 3 of 12 Anganwadi workers interviewed could correctly identify the minimum marriage age for girls under the PCMA. Nine of 18 gram panchayat functionaries stated they believed child marriages under personal law were legally valid regardless of the PCMA, reflecting a widespread misconception with significant enforcement implications. The Supreme Court's 2017 judgment in *Independent Thought* was unknown to virtually all non-legal stakeholders interviewed, underscoring the absence of legal literacy dissemination mechanisms.

4. Discussion

The void versus voidable distinction in the PCMA 2006 has long been identified by legal scholars as the Act's most significant substantive weakness. A void marriage would carry no legal consequences whatsoever, removing any incentive for families to proceed with a child marriage and making post-facto legal proceedings unnecessary. A voidable marriage, by contrast, requires affirmative action by the minor to seek annulment — an action that, in the patriarchal and economically constrained rural contexts studied, is rarely a realistic option for young girls. The Supreme Court's directions to Parliament in November 2023 to address this lacuna represent a positive development, but legislative action remains pending.

The conflict between the PCMA and personal law statutes continues to generate judicial uncertainty. While the Supreme Court's position in *Independent Thought* (2017) implicitly strengthened the PCMA's applicability across religious communities, High Court decisions from several states have at times carved out exceptions based on personal law, creating a patchwork of enforcement that undermines the Act's universality. A clear legislative provision explicitly stating that the PCMA supersedes personal law in all matters of child marriage would eliminate this uncertainty.

The institutional incapacity of CMPOs documented in this study mirrors findings from similar studies in other states, suggesting a systemic rather than state-specific failure. The root cause appears to be the model of assigning child marriage prevention duties as an add-on responsibility to existing officials rather than creating dedicated positions with specialised training and resources. The Maharashtra model — which has piloted dedicated district child protection cells with legal expertise and community liaison functions — may offer a workable template for Rajasthan.

5. Conclusion

This paper has documented a significant gap between the legislative intent of the Prohibition of Child Marriage Act 2006 and its practical implementation in rural Rajasthan. Structural institutional deficiencies, the voidable rather than void legal status of child marriages, conflicts with personal law, and near-absent legal literacy among frontline workers collectively perpetuate the practice despite statutory prohibition.

Targeted recommendations include: (i) amending the PCMA to declare all child marriages void ab initio as per the Supreme Court's directions; (ii) explicitly providing that the PCMA supersedes personal law in all cases; (iii) creating dedicated, adequately remunerated CMPO positions with mandatory legal training; (iv) integrating PCMA legal literacy modules into Anganwadi and ASHA worker training programmes under the NHM and POSHAN Abhiyaan; and (v) establishing district-level rapid response teams empowered to seek ex parte injunctions. Child marriage is a multi-dimensional problem requiring convergent action across legal, institutional, and social domains.

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Prevalence and Determinants of Anaemia Among Adolescent Girls in Tribal Districts of Chhattisgarh: A Cross-Sectional Study

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Abstract: Anaemia remains a persistent public health burden in India, disproportionately affecting adolescent girls in tribal and rural populations. This cross-sectional study was conducted across three tribal-majority districts of Chhattisgarh — Bastar, Narayanpur, and Bijapur — to assess the prevalence and determinants of anaemia among adolescent girls aged 10 to 19 years. A total of 450 participants were enrolled through cluster sampling from government school and Anganwadi settings. Blood haemoglobin levels were measured using a calibrated digital haemoglobinometer, and a validated structured questionnaire gathered data on dietary habits, menstrual patterns, household socioeconomic characteristics, and awareness of the POSHAN Abhiyaan. The study found an overall anaemia prevalence of 67.6% by WHO haemoglobin cut-offs, of which 29.1% was classified as severe (Hb below 7 g/dL), 48.3% as moderate, and 22.6% as mild. Multivariate logistic regression identified low dietary iron intake (OR=3.21, 95% CI: 2.14–4.82), irregular consumption of iron-folic acid tablets (OR=2.87, 95% CI: 1.93–4.28), and below-poverty-line household status (OR=2.14, 95% CI: 1.42–3.22) as significant independent determinants. Access to POSHAN Abhiyaan services was negatively associated with anaemia severity. Findings underscore the urgent need for targeted nutritional interventions, improved IFA distribution mechanisms, and community-level health education in Chhattisgarh's tribal districts.

Keywords: *Anaemia, Adolescent Girls, Tribal Population, Chhattisgarh, POSHAN Abhiyaan, Iron-Folic Acid*

1. Introduction

Anaemia, defined by the World Health Organization as a haemoglobin concentration below 12 g/dL in non-pregnant adolescent girls, is among the most prevalent nutritional disorders globally, affecting approximately 1.62 billion people worldwide. In India, anaemia among adolescent girls is a particularly acute public health concern: the National Family Health Survey-5 (NFHS-5, 2019–21) reported that 59.1% of non-pregnant women aged 15–19 years were anaemic nationally, with tribal-populated states such as Chhattisgarh recording substantially higher proportions.

The consequences of adolescent anaemia extend well beyond immediate health impacts. Anaemia in adolescent girls is associated with impaired cognitive development, reduced physical capacity, poor academic performance, increased susceptibility to infections, and, when anaemia persists into pregnancy, substantially elevated risks of maternal and perinatal mortality. In tribal communities of central India, where dietary diversity is

limited, food insecurity is widespread, and access to healthcare facilities remains constrained, adolescent girls face a compounded vulnerability that standard national-level interventions often fail to adequately address.

The Government of India has implemented several programmes to combat nutritional deficiencies among adolescents, including the Weekly Iron and Folic Acid Supplementation (WIFS) programme and the more comprehensive POSHAN Abhiyaan (National Nutrition Mission) launched in 2018. While these programmes have shown measurable impact in some states, implementation gaps in remote tribal districts — particularly those in Chhattisgarh's southern region — remain poorly documented. District-level anaemia prevalence data is often missing or out of date, making it difficult to target interventions effectively.

This study was designed to fill this knowledge gap by generating district-specific, disaggregated data on anaemia prevalence and its determinants among adolescent girls in three of Chhattisgarh's most tribal-concentrated districts. The findings are intended to inform the design of more contextually appropriate and effective nutritional interventions at the block and district level.

2. Methodology

A cross-sectional study design was adopted. The study population comprised adolescent girls aged 10 to 19 years residing in Bastar, Narayanpur, and Bijapur districts of Chhattisgarh. These districts were selected purposively on the basis of their high proportion of Scheduled Tribe population (above 65%), their remote geographic location, and documented deficits in healthcare infrastructure as per Chhattisgarh HMIS data for 2021–22. A two-stage cluster sampling design was employed: in Stage 1, 15 clusters (government schools and Anganwadi centres) were selected per district using probability proportional to size sampling; in Stage 2, 10 eligible girls were selected per cluster using systematic sampling, yielding a total sample of 450 participants (150 per district).

Haemoglobin estimation was performed using a Hemocue Hb 301 haemoglobinometer, which was calibrated daily using the manufacturer's standard cuvette. Blood samples were collected by trained ANMs using capillary fingerprick technique following standard aseptic precautions. WHO cut-offs were used to classify anaemia severity: mild (Hb 10.0–11.9 g/dL for girls aged 12–19; 11.0–11.9 g/dL for girls aged 10–11), moderate (Hb 7.0–9.9 g/dL), and severe (Hb below 7.0 g/dL). A pre-tested structured questionnaire, available in Hindi and the Halbi dialect, was administered by trained female field investigators to gather data on dietary habits (24-hour dietary recall), IFA tablet receipt and adherence, menstrual pattern, socioeconomic status, and exposure to POSHAN Abhiyaan services.

Data were entered into Epi Info version 7.2 and analysed using SPSS version 23.0. Descriptive statistics were computed for all variables. Chi-square tests were used to assess bivariable associations between anaemia status and categorical independent variables. Variables significant at $p < 0.25$ in bivariable analysis were entered into a multivariate binary logistic regression model to identify independent predictors of anaemia. Ethical approval was obtained from the Institutional Ethics Committee of Government Medical College, Dhamtari (Ref. IEC/GMC/DTR/2022/034). Written informed consent was obtained from participants and their parents or guardians.

3. Results and Findings

Of the 450 participants, 448 had valid haemoglobin readings; two samples were excluded due to haemolysis. Overall anaemia prevalence was 67.6% ($n=303$). Among those diagnosed with anaemia, 29.1% had severe anaemia (Hb below 7 g/dL), 48.3% had moderate anaemia, and 22.6% had mild anaemia. Bijapur district recorded the highest prevalence at 74.2%, followed by Narayanpur (68.9%) and Bastar (59.4%). The mean haemoglobin value for the entire sample was 9.8 g/dL ($SD=2.1$), significantly below the WHO threshold for all age-sex categories represented.

On dietary assessment, 72.4% of anaemic girls reported consuming iron-rich foods (leafy vegetables, legumes) less than three times per week. Among the 448 participants, 241 (53.8%) reported receiving IFA tablets from school or Anganwadi sources in the preceding three months; of these, only 118 (49.0%) reported consuming the tablets regularly as advised, with common reasons for non-adherence including forgetfulness (42%), side effects (nausea and constipation) (31%), and loss of tablets (18%). Menstrual irregularity was reported by 38.4% of severely anaemic girls. Prevalence of anaemia among girls from BPL households was 76.3% compared to 54.1% among non-BPL households ($p<0.001$).

Multivariate logistic regression identified four independent significant predictors of anaemia: low dietary iron intake (OR=3.21; 95% CI: 2.14–4.82; $p<0.001$), irregular IFA tablet consumption (OR=2.87; 95% CI: 1.93–4.28; $p<0.001$), BPL household status (OR=2.14; 95% CI: 1.42–3.22; $p<0.001$), and absence of access to POSHAN Abhiyaan Anganwadi services (OR=1.78; 95% CI: 1.18–2.68; $p=0.006$). Age, district of residence, and school enrolment status were not independently significant after controlling for other covariates in the multivariate model.

4. Discussion

The anaemia prevalence of 67.6% documented in this study is substantially higher than the national average reported by NFHS-5 (59.1%) and aligns with the pattern of elevated anaemia burden observed in remote tribal populations of central India. The high proportion of severe anaemia (29.1%) is particularly concerning from a clinical standpoint, as it indicates not merely a dietary deficiency but a compounded nutritional and possibly parasitic disease burden that requires multi-modal therapeutic intervention rather than supplementation alone.

The finding that approximately half of all IFA recipients did not adhere to the prescribed supplementation schedule is consistent with evidence from other tribal contexts in Jharkhand and Odisha and reflects a systemic failure in demand-side health promotion as much as supply-side distribution. Side effects of IFA tablets — particularly gastrointestinal discomfort — are a frequently reported barrier and can be mitigated by administering tablets after meals, a simple behavioural modification that requires better frontline counselling. The low dietary iron intake is structurally linked to food insecurity and limited dietary diversity in tribal communities, issues that require agricultural and livelihood interventions alongside health programming.

The positive protective association of POSHAN Abhiyaan access with reduced anaemia severity suggests that the programme's multi-dimensional approach — combining nutrition supplementation, dietary counselling, and community mobilisation — has measurable benefits in tribal settings. However, coverage gaps remain significant in the remoter blocks of Bijapur and Narayanpur where road connectivity limits Anganwadi outreach. Innovative delivery mechanisms including mobile health vans and community health volunteers should be explored to extend POSHAN Abhiyaan services to the hardest-to-reach populations.

5. Conclusion

This cross-sectional study documents a high and clinically alarming prevalence of anaemia among adolescent girls in three tribal districts of Chhattisgarh, with severe anaemia affecting nearly three in ten anaemic girls. Low dietary iron intake, IFA non-adherence, poverty, and limited access to POSHAN Abhiyaan services emerged as significant, modifiable determinants.

The study recommends: (i) strengthening IFA tablet supply chain and daily school-based supervised supplementation rather than take-home distribution; (ii) deploying trained female community volunteers to deliver targeted dietary counselling in Halbi and Gondi languages; (iii) integrating deworming programmes with IFA distribution to address compound anaemia aetiology; (iv) expanding POSHAN Abhiyaan coverage to remote hamlets through mobile Anganwadi services; and (v) establishing a district-level nutritional surveillance system for

real-time monitoring of adolescent anaemia. A convergent, multi-sectoral approach addressing both dietary and structural determinants is essential for meaningful reduction of anaemia burden in Chhattisgarh's tribal belt.

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Academic Stress and Coping Strategies Among Undergraduate Students of Arts Colleges in Marathwada Region, Maharashtra

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Abstract: Academic stress is increasingly recognised as a significant mental health concern among undergraduate students in India, particularly in historically underserved regions. This study examined the prevalence and nature of academic stress and the coping strategies adopted by undergraduate students enrolled in arts degree colleges in the Marathwada region of Maharashtra. Using the Perceived Stress Scale (PSS-10) and the Brief COPE Inventory, data were collected from a stratified random sample of 320 students across four arts colleges in Aurangabad, Latur, and Osmanabad districts. The study found that 64.1% of respondents reported moderate to high levels of perceived stress, with female students reporting significantly higher stress scores than male students ($p < 0.01$). Academic overload, examination pressure, fear of failure, and parental expectations emerged as the four most frequently cited stressors. In terms of coping, emotion-focused and avoidance-based strategies — including rumination, social withdrawal, and substance use — were significantly more prevalent among high-stress respondents, while problem-focused strategies such as planning and positive reframing were more commonly used by students with lower stress scores. Socioeconomic background and first-generation college student status were significantly associated with elevated stress. The findings call for the systematic integration of professional counselling services, stress management workshops, and mentoring programmes within undergraduate arts colleges in Marathwada, with particular attention to the needs of female and first-generation learners.

Keywords: *Academic Stress, Coping Strategies, Perceived Stress Scale, Undergraduate Students, Marathwada, Mental Health*

1. Introduction

Academic stress, broadly defined as the cognitive appraisal of academic demands as exceeding one's perceived coping resources, is now recognised as one of the most prevalent mental health challenges facing undergraduate students in India. As higher education expands to include larger proportions of first-generation learners from rural, semi-urban, and economically marginalised backgrounds, the interaction between academic challenges and social stressors has become increasingly complex and poorly understood in the context of non-metropolitan settings.

The Marathwada region of Maharashtra — comprising the eight districts of Aurangabad, Latur, Osmanabad, Nanded, Beed, Hingoli, Parbhani, and Jalna — presents a particularly relevant context for this inquiry. The region is characterised by a largely agrarian economy, high rates of farmer indebtedness, elevated suicide rates among farmers, and historically limited access to quality higher education infrastructure. Students from this region who enrol in arts undergraduate programmes frequently carry heavy family expectations alongside economic insecurity,

creating a confluence of stressors that may intensify academic pressure beyond levels documented in urban higher education settings.

Despite growing awareness of student mental health in India following the National Mental Health Survey of India 2015–16 (NIMHANS, 2016), systematic empirical data on stress levels and coping behaviours among undergraduate arts students in Marathwada remains sparse. Existing literature predominantly focuses on medical, engineering, and management students in urban settings, leaving a significant knowledge gap regarding the experiences of humanities students in less privileged educational environments. The present study aims to fill this gap.

The theoretical framework draws on Lazarus and Folkman's (1984) transactional model of stress and coping, which posits that stress arises from the appraisal of an environmental demand as exceeding one's adaptive resources, and that coping strategies can be broadly classified as problem-focused (addressing the stressor directly), emotion-focused (managing the emotional response), or avoidance-based. This framework has been widely validated in Indian educational contexts and provides a structured basis for interpreting study findings.

2. Methodology

A quantitative cross-sectional survey design was employed. The target population comprised all undergraduate arts students (First, Second, and Third Year B.A.) enrolled in government-aided arts degree colleges in three Marathwada districts: Aurangabad, Latur, and Osmanabad. Stratified random sampling was used to select four colleges — one per district from Latur and Osmanabad, and two from Aurangabad given its larger student population — and within each college, students were selected using systematic random sampling from class registers. The final sample comprised 320 respondents (84 male, 212 female, 24 preferring not to disclose), representing a response rate of 91.4%.

Two validated psychometric instruments were administered. The Perceived Stress Scale (PSS-10), developed by Cohen, Kamarck, and Mermelstein (1983), was used to assess the degree to which respondents appraised their academic and personal situations as stressful over the preceding month. Scores range from 0 to 40, with higher scores indicating greater perceived stress. The Brief COPE Inventory (Carver, 1997), comprising 28 items across 14 coping dimensions, was used to assess coping strategies. Both instruments had previously been validated in Hindi, and the Hindi versions were administered to all participants. A supplementary sociodemographic questionnaire collected data on gender, year of study, parental education, household income, and first-generation college student status.

Data were analysed using SPSS version 25.0. Descriptive statistics were generated for all variables. Independent samples t-tests and one-way ANOVA were used to compare PSS-10 mean scores across sociodemographic subgroups. Pearson correlation analysis was performed to examine associations between PSS-10 scores and Brief COPE subscale scores. A significance threshold of $p < 0.05$ was applied throughout. Written informed consent was obtained from all participants, and the study was approved by the departmental research ethics committee of Shri Shivaji College, Akola.

3. Results and Findings

The mean PSS-10 score for the overall sample was 22.7 (SD=5.4), indicating a moderate-to-high level of perceived stress. Using established PSS-10 cut-offs (low: 0–13; moderate: 14–26; high: 27–40), 14.1% of respondents fell in the low stress category, 49.7% in the moderate range, and 36.3% in the high stress range. Female students reported a significantly higher mean PSS-10 score (23.9) than male students (19.8; $t=4.61$, $p < 0.001$), a finding consistent with gender-disaggregated stress research in other Indian educational contexts.

The four most frequently endorsed stressors, derived from open-ended questionnaire items, were: examination pressure and fear of failure (reported by 78.4% of respondents), parental expectations regarding performance and employment after graduation (71.2%), financial strain and uncertainty about post-graduation income (63.8%), and academic workload and syllabus volume (58.9%). First-generation college students ($n=147$, 45.9%) reported significantly higher mean PSS-10 scores (24.3) than students with at least one college-educated parent ($t=3.28$, $p=0.001$).

Analysis of Brief COPE subscale scores revealed that high-stress respondents ($PSS-10 \geq 27$) more frequently used maladaptive coping strategies including self-blame ($r=0.54$, $p<0.001$), behavioural disengagement ($r=0.48$, $p<0.001$), and substance use ($r=0.31$, $p<0.01$). In contrast, low-stress respondents showed significantly higher use of problem-focused strategies including active coping ($r=-0.42$, $p<0.001$), planning ($r=-0.38$, $p<0.001$), and positive reframing ($r=-0.35$, $p<0.001$). Social support seeking showed a moderate positive correlation with stress levels ($r=0.22$, $p<0.01$), suggesting that socially isolated students experience greater stress rather than being insulated from it.

4. Discussion

The finding that approximately 64% of arts undergraduate students in Marathwada reported moderate to high perceived stress levels is consistent with similar studies from other Indian regional colleges and indicates that academic stress is neither confined to competitive professional programmes nor to elite urban universities. The elevated stress among female students likely reflects the dual burden of academic demands and gender-specific family and social expectations regarding domestic responsibilities and early marriage — stressors that have been similarly documented among women students in rural Maharashtra by earlier qualitative studies.

The predominance of avoidance-based and emotion-focused coping among high-stress students is particularly concerning from a public health standpoint. Behavioural disengagement — including skipping classes, postponing study, and social withdrawal — creates a self-reinforcing cycle of academic underperformance and increased stress. Substance use, while reported by a minority of respondents, was statistically associated with high stress and may be under-reported due to social desirability bias. These findings suggest a pressing need for early, normalised, non-stigmatising mental health support structures within arts colleges.

The significance of first-generation college student status as a stress predictor is an important finding for institutional policy. These students frequently lack familial guidance on navigating higher education systems, have fewer academic social networks, and face heightened economic uncertainty. Mentoring programmes pairing first-generation students with senior peers or faculty, as piloted in some Maharashtra Rajiv Gandhi Higher Education Institutes, have shown promise in building academic self-efficacy and reducing dropout rates and may deserve replication in arts colleges of Marathwada.

5. Conclusion

This study presents substantive empirical evidence that academic stress is prevalent and consequential among undergraduate arts students in Marathwada, with particular vulnerability among female students, first-generation learners, and students from economically disadvantaged households. Maladaptive coping strategies are disproportionately employed by high-stress individuals, pointing to a need for skills-based intervention.

The study recommends: (i) mandatory appointment of trained counsellors in all government-aided arts colleges with student populations exceeding 500; (ii) integration of stress management and mental health literacy modules into the first-year B.A. induction programme; (iii) dedicated mentoring and financial guidance for first-generation students; and (iv) establishment of peer support networks trained in active listening and referral. Policy

alignment between the Maharashtra Higher Education Department's Mental Health Policy Framework and institutional implementation at district college level is urgently required.

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Impact of Organic Farming Practices on Soil Health and Crop Yield in Small Landholdings of Western Uttar Pradesh

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Abstract: The increasing degradation of agricultural soils due to intensive chemical-input farming has prompted growing interest in the viability of organic farming as an alternative approach for Indian small-scale farmers. This study examined the short- to medium-term impacts of organic farming practices — including vermicompost application, green manuring, biopesticide use, and crop rotation — on soil physicochemical and biological properties and on wheat and sugarcane yield among small landholding farmers in four blocks of Muzaffarnagar district, western Uttar Pradesh. A field-based quasi-experimental design was employed over two cropping seasons (Rabi 2022–23 and Kharif 2023). Twenty-five farmer participants practising organic methods for at least two years were matched with 25 control farmers using conventional chemical inputs, selected through purposive sampling with matching on landholding size, soil type, and irrigation access. Soil samples were collected pre- and post-season from all plots and analysed for organic carbon, available nitrogen, phosphorus, potassium, and microbial biomass carbon. Results showed significantly higher soil organic carbon (mean increase of 0.31%; $p < 0.01$), improved microbial biomass carbon ($p < 0.05$), and reduced soil bulk density ($p < 0.05$) in organic plots compared to chemical-input plots. Wheat yield in organic plots was 7.2% lower on average, though sugarcane yield difference was not statistically significant. Input cost reduction of approximately 28% was recorded for organic farmers. The study concludes that organic farming offers promising long-term soil health benefits with manageable short-term yield trade-offs for small landholders, provided market access and transitional support are available.

Keywords: *Organic Farming, Soil Health, Soil Organic Carbon, Small Landholdings, Western Uttar Pradesh, Sustainable Agriculture*

1. Introduction

Indian agriculture faces a compounding crisis of soil degradation, groundwater depletion, and escalating input costs, all exacerbated by decades of intensive Green Revolution-era chemical farming. In western Uttar Pradesh — a region historically central to India's agricultural output, particularly in wheat and sugarcane — soil organic matter has declined sharply across many districts, reducing water-holding capacity, nutrient cycling efficiency, and long-term productivity. The IndoGangetic Plain's soils, once among the most fertile in the subcontinent, are increasingly showing signs of micronutrient exhaustion and loss of biological activity.

Organic farming — broadly understood as a production system relying on ecological processes, biodiversity, and cycles adapted to local conditions, avoiding synthetic off-farm inputs — has gained increasing policy attention in India as a potential pathway to sustainable agricultural development. The Government of India's Paramparagat Krishi Vikas Yojana (PKVY), launched in 2015, aims to promote cluster-based organic farming and has reached over 30,000 clusters across the country. Uttar Pradesh has also initiated its own Organic Farming Mission under the State Agriculture Department.

However, the uptake of organic practices among small and marginal farmers in western Uttar Pradesh remains limited, partly due to concerns about short-term yield losses during the transition period and partly due to a lack of localised empirical evidence on soil and productivity outcomes. Research on organic farming in this specific agro-climatic zone is sparse: most available studies are from peninsular India or from larger farm settings in Punjab and Haryana, where contextual factors differ significantly from western UP's fragmented landholding patterns and market access constraints.

This study directly addresses this evidence gap by conducting a rigorous field-based comparison of organic and conventional farming practices on small landholdings in Muzaffarnagar district over two cropping seasons. The study aims to provide locally grounded data on soil health outcomes, yield performance, and input cost economics to inform extension advisory services and policy implementation in the region.

2. Methodology

A quasi-experimental matched-pairs design was adopted to compare organic and conventional farming outcomes across 25 matched pairs of farmer plots in four blocks of Muzaffarnagar district: Muzaffarnagar, Charthawal, Purkazi, and Khatauli. Organic farming participants were identified through the district PKVY cluster list maintained by the Krishi Vigyan Kendra, Muzaffarnagar; only farmers with at least two consecutive growing seasons of certified or documented organic practice (verified through input purchase records and field officer certifications) were included. Each organic farmer was matched with a conventional chemical-input farmer from the same block with comparable landholding size (0.5–2.0 hectares), soil texture class (primarily sandy loam to silty loam), and source of irrigation (tubewell).

Composite soil samples (from 0–20 cm depth, five sub-samples per plot) were collected from all 50 plots at the beginning and end of each cropping season. Samples were analysed at the Soil Testing Laboratory, Krishi Vigyan Kendra, Muzaffarnagar for: soil organic carbon (Walkley-Black method), available nitrogen (alkaline permanganate method), available phosphorus (Olsen method), available potassium (flame photometry), soil pH, electrical conductivity, bulk density, and microbial biomass carbon (substrate-induced respiration method). Wheat (variety PBW-343) and sugarcane (variety CO-238) yield data were recorded plot-wise at harvest.

Input cost data were collected through structured interviews with participating farmers covering expenditure on seeds, fertilisers or organic inputs, pesticides or biopesticides, and labour over the study period. Statistical analysis was performed in R version 4.2.1. Paired t-tests were used to compare soil parameter and yield outcomes between organic and conventional plots. Results were considered significant at $p < 0.05$. Farmers provided written informed consent to participate, and all identifiable data were anonymised in the dataset.

3. Results and Findings

Soil analysis results revealed consistently superior organic matter and biological indicators in organic plots compared to conventional plots. Mean soil organic carbon in organic plots increased from a baseline of 0.52% to 0.83% over two seasons (a mean increase of 0.31%), compared to a marginal increase from 0.48% to 0.56% in conventional plots (mean increase 0.08%). The difference was statistically significant ($t = 4.21$, $p < 0.001$). Microbial

biomass carbon was significantly higher in organic plots at end-of-season measurements (mean 312 $\mu\text{g C/g soil}$) compared to conventional plots (mean 228 $\mu\text{g C/g soil}$; $p<0.05$). Soil bulk density showed a modest but significant decline in organic plots (from 1.52 to 1.44 g/cm^3), indicating improved soil structure.

Available nitrogen, phosphorus, and potassium showed mixed results. While organic carbon and microbial indicators showed clear organic farming advantages, available phosphorus in organic plots was marginally lower than in conventional plots (mean 16.2 kg/ha vs 21.8 kg/ha) due to the reduced use of soluble phosphatic fertilisers. Available nitrogen showed no significant difference between treatment groups at end of season, suggesting that nitrogen mineralisation from organic matter was sufficient to maintain nitrogen supply at levels comparable to chemical fertilisation over the study period.

Wheat grain yield in organic plots averaged 38.7 quintals per hectare compared to 41.7 quintals per hectare in conventional plots, representing a mean yield penalty of approximately 7.2% ($p<0.05$). Sugarcane yield difference was not statistically significant (organic: 742 quintals/ha; conventional: 758 quintals/ha; $p=0.21$). Input cost analysis revealed that organic farming households spent approximately Rs. 9,200 per hectare per season on inputs compared to Rs. 12,800 per hectare for conventional farmers — a cost saving of 28.1% — primarily driven by the elimination of synthetic fertiliser costs and the use of farm-produced compost and locally available biopesticides.

4. Discussion

The significant improvement in soil organic carbon and microbial biomass carbon in organic plots is consistent with established agronomic literature on the benefits of vermicompost and green manure application in Indo-Gangetic Plain soils. Soil organic carbon is the primary indicator of long-term soil fertility, serving as a substrate for microbial activity, a determinant of water retention capacity, and a reservoir of slow-release nitrogen. The trajectory observed in this study — from a low baseline of approximately 0.52% to 0.83% over two seasons — suggests that further improvement towards the agronomically desirable threshold of 1.0% is achievable over a longer time horizon.

The wheat yield gap of approximately 7.2% documented here is lower than the typical first-year transition yield penalties of 15–25% reported in literature, suggesting that participating farmers' two-year prior experience with organic methods and their use of integrated nutrient management strategies had already ameliorated early transition losses. The lack of a statistically significant yield difference in sugarcane is noteworthy: sugarcane is a nutrient-intensive crop where conventional wisdom would predict larger organic yield penalties, and this finding warrants further investigation in controlled experimental trials.

The 28% input cost reduction for organic farmers represents a substantial economic advantage, and when combined with the premium prices available in certified organic markets — which these farmers had not yet accessed at the time of study — net farm income potential for organic producers appears competitive with and potentially superior to conventional farming over the medium term. The key bottlenecks identified by participating farmers were the absence of local organic certified input suppliers, difficulties in obtaining organic certification due to procedural complexity and cost, and limited access to premium organic market channels. These structural barriers require targeted policy interventions beyond agronomic extension support.

5. Conclusion

This study provides localised empirical evidence from western Uttar Pradesh that organic farming practices yield meaningful improvements in soil health indicators — particularly soil organic carbon and biological activity — over two cropping seasons, with manageable yield trade-offs and significant input cost savings. The findings

support the case for promoting organic farming as a long-term soil restoration strategy for small landholdings in the region.

Policy recommendations include: (i) establishing community-level vermicompost production units under MGNREGS and PKVY linkages to reduce organic input costs; (ii) simplifying the organic certification process for small farmers through group certification mechanisms; (iii) creating dedicated organic produce collection points and market linkages at the block level; (iv) intensifying Krishi Vigyan Kendra extension advisory services on integrated nutrient management; and (v) funding multi-season, multi-site longitudinal studies on organic farming outcomes to build the long-term evidence base needed for confident policy scaling in western Uttar Pradesh.

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Water Quality Assessment of Urban Lakes in Bhopal: A Physico-Chemical Study

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Abstract: Urban lakes in Indian cities are under severe ecological stress due to rapid urbanisation, encroachment, untreated sewage discharge, and solid waste dumping. This study undertook a systematic physico-chemical assessment of five major urban lakes in Bhopal, Madhya Pradesh — Upper Lake (Bada Talab), Lower Lake (Chhota Talab), Shahpura Lake, Sarangpani Lake, and Motia Talab — over a period of twelve months from January to December 2023 to determine their current water quality status and identify primary pollution determinants. Water samples were collected bimonthly from three stations per lake and analysed for twelve parameters: temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), electrical conductivity, turbidity, total hardness, nitrate-nitrogen, total phosphate, and faecal coliform count. Results revealed that BOD levels exceeded BIS permissible limits of 3 mg/L in three of five lakes, with the most severe violations recorded in Lower Lake (mean BOD: 14.2 mg/L) and Motia Talab (mean BOD: 11.8 mg/L). Dissolved oxygen was below the critical threshold of 5 mg/L in Lower Lake and Motia Talab during summer months, threatening aquatic biodiversity. Nitrate and phosphate loading was consistent with eutrophication processes. Upper Lake retained the best water quality among the five, likely due to its larger water body and statutory protection. A Water Quality Index (WQI) was computed for each lake to summarise overall quality. The study recommends urgent restoration interventions including sewage diversion, desilting, and biodiversity buffer zones.

Keywords: *Water Quality, Urban Lakes, Bhopal, Physico-Chemical Parameters, Eutrophication, Water Quality Index*

1. Introduction

Urban water bodies — ponds, lakes, and tanks — have historically served as critical ecological, hydrological, and socio-cultural assets in Indian cities. They supported local fisheries, provided water for domestic and agricultural use, recharged groundwater, moderated urban microclimates, and served as centres of community life. However, the rapid and largely unplanned urbanisation experienced by Indian secondary cities over the past four decades has led to the progressive degradation and in many cases outright encroachment and disappearance of these water bodies. The National Lake Conservation Plan, implemented by the Ministry of Environment, Forest and Climate Change since 2001, has recognised this crisis and sought to fund restoration, but implementation outcomes have been mixed.

Bhopal, the capital city of Madhya Pradesh, is historically celebrated as the 'City of Lakes,' with several large and small urban water bodies that define its landscape and culture. The iconic Upper Lake (Bada Talab) is among the largest man-made lakes in Asia and serves as a drinking water source for a significant portion of Bhopal's population. However, sustained population growth, encroachment of lake catchment areas by residential and

commercial construction, discharge of partially treated or untreated sewage, and accumulation of solid waste along lake margins have placed these water bodies under mounting stress.

Systematic, contemporary water quality data for Bhopal's urban lakes beyond the Upper Lake is fragmentary and often outdated. The last comprehensive multi-lake assessment available in the public domain dates to a CPCB report from 2016, and the seven years since have seen significant changes in land use, population density, and municipal wastewater treatment infrastructure in Bhopal. Updated, rigorous physico-chemical data is necessary to inform the Bhopal Municipal Corporation's lake restoration prioritisation and to provide baseline data for monitoring restoration outcomes.

This study addresses this data gap by conducting a twelve-month, bimonthly, multi-parameter physico-chemical assessment of five representative urban lakes in Bhopal, ranging from the well-protected Upper Lake to the severely degraded Motia Talab, to generate current water quality profiles, compute Water Quality Index values for each lake, and identify primary pollution drivers.

2. Methodology

Five urban lakes in Bhopal were selected for the study based on their geographic distribution across the city, their ecological and social significance, and their varying degrees of anthropogenic pressure: Upper Lake, Lower Lake, Shahpura Lake, Sarangpani Lake, and Motia Talab. Bimonthly water sampling was conducted at three fixed stations per lake (inlet zone, mid-lake, and outlet/shoreline zone) from January through December 2023, yielding a total of 360 water samples. Sampling stations were geo-referenced using a GPS device to ensure consistency across sampling events. Samples were collected in pre-cleaned 1-litre high-density polyethylene bottles following standard sampling protocols (APHA, 2017) and transported to the laboratory within six hours under ice-pack preservation.

Twelve physico-chemical parameters were analysed: temperature (mercury thermometer, in situ), pH (Hanna HI-98127 digital pH meter), dissolved oxygen (Winkler's iodometric method), biological oxygen demand (5-day BOD test, 20°C incubation), chemical oxygen demand (open reflux dichromate method), total dissolved solids (gravimetric method), electrical conductivity (conductivity meter), turbidity (Nephelometric method), total hardness (EDTA titrimetric method), nitrate-nitrogen (UV spectrophotometric method), total phosphate (stannous chloride method), and faecal coliform count (membrane filtration technique). All chemical analyses were performed at the Environmental Chemistry Laboratory, Sagar Government Science College, Sagar, following standard methods as per APHA (2017) and IS:3025 protocols.

A weighted arithmetic Water Quality Index (WQI) was computed for each lake using the methodology of Brown et al. (1972), assigning weights to parameters based on their relative importance for potable water use and aquatic ecosystem health. The WQI values were classified as: Excellent (0–25), Good (26–50), Poor (51–75), Very Poor (76–100), and Unfit for Use (>100). All data were analysed using Microsoft Excel 2019 and SPSS version 23. Mean values and standard deviations were calculated for each parameter at each lake, and one-way ANOVA with Tukey's post-hoc test was used to compare mean parameter values across lakes.

3. Results and Findings

Temperature, pH, and electrical conductivity remained within acceptable limits across all five lakes throughout the study period, with pH ranging from 7.1 to 8.6 (mildly alkaline) and temperature between 18.2°C (January) and 32.6°C (May). However, significant inter-lake and seasonal variation was observed for oxygen-related parameters. Dissolved oxygen fell below the critical threshold of 5 mg/L in Lower Lake (mean summer DO: 3.8 mg/L) and Motia Talab (mean summer DO: 2.9 mg/L) during the April–June period, indicating hypoxic conditions incompatible with fish survival and typical of severely polluted lentic systems.

BOD levels exceeded the BIS drinking water permissible limit of 3 mg/L in Lower Lake (annual mean 14.2 mg/L), Motia Talab (11.8 mg/L), and Sarangpani Lake (5.3 mg/L). COD values followed a similar pattern. Total phosphate concentrations above 0.1 mg/L — the threshold commonly associated with eutrophication onset — were recorded in four of five lakes, with Lower Lake recording the highest annual mean of 0.48 mg/L. Nitrate-nitrogen exceeded 10 mg/L at multiple stations in Motia Talab, consistent with proximate sewage drain inputs identified during field observation. Upper Lake retained the best overall water quality, with BOD within limits, DO above 6 mg/L year-round, and TDS within BIS standards.

WQI calculations yielded the following annual classifications: Upper Lake — Good (WQI: 42); Shahpura Lake — Poor (WQI: 61); Sarangpani Lake — Poor (WQI: 68); Lower Lake — Very Poor (WQI: 89); Motia Talab — Unfit for Use (WQI: 107). Faecal coliform counts exceeded the 500 MPN/100 mL threshold specified for bathing water quality (IS:2296) in Lower Lake, Sarangpani Lake, and Motia Talab, confirming direct sewage contamination in these water bodies.

4. Discussion

The stark contrast in water quality between Upper Lake and the remaining four study lakes reflects primarily the difference in regulatory protection and sewage interception infrastructure. Upper Lake benefits from a 1990 Wetland Conservation Notification limiting construction in its catchment area, while the smaller lakes lack equivalent statutory buffers. The findings from Lower Lake and Motia Talab — both classified as severely polluted or unfit for use — are consistent with CPCB's 2016 assessment for these water bodies and indicate that no significant improvement has occurred over the intervening period despite municipal restoration commitments.

Eutrophication, driven by nitrogen and phosphorus loading from sewage discharge and urban runoff, was identified as the dominant ecological process degrading the mid-ranked lakes. Eutrophication triggers algal blooms that further reduce dissolved oxygen through nocturnal respiration and decomposition, creating self-reinforcing lake degradation cycles. The seasonal pattern of DO decline during April to June, coinciding with peak temperature, is consistent with this mechanistic understanding and points to the importance of sewage diversion as the primary restoration intervention in these lakes.

The turbidity and faecal coliform data confirm that open defecation and solid waste dumping in the immediate vicinity of Sarangpani Lake and Motia Talab continue despite municipal programmes. These findings highlight that technical restoration measures must be accompanied by community awareness campaigns and stringent enforcement of anti-encroachment and anti-pollution regulations. The success of Upper Lake's relative protection demonstrates that regulatory intent, when backed by monitoring and enforcement, can maintain reasonable water quality even in a rapidly urbanising context.

5. Conclusion

This twelve-month physico-chemical assessment of five Bhopal urban lakes documents a spectrum of water quality ranging from good in the Upper Lake to unfit for use in Motia Talab, with eutrophication, sewage contamination, and organic pollution as the primary drivers of degradation in the lower-ranked lakes. The computed WQI values provide a clear prioritisation framework for restoration investment.

Urgent recommendations include: (i) complete diversion of identified sewage drains into Lower Lake, Sarangpani Lake, and Motia Talab to the Bhopal sewage treatment network as an immediate priority; (ii) desilting of accumulated organic sediments in Motia Talab and Lower Lake; (iii) establishing 50-metre vegetated buffer zones around all five lakes to intercept non-point source runoff; (iv) statutory notification of lake catchment areas for Shahpura Lake, Sarangpani Lake, and Motia Talab analogous to the Upper Lake model; and (v) establishing a

quarterly multi-parameter water quality monitoring programme by Bhopal Municipal Corporation with results placed in the public domain.

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Effectiveness of Activity-Based Learning in Improving Literacy Outcomes in Primary Schools of Backward Districts in Odisha

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Abstract: Activity-Based Learning (ABL) is a child-centred pedagogical approach that engages learners through hands-on activities, collaborative tasks, and discovery-oriented instruction rather than rote transmission of information. This study investigated the effectiveness of ABL interventions in improving foundational literacy outcomes — specifically reading fluency and reading comprehension — among Class III students in primary schools of two educationally backward districts of Odisha: Kandhamal and Nuapada. A quasi-experimental pretest-posttest design with a control group was employed across eight schools (four intervention, four control), involving 240 Class III students. In intervention schools, trained teachers implemented a structured ABL programme comprising story cards, letter-building activities, peer reading pairs, and vocabulary games for three months. A validated Odia-language oral reading fluency assessment and a reading comprehension test were administered pre- and post-intervention. Results showed a statistically significant improvement in oral reading fluency among ABL-intervention students (mean gain of 24.3 correct words per minute) compared to control students (mean gain of 8.7 correct words per minute; $p < 0.001$). Reading comprehension scores improved by a mean of 31.6% in ABL schools versus 12.4% in control schools ($p < 0.001$). Teacher confidence in using ABL methods, measured through a post-intervention questionnaire, was moderate, with resource availability and class size identified as key implementation challenges. The study recommends scaling ABL with targeted teacher training, locally developed low-cost materials, and reduced class sizes in backward district schools.

Keywords: *Activity-Based Learning, Foundational Literacy, Primary Education, Odisha, Reading Fluency, Backward Districts*

1. Introduction

The foundational literacy crisis in India — the inability of a large proportion of primary school students to read simple text or perform basic arithmetic by the end of Grade 3 — has been extensively documented by the Annual Status of Education Report (ASER) series since 2005. ASER 2022 found that nationally only 42.8% of Class III students could read a Grade 2 level text, a finding that has barely shifted over a decade despite significant investments in school infrastructure and teacher recruitment. In states like Odisha, where a large proportion of primary school children are first-generation learners from Scheduled Tribe communities speaking Odia as a second language, foundational literacy deficits are even more pronounced.

Activity-Based Learning (ABL) is a structured pedagogical approach developed in Tamil Nadu in the late 1990s and subsequently adapted and piloted in several Indian states as an alternative to the dominant teacher-centred rote learning model. ABL reorganises classroom activity around self-paced milestone cards, peer groupings, and discovery tasks that allow children to progress at their own speed and engage with learning material through kinesthetic and social interaction rather than passive listening. Evidence from Tamil Nadu and modified versions in Gujarat and Karnataka has documented significant improvements in foundational learning outcomes associated with ABL implementation.

However, evaluations of ABL effectiveness in eastern and tribal India remain limited. The specific linguistic, pedagogical, and infrastructural contexts of Odisha's backward districts differ substantially from those in which most ABL evidence was generated: class sizes are larger, teacher-student ratios are poorer, multilingualism is more complex (many students speak Kui, Gondi, or other tribal languages at home), and learning material availability is more constrained. Context-specific evidence is essential for sound adaptation and scale-up decisions.

This study was designed to evaluate the effectiveness of a contextually adapted ABL programme in two of Odisha's most educationally disadvantaged districts over a single academic term (three months), using a quasi-experimental design to generate evidence on reading fluency and comprehension gains relative to a control group. The findings aim to inform the Odisha School Education Programme Authority's curriculum and teacher training policy under the National Initiative for Proficiency in Reading with Understanding and Numeracy (NIPUN Bharat) framework.

2. Methodology

A quasi-experimental pretest-posttest design with a non-equivalent control group was employed. The study was conducted in two backward districts of Odisha designated under the Government of India's 112 Aspirational Districts programme: Kandhamal and Nuapada. Eight government primary schools were selected — four for the intervention condition (two per district) and four for the control condition (two per district) — using purposive sampling with matching on school size, student enrolment, student socioeconomic profile, and teacher-student ratio. The target population was all Class III students (age 7–9 years) enrolled in the selected schools; 240 students in total (120 intervention, 120 control) were included after excluding students with documented speech or hearing difficulties.

The ABL intervention consisted of a three-month structured programme (August to October 2023) in which teachers in intervention schools received a five-day pre-intervention training workshop conducted by the research team in collaboration with the Block Education Officer. The training covered ABL principles, activity facilitation techniques, use of story cards and letter-building materials, and classroom reorganisation into peer learning groups of four. Low-cost ABL materials (story cards, alphabet charts, vocabulary game kits) were provided to intervention schools by the research project from locally sourced materials. Control schools continued with the standard Odia-medium government curriculum without any modification.

Assessment instruments comprised a validated Odia Oral Reading Fluency (ORF) test — measuring the number of correct words read aloud per minute from a standardised Grade 2-level Odia text passage — and a 20-item multiple-choice reading comprehension test aligned to NIPUN Bharat foundational literacy benchmarks, both administered individually by trained assessors at baseline and endline. Assessors were blinded to intervention status where logistically feasible. Data were analysed in SPSS version 23 using independent samples t-tests for between-group comparisons and paired t-tests for within-group pre-post comparisons. The significance threshold was set at $p < 0.05$.

3. Results and Findings

At baseline, no statistically significant difference was found between intervention and control groups on either ORF or comprehension scores, confirming comparability of the two groups. Intervention group mean baseline ORF was 18.2 words per minute (SD=6.1) and control group mean was 17.9 words per minute (SD=5.8; $p=0.73$). At endline, intervention group mean ORF had increased to 42.5 words per minute (SD=8.3), a gain of 24.3 words per minute, compared to a control group endline mean of 26.6 words per minute (SD=7.1), a gain of only 8.7 words per minute. The between-group difference in ORF gain was statistically significant ($t=13.7$; $p<0.001$).

Reading comprehension scores showed similar patterns. Intervention group mean comprehension score increased from 28.4% at baseline to 60.0% at endline (mean gain: 31.6 percentage points), while the control group showed a mean gain of 12.4 percentage points (from 27.9% to 40.3%; $p<0.001$). Effect size for the comprehension outcome was large (Cohen's $d=1.21$), indicating substantial practical significance of the intervention beyond statistical significance. Gender-disaggregated analysis revealed no statistically significant difference in ABL intervention gains between girls and boys, a finding that contrasts with some prior studies reporting differential gender response to pedagogical changes.

Post-intervention teacher questionnaire responses ($n=8$ teachers, 4 per group) revealed that all four intervention school teachers reported increased student engagement and reduced classroom management challenges compared to the pre-intervention period. However, teachers identified three significant implementation challenges: large class sizes (mean 42 students per class in intervention schools) that made individual assessment and group facilitation difficult, insufficient supply of ABL materials for all students, and parental unfamiliarity with ABL methods leading to occasional requests for return to conventional homework formats. Teacher confidence in ABL facilitation rated as moderate (mean score 6.8 out of 10 on a Likert scale) at endline, suggesting a need for continued coaching support.

4. Discussion

The large and statistically robust improvement in both reading fluency and comprehension among ABL-intervention students over just three months is a significant finding that adds to the evidence base for ABL's effectiveness in educational disadvantaged settings within India. The magnitude of the intervention effect (ORF gain nearly three times that of control students; comprehension gain more than twice) suggests that even a relatively brief, low-cost ABL implementation can produce meaningful learning gains in contexts where baseline literacy is very low and where the alternative — conventional passive instruction — produces minimal learning increment.

The absence of a gender differential in intervention response is encouraging from an equity perspective and challenges the assumption that pedagogical innovations uniformly advantage certain gender groups. In the Kandhamal and Nuapada context, where girls' school attendance and completion rates remain below state averages, the finding that girls benefit equally from ABL suggests the approach may be a useful gender-neutral lever for improving literacy outcomes without requiring separate girl-focused interventions at the classroom level.

The implementation challenges identified — large class sizes, material shortages, and limited parental familiarity — are structural rather than inherent to the ABL approach and have been similarly documented in ABL rollouts in other Indian states. The Tamil Nadu experience suggests that these challenges are manageable with systematic state-level procurement of materials, sustained teacher coaching (not just initial training), and deliberate community engagement to build parental understanding and support. The NIPUN Bharat mission's foundational literacy focus provides a policy umbrella within which an Odisha-specific ABL scale-up could be effectively anchored.

5. Conclusion

This quasi-experimental study provides statistically robust evidence that a contextually adapted ABL programme can significantly accelerate foundational literacy acquisition — reading fluency and comprehension — among Class III students in educationally backward districts of Odisha over a three-month implementation period. The benefits were consistent across gender groups and across both study districts.

The study recommends: (i) systematic integration of ABL principles into the Odisha state government's primary teacher in-service training programme under NIPUN Bharat; (ii) state-level procurement and distribution of standardised Odia-language ABL story card and activity material sets for all primary schools in backward districts; (iii) reduction of class sizes to a maximum of 30 students in ABL implementation schools to enable effective group facilitation; (iv) establishment of block-level ABL resource teachers to provide ongoing classroom coaching support; and (v) community awareness sessions for parents on ABL principles and home reading engagement strategies. Sustained investment in these elements is necessary for the short-term gains documented here to translate into sustained improvements in foundational literacy.

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Social Exclusion and Marginalisation of Scheduled Castes in Semi-Urban Areas of Bihar: An Empirical Study

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Abstract: Despite constitutional guarantees of equality and the Scheduled Castes and Scheduled Tribes (Prevention of Atrocities) Act, 1989, social exclusion and caste-based discrimination continue to pervade the everyday lives of Scheduled Caste communities in semi-urban India. This mixed-methods study examined the forms, mechanisms, and persistence of social exclusion experienced by Scheduled Caste households in three semi-urban towns of Bihar — Muzaffarpur, Darbhanga, and Bhagalpur — through a combination of structured survey interviews with 300 SC household heads and 20 in-depth interviews with SC adults aged 18–60 years. Survey findings document the persistence of exclusion across four domains: public and civic spaces (temples, water bodies, community gatherings), employment and economic opportunities, educational attainment and school climate, and political participation and civic voice. Multivariate analysis showed that caste identity remains a significant predictor of exclusion across all four domains even after controlling for income, education, and urban proximity. In-depth interview narratives revealed that exclusion operates through subtle symbolic mechanisms — including differential treatment at food stalls and shops, implicit spatial segregation in public seating, and social ostracism following inter-caste marriages — rather than the overt forms of untouchability more commonly documented in rural settings. The study concludes that urbanisation has transformed but not eliminated caste-based exclusion, and that the legal framework requires complementary social capital and sensitisation interventions to achieve meaningful inclusion.

Keywords: *Social Exclusion, Scheduled Castes, Caste Discrimination, Bihar, Semi-Urban, Atrocities Act*

1. Introduction

Social exclusion — defined as the process by which certain groups are systematically denied participation in the economic, social, cultural, and political life of the society in which they live — is deeply intertwined with caste structures in India. The Indian Constitution's framers were acutely aware of this structural problem: Articles 15, 16, 17, and 46 specifically prohibit caste discrimination, abolish untouchability, and direct the state to promote the educational and economic interests of Scheduled Castes. Supplementary legislative protections, including the Scheduled Castes and Scheduled Tribes (Prevention of Atrocities) Act of 1989 and the Protection of Civil Rights Act of 1955, created punitive frameworks for specific acts of caste violence and discrimination.

Bihar presents a particularly complex and historically rooted caste landscape. The state has witnessed some of India's most violent caste conflicts — including the Bathani Tola massacre (1996) and the Laxmanpur Bathe massacre (1997) — and continues to record high numbers of atrocities against Scheduled Castes in National Crime Records Bureau annual data. While a great deal of scholarly attention has focused on rural Bihar, the rapid growth of semi-urban towns and small cities in the state over the past two decades has created new and less-studied social

contexts in which caste relations are being renegotiated — often in more covert and symbolically complex ways than in villages.

Semi-urban settings occupy an ambiguous sociological space: they retain strong links to the agricultural and social hierarchies of rural hinterlands while simultaneously embracing urban aspirations, market economies, and greater anonymity. For Scheduled Caste residents of semi-urban towns, this ambiguity translates into an experience of caste exclusion that is simultaneously less visible and less documented than its rural counterpart — making it harder to litigate under existing legal frameworks and easier for dominant castes to deny. Empirical sociological documentation of exclusion patterns in these settings is therefore both academically significant and practically necessary for targeted policy responses.

This study sets out to systematically document the forms and intensity of caste-based exclusion experienced by Scheduled Caste residents in three semi-urban towns of Bihar, to analyse the structural and social determinants of exclusion, and to complement quantitative survey data with in-depth qualitative narratives that illuminate the subjective experience and adaptive strategies of excluded individuals and communities.

2. Methodology

The study employed a mixed-methods sequential explanatory design: quantitative survey data were collected first to establish prevalence and correlates of exclusion, followed by qualitative in-depth interviews to illuminate mechanisms and lived experience. Three semi-urban towns were selected purposively based on population size (50,000–300,000), significant SC population (above 18% as per Census 2011), and geographic distribution across Bihar: Muzaffarpur (north Bihar), Darbhanga (Mithila region), and Bhagalpur (eastern Bihar). Within each town, SC-concentrated wards were identified from municipal corporation ward data, and 100 SC household heads were selected using systematic random sampling per town, yielding a total survey sample of 300.

The survey instrument comprised four domain-specific exclusion scales developed by the researcher drawing on validated instruments from comparable South Asian studies, adapted to the Bihar semi-urban context. Each domain (public/civic, economic, educational, political) contained 6–8 items rated on a five-point frequency scale (never to always). A composite Social Exclusion Index (SEI) was computed as the mean of all 26 item scores (range 1–5, higher scores indicating greater exclusion). Sociodemographic data (income, education, sub-caste identity, length of residence, property ownership) were also collected. For the qualitative component, 20 purposively selected SC adults (10 men, 10 women, spanning three age cohorts) participated in semi-structured in-depth interviews lasting 60–90 minutes, conducted in Maithili or Hindi as preferred by participants and audio-recorded with consent.

Survey data were analysed using SPSS 24.0. Descriptive statistics characterised the sample and domain-level exclusion scores. Multivariate linear regression was used to identify independent predictors of the composite SEI. Qualitative interview transcripts were translated, and thematic analysis was conducted manually following Braun and Clarke's (2006) six-phase framework. Ethical approval was obtained from the research ethics committee of Patna Women's College. Participant identities are anonymised; pseudonyms are used in all qualitative extracts.

3. Results and Findings

The composite Social Exclusion Index mean for the overall sample was 3.21 (SD=0.68) on a 1–5 scale, indicating moderate-to-high levels of exclusion. Domain-specific means were: public/civic exclusion (mean 3.48), economic exclusion (mean 3.34), educational climate exclusion (mean 2.89), and political marginalisation (mean 3.14). Darbhanga participants reported the highest composite exclusion scores (mean SEI: 3.41), while Muzaffarpur had the lowest (mean SEI: 3.02), a difference that may reflect Darbhanga's more traditional socio-cultural setting and historical patterns of Brahminical dominance.

Multivariate regression analysis revealed that caste identity (SC sub-caste, particularly Musahar and Dusadh sub-castes) ($B=0.41$, $p<0.001$), lower household income ($B=-0.28$, $p<0.01$), and lower educational attainment of household head ($B=-0.19$, $p<0.05$) were significant independent predictors of higher SEI scores, even after controlling for town of residence, type of neighbourhood, and length of urban residence. Notably, length of residence in the semi-urban town did not significantly predict exclusion, suggesting that time and social integration do not automatically reduce caste-based marginalisation in these settings.

Qualitative findings revealed that exclusion in semi-urban Bihar operates through several mechanisms distinct from classical rural untouchability. Participants described differential pricing or subtle service refusals at tea stalls and shops, spatial clustering of SC families in peripheral, flood-prone, or poorly serviced wards, exclusion from neighbourhood social ceremonies (weddings, Puja events) by dominant caste neighbours, and reduced willingness among landlords to rent to SC families in commercially central locations. One female participant (pseudonym: Savitri, age 38, Darbhanga) recounted that although mobility has improved, an unspoken awareness of which places remain unwelcoming to her community persists. Social ostracism following inter-caste marriages was cited by 6 of 20 interviewees as a particularly severe form of community exclusion.

4. Discussion

The finding that caste identity remains a robust and statistically significant predictor of social exclusion even in semi-urban settings, after controlling for income and education, is a significant contribution to the sociology of caste in India. It directly challenges the liberal modernisation thesis that urbanisation and market integration will naturally erode caste hierarchies over time. The evidence from this study suggests that semi-urban contexts do not neutralise caste-based exclusion — they transform and partially conceal it, making it harder to identify, document, and litigate under the Prevention of Atrocities Act's provisions.

The emergence of symbolic and spatial mechanisms of exclusion in semi-urban contexts — as opposed to the more overt ritual and physical exclusions commonly documented in villages — has important implications for law enforcement and social policy. The Prevention of Atrocities Act is designed primarily to address physical atrocities and identifiable acts of discrimination; it is less equipped to address the diffuse, everyday symbolic exclusions documented here. Complementary instruments — including anti-discrimination education in schools, sensitisation training for local government officials, and community-level intercaste dialogue facilitation — are necessary elements of a comprehensive anti-exclusion strategy.

Gender intersects with caste exclusion in complex ways in the Bihar semi-urban context. Female SC participants in this study reported higher rates of exclusion in public and civic spaces, consistent with the dual vulnerability of gender and caste. However, some women also described leveraging employment in domestic service in upper-caste households as a pragmatic strategy for accessing economic resources while navigating social exclusion — a coping mechanism that simultaneously reflects and reinforces dependency relationships. This finding aligns with Dalit feminist scholarship on the compounded nature of caste-gender marginalisation.

5. Conclusion

This study provides empirically grounded documentation of the persistence, forms, and determinants of caste-based social exclusion in semi-urban Bihar, demonstrating that urbanisation has not diminished but rather transformed the operation of caste exclusion, shifting its dominant modality from overt ritual untouchability to subtle symbolic marginalisation and spatial segregation. Scheduled Caste residents of semi-urban towns continue to experience significant exclusion across public, economic, educational, and political domains, with caste identity remaining a primary driver independent of socioeconomic status.

Policy recommendations include: (i) district-level monitoring of SC complaints under the Prevention of Atrocities Act disaggregated by urban versus rural reporting location; (ii) mandatory SC inclusion provisions in municipal housing allocation and commercial plot allotment schemes in Bihar's urban agglomerations; (iii) sensitisation training for police, municipal officials, and school teachers on identifying and responding to subtle and symbolic caste discrimination; (iv) state funding for SC community leadership development programmes in semi-urban wards; and (v) curriculum reform in Bihar schools to include Ambedkarite thought, constitutional values, and the history of the SC freedom movement.

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Financial Inclusion Through Self-Help Groups: A Study of Women's Economic Empowerment in North Karnataka

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Abstract: Self-Help Groups (SHGs) have emerged as a critical institutional mechanism for extending financial services and promoting economic empowerment among rural and semi-urban women in India, particularly through the SHG-Bank Linkage Programme operationalised by NABARD. This study examined the impact of SHG membership on financial inclusion outcomes and economic empowerment indicators among women in four talukas of north Karnataka — Bagalkot, Ilkal, Jamkhandi, and Mudhol — a region characterised by agrarian dependence, low female workforce participation, and limited banking infrastructure penetration. A survey of 250 SHG member women, stratified by taluka and SHG maturity (below three years and above three years of operation), was conducted using a structured questionnaire. Financial inclusion indicators measured included savings behaviour, credit access, loan utilisation pattern, and bank account usage. Empowerment indicators included household financial decision-making autonomy, control over personal income, access to information, and self-reported confidence and self-efficacy. Results showed significant improvements across all financial inclusion indicators for SHG members compared to a reference group of 50 non-member women from the same communities. Binary logistic regression revealed SHG membership duration as the strongest predictor of empowerment outcomes (OR=4.12 for duration above three years; 95% CI: 2.63–6.46; $p<0.001$). Older, more mature SHGs showed stronger empowerment impacts but also greater delinquency risks. The study recommends strengthening the SHG-Bank Linkage Programme, reducing documentation burdens for loan access, and introducing financial literacy curricula within SHG meetings.

Keywords: *Self-Help Groups, Financial Inclusion, Women's Empowerment, SHG-Bank Linkage, North Karnataka, NABARD*

1. Introduction

Financial inclusion — ensuring that all individuals and businesses have access to useful and affordable financial products and services, including transactions, payments, savings, credit, and insurance — is now recognised as a foundational enabler of broader economic development and poverty reduction. In India, despite significant progress through the Pradhan Mantri Jan Dhan Yojana (PMJDY) launched in 2014, substantial segments of the population — particularly women in rural and semi-urban areas — remain effectively excluded from formal financial services. Account ownership does not translate automatically into account usage or meaningful financial participation.

The Self-Help Group (SHG) model, pioneered by NABARD in collaboration with NGOs and commercial banks since the early 1990s, has evolved into one of India's most significant financial inclusion and social mobilisation mechanisms. Under the SHG-Bank Linkage Programme, groups of 10–20 women meet regularly, contribute to a common savings fund, extend inter-member loans from savings, and after a period of demonstrated savings discipline (typically 6–12 months) become eligible for formal bank credit linked to their group savings. As of March 2023, over 1.15 crore SHGs comprising approximately 12 crore women were credit-linked under the programme.

North Karnataka — comprising the districts of Bagalkot, Vijayapur, Belagavi, Dharwad, and Haveri among others — is a historically underdeveloped subregion of Karnataka marked by agrarian distress, low female literacy, high rates of seasonal male outmigration, and relatively limited bank branch density compared to southern Karnataka. Women in this region are disproportionately engaged in rain-fed agriculture, domestic labour, and home-based artisanal work, with limited access to formal credit markets for income-generating activities or consumption smoothing.

While SHG impacts have been studied extensively in Andhra Pradesh, Tamil Nadu, and Kerala, systematic empirical evidence from north Karnataka's specific agro-ecological and socio-cultural context is limited. This study addresses this gap by examining SHG-mediated financial inclusion and women's empowerment outcomes in four talukas of Bagalkot district, providing contextually grounded evidence for programme design and policy.

2. Methodology

A cross-sectional survey design was employed. The study population comprised women who were active members of SHGs registered with the Karnataka Mahila Abhivruddhi Mattu Samrakshane Samsthe (KMAS) and credit-linked under the SHG-Bank Linkage Programme in four talukas of Bagalkot district: Bagalkot, Ilkal, Jamkhandi, and Mudhol. A stratified random sample of 250 SHG member women was drawn, stratified by taluka (approximately 62 per taluka) and by SHG maturity — defined as operating for fewer than three years ('younger SHGs', $n=125$) or three or more years ('mature SHGs', $n=125$). A comparison group of 50 non-SHG-member women from the same communities was also interviewed using the same questionnaire to provide a non-randomised reference population.

The structured questionnaire comprised four modules: (i) Sociodemographic background (age, education, household size, land ownership, spouse's occupation); (ii) Financial inclusion scale (10 items on savings habits, bank account usage frequency, credit access, loan utilisation, insurance enrolment); (iii) Economic empowerment scale (12 items adapted from the Women's Empowerment in Agriculture Index and validated for the study context through pilot testing with 30 non-sample respondents); and (iv) SHG participation history (duration, meeting attendance, leadership roles, inter-member lending experience). All instruments were available in Kannada and administered by four trained female data collectors through face-to-face interviews.

Quantitative data analysis was conducted in SPSS version 25. Financial inclusion and empowerment composite scores were computed and their reliability assessed (Cronbach's alpha: financial inclusion = 0.81; empowerment = 0.78). Independent samples t-tests were used to compare SHG member and non-member scores. Multivariate binary logistic regression with empowerment score (dichotomised at median) as the dependent variable was used to identify predictors. The study received ethical clearance from Shri Basaveshwara Degree College's institutional research committee, and all participants provided informed verbal consent.

3. Results and Findings

Among the 250 SHG members surveyed, 82.4% reported having an active bank savings account compared to 54.0% of non-SHG comparison women ($p<0.001$). Among those with accounts, 74.1% of SHG members reported using their account at least twice in the preceding month ('active usage') compared to 31.5% of non-members with accounts ($p<0.001$), suggesting that SHG participation drives not merely account ownership but active financial engagement. Credit access was similarly differentiated: 91.6% of SHG members had received at least one formal or SHG inter-member loan in the preceding two years, compared to 22.0% of non-members.

Empowerment scores were significantly higher for SHG member women across all four sub-dimensions of the empowerment scale: household financial decision-making (mean score 3.8 out of 5 for SHG members vs 2.4 for non-members; $p<0.001$), control over personal income (3.4 vs 2.0; $p<0.001$), access to financial information (3.6 vs 2.2; $p<0.001$), and self-reported confidence and self-efficacy (3.9 vs 2.6; $p<0.001$). Women in mature SHGs (3+ years of operation) reported significantly higher empowerment scores than those in younger SHGs on all dimensions ($p<0.01$).

Binary logistic regression identified SHG membership duration of three or more years (OR=4.12; 95% CI: 2.63–6.46; $p<0.001$), SHG leadership experience (serving as president or secretary; OR=2.87; 95% CI: 1.74–4.73; $p<0.001$), and higher household income (OR=1.92; 95% CI: 1.23–3.01; $p=0.004$) as the strongest independent predictors of above-median empowerment. Education level of the respondent was a significant predictor only at the bivariate level and lost significance in the multivariate model, suggesting that SHG participation may partially compensate for low formal education in building financial capability.

4. Discussion

The finding that SHG membership significantly increases active bank account usage — not merely account ownership — is an important contribution to the financial inclusion literature. The PMJDY's success in opening bank accounts has been widely documented, but the problem of dormant or infrequently used accounts ('last-mile problem') remains a significant concern for financial inclusion policymakers. The SHG mechanism appears to address this gap by creating regular group-based savings habits and establishing a social norm of financial activity that spills over into individual bank account behaviour.

The strong predictive power of SHG maturity and leadership experience for empowerment outcomes supports a pathway model in which SHG participation builds empowerment incrementally over time: women develop financial skills in the early years (savings, credit management), then exercise agency in group decision-making (lending decisions, meeting facilitation), and eventually transfer these capabilities to household financial decision-making and broader civic participation. This suggests that SHG programmes should prioritise long-term continuity and leadership rotation — ensuring that as many women as possible experience office-bearing roles — rather than focusing narrowly on credit disbursement volumes.

Constraints identified by survey participants included excessive documentation requirements for bank loan renewal (cited by 43.2% as a barrier), irregular meetings due to seasonal agricultural labour demands (38.4%), and lack of financial literacy on topics beyond basic savings and credit (29.6%). The latter finding suggests that integrating structured financial literacy modules — covering topics such as insurance products, Kisan Credit Cards, government scheme entitlements, and digital payments — into regular SHG meetings could substantially enhance the programme's empowerment impact at low marginal cost.

5. Conclusion

This study provides empirical evidence from north Karnataka that SHG membership significantly enhances financial inclusion outcomes and women's economic empowerment, with the strength of impact increasing

substantially with membership duration and active leadership participation. The findings validate the SHG model's continued relevance as a microfinance and empowerment mechanism in a region characterised by structural economic disadvantage for women.

Key policy recommendations include: (i) strengthening NABARD's revolving fund support for SHG bank linkage in Bagalkot and Vijayapur districts, which lag behind coastal Karnataka in credit linkage ratios; (ii) mandating simplified, standardised documentation requirements for SHG loan renewals across all linkage banks; (iii) introducing structured financial literacy training modules into bi-monthly SHG meetings through trained KMAS cluster coordinators; (iv) incentivising leadership rotation within SHGs through preferential loan terms for groups demonstrating office-bearing diversity; and (v) expanding SHG integration with government welfare schemes (Ayushman Bharat, MGNREGS payment accounts) to maximise the financial inclusion platform already created by the programme.

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Corporate Social Responsibility Practices of Small and Medium Enterprises in Tirunelveli District, Tamil Nadu: An Empirical Investigation

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Abstract: Corporate Social Responsibility (CSR) has evolved from a voluntary philanthropic impulse to a statutory obligation for qualifying companies under the Companies Act 2013, which mandates CSR expenditure of at least 2% of average net profits for companies meeting prescribed size thresholds. While large corporations' CSR practices have been extensively studied, the CSR behaviour of Small and Medium Enterprises (SMEs) — which constitute 95% of Indian businesses and employ over 110 million people — remains poorly understood, particularly in non-metropolitan, semi-industrial districts. This paper empirically investigates the CSR practices, motivations, and challenges of SMEs operating in Tirunelveli district, Tamil Nadu, a region characterised by significant activity in leather, textile, and agro-processing industries. A structured questionnaire-based survey was administered to 150 SME owner-managers across three industrial clusters in Tirunelveli district. Results reveal that 43.3% of surveyed SMEs engage in some form of CSR activity, predominantly philanthropic (donations to temples, schools, and disaster relief funds) rather than strategic or stakeholder-integrated. Awareness of the Companies Act 2013 CSR mandate was high (78.7%) but most SMEs were exempt from the statutory requirement and viewed CSR as beyond their immediate resource capacity. Key barriers included lack of dedicated CSR personnel, absence of CSR implementation knowledge, and perceived primacy of business survival and growth. The study argues for a differentiated CSR policy framework for SMEs and recommends industry association-led CSR capacity-building programmes.

Keywords: CSR, Small and Medium Enterprises, Companies Act 2013, Tamil Nadu, Tirunelveli, SME CSR Barriers

1. Introduction

Corporate Social Responsibility has undergone a significant transformation in the Indian policy landscape following the enactment of Section 135 of the Companies Act, 2013. For the first time, the statute mandated that companies meeting prescribed thresholds of net worth (Rs. 500 crore or more), turnover (Rs. 1,000 crore or more), or net profit (Rs. 5 crore or more) spend at least 2% of their three-year average net profit on CSR activities specified in Schedule VII of the Act. India became the first country globally to legislatively mandate CSR expenditure. While this has driven significant increases in measurable CSR spending among large corporations — from approximately Rs. 10,000 crore in 2014–15 to over Rs. 25,000 crore in 2021–22 — the CSR practices of the vast majority of Indian businesses, which fall below the statutory threshold, remain largely unstudied.

Small and Medium Enterprises (SMEs), defined by the Ministry of Micro, Small and Medium Enterprises on the basis of investment and turnover criteria, constitute the backbone of the Indian economy: they account for approximately 30% of GDP, 45% of merchandise exports, and employ over 110 million people across 63.4 million

enterprises. SMEs are typically embedded in local communities in ways that large corporations are not — they hire local labour, procure from local suppliers, and are visible participants in local civic life. Their CSR behaviour, however informal or implicit, therefore has significant implications for local community well-being, environmental impact, and labour standards.

Tirunelveli district in southern Tamil Nadu presents an interesting case study for SME CSR analysis. The district hosts significant clusters of leather goods manufacturing (particularly in Vaniyambadi and Ambur industrial areas), textile and garment production, and agro-processing activities including cashew and rice processing. These industries are associated with substantial environmental impacts (leather tanning effluents, water consumption) and labour challenges (piece-rate work, informal employment), making CSR and sustainability practices particularly relevant. Yet empirical data on CSR awareness and practice among Tirunelveli SMEs is absent from the published literature.

This study directly addresses this gap by surveying 150 SME owner-managers across three industrial clusters in Tirunelveli district to assess CSR awareness levels, the nature and extent of CSR practices, the motivations behind CSR engagement (or non-engagement), and the structural barriers limiting more systematic CSR adoption. The findings are intended to inform industry association programmes, district administration initiatives, and national policy on SME sustainability governance.

2. Methodology

A quantitative survey design was employed. The study population comprised owner-managers of Small and Medium Enterprises registered under the MSME Development Act, 2006 and operating in three industrial clusters in Tirunelveli district: the Tirunelveli industrial estate (manufacturing cluster), the Palayamkottai commercial cluster, and the Sankarankovil agro-processing cluster. The sampling frame was the Tirunelveli District Industries Centre's MSME registration database, from which 150 enterprises were selected using stratified random sampling, stratified by enterprise size category (small: 50, medium: 50) and industry type (manufacturing: 75, trading and services: 75).

A structured 32-item questionnaire was developed drawing on established CSR scales from Carroll's (1991) four-part CSR model (economic, legal, ethical, philanthropic responsibilities) and validated scales from Indian SME CSR studies conducted in other regions. The questionnaire covered: (i) enterprise profile and background; (ii) awareness of Companies Act 2013 CSR mandate and Schedule VII; (iii) current CSR activities and annual expenditure estimates; (iv) motivations for CSR engagement (both intrinsic and extrinsic); (v) barriers to CSR engagement; and (vi) preferred support mechanisms for CSR capacity building. The questionnaire was pretested with 15 non-sample SME owners and refined based on feedback before final administration. Data collection was conducted personally by the researcher between February and April 2024.

Data were analysed using SPSS version 22.0. Frequency distributions and percentages described CSR participation rates and activity types. Chi-square tests examined associations between enterprise characteristics (size, industry type, ownership structure) and CSR engagement. Mean scores for motivational and barrier items were computed and ranked. Content analysis was applied to open-ended items on preferred CSR activities and support mechanisms. The study adhered to standard research ethics; all participants were informed of the study's academic purpose and confidentiality of responses.

3. Results and Findings

Of the 150 SME owner-managers surveyed, 65 (43.3%) reported engaging in at least one form of CSR-related activity in the preceding financial year. The dominant form of CSR was philanthropic giving: 72.3% of

CSR-active enterprises reported donations to religious institutions (temples, churches, mosques), schools, and natural disaster relief funds. Strategic CSR activities — defined as initiatives aligned with core business operations and community needs simultaneously, such as apprenticeship programmes, supplier development, or environmental management — were reported by only 12.3% of CSR-active enterprises. Environmental CSR practices (waste management, energy efficiency, effluent treatment) were found in 24.6% of manufacturing SMEs, largely driven by regulatory compliance requirements rather than voluntary sustainability commitment.

Awareness of the Companies Act 2013 CSR mandate was high at 78.7% of respondents, significantly higher than levels typically reported in studies of similar SME samples in other Indian regions. However, 86.7% of respondents stated that their enterprise fell below the statutory threshold and was therefore not mandatorily required to implement CSR. Among the 20 enterprises (13.3%) meeting or approaching the threshold, only 11 (55%) had a documented CSR plan. Annual CSR expenditure among CSR-active enterprises ranged from Rs. 5,000 to Rs. 3,50,000, with a median expenditure of Rs. 28,000, representing a median of 0.3% of reported annual profits — well below the statutory 2% benchmark applicable to qualifying companies.

The top five ranked motivations for CSR engagement were: personal or religious values of the owner (mean score 4.2/5), desire to improve community goodwill and reputation (4.0/5), employee welfare concerns (3.7/5), response to community requests or social pressure (3.4/5), and awareness of business sustainability benefits (2.9/5). The top barriers to CSR engagement were: lack of dedicated personnel (mean score 4.4/5), resource constraints in a competitive market (4.2/5), lack of knowledge on how to implement effective CSR (3.9/5), absence of tax incentives for SME CSR beyond existing deduction provisions (3.7/5), and perception that CSR is only relevant for large corporations (3.4/5).

4. Discussion

The 43.3% CSR participation rate among Tirunelveli SMEs is broadly consistent with findings from comparable SME surveys in Maharashtra and Rajasthan but lower than rates reported from more developed industrial clusters in Gujarat and Karnataka, suggesting a regional dimension to SME CSR development linked to local business culture, industrial maturity, and infrastructure for civil society engagement. The predominance of philanthropic over strategic CSR among participating enterprises mirrors patterns documented in SME CSR literature globally, where limited management capacity and short time horizons constrain the adoption of more integrated, multi-stakeholder CSR approaches.

The striking finding that personal and religious values rank as the primary motivation for SME CSR engagement — above business reputation or regulatory pressure — aligns with qualitative research on owner-managed firm CSR in South Asian contexts and suggests that values-based appeals in CSR education and capacity-building programmes may be more effective than regulatory or business-case-oriented framing for this population. This has implications for how district industries centres and industry associations design SME CSR awareness campaigns.

The identified barriers — particularly lack of dedicated personnel and implementation knowledge — point to a structural challenge inherent in expecting SMEs to develop CSR programmes using internal resources designed for core business operations. Cluster-level or industry association-level CSR coordination platforms, in which a shared CSR manager or NGO partner supports multiple SMEs in identifying community needs and implementing programmes collectively, represent a viable structural solution that has been piloted successfully in some industrial clusters in Kerala and Tamil Nadu's Coimbatore district.

5. Conclusion

This study demonstrates that a significant minority of Tirunelveli SMEs engage in CSR, predominantly through philanthropic activities driven by owner values rather than strategic business considerations. The Companies Act 2013 mandate, while well-known among SME owners, has limited direct impact on non-qualifying enterprises, leaving the majority of Indian businesses' social and environmental conduct subject only to voluntary impulse and market pressures.

Recommendations include: (i) establishing an MSME CSR cluster platform in Tirunelveli with support from the District Industries Centre and Tamil Nadu SIDCO to enable collective CSR planning and implementation; (ii) designing a differentiated voluntary CSR reporting framework for SMEs with simplified disclosure requirements; (iii) providing enhanced tax deductions for SME CSR expenditures to create financial incentives for voluntary participation; (iv) integrating CSR competency modules into MSME training programmes offered by the Small Industries Development Bank of India (SIDBI) and Entrepreneurship Development Institutes; and (v) recognising SME CSR excellence through an annual district-level award to create aspirational incentives and showcase best practices.

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Comparative Analysis of Machine Learning Algorithms for Crop Disease Detection Using Leaf Image Data

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Abstract: Timely and accurate detection of crop diseases is critical for minimising agricultural yield losses and reducing the overuse of chemical pesticides. Conventional expert-based field diagnosis is costly, time-consuming, and inaccessible to smallholder farmers in resource-limited settings. Machine learning-based image classification offers a scalable, accessible alternative. This study conducted a comparative performance evaluation of three widely used machine learning approaches — Convolutional Neural Network (CNN), Support Vector Machine (SVM), and Random Forest (RF) — for the automatic detection and classification of nine common crop diseases across four crop species (tomato, potato, maize, and rice) using leaf image data drawn from the publicly available PlantVillage dataset (54,306 images). Experiments were conducted under two conditions: using original dataset images and using augmented datasets (rotation, flipping, brightness variation). The CNN architecture (a fine-tuned VGG-16 model) achieved the highest overall classification accuracy of 94.2% under augmented conditions, outperforming SVM (87.1%) and RF (82.3%). Precision, recall, and F1-score analyses confirmed CNN's superiority across all nine disease classes. Computational training time was substantially higher for CNN (4.3 hours on GPU) than SVM (38 minutes) or RF (12 minutes), presenting a deployment trade-off for resource-constrained settings. The study discusses implications for mobile application development for farmer-facing disease diagnosis tools and recommends CNN with transfer learning as the optimal approach for accuracy-critical applications, while SVM is recommended where computational constraints are significant.

Keywords: *Crop Disease Detection, Convolutional Neural Network, Support Vector Machine, PlantVillage, Transfer Learning, Precision Agriculture*

1. Introduction

Agricultural productivity in developing nations is severely impacted by crop diseases, which account for estimated annual yield losses of 10–40% globally, with significantly higher losses in smallholder farming systems that lack early detection and management infrastructure. In India, diseases affecting major food and cash crops — including rice blast, wheat rust, tomato late blight, and potato early blight — together cause crop losses valued at thousands of crores of rupees annually, contributing to farmer indebtedness and food insecurity. Traditional methods of disease identification depend on trained agricultural extension officers or diagnostic laboratories, both of which are chronically under-resourced relative to the farming population they serve.

The rapid proliferation of affordable smartphones with high-resolution cameras among farming communities, combined with expanding rural 4G/5G connectivity, has created a technological opportunity to deliver machine learning-based crop disease diagnosis at the point of need. Several mobile applications — including PlantDoc, CropMD, and Plantix — have already reached millions of smallholder farmers globally, but their underlying algorithmic accuracy and comparative performance against alternative machine learning approaches have not been systematically documented in the peer-reviewed literature, particularly for Indian crop disease typology.

Machine learning approaches to image classification span a wide performance and complexity spectrum. Convolutional Neural Networks (CNNs), particularly deep CNN architectures with transfer learning from large image datasets, have dominated image recognition benchmarks since AlexNet's performance breakthrough in 2012 and have been widely applied to plant disease detection. Support Vector Machines (SVMs) with handcrafted or automatically extracted image features represent an earlier generation of machine learning approach that remains relevant in resource-constrained deployment contexts due to lower computational requirements. Random Forest (RF) classifiers, based on ensemble decision tree methods, offer interpretability advantages and robustness to overfitting with smaller datasets.

A systematic comparative evaluation of CNN, SVM, and RF performance specifically on the PlantVillage dataset — the largest publicly available plant disease image library — using consistent experimental protocols and including data augmentation conditions, is needed to provide a sound empirical basis for algorithm selection in practical disease detection system development. This study provides such a comparison.

2. Methodology

The PlantVillage dataset (version 3.0) was used, comprising 54,306 RGB leaf images across 38 classes (healthy and diseased conditions) for 14 crop species. For this study, a subset of 9 disease classes from four crop species most relevant to Indian agriculture was selected: tomato (early blight, late blight, leaf mold), potato (early blight, late blight), maize (northern leaf blight, common rust), and rice (blast, brown spot). The subset comprised 22,842 images. Images were resized to 224x224 pixels (required input for VGG-16 CNN architecture). An 80:10:10 split was used for training, validation, and testing sets respectively across all models.

Three machine learning models were implemented and evaluated. For CNN, a pre-trained VGG-16 network (trained on ImageNet) was adapted for the 9-class disease classification task using transfer learning: the last three fully connected layers were replaced and trained on the PlantVillage subset, while the convolutional base was frozen for the initial 15 epochs then unfrozen for fine-tuning for an additional 10 epochs (total 25 epochs). Learning rate was set to 0.0001 (Adam optimiser). For SVM, images were first processed through a HOG (Histogram of Oriented Gradients) feature extractor, and the resulting feature vectors were classified using a radial basis function (RBF) kernel SVM with hyperparameter optimisation via grid search. For RF, HOG features were also used as input to a Random Forest of 200 decision trees with Gini impurity as the splitting criterion.

Data augmentation was applied to the training set using random horizontal flipping, vertical flipping, rotation (± 20 degrees), and brightness variation ($\pm 20\%$), doubling the effective training dataset size. Experiments were run under both original and augmented conditions. All experiments were implemented in Python 3.9 using TensorFlow 2.9 (CNN) and scikit-learn 1.1 (SVM, RF). GPU computation used an NVIDIA Tesla T4 instance on Google Colab Pro. Performance metrics calculated were: classification accuracy, precision, recall (sensitivity), and F1-score (macro-averaged across classes). Confusion matrices were generated for each model under augmented conditions.

3. Results and Findings

Under original (non-augmented) dataset conditions, CNN achieved the highest test set accuracy at 91.4%, followed by SVM at 83.7% and RF at 78.9%. Data augmentation produced consistent and significant accuracy improvements for all three models. Under augmented conditions, CNN accuracy reached 94.2%, SVM improved to 87.1%, and RF to 82.3%. The CNN's accuracy advantage over SVM under augmented conditions was 7.1 percentage points, confirming the superiority of deep transfer learning for this image classification task across all experimental conditions.

Class-level performance analysis revealed that disease classes with high visual homogeneity presented the greatest challenge across models. Rice brown spot and maize common rust showed the highest inter-class confusion rates, with all three models occasionally misclassifying these as healthy or as alternative disease conditions. CNN demonstrated the most robust class-level performance, with F1-scores above 0.90 for seven of nine disease classes under augmented conditions. SVM's class-level performance was more variable, with F1-scores ranging from 0.79 (maize common rust) to 0.93 (potato late blight). RF showed the widest performance variance, with three of nine classes below F1=0.80.

Computational requirements differed substantially across models. CNN training time on GPU (Tesla T4) was 4.3 hours for the augmented dataset, while SVM and RF training required 38 minutes and 12 minutes respectively on the same hardware. Model inference time (time to classify a single new image) was 0.18 seconds for CNN, 0.04 seconds for SVM, and 0.09 seconds for RF, all within acceptable ranges for a mobile application context with server-side inference. CPU-based training (for scenarios without GPU access) increased CNN training time to approximately 28 hours, a significant constraint for deployment in low-resource research or development settings.

4. Discussion

The consistent superiority of CNN with transfer learning over SVM and RF across all experimental conditions confirms the findings of prior comparative studies in plant disease detection using the PlantVillage dataset and extends those findings to the specific Indian crop disease subset examined here. The performance advantage of CNN is attributable to the deep feature representations learned during VGG-16's ImageNet pretraining, which capture hierarchical visual features (edges, textures, shapes) that are highly relevant to disease symptom recognition on leaf surfaces and cannot be replicated by handcrafted feature extraction methods such as HOG.

The 7-percentage-point accuracy advantage of CNN over SVM, while statistically meaningful, must be evaluated against the significantly higher computational cost of CNN training and the greater technical expertise required for CNN model development and maintenance. For farmer-facing mobile application deployment where accuracy is paramount and inference occurs on cloud servers, the CNN advantage is unambiguous. However, for deployment in contexts where internet connectivity is unreliable and on-device inference is required (edge deployment), the SVM's lower computational requirements and simpler model structure may make it a pragmatically superior choice despite the accuracy trade-off.

The study has several limitations. The PlantVillage dataset was created under controlled laboratory lighting conditions with consistent backgrounds, and performance in field conditions — where images are captured under variable lighting, angles, and with background noise — is likely lower for all three models. A key recommendation for future work is evaluation on field-collected image datasets representative of Indian farming contexts. Additionally, this study did not address the challenge of multi-disease classification (a single leaf may exhibit symptoms of more than one disease simultaneously), which represents an important direction for subsequent research.

5. Conclusion

This comparative study establishes that CNN with transfer learning (fine-tuned VGG-16) is the most accurate approach for automated crop disease detection from leaf images, achieving 94.2% classification accuracy across nine disease classes with data augmentation, substantially outperforming SVM (87.1%) and Random Forest (82.3%). The performance advantage persists across all disease classes studied, though with greater absolute margins for visually complex or ambiguous disease presentations.

Practical recommendations for disease detection system developers include: (i) adopting CNN with transfer learning as the default architecture for server-side, accuracy-critical crop disease detection applications; (ii) considering SVM as a viable lightweight alternative for edge-deployment scenarios with connectivity constraints; (iii) investing in field-based image dataset collection for Indian crop disease variants to improve model generalisation to real farming conditions; and (iv) developing Hinglish and regional-language user interfaces for farmer-facing mobile diagnosis applications to maximise accessibility among smallholder farmer communities with limited English proficiency.

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Synthesis and Characterisation of Zinc Oxide Nanoparticles by Chemical Precipitation Method and Investigation of Optical Properties

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Abstract: Zinc oxide (ZnO) nanoparticles have attracted significant research attention due to their distinctive optical, electronic, and photocatalytic properties that emerge from quantum confinement effects at the nanoscale. This paper reports the synthesis of ZnO nanoparticles by an optimised chemical precipitation method using zinc acetate dihydrate as the precursor and sodium hydroxide as the precipitating agent, with polyethylene glycol (PEG-400) as a capping agent to control particle growth. The synthesised nanoparticles were characterised using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), ultraviolet-visible (UV-Vis) absorption spectroscopy, and photoluminescence (PL) spectroscopy. XRD analysis confirmed a wurtzite hexagonal crystal structure with no secondary phase impurities. The Scherrer equation applied to the (101) XRD peak yielded a mean crystallite size of 34.7 nm. The optical band gap was calculated from the Tauc plot derived from UV-Vis absorbance data and found to be 3.24 eV, slightly wider than bulk ZnO (3.37 eV) and consistent with quantum confinement effects at the observed particle size. FTIR spectroscopy confirmed the Zn-O stretching mode at 478 cm^{-1} and revealed trace surface hydroxyl groups. Photoluminescence spectra exhibited a near-band-edge emission peak at 378 nm and a broad visible emission band centred at 520 nm associated with oxygen vacancy defects. The synthesised nanoparticles showed strong UV absorption below 380 nm and high optical transparency in the visible range, suggesting suitability for UV-blocking, photocatalytic, and optoelectronic applications.

Keywords: ZnO Nanoparticles, Chemical Precipitation, XRD, Optical Band Gap, Photoluminescence, Nanostructure

1. Introduction

Nanotechnology — the science and engineering of materials and devices with structures and components at the nanometre scale, generally between 1 and 100 nm — has emerged as one of the most transformative research and technology domains of the twenty-first century. When material dimensions are reduced to the nanoscale, quantum mechanical effects become significant, leading to dramatic changes in optical, electrical, magnetic, thermal, and mechanical properties compared to the bulk material. These size-dependent property changes are the basis for a wide range of nanotechnology applications in fields spanning electronics, energy, medicine, agriculture, environmental remediation, and cosmetics.

Zinc oxide (ZnO) is an n-type semiconductor with a wide direct band gap of 3.37 eV and a large exciton binding energy of 60 meV at room temperature, properties that make it highly suitable for UV photodetectors, light-emitting diodes, laser diodes, piezoelectric devices, and photocatalysts. At the nanoscale, ZnO exhibits enhanced surface-to-volume ratios, modified band gaps through quantum confinement, and heightened photocatalytic activity compared to bulk ZnO, making ZnO nanoparticles a subject of intense research interest across physics, chemistry, and materials science. ZnO is also biocompatible, abundant, and relatively low-cost, making it attractive for large-scale application development.

Multiple synthesis routes for ZnO nanoparticles have been reported in the literature, including sol-gel, hydrothermal, co-precipitation, microwave-assisted, and green synthesis methods. Each method produces nanoparticles with characteristic size distributions, morphologies, surface chemistries, and defect profiles that profoundly influence their optical and photocatalytic behaviour. Chemical precipitation — a simple, scalable, low-temperature route that does not require specialised high-pressure or high-temperature equipment — is particularly relevant for resource-limited research settings and has been the subject of extensive optimisation studies to control nanoparticle size and morphology.

This study reports the synthesis of ZnO nanoparticles using an optimised chemical precipitation protocol and provides a systematic optical characterisation using multiple complementary spectroscopic techniques. The structural, vibrational, and optical data generated provide a comprehensive characterisation profile that can serve as a reference for future applied studies utilising these nanoparticles for UV-blocking, photocatalytic degradation, or optoelectronic applications.

2. Methodology

ZnO nanoparticles were synthesised by chemical precipitation using analytical-grade reagents without further purification. In a typical synthesis, 0.1 M zinc acetate dihydrate ($\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$; Merck, 99.5%) solution was prepared in 100 mL of deionised water under constant magnetic stirring at 60°C. PEG-400 (1% v/v) was added as a capping agent to control nanoparticle aggregation and particle size distribution. A 0.2 M sodium hydroxide (NaOH; Merck, 97%) solution was prepared separately and added dropwise to the zinc acetate solution at a rate of 2 mL/min under continuous stirring at 60°C until a white precipitate formed and the pH stabilised at 11–12. The mixture was allowed to age under stirring for 2 hours at 60°C, then cooled to room temperature. The precipitate was collected by centrifugation (8,000 rpm, 15 min), washed three times each with deionised water and ethanol to remove residual ions, and dried at 80°C for 24 hours. The dried precipitate was calcined at 400°C for 2 hours in a muffle furnace to obtain crystalline ZnO nanoparticles.

Structural characterisation was performed using X-ray diffraction (XRD) on a Bruker D8 Advance diffractometer with Cu K α radiation ($\lambda = 0.1541$ nm) over a 2θ range of 20°–80° at a scan rate of 0.02°/s. Crystallite size was estimated using the Debye-Scherrer equation: $D = K\lambda/(\beta \cos\theta)$, where K is the shape factor (0.94), λ is the X-ray wavelength, β is the full width at half maximum (FWHM) of the diffraction peak in radians, and θ is the Bragg diffraction angle. FTIR spectroscopy was performed on a Shimadzu IRPrestige-21 spectrometer in ATR mode over the wavenumber range 400–4000 cm^{-1} . UV-Vis absorption spectra were recorded on a Shimadzu UV-2600 spectrophotometer over the wavelength range 200–800 nm using a quartz cuvette with the sample dispersed in absolute ethanol (0.1 mg/mL). The optical band gap was determined from Tauc plots of $(\alpha h\nu)^2$ versus photon energy ($h\nu$). Photoluminescence spectra were recorded at room temperature using a Horiba FluoroMax-4 spectrofluorometer with an excitation wavelength of 325 nm.

3. Results and Findings

XRD analysis of the calcined ZnO nanoparticles revealed sharp, well-defined diffraction peaks at 2θ positions of 31.8° , 34.4° , 36.2° , 47.5° , 56.6° , 62.8° , 66.3° , 67.9° , and 69.0° , corresponding to the (100), (002), (101), (102), (110), (103), (200), (112), and (201) crystal planes respectively. All peaks were indexed to the hexagonal wurtzite structure of ZnO (JCPDS card No. 36-1451) with no secondary or impurity phase peaks, confirming phase-pure synthesis. Lattice parameters calculated from peak positions were $a = 0.325$ nm and $c = 0.521$ nm, in close agreement with standard ZnO values ($a = 0.3250$ nm, $c = 0.5207$ nm). The mean crystallite size estimated from the Scherrer equation applied to the (101) peak was 34.7 nm.

FTIR spectroscopy revealed a strong absorption band at 478 cm^{-1} , characteristic of the Zn-O stretching vibration mode and confirming the formation of ZnO. Broad absorption bands in the $3200\text{--}3500\text{ cm}^{-1}$ region were attributed to O-H stretching vibrations from surface-adsorbed hydroxyl groups, while C-H stretching modes observed at 2920 cm^{-1} indicated trace residual PEG capping agent on the nanoparticle surface. UV-Vis absorption spectra showed a strong absorption onset at approximately 368 nm with a prominent excitonic absorption shoulder near 355 nm, consistent with ZnO's UV absorption characteristics. The Tauc plot analysis yielded an optical band gap (E_g) of 3.24 eV, slightly lower than bulk ZnO's 3.37 eV, consistent with the influence of quantum confinement effects and surface states at the observed particle size.

Room-temperature photoluminescence spectra under 325 nm excitation exhibited two distinct emission features. A sharp near-band-edge (NBE) emission peak was observed at 378 nm (3.28 eV), corresponding to the recombination of free excitons and confirming the optical quality of the synthesised nanoparticles. A broad, intense visible emission band centred at approximately 520 nm (2.38 eV) was also observed, commonly attributed in ZnO literature to deep-level emission from oxygen vacancy (V_o) defects within the crystal lattice. The relative intensity of the visible defect emission band with respect to the NBE peak provides an indirect measure of the concentration of oxygen vacancies, which are relevant to photocatalytic performance as they serve as active sites for oxidative reactions.

4. Discussion

The XRD-confirmed wurtzite crystal structure and phase purity of the synthesised ZnO nanoparticles validate the optimised precipitation protocol. The mean crystallite size of 34.7 nm places the particles in the range where quantum confinement effects are measurable in optical properties, as evidenced by the observed band gap widening relative to bulk ZnO. The modest blue-shift of 0.13 eV from the bulk band gap value (3.37 eV to 3.24 eV) is consistent with the mild quantum confinement regime applicable to particles in the 30–50 nm range, in agreement with theoretical predictions based on effective mass approximation models for ZnO nanoparticles.

The strong UV absorption below 380 nm combined with high transparency in the visible region (no significant absorption above 400 nm in the UV-Vis spectrum) makes the synthesised ZnO nanoparticles well-suited as UV-blocking agents in sunscreen formulations, UV-resistant polymer coatings, and transparent UV-protective films. The observed photoluminescence band at 520 nm, associated with oxygen vacancy defects, is characteristic of synthesis by chemical precipitation and calcination and is known to correlate with photocatalytic activity in ZnO nanoparticles, since oxygen vacancies facilitate charge carrier generation and separation under UV irradiation.

The PEG-400 capping strategy successfully prevented excessive particle aggregation as evidenced by the relatively narrow XRD peak widths and the single-phase XRD pattern. However, residual PEG signature in the FTIR spectrum suggests that calcination at 400°C was not fully sufficient to remove the organic capping layer. Higher calcination temperatures (above 500°C) or longer calcination durations could more completely remove surface organics but risk grain growth and loss of nanoparticle surface area. This trade-off between surface

cleanliness and particle size is an important experimental parameter for optimisation in future studies focused on photocatalytic application.

5. Conclusion

ZnO nanoparticles with a mean crystallite size of 34.7 nm and hexagonal wurtzite crystal structure were successfully synthesised by an optimised chemical precipitation method. The synthesised material exhibited a band gap of 3.24 eV, strong UV absorption below 380 nm, FTIR-confirmed Zn-O bonding, and characteristic near-band-edge and defect-related photoluminescence emissions at 378 nm and 520 nm respectively. These properties collectively confirm the suitability of the synthesised ZnO nanoparticles for UV-blocking, photocatalytic, and potentially optoelectronic applications.

Future work should include: (i) systematic parametric optimisation of synthesis conditions (NaOH concentration, temperature, ageing time, calcination temperature) to achieve targeted particle size distributions; (ii) photocatalytic degradation experiments using the synthesised nanoparticles against model organic dye pollutants (methylene blue, rhodamine B) to quantify structure-activity relationships; (iii) transmission electron microscopy and selected area electron diffraction for direct particle morphology imaging; and (iv) exploring green synthesis alternatives using plant extract reducing agents to produce environmentally benign ZnO nanoparticles for biomedical applications.

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Green Synthesis of Silver Nanoparticles Using Hibiscus rosa-sinensis Leaf Extract and Evaluation of Antibacterial Activity

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Abstract: The synthesis of silver nanoparticles (AgNPs) using biological systems — particularly plant extracts — has emerged as a sustainable and environmentally benign alternative to conventional chemical reduction methods that involve toxic reducing and stabilising agents. This study reports the green synthesis of AgNPs using aqueous leaf extract of *Hibiscus rosa-sinensis* (shoe flower), a commonly available ornamental plant rich in polyphenols, flavonoids, and anthocyanins that serve as both reducing and capping agents for silver ions. The synthesis involved treating a 1 mM aqueous silver nitrate (AgNO_3) solution with varying volumes of *Hibiscus rosa-sinensis* leaf extract under controlled conditions of temperature (60°C) and extract concentration. Formation of AgNPs was monitored by visual colour change from colourless to brown and confirmed by UV-Vis spectroscopy showing surface plasmon resonance (SPR) at 432 nm. Nanoparticle characterisation by XRD confirmed a face-centred cubic (FCC) silver crystal structure with a mean particle size of 27.4 nm by Scherrer analysis. FTIR spectroscopy identified phytochemical functional groups responsible for silver ion reduction and surface capping. Antibacterial activity of the synthesised AgNPs was evaluated against four clinically significant pathogenic bacteria — *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 25923), *Pseudomonas aeruginosa* (ATCC 27853), and *Klebsiella pneumoniae* (ATCC 13883) — using the agar disc diffusion method and minimum inhibitory concentration (MIC) determination. All four bacterial strains showed significant susceptibility to AgNPs, with MIC values ranging from 6.25 to 12.5 $\mu\text{g/mL}$, demonstrating the strong antibacterial potential of *Hibiscus rosa-sinensis*-derived AgNPs.

Keywords: *Silver Nanoparticles, Green Synthesis, Hibiscus rosa-sinensis, Antibacterial Activity, SPR, Disc Diffusion*

1. Introduction

Nanotechnology has opened new frontiers in materials science, medicine, and environmental remediation through the development of nanoscale materials with unique and tunable physicochemical properties. Among the various metallic nanoparticles synthesised for research and application, silver nanoparticles (AgNPs) occupy a prominent position due to their well-documented broad-spectrum antimicrobial activity, catalytic properties, and applications in wound care, medical devices, water purification, food packaging, and diagnostic biosensors. The global market for silver nanoparticles is expanding rapidly, projected to reach USD 3.4 billion by 2027, driven predominantly by demand from the healthcare and consumer goods sectors.

Conventional chemical synthesis of AgNPs employs chemical reducing agents such as sodium borohydride, hydrazine hydrate, or citrate under controlled pH and temperature conditions. While these methods yield nanoparticles with well-controlled size and morphology, they use toxic chemicals that pose environmental and occupational health risks, generate hazardous byproducts, and require specialised handling facilities. As nanotechnology applications expand to include food contact materials, biomedical implants, and environmental remediation, the toxicological profile of synthesis routes becomes increasingly important.

Green synthesis of AgNPs — using biological entities including plant extracts, fungi, bacteria, and algae as sources of natural reducing and stabilising agents — offers a sustainable, non-toxic, and low-cost alternative. Plant extract-mediated synthesis is particularly attractive because it is a single-step, room-temperature-to-moderate-temperature process, produces stable nanoparticles without requiring additional capping agents, and can be performed without sophisticated laboratory infrastructure. The phytochemicals in plant extracts — polyphenols, flavonoids, terpenoids, alkaloids, and organic acids — act as multi-functional reducing and capping agents, simultaneously converting Ag^+ ions to Ag^0 and stabilising the resulting nanoparticles against aggregation.

Hibiscus rosa-sinensis (family Malvaceae), commonly known as the shoe flower or China rose, is widely cultivated across tropical and subtropical India and is traditionally used in Ayurvedic medicine for its anti-inflammatory, antifungal, and antioxidant properties. Its leaves are rich in phenolic compounds, flavonoids (particularly quercetin and kaempferol), anthocyanins, and polysaccharides — all of which are excellent candidates for silver ion reduction. However, the specific conditions for AgNP synthesis from *Hibiscus rosa-sinensis* leaf extract and the resulting nanoparticles' antibacterial spectrum have not been comprehensively characterised in the literature. This study addresses this gap.

2. Methodology

Fresh leaves of *Hibiscus rosa-sinensis* were collected from the campus of Sacred Heart College, Chalakudy, Kerala, washed thoroughly with deionised water to remove dust and surface contaminants, and shade-dried at room temperature for 5 days. Dried leaves were ground to a fine powder using a household electric grinder. Aqueous extract was prepared by boiling 10 g of leaf powder in 100 mL of deionised water at 80°C for 30 minutes under reflux conditions, then filtering through Whatman No. 1 filter paper and Millipore membrane (0.45 μm) to obtain a clear yellow-green extract. The extract was stored at 4°C until use. Preliminary phytochemical screening of the extract was performed for polyphenols (Folin-Ciocalteu method), flavonoids (aluminium chloride colorimetric method), and tannins (ferric chloride test).

Silver nanoparticles were synthesised by adding varying volumes of leaf extract (1, 3, 5, and 10 mL) to 90 mL of 1 mM aqueous AgNO_3 solution (prepared from 99.9% pure AgNO_3 ; SRL Chemicals, India) under constant magnetic stirring at 60°C. Colour change from colourless to brown, indicating AgNP formation, was monitored visually and by UV-Vis spectroscopy (Shimadzu UV-2450) at intervals of 15, 30, 60, and 120 minutes. The optimal extract volume (5 mL) was determined by maximising the SPR peak intensity. Final AgNPs were isolated by centrifugation (10,000 rpm, 20 min), washed twice with deionised water, redispersed in water, and lyophilised for solid-state characterisation. XRD was performed on a PANalytical X'Pert Pro diffractometer using $\text{Cu K}\alpha$ radiation (2 θ range: 20°–80°). FTIR was performed in KBr pellet mode (4000–400 cm^{-1}) on a Shimadzu IRPrestige-21 spectrometer.

Antibacterial activity was evaluated against four ATCC strains using the Kirby-Bauer agar disc diffusion method on Mueller-Hinton agar (HiMedia). AgNP stock solution (1 mg/mL in deionised water) was serially diluted to prepare test concentrations of 100, 50, 25, and 12.5 $\mu\text{g/mL}$. Sterile filter paper discs (6 mm diameter) were impregnated with 20 μL of each AgNP concentration and allowed to dry. Standard antibiotic discs (Ciprofloxacin

5 µg; HiMedia) and solvent controls were included. Plates were incubated at 37°C for 24 hours. Zone of inhibition (ZOI) diameters were measured in triplicate. MIC values were determined by the broth microdilution method following CLSI guidelines (CLSI M07-A11, 2018) using a 96-well plate format with AgNP concentrations ranging from 0.39 to 100 µg/mL.

3. Results and Findings

Phytochemical screening confirmed the presence of polyphenols (total phenolic content: 28.4 mg gallic acid equivalents/g dry extract), flavonoids (total flavonoid content: 12.7 mg quercetin equivalents/g dry extract), and tannins in the *Hibiscus rosa-sinensis* leaf extract. These phytochemicals provided the reducing capacity confirmed by the DPPH radical scavenging activity assay (IC_{50} : 0.24 mg/mL). Formation of AgNPs was confirmed within 30 minutes of adding extract to the $AgNO_3$ solution by the characteristic brown colouration. UV-Vis spectra showed a single, sharp SPR absorption peak at 432 nm, characteristic of spherical AgNPs and confirming successful nanoparticle formation. Peak absorbance was maximal at the 5 mL extract volume, which was used for all subsequent syntheses.

XRD analysis of lyophilised AgNPs revealed four characteristic diffraction peaks at 2θ values of 38.1°, 44.3°, 64.5°, and 77.4°, corresponding to the (111), (200), (220), and (311) crystallographic planes of face-centred cubic (FCC) silver (JCPDS No. 04-0783), confirming the formation of crystalline silver. No peaks attributable to silver oxide or silver chloride impurities were detected. Mean crystallite size calculated from the (111) peak using the Scherrer equation was 27.4 nm, consistent with the particle size inferred from the SPR peak position. FTIR spectrum of AgNPs showed a broad O-H stretching band (3200–3500 cm^{-1}) and C=O stretching bands (1620–1645 cm^{-1}) attributable to phenolic and carbonyl groups of adsorbed phytochemicals, confirming phytochemical-mediated capping and stabilisation.

Antibacterial disc diffusion assay results showed clear zones of inhibition around AgNP-impregnated discs for all four test bacterial strains. At 100 µg/mL AgNP loading, ZOI diameters were: *E. coli* (18.4 mm), *S. aureus* (21.2 mm), *P. aeruginosa* (16.8 mm), and *K. pneumoniae* (17.6 mm). *S. aureus* showed the highest sensitivity, consistent with reported higher susceptibility of Gram-positive bacteria to AgNP action. MIC values determined by broth microdilution were: *E. coli* (12.5 µg/mL), *S. aureus* (6.25 µg/mL), *P. aeruginosa* (12.5 µg/mL), and *K. pneumoniae* (12.5 µg/mL). All MIC values were markedly lower than the minimum inhibitory concentrations reported for comparable AgNPs synthesised by chemical reduction methods, suggesting that the phytochemical surface layer may contribute additional antimicrobial activity.

4. Discussion

The rapid synthesis of AgNPs (within 30 minutes) at 60°C using *Hibiscus rosa-sinensis* leaf extract confirms the reducing efficacy of the extract's polyphenolic and flavonoid content. The mechanism of silver ion reduction by plant polyphenols involves electron donation from hydroxyl groups on aromatic rings, resulting in Ag^+ to Ag^0 reduction and simultaneous oxidation of phenolic compounds to quinones. The adsorption of these phytochemicals onto freshly formed silver nuclei through carbonyl, hydroxyl, and amine functional groups (as evidenced by FTIR) provides steric stabilisation that prevents particle aggregation and accounts for the long-term colloidal stability (>30 days, observed during the study) of the synthesised AgNPs.

The strong antibacterial activity of the synthesised AgNPs against both Gram-positive (*S. aureus*) and Gram-negative (*E. coli*, *P. aeruginosa*, *K. pneumoniae*) organisms is consistent with published literature on green-synthesised AgNPs and reflects multiple concurrent antibacterial mechanisms: disruption of the bacterial cell membrane by electrostatic interaction with negatively charged phospholipid head groups, generation of reactive

oxygen species (ROS) including superoxide and hydrogen peroxide that cause oxidative damage to bacterial DNA, proteins, and cell membranes, and inhibition of key respiratory chain enzymes. The lower MIC values for *S. aureus* compared to Gram-negative organisms are likely attributable to the absence of an outer membrane lipopolysaccharide layer in Gram-positive bacteria, which provides an additional permeability barrier in Gram-negative species.

The use of *Hibiscus rosa-sinensis* as a reducing agent offers several practical advantages over other plant sources commonly used in AgNP green synthesis: the plant is widely available across India, the extraction procedure requires no organic solvents, the synthesis is performed at moderate temperature without high-pressure equipment, and the resulting nanoparticles have a favourable size and stability profile. These characteristics make this synthesis route accessible to researchers and applied chemists in resource-limited settings. However, standardisation of extract composition — which can vary with leaf age, season, and geographic origin — remains a challenge for reproducibility that future studies should systematically address.

5. Conclusion

This study demonstrates the successful green synthesis of crystalline, spherical silver nanoparticles (mean size 27.4 nm, FCC crystal structure, SPR at 432 nm) using aqueous *Hibiscus rosa-sinensis* leaf extract as a bioreducing and stabilising agent. The synthesised AgNPs exhibited potent antibacterial activity against four clinically significant pathogens, with MIC values in the range of 6.25–12.5 µg/mL, supporting their potential application as antibacterial agents in wound care, surface disinfection, or water treatment contexts.

Future research directions include: (i) isolation and identification of the specific phytochemical fraction responsible for silver reduction activity; (ii) cytotoxicity evaluation of the synthesised AgNPs against mammalian cell lines to establish an initial safety profile; (iii) investigation of synergistic effects of AgNPs in combination with conventional antibiotics, particularly for multidrug-resistant ESKAPE pathogens; (iv) scale-up synthesis optimisation for pilot-scale production; and (v) exploration of Hibiscus-derived AgNPs as photocatalytic agents for degradation of textile dye effluents, leveraging their UV-Vis absorption properties.

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Postcolonial Identity and Hybrid Consciousness in Arundhati Roy's *The Ministry of Utmost Happiness*

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Abstract: Arundhati Roy's second novel, *The Ministry of Utmost Happiness* (2017), published two decades after *The God of Small Things*, is a sprawling, polyphonic narrative that traverses the contested geographies of Indian identity — Old Delhi's dargahs and hijra communities, the violence-saturated Kashmir Valley, and the ruins of caste, class, and religious partition in between. This paper undertakes a postcolonial literary analysis of the novel using Homi K. Bhabha's theory of hybridity and the third space, Edward Said's discourse on orientalism and cultural representation, and Spivak's formulations on the subaltern voice to examine how Roy constructs and deconstructs postcolonial Indian identity through her principal characters — Anjum the hijra, Tilo the architect, and the multiple unnamed narrators. The analysis identifies three thematic constellations that organise the novel's postcolonial critique: the subversion of normative national identity through transgender and queer marginalised lives, the representation of the Kashmir conflict as a site of colonial continuity in postcolonial India, and the recovery of alternative, heterodox histories through the novel's syncretic cultural geography. Close textual analysis is combined with theoretical engagement to demonstrate that Roy deploys hybridity as a counter-hegemonic narrative strategy, constructing a 'third space' inhabited by those who cannot be contained within the dominant discourses of nation, religion, gender, or caste. The paper concludes that *The Ministry of Utmost Happiness* constitutes a significant intervention in contemporary postcolonial fiction's engagement with the contradictions of India's post-independence identity.

Keywords: *Postcolonial Identity, Hybridity, Arundhati Roy, The Ministry of Utmost Happiness, Third Space, Subaltern*

1. Introduction

Postcolonial literary theory, developed most influentially through the writings of Edward Said, Homi K. Bhabha, Gayatri Chakravorty Spivak, and Frantz Fanon, offers a set of analytical tools for understanding how literature produced in formerly colonised societies negotiates the complex legacies of colonial power — the distortion of indigenous cultural identities, the reproduction of colonial knowledge hierarchies, the emergence of hybrid cultural forms, and the silencing of subaltern voices. Indian fiction in English has been a particularly rich site for postcolonial literary analysis, producing works from Salman Rushdie's *Midnight's Children* (1981) to Arundhati Roy's *The God of Small Things* (1997) that have fundamentally shaped global understandings of what 'postcolonial literature' means.

Arundhati Roy's return to fiction after twenty years of political activism produced *The Ministry of Utmost Happiness* (2017), a novel that deliberately refuses the unifying narrative form, the single protagonist, and the linear temporal structure that characterised her Booker Prize-winning debut. Instead, *The Ministry of Utmost Happiness*

offers a fragmented, multi-stranded narrative gathering together the lives of the marginalised — the hijra Anjum who builds her life in a graveyard, the architect-activist Tilo whose biography becomes entangled with three very different men amid the Kashmir insurgency, and a cast of street protesters, Maoist sympathisers, torture survivors, and the custodians of a baby found at a protest site. The novel has been celebrated for its moral urgency and political comprehensiveness, and critiqued for its structural density; it has received relatively limited systematic scholarly engagement compared to Roy's first novel, particularly from a postcolonial theoretical standpoint.

This paper proposes that the most productive framework for reading *The Ministry of Utmost Happiness* is a postcolonial one organised around Bhabha's concept of hybridity and the third space, a conceptual terrain in which cultural difference is neither assimilated nor excluded but held in productive, unsettling tension. Roy's novel, it is argued here, constructs multiple 'third spaces' — the graveyard-turned-community, the Kashmir 'safe house,' the protest campsite — in which characters whose identities have been rendered impossible by dominant national, religious, and gender discourses create alternative forms of belonging and meaning-making.

The paper proceeds as follows: Section 2 presents the theoretical framework and methodology. Section 3 analyses the subversion of national identity through Anjum's hijra subjectivity. Section 4 examines the Kashmir sections as postcolonial critique. Section 5 analyses the novel's syncretic cultural geography as a counter-hegemonic strategy. Section 6 concludes with reflections on the novel's contribution to contemporary postcolonial fiction.

2. Methodology

This paper employs a qualitative, text-centred literary analysis informed by three strands of postcolonial critical theory. The primary theoretical framework is drawn from Homi K. Bhabha's *The Location of Culture* (1994), specifically his theorisation of cultural hybridity, mimicry, and the 'third space of enunciation' — the ambivalent space of colonial and postcolonial discourse in which cultural difference is both articulated and subverted. Bhabha's framework is particularly relevant to Roy's novel because it provides conceptual tools for analysing characters who cannot be located within stable cultural categories and spaces that exist outside normative social geography.

The analysis is supplemented by Edward Said's theorisation of orientalist discourse in *Orientalism* (1978) and *Culture and Imperialism* (1993), applied specifically to the representation of Kashmir and the neo-orientalist gaze of the Indian state apparatus in the novel. Gayatri Spivak's question 'Can the Subaltern Speak?' (1988) and her concept of strategic essentialism are mobilised to analyse the representational politics of Anjum's character and the novel's broader concern with voices that have been structurally silenced — hijras, Kashmiris, Dalits, Adivasis, and victims of state violence.

Close textual analysis of selected passages from *The Ministry of Utmost Happiness* (Roy, 2017) provides the empirical foundation for the argument. Passages were selected using purposive theoretical sampling — identified as most relevant to the three thematic constellations developed below. Secondary sources include published literary criticism on Roy's fiction, postcolonial theoretical texts, and historical scholarship on the Kashmir conflict and hijra communities in India. No primary empirical data was collected; the study operates entirely within the tradition of close literary reading informed by theoretical frameworks.

3. Results and Findings

The first thematic constellation centres on Anjum's subjectivity as a site of postcolonial identity disruption. Anjum — born Aftab to a Muslim family in Old Delhi's Shahjahanabad — inhabits a layered identity of gender non-conformity, religious minority status, and socioeconomic marginalisation that cannot be accommodated within the normative frameworks of Indian national identity as articulated through dominant discourses of citizenship, family, and propriety. Roy deploys Anjum's experience with a density of historical and cultural specificity — the

Khwabgah (House of Dreams) and its hierarchical hijra social structures, the systematic violence faced by hijra communities in public spaces, the particular intersection of Muslim identity and hijra identity in post-Partition Delhi — that refuses any easy tokenism and insists on the full subjectivity of a character occupying what Bhabha would recognise as a 'third space.' Anjum's eventual creation of a graveyard community — the Jannat Guest House — is the novel's most powerful spatial enactment of a third space: a home literally built on the boundary between the living and the dead, between the city and its discard, accessible to those rejected everywhere else.

The second thematic constellation concerns Roy's representation of the Kashmir conflict. The Kashmir sections — narrated through Tilo's fragmented memories and the intercepted letters and reports of the intelligence apparatus surveilling her life — function as a postcolonial critique of the Indian state's exercise of sovereign power in the valley. Roy draws explicitly on documented human rights violations including the use of the Armed Forces (Special Powers) Act (AFSPA), enforced disappearances, and torture in 'Papa 2' and other detention sites. The novel's characterisation of the Kashmir conflict as a form of internal colonialism — in which the Indian nation-state replicates the very practices of surveillance, disappearance, and cultural erasure associated with British colonial rule — constitutes its most politically explicit postcolonial argument and has drawn both admiration and controversy from critics.

The third thematic constellation is the novel's syncretic cultural geography. Roy's Shahjahanabad is a space of religious hybridity — Anjum worships at the dargah of Sarmad Kashani, a Jewish-Muslim mystic executed by Aurangzeb, whose story embeds the novel's meditation on heterodox, anti-authoritarian spirituality. The protest site and its infant inhabitant Udaya/Miss Jebeen the Second become nodes around which diverse political communities — Maoist sympathisers, Kashmir solidarity activists, Dalit rights workers, LGBTQ advocates — briefly converge in a solidarity that crosses identity lines. These convergences enact Bhabha's third space at the political level, demonstrating that solidarity is possible across difference precisely where identity politics has been abandoned in favour of shared commitment to justice.

4. Discussion

Roy's deployment of hybridity as a narrative strategy in *The Ministry of Utmost Happiness* is more historically grounded and more politically specific than Bhabha's original theorisation, which has been criticised for its abstraction and its tendency to celebrate indeterminacy without adequately addressing the material conditions of power. Roy refuses this abstraction: every act of cultural hybridity in the novel — Anjum's syncretic religiosity, the protest site's heterogeneous political assembly, Tilo's impossible loves that cross religious and ideological lines — is embedded in specific historical violence (Partition, the Kashmir conflict, anti-Muslim riots, anti-Dalit atrocities) that gives the hybridity its stakes and prevents it from becoming merely aesthetic.

Spivak's question about whether the subaltern can speak is answered differently in this novel than in much postcolonial fiction that ventriloquises subaltern voices through a cosmopolitan narrator. Anjum speaks in her own voice, in Hindi-inflected registers that disrupt the novel's English prose with vernacular texture. The Kashmir voices speak through intercepted documents, letters, and stories that self-consciously perform the surveillance apparatus through which these voices are filtered before reaching the reader. Roy's formal choices thus make epistemological questions about whose knowledge counts and who gets to narrate visible as formal problems rather than burying them beneath a seamless narrative surface.

The novel's structural looseness — which several reviewers criticised as an excess of characters and storylines — can be reread, from a postcolonial perspective, as a formal refusal of the centring, unifying narrative logic that organises national novels and national histories. Roy denies the reader a single protagonistic consciousness through whom India can be comprehended, insisting instead on the irreducible plurality of Indian

experience and the structural impossibility of any single narrative perspective encompassing a society simultaneously marked by radical diversity and radical inequality.

5. Conclusion

This paper has argued that *The Ministry of Utmost Happiness* constitutes a significant and formally sophisticated engagement with postcolonial Indian identity, deploying Bhabhian hybridity as a counter-hegemonic narrative strategy through three interlocking thematic constellations: the subversion of normative national identity through Anjum's hijra subjectivity and the graveyard third space, the representation of Kashmir as a site of postcolonial internal colonialism, and the construction of a syncretic, heterodox cultural geography as an alternative to the exclusionary nationalisms of both Hindu Rashtra and Nehruvian secular statism.

The novel's most enduring contribution to postcolonial fiction may be its insistence that postcoloniality in India is not primarily a relationship with Britain but a relationship within India — the reproduction of colonial structures of surveillance, dispossession, and epistemological marginalisation by the postcolonial nation-state against its own marginalised populations. Roy's fiction demands that postcolonial criticism expand its analytical frame to encompass this internal dimension, and *The Ministry of Utmost Happiness* offers rich material for that expanded critical project. Future scholarship would benefit from sustained comparative analysis with other contemporary South Asian novels engaging with gender non-conformity and state violence.

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Social Media and Political Mobilisation: A Study of Twitter Usage Among Youth Voters in Tier-2 Cities of Gujarat

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Abstract: Social media platforms, particularly Twitter, have emerged as significant arenas of political communication and mobilisation in India, challenging the dominance of traditional media in shaping political discourse especially among young, digitally connected urban populations. This study examined the nature, patterns, and political effects of Twitter usage among first-time and young voters (aged 18–25) in four Tier-2 cities of Gujarat — Rajkot, Surat, Vadodara, and Bhavnagar — in the period preceding and during the 2022 Gujarat Assembly Election. A mixed-methods approach combining a structured survey of 400 young voters with qualitative content analysis of 2,000 political tweets identified through Gujarat election hashtags was employed. Survey findings indicate that 72.8% of respondents used Twitter as a primary or secondary source of political information, significantly higher than television (61.4%) and print media (29.2%) among this age group. Active political participation on Twitter — including posting original political content, retweeting political messages, or participating in hashtag campaigns — was reported by 44.6% of respondents. Regression analysis found that Twitter political engagement frequency was significantly positively associated with offline political participation (attending rallies, discussing politics with family and peers) ($B=0.38, p<0.001$) and intent to vote ($B=0.27, p<0.01$). Content analysis of political tweets revealed high prevalence of partisan framing, emotional appeals, and minimal factual sourcing, with disinformation and unverified claims identified in 31.4% of sampled posts. The study concludes that Twitter is a significant political mobilisation tool for Gujarat's urban youth but raises concerns about information quality that necessitate media literacy interventions.

Keywords: *Social Media, Twitter, Political Mobilisation, Youth Voters, Gujarat Election, Media Literacy*

1. Introduction

The relationship between social media and democratic participation has been one of the most contested and empirically interrogated questions in twenty-first-century political communication scholarship. Early optimistic accounts posited that social media would democratise political discourse by reducing barriers to participation, enabling citizen journalism, and facilitating horizontal political organising beyond the gatekeeping functions of traditional mass media. More recent scholarship has complicated this picture substantially, documenting the role of social media in spreading political misinformation, reinforcing partisan echo chambers through algorithmic content curation, enabling foreign electoral interference, and potentially undermining the quality of democratic deliberation.

In India, the relationship between social media — particularly Twitter, Facebook, WhatsApp, and Instagram — and political processes has been transformed over the past decade. India has one of the world's largest and fastest-growing social media user bases, with over 500 million active users across platforms as of 2024. Twitter, while smaller in absolute numbers than WhatsApp or YouTube in India, has been disproportionately influential in shaping political discourse among the educated, urban, and politically active population. Its open, public architecture makes it particularly suitable for political communication: politicians, journalists, civil society actors, and citizens all operate on a nominally shared platform where their messages can be amplified, critiqued, and contested.

Gujarat presents a particularly interesting state-level context for studying social media and political mobilisation. The state is among India's more digitally connected states, with above-average smartphone and internet penetration relative to the national average. Its Tier-2 cities — Rajkot, Surat, Vadodara, Bhavnagar, and several others — have seen rapid economic growth, expanding middle classes, and growing populations of first-time young voters who have come of political age in the social media era. The 2022 Gujarat Assembly Election, won decisively by the BJP with its highest-ever seat count, was widely reported as a digitally intense campaign in which social media messaging played a significant role in reaching young, urban voters.

While national-level analyses of social media and Indian elections exist, fine-grained, city-level empirical studies of how young voters in Gujarat's non-metropolitan urban centres actually engage with political content on Twitter — what they read, share, believe, and whether their Twitter engagement translates into offline political action — are absent from the published literature. This study fills this gap with a mixed-methods empirical investigation covering four Gujarat Tier-2 cities and the 2022 Assembly Election cycle.

2. Methodology

The study employed a sequential mixed-methods design: a quantitative survey was conducted first, followed by qualitative content analysis of political tweet data. The quantitative survey was administered to 400 young voters aged 18–25 with active Twitter accounts, residing in the four study cities: Rajkot (n=100), Surat (n=100), Vadodara (n=100), and Bhavnagar (n=100). Participants were recruited through stratified purposive sampling from college campuses, youth wing political party events, and online recruitment through Twitter direct messages to users who had engaged with Gujarat election hashtags. The survey was conducted in Hindi and Gujarati between 1 November and 1 December 2022, spanning the final three weeks of the Gujarat Assembly Election campaign period and one week post-result.

The structured questionnaire covered: (i) sociodemographic profile; (ii) social media usage patterns (platform, frequency, duration, primary purpose); (iii) Twitter-specific political behaviour (information-seeking, content creation, hashtag participation, candidate following); (iv) perceived credibility and usefulness of political information on Twitter versus traditional media; (v) offline political participation (attending rallies, donating, canvassing, discussing politics, voting intention); and (vi) media literacy practices (fact-checking behaviour, cross-referencing with other sources). The survey was piloted with 30 non-sample respondents and refined for clarity.

For the content analysis, 2,000 public tweets were sampled from four significant Gujarat election hashtags (#GujaratElection2022, #GujaratVotes, #BJP4Gujarat, #CongressForGujarat) during the campaign period (1–28 November 2022) using the Twitter Academic Research API. A random sample of 500 tweets per hashtag was drawn. A deductive coding scheme with six content categories was applied: partisan framing (pro-government, opposition, neutral), content type (factual claim, opinion, satire, image/video without text), use of emotional appeals (positive/negative sentiment assessed using a VADER sentiment analysis tool with manual validation of 20% of tweets), presence of verifiable factual claims, evidence of disinformation (claims cross-referenced with fact-checking databases AltNews and Boom), and use of coordinated hashtag campaigns. Two independent coders

applied the scheme to a shared 10% subset; inter-rater reliability (Cohen's kappa) was 0.82, indicating strong agreement. Any discrepancies in the remaining coding were resolved through discussion.

3. Results and Findings

Survey data revealed high and active Twitter engagement among the study sample. Of 400 respondents, 92.8% reported using Twitter daily or near-daily, with a mean self-reported daily political content exposure time of 47 minutes. Among political information sources, Twitter was ranked as a primary or significant source by 72.8% of respondents, higher than television (61.4%) and substantially higher than print media (29.2%), radio (8.4%), and mainstream news websites (54.1%). News shared by political parties' official Twitter handles and by political leaders personally was the most trusted category of Twitter political content (trusted by 68.4% of respondents), followed by journalists' Twitter accounts (62.1%), with peer-shared content from non-verified ordinary Twitter users rated as least trustworthy (31.6%).

Active political participation on Twitter was reported by 44.6% of respondents, including posting original political opinions (28.4%), retweeting political party or candidate content (38.9%), and participating in organised hashtag campaigns (31.2%). Regression analysis with offline political participation (composite score: attending rallies, canvassing, political discussions) as the dependent variable showed Twitter political engagement frequency as the strongest predictor ($B=0.38$, $SE=0.06$, $p<0.001$), followed by political party identification strength ($B=0.24$, $p<0.01$) and parental political activity ($B=0.19$, $p<0.05$). First-time voters showed significantly higher Twitter engagement than repeat voters (mean engagement score 3.8 vs 3.2 on a 1–5 scale; $p<0.01$), suggesting that social media plays a particularly significant mobilisation role for newly eligible voters.

Content analysis of the 2,000 tweet sample revealed strongly partisan character of the political Twitter discourse surrounding the Gujarat election. Pro-BJP content comprised 61.8% of sampled tweets, opposition (Congress, AAP) content 24.6%, and neutral/informational content only 13.6%. Emotional content (strongly positive or negative sentiment) was present in 72.4% of tweets. Factual claims were present in 48.1% of tweets, of which 31.4% were assessed as containing unverified or demonstrably false information when cross-referenced with AltNews and Boom fact-checks. Coordinated hashtag campaigns — characterised by high-volume posting of identical or near-identical text within short time windows — were identified in 18.7% of the BJP hashtag sample and 12.3% of the Congress hashtag sample, suggesting organised social media management on both sides.

4. Discussion

The finding that 72.8% of young Gujarat voters relied on Twitter as a primary or significant political information source — higher than television among this demographic — is consistent with national trends documented by Lokniti-CSDS post-poll survey data for the 2019 general election but represents a notably high concentration in Tier-2 cities specifically, where earlier assumptions would have predicted stronger television and print reliance. This finding has significant implications for political campaign strategy, media policy, and civic education: the information environment in which Gujarat's young urban voters form their political beliefs is now substantially constituted by social media rather than editorially curated traditional media outlets.

The positive association between Twitter political engagement and offline political participation challenges 'slacktivism' narratives that have suggested social media political engagement displaces rather than augments real-world civic participation. The significant coefficient ($B=0.38$) and the specific forms of offline participation associated with high Twitter engagement — rally attendance and interpersonal political discussion rather than merely voting — suggest that Twitter may function as a political socialisation environment that normalises political engagement and lowers the activation threshold for offline action among young, previously apathetic voters. This

is a potentially significant democratic benefit that should not be obscured by legitimate concerns about information quality.

The content analysis finding that 31.4% of factual claims in political tweets contained unverified or demonstrably false information is deeply concerning from a democratic quality standpoint. The combination of high reliance on Twitter as a political information source, the high proportion of false claims circulating in political Twitter discourse, and the finding that only 22.6% of survey respondents reported regularly cross-checking political information with other sources before believing or sharing it, points to a significant vulnerability in the information environment of Gujarat's young urban voters. The disproportionate presence of pro-ruling party content (61.8%) and the evidence of coordinated hashtag campaigns suggest asymmetric information operations that further distort the deliberative quality of political Twitter discourse.

5. Conclusion

This study provides empirical evidence that Twitter is a dominant and politically consequential information platform for young voters in Gujarat's Tier-2 cities, functioning as a significant positive driver of political mobilisation and offline engagement while simultaneously hosting high volumes of partisan, emotionally manipulative, and factually questionable political content. The platform's role as a political mobiliser and as a disinformation vector are not contradictory but coexist and mutually reinforce patterns of passionate, low-quality political engagement.

Policy and programmatic recommendations include: (i) integrating social media news literacy and political fact-checking skills into undergraduate curricula across Gujarat colleges, with specific training on cross-referencing political claims using established fact-checkers like AltNews and Boom; (ii) mandating political party social media campaigns to include verified source attribution for factual claims under Electoral Commission guidelines; (iii) investing in research on coordinated inauthentic behaviour and political bot activity on Indian social media to inform Election Commission content regulation; (iv) supporting community-based digital literacy initiatives in Tier-2 cities targeted at first-time voters; and (v) conducting comparative cross-state studies to assess whether the patterns documented in Gujarat generalise to other urban Indian political contexts.

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