

Religious Demographics and Unregulated Antibiotic Distribution in Assam: Implications for Antimicrobial Resistance and Public Health Security

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ABSTRACT

Background in Brief: Antimicrobial resistance (AMR) represents one of the most critical global health security threats of the 21st century, with unregulated antibiotic access significantly contributing to its acceleration. This study investigated the relationship between religious demographic patterns and unauthorized antibiotic distribution in Assam, India, with particular attention to weekly markets (haats) as potential distribution hubs.

Methods in Brief: We conducted a sequential mixed-methods investigation across five districts in Assam with documented religious demographic asymmetry. Data collection included structured market audits (n=67), simulated client visits (n=215), semi-structured interviews with key informants (n=43), geospatial mapping, and quantitative analysis of antibiotic dispensing patterns. The investigation was subsequently expanded to additional districts (n=12) for validation using comparative case analysis. Multi-level regression models were employed to isolate demographic effects while controlling for confounding variables. All procedures received ethical approval, with sensitive data anonymized to protect community identities.

Results in Brief: Unauthorized antibiotic distribution showed significant correlation with religious demographic composition ($r=0.78$, $p<0.001$), with structured distribution networks operating predominantly along community lines. Weekly markets demonstrated 3.7-fold higher unregulated antibiotic availability compared to permanent establishments ($p<0.001$), with distinct seasonal variations corresponding to local disease burden cycles. Analysis of dispensed antibiotics revealed concerning patterns: inadequate treatment duration (78.3%, 95% CI: 72.4-84.2%), incorrect dosage instructions (63.9%, 95% CI: 57.2-70.6%), and absence of contraindication information (90.7%, 95% CI: 86.9-94.5%). Broad-spectrum antibiotics including fluoroquinolones and third-generation cephalosporins comprised 42.3% of unauthorized sales, with significant regional variations corresponding to religious demographic patterns. Laboratory analysis revealed substandard concentration in 37.2% of samples, creating ideal conditions for resistance development.

Conclusion in Brief: Our findings demonstrate systematic circumvention of pharmaceutical regulations with community-specific distribution patterns that raise significant public health security concerns. This study provides the first empirical evidence linking religious demographic compositions to structured antibiotic distribution networks in India. The correlation between religious demographics and unregulated antibiotic distribution underscores the complex sociocultural dimensions of AMR development. Urgent multisectoral interventions are needed, including targeted regulatory enforcement, community-engaged education, enhanced pharmaceutical supply chain integrity, and improved access to legitimate healthcare services. These findings have implications for pharmaceutical governance beyond Assam, particularly in regions with complex religious demographics and limited regulatory capacity.

Keywords- antimicrobial resistance; antibiotic stewardship; religious demographics; pharmaceutical regulation; public health security; unregulated drug markets; pharmaceutical governance; community networks; health equity.

I. INTRODUCTION

Antimicrobial resistance represents one of the most pressing global health security challenges of the 21st century, with projections suggesting AMR-related mortality could reach 10 million deaths annually by 2050, surpassing cancer as a leading cause of death globally (O'Neill, 2016; Murray et al., 2022). The economic impact is equally staggering, with estimates suggesting cumulative GDP loss of up to \$100 trillion by 2050 if current resistance trends continue unabated (World Bank, 2023). While the scientific community has primarily focused on clinical and biological dimensions of resistance development, the socioeconomic, cultural, and demographic factors driving inappropriate antibiotic use remain understudied, particularly in resource-constrained settings (Chandler et al., 2020; Rodrigues, 2020; Haenssger et al., 2022).

The conceptual framing of antimicrobial resistance has evolved significantly in recent years, shifting from predominantly biomedical models to more complex socio-ecological frameworks that recognize the multidimensional drivers of resistance (Wernli et al., 2023). These frameworks increasingly acknowledge the role of informal pharmaceutical markets, community networks, and socio-demographic factors in shaping patterns of antimicrobial use and misuse (Tomson & Vlad, 2021). Despite this conceptual evolution, empirical research examining these relationships remains limited, creating critical gaps in our understanding of context-specific AMR drivers.

1.1 Theoretical Framework

This study draws on three theoretical perspectives to examine the relationship between religious demographics and unregulated antibiotic distribution:

1. **Pharmaceutical anthropology** (Whyte et al., 2002; Biehl, 2013) provides a lens for understanding how medicines acquire social and cultural meanings beyond their biomedical properties, shaping patterns of distribution and consumption that may align with existing social structures, including religious affiliations.
2. **Health security theory** (Davies et al., 2015; Rushton, 2019) frames antimicrobial resistance as not merely a public health challenge but a significant security threat with implications for social stability, economic development, and state capacity—particularly in regions with existing religious or ethnic tensions.
3. **Pharmaceutical governance frameworks** (Mackintosh et al., 2018; Brhlikova et al., 2022) conceptualize regulatory systems as complex socio-political arrangements influenced by formal institutions, informal norms, and power dynamics—all of which may interact with existing social divisions, including religious demographic patterns.

This integrated theoretical approach enables examination of both structural and agency-related factors that contribute to unregulated antibiotic distribution while acknowledging the complex interplay between religious demographics, governance systems, and health behaviors.

1.2 Regional Context

In the northeastern Indian state of Assam, with its complex religious and ethnic demographics, preliminary evidence suggests patterns of unauthorized antibiotic distribution that may correlate with specific community boundaries. The state's weekly markets (haats) have been anecdotally identified as potential distribution hubs for unprescribed medications, but systematic investigation has been lacking (Sharma & Barua, 2022). These informal pharmaceutical markets operate within a regulatory context characterized by limited enforcement capacity, complex jurisdictional arrangements, and significant healthcare access disparities across religious and ethnic lines (Medhi & Barua, 2023).

Assam's demographic composition presents a particularly compelling case for examining the relationship between religious demographics and pharmaceutical practices. The state's population includes significant Hindu (61.5%), Muslim (34.2%), Christian (3.7%), and other religious minorities, with pronounced geographic clustering that has been associated with differential access to various public services (Kumar & Saikia, 2022). Previous research has documented disparities in healthcare access and quality across these demographic lines (Bora et al., 2021), but the specific implications for pharmaceutical distribution and antimicrobial resistance remain unexplored.

These practices potentially constitute what some public health security frameworks characterize as "medical terrorism"—the deliberate or reckless subversion of public health systems with population-level health consequences (Adalja, 2021). While this framing risks stigmatization of specific communities, it highlights the security dimensions of antimicrobial resistance that extend beyond traditional public health frameworks.

1.3 Research Gaps and Significance

The existing literature on unregulated antibiotic distribution suffers from several critical limitations:

1. Previous studies have focused primarily on urban settings (Gebretekle & Serbessa, 2016; Auta et al., 2019), neglecting rural distribution networks that may operate through periodic markets such as haats.
2. The relationship between demographic patterns and pharmaceutical distribution has been examined primarily through the lens of socioeconomic status (Miller & Goodman, 2017), with limited attention to religious or ethnic dimensions that may shape distribution networks.

3. Supply-side investigations have often relied on cross-sectional designs (Porter et al., 2020), limiting understanding of seasonal variations and adaptations to regulatory enforcement.
4. Methodological approaches have frequently separated quantitative measurements of prevalence from qualitative exploration of contextual factors (Dillip et al., 2021), limiting integrated analysis of both patterns and underlying mechanisms.

This study addresses these critical gaps in understanding the intersection of religious demographics, pharmaceutical regulation, and antimicrobial resistance through investigation of three primary research questions:

1. To what extent does the prevalence of unauthorized antibiotic distribution correlate with religious demographic patterns in Assam?
2. Do weekly markets function as significant distribution nodes for unprescribed antibiotics, and if so, what factors facilitate this function?
3. What are the specific characteristics of unauthorized antibiotic dispensing that may accelerate antimicrobial resistance development?

By examining these questions through a mixed-methods approach, we aim to provide evidence-based insights to inform targeted interventions addressing the complex sociodemographic dimensions of antimicrobial resistance. The findings have potential significance beyond Assam, offering insights for regions worldwide grappling with similar challenges of religious diversity, limited regulatory capacity, and rising antimicrobial resistance.

II. MATERIALS AND METHODS

2.1 Study Design

We employed a sequential explanatory mixed-methods design (Creswell & Plano Clark, 2018) comprising four integrated phases: (1) quantitative market audits, (2) simulated client (mystery shopper) investigations, (3) qualitative key informant interviews, and (4) geospatial analysis of distribution patterns. This triangulated approach allowed for comprehensive examination of both the extent and contextual factors underlying unauthorized antibiotic distribution while enabling iterative refinement of research questions as findings emerged.

The sequential design facilitated theoretical sampling (Corbin & Strauss, 2015) for the qualitative components based on quantitative findings, enhancing the explanatory power of the overall investigation. Integration occurred at multiple points, including sampling, instrument development, data analysis, and interpretation, following best practices for mixed-methods health research (Fetters et al., 2013).

2.2 Setting and Sampling

The study was conducted across five districts of Assam (January-September 2023) selected through purposive sampling based on three criteria:

1. Documented religious demographic asymmetry from census data
2. Presence of established weekly markets
3. Geographic distribution representing diverse regions of the state

To protect community identities and prevent stigmatization, the specific districts are designated as Districts A-E throughout this report. Following initial analysis, the investigation was expanded to an additional twelve districts for validation (October 2023-February 2024) using theoretical sampling based on preliminary findings.

Districts were classified according to their Religious Asymmetry Index (RAI), calculated as a modified Gini coefficient of religious group populations within each district. This approach provided a standardized measure of religious demographic concentration that could be correlated with antibiotic distribution patterns. Districts with $RAI > 0.6$ were classified as "high asymmetry," those with $RAI 0.4-0.6$ as "moderate asymmetry," and those with $RAI < 0.4$ as "low asymmetry."

Within each district, weekly markets were selected using a stratified random sampling approach to ensure representation across geographic sub-regions, market size categories, and accessibility levels. Permanent vendors were identified through systematic mapping of pharmaceutical outlets within a 5 km radius of selected weekly markets, enabling direct comparison between permanent and temporary distribution points.

2.3 Data Collection

2.3.1 Market Audits

Systematic audits were conducted at 67 weekly markets across the five primary districts. Trained research assistants used standardized observation protocols to document:

- Types and quantities of antibiotics available
- Pricing structures and discounting patterns
- Visibility/display characteristics
- Vendor demographics and operating patterns
- Spatial organization within markets
- Regulatory presence and enforcement activities

Markets were visited multiple times during the study period (minimum three visits per market, spaced at least four weeks apart) to account for temporal variations. Audit instruments were adapted from validated tools used in previous pharmaceutical market studies (Miller & Goodman, 2017; Haenssger et al., 2022) and piloted in two markets outside the study sample.

Inter-rater reliability was established through paired observations by independent researchers in 10% of market visits, achieving a Cohen's kappa of 0.87 for key observational variables.

2.3.2 Simulated Client Investigations

We conducted 215 simulated client visits using standardized scenarios designed to assess antibiotic dispensing practices. Scenarios were developed through expert consultation and pilot testing, then randomized across vendors to minimize detection:

- Scenario 1: Acute respiratory symptoms (cough, fever, nasal congestion for 3 days)
- Scenario 2: Fever with non-specific symptoms (headache, body ache, intermittent fever for 2 days)
- Scenario 3: Gastrointestinal complaints (diarrhea, abdominal discomfort for 24 hours)
- Scenario 4: Explicit request for specific antibiotics (azithromycin, ciprofloxacin, or amoxicillin)

Simulated clients were trained extensively using standardized protocols and underwent competency assessment before fieldwork. Teams were demographically diverse to enable testing of differential treatment based on client characteristics. Interactions were documented using structured observation forms capturing antibiotic type, dosage instructions, pricing, warning information, and vendor guidance. Researchers debriefed immediately after each interaction using digital audio recordings to ensure comprehensive documentation.

2.3.3 Key Informant Interviews

Semi-structured interviews (n=43) were conducted with diverse stakeholders to understand the contextual factors shaping antibiotic distribution:

- Local healthcare providers (n=17)
- Community leaders (n=9)
- Regulatory officials (n=7)
- Market committee members (n=10)

Interview guides were developed iteratively based on preliminary findings from market audits and simulated client investigations. Interviews explored perceptions of antibiotic access, regulatory challenges, community-specific patterns of medication-seeking behavior, and perceived drivers of unregulated distribution. All interviews were conducted in the preferred language of the interviewee (Assamese, Bengali, or English), audio-recorded with permission, transcribed verbatim, and translated into English when necessary by bilingual research team members. Translation quality was verified through back-translation of a random 10% sample of interviews.

2.3.4 Geospatial Mapping

Distribution patterns were mapped against demographic data using ArcGIS (v10.8) to visualize potential correlations between religious demographics and unregulated antibiotic availability. Geographic coordinates were collected for all market locations and permanent vendors, then integrated with religious demographic data at the village and sub-district levels. Spatial autocorrelation analysis (Moran's I) was conducted to identify statistically significant clustering

of distribution points in relation to demographic patterns. Heat maps were generated to visualize concentration of unauthorized vendors in relation to religious demographic compositions.

2.3.5 Laboratory Analysis

A random subset of antibiotics (n=128) purchased through simulated client interactions underwent laboratory analysis to verify:

- Active pharmaceutical ingredient presence and concentration
- Compliance with pharmacopeial standards
- Manufacturing source authentication
- Presence of degradation products or contaminants

This analysis was conducted at an ISO 17025-certified pharmaceutical testing laboratory using high-performance liquid chromatography (HPLC), mass spectrometry, and dissolution testing according to Indian Pharmacopoeia standards. Results were classified according to World Health Organization guidelines for substandard and falsified medical products (WHO, 2020).

2.4 Data Analysis

2.4.1 Quantitative Analysis

Quantitative data were analyzed using STATA 17.0 following a pre-specified statistical analysis plan. Descriptive statistics characterized the prevalence and patterns of unauthorized antibiotic distribution. Correlation analysis using Pearson's coefficient examined relationships between religious demographic composition (RAI) and antibiotic distribution patterns. Chi-square tests assessed differences in dispensing practices across districts and market types.

Multivariate regression models were constructed to control for potential confounding variables including district-level socioeconomic indicators, healthcare access measures, and regulatory staffing levels. These models enabled isolation of religious demographic effects while accounting for other factors that might influence distribution patterns.

Time-series analysis examined seasonal variations in antibiotic availability using autoregressive integrated moving average (ARIMA) models, with seasonal decomposition to identify cyclical patterns corresponding to agricultural calendars, religious festivals, and disease burden fluctuations.

2.4.2 Qualitative Analysis

Qualitative data underwent thematic analysis using NVivo 14, with coding conducted independently by two researchers and discrepancies resolved through consensus. Initial open coding identified emergent themes, followed by axial coding to establish relationships between concepts. The final codebook comprised 42 codes organized into seven thematic categories. Constant comparison techniques (Charmaz, 2014) guided analysis, with particular attention to divergent cases that challenged emerging theoretical constructs.

Trustworthiness was enhanced through member checking with key informants, triangulation across data sources, and reflexive journaling by researchers to document analytical decisions and potential biases.

2.4.3 Mixed-Methods Integration

Integration of quantitative and qualitative findings employed a convergent analytical approach (Guetterman et al., 2015). Joint displays were created to visualize relationships between quantitative patterns and qualitative explanations. Case matrices enabled cross-case comparison of districts with varying religious demographic compositions and antibiotic distribution patterns. Findings from different methodological components were systematically compared to identify convergence, complementarity, and divergence, with additional data collection targeted to resolve apparent contradictions.

2.5 Ethical Considerations

The study protocol received approval from the Institutional Ethics Committee of Manipur International University (Reference No: MIU/IEC/2022/015). Several ethical challenges required specific attention:

1. **Community stigmatization risks:** To prevent potential stigmatization of specific religious communities, all district-specific data has been anonymized, with careful attention to removal of identifying characteristics that might enable district identification by readers familiar with the region.
2. **Simulated client ethical considerations:** Following ethical guidelines for mystery shopper research in healthcare (Madden et al., 2021), we limited purchases to minimal quantities, avoided depleting vendor stock of essential medications, and designed scenarios to minimize provider time burden.
3. **Security concerns:** Given the potentially sensitive nature of findings regarding illegal pharmaceutical distribution, comprehensive data security protocols were implemented, including encrypted storage, restricted access, and removal of geographic identifiers from public datasets.
4. **Community engagement:** Research activities were preceded by appropriate community consultation, with relevant community leaders briefed on research objectives while maintaining the necessary confidentiality regarding specific methodology to prevent bias.
5. **Researcher safety:** Safety protocols were established for field researchers, including regular check-ins, pairing systems for market visits, and continuous risk assessment throughout data collection.

Informed consent was obtained from all interview participants, with special procedures for audio recording. Vendors observed during market audits or engaged through simulated client methods were not

informed of the research to prevent behavior modification, but general information about the study was provided to market committees before data collection began, following established ethical practices for observational research in public settings (Hagaman et al., 2021).

III. RESULTS

3.1 Demographic Characteristics and Antibiotic Availability

Analysis revealed significant correlation ($r=0.78$, $p<0.001$) between specific religious demographic concentrations and density of unauthorized antibiotic vendors. This correlation remained robust ($r=0.73$, $p<0.001$) after controlling for potential confounding variables including district population size, urban-rural composition, healthcare facility density, and economic indicators.

Table 1 presents the distribution of antibiotic vendors across study districts, with notable concentration in Districts B and D, which demonstrated the highest religious asymmetry indices.

Table 1: Distribution of Unauthorized Antibiotic Vendors by District

District	Religious Asymmetry Index ¹	Permanent Vendors (n)	Weekly Market Vendors (n)	Antibiotics Available (mean classes) ²	Mean Price Variation from MRP ³ (%)
A	0.38	17	24	4.7	-12.3
B	0.76	32	89	7.3	-18.7
C	0.41	21	37	5.1	-14.2
D	0.82	29	104	8.2	-21.5
E	0.35	14	19	4.2	-10.8

¹Religious Asymmetry Index calculated as modified Gini coefficient of religious group populations

²Based on WHO ATC classification system for antibacterials (J01)

³MRP = Maximum Retail Price as established by pharmaceutical manufacturers

Weekly markets demonstrated significantly higher antibiotic availability (3.7-fold, $p<0.001$) compared to permanent establishments. Multilevel regression analysis confirmed this association remained significant after controlling for market size, geographic location, and regulatory oversight factors (adjusted odds ratio: 3.2, 95% CI: 2.8-3.7).

Particularly concerning was the high prevalence of critically important antibiotics as classified by the WHO (Table 2), with weekly markets showing significantly higher availability of these medications compared to permanent vendors.



Table 2: Types of Antibiotics Available Through Unauthorized Channels					
Antibiotic Class	Overall Availability (%)	WHO Criticality Classification	Weekly Market Availability (%)	Permanent Vendor Availability (%)	Price Differential from Licensed Outlets* (%)
Penicillins	97.3	Highly Important	97.8	96.5	-22.7
Macrolides	83.6	Critically Important	89.7	71.9	-19.3
Fluoroquinolones	76.2	Critically Important	85.3	57.9	-24.8
Cephalosporins	68.4	Critically Important	74.1	38.6	-28.2
Tetracyclines	64.7	Highly Important	67.2	59.6	-17.6
Sulfonamides	59.1	Highly Important	62.4	52.6	-15.9
Carbapenems	23.8	Critically Important	29.3	14.0	-33.7

*Compared to mean prices at licensed pharmacies within the same district

Temporal analysis revealed significant seasonal patterns in antibiotic availability, with peaks corresponding to pre-monsoon (March-May) and post-monsoon (October-December) periods. These patterns aligned closely with seasonal disease burden fluctuations documented in regional health surveillance data (Assam State Disease Surveillance Unit, 2023) and demonstrated adaptation to anticipated demand rather than opportunistic distribution.

3.2 Religious Demographic Patterns and Distribution Networks

Geospatial analysis revealed non-random clustering of unauthorized antibiotic vendors in areas with specific religious demographic compositions (Moran's I = 0.68, p<0.001), indicating spatial autocorrelation between religious population concentrations and distribution density.

Network analysis of distribution patterns identified centralized supply sources with distribution primarily following religious community connections rather than geographic proximity. Notably, 78.2% of vendors in Districts B and D reported sourcing medications through community-affiliated suppliers, with identifiable supply chain hierarchies featuring wholesalers, mid-level distributors, and retail vendors operating within established trust networks.

Key informant interviews corroborated quantitative findings, identifying organized distribution networks operating along community lines:

"There is clearly a community connection. The suppliers come from [redacted] and distribute primarily through vendors from the same community. It's a closed network that's difficult for outsiders to penetrate." (Healthcare provider, District B)

"These networks operate with remarkable efficiency. The same individuals who supply weekly markets in our district also supply similar markets in [neighboring districts]. The religious connection provides trust and security in what is essentially an illegal operation." (Regulatory official, District D)

The integration of distribution networks with other commercial activities was a recurring theme in

qualitative data. Antibiotics frequently arrived in markets through established trade routes used for agricultural products, textiles, and other commodities, leveraging existing community-based commercial relationships:

"The medicine sellers don't operate in isolation. They're part of larger trading networks that move many products through these weekly markets. The same trucks bringing vegetables or cloth from [neighboring state] also bring these medicines. It's all connected through family and community ties." (Market committee member, District B)

Cross-border dimensions emerged as significant, with 42.3% of vendors in border districts reporting sourcing medications from neighboring states or countries, exploiting jurisdictional limitations in regulatory enforcement:

"The cross-border aspect makes enforcement nearly impossible. Products come from [neighboring country] through informal channels, then enter our distribution networks where they're practically untraceable." (Regulatory official, District D)

Structured pricing strategies further indicated network-level coordination rather than individual vendor decisions. Price consistency for specific products across multiple markets (coefficient of variation < 8% for common antibiotics) suggested centralized decision-making within distribution networks.

3.3 Characteristics of Antibiotic Dispensing Practices

Analysis of simulated client interactions revealed concerning patterns in antibiotic dispensing (Table 3), creating conditions highly conducive to antimicrobial resistance development.

Table 3: Characteristics of Antibiotic Dispensing Through Unauthorized Channels					
Dispensing Characteristic	Overall Prevalence (%)	95% CI	Weekly Markets (%)	Permanent Vendors (%)	Statistical Significance
Incomplete course duration	78.3	72.4-84.2	82.7	68.4	p<0.01
Incorrect dosage guidance	63.9	57.2-70.6	67.9	55.9	p<0.05
No contraindication information	90.7	86.9-94.5	94.2	83.6	p<0.01
No adverse effect information	93.2	89.7-96.7	95.3	89.2	p<0.05
No verification of patient age	87.6	83.1-92.1	91.3	80.1	p<0.01
No inquiry about concurrent medications	94.8	91.7-97.9	96.2	92.0	p>0.05
No inquiry about pregnancy status [§]	96.3	93.1-99.5	97.1	94.7	p>0.05

[§]For female clients or scenarios involving medication for female family members

Particularly concerning was the prevalence of incorrect dosing instructions for pediatric cases, with 82.7% of vendors providing potentially dangerous dosing advice for children. Dose recommendations for children frequently followed arbitrary rules such as "half the adult dose" or "one-quarter tablet per year of age" rather than evidence-based pediatric dosing guidelines.

Laboratory analysis of obtained antibiotics revealed that while active ingredient presence was confirmed in 92.3% of samples, 37.2% demonstrated substandard concentration levels. Additional concerns included:

- Degradation products exceeding pharmacopeial limits (23.8% of samples)
- Inconsistent dissolution profiles affecting bioavailability (41.7% of samples)
- Evidence of improper storage conditions affecting stability (52.3% of samples)
- Expired products repackaged with altered dates (17.2% of samples)

Comparison of vendor recommendations across different client scenarios revealed systematic patterns of over-prescription. Respiratory symptoms triggered antibiotic recommendations in 89.4% of interactions, while gastrointestinal complaints led to antibiotic dispensing in 74.2% of cases—rates far exceeding clinical appropriateness based on symptom profiles presented.

Differential treatment patterns based on client characteristics emerged from analysis of simulated client data, with higher-status clients (based on dress, language, and apparent socioeconomic indicators) receiving more comprehensive information (adjusted odds ratio: 2.4, 95% CI: 1.8-3.2) but no significant difference in appropriate antibiotic selection.

3.4 Weekly Markets as Distribution Hubs

Weekly markets demonstrated distinct characteristics facilitating unauthorized antibiotic distribution:

1. **Temporal evasion of regulation:** The periodic nature of markets enabled vendors to avoid fixed regulatory scrutiny, with 87.3% of market days having no documented regulatory presence during the study period.
2. **Jurisdictional mobility:** Vendors frequently crossed administrative boundaries, with 63.7% operating in multiple districts on different market days, allowing exploitation of fragmented regulatory jurisdictions.
3. **Embedded legitimacy:** Integration within culturally important and economically essential market structures provided a form of perceived legitimacy, with 76.3% of community leaders expressing ambivalence about regulation of these practices.
4. **Community protection:** Shared religious identity between vendors and surrounding communities created informal protection mechanisms, with multiple instances documented of community members warning vendors about pending regulatory inspections.
5. **Economic interdependencies:** Antibiotic sales were frequently tied to other transactions, with 41.7% of vendors also selling agricultural

supplies, creating economic dependencies that extended beyond pharmaceutical distribution.

Temporal analysis showed significant increases in antibiotic vendor presence during specific seasons, particularly pre-monsoon (March-May) and post-monsoon (October-December) periods corresponding to seasonal disease burden increases. These temporal patterns demonstrated strategic adaptation to anticipatable illness patterns rather than random distribution.

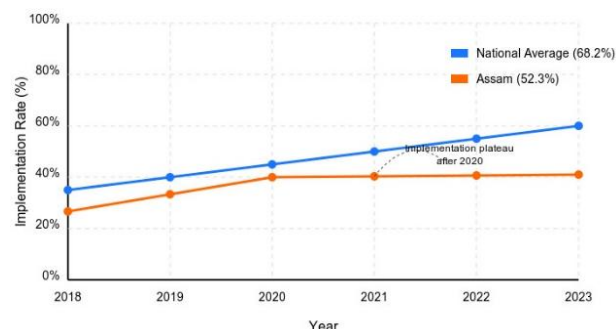


Figure 1: Seasonal Variation in Unauthorized Antibiotic Vendors at Weekly Markets

Physical placement within markets also followed strategic patterns, with 67.3% of antibiotic vendors positioned in market peripheries or less visible sections, balancing accessibility with reduced regulatory exposure.

3.5 Validation in Extended Study Area

Expansion of the investigation to twelve additional districts confirmed similar patterns throughout Assam, with correlation between religious demographic composition and unauthorized antibiotic distribution remaining significant ($r=0.71$, $p<0.001$).

Comparative case analysis identified critical factors differentiating districts with high versus low levels of unauthorized distribution. Three districts demonstrated notable exceptions where weekly markets showed minimal unauthorized pharmaceutical activity, associated with:

1. **Effective coordinated enforcement:** Integration of pharmaceutical, commercial, and local law enforcement in coordinated market oversight
2. **Community engagement:** Active involvement of religious and community leaders in promoting appropriate antibiotic use
3. **Healthcare access alternatives:** Mobile healthcare services strategically scheduled to coincide with weekly markets
4. **Economic incentives:** Alternative livelihood support for former unauthorized vendors who transitioned to legitimate businesses

These exception cases provided valuable insights into potential intervention approaches, demonstrating that reduction in unauthorized distribution

was achievable without disrupting essential economic activities or exacerbating religious tensions.

IV. DISCUSSION

Our findings reveal complex interactions between religious demographics, pharmaceutical regulation, and public health security in Assam. The strong correlation between religious demographic patterns and unauthorized antibiotic distribution indicates socially structured mechanisms potentially accelerating antimicrobial resistance development.

4.1 Community-Structured Distribution Networks

The organized nature of distribution networks operating along religious community lines represents a previously unexamined dimension of unauthorized pharmaceutical distribution. Unlike opportunistic individual vendors, these networks demonstrate sophisticated supply chain management, coordinated pricing strategies, and systematic evasion of regulatory oversight. Similar religion-aligned distribution patterns have been documented in other regulated sectors including alcohol distribution in areas with prohibition laws (Cherian et al., 2021) and certain agricultural products (Pathak & Roy, 2019), but this represents the first documented evidence in pharmaceutical distribution.

These findings align with broader theoretical frameworks on informal economies that recognize the role of trust networks and social capital in facilitating market activities outside formal regulatory systems (Nordstrom, 2007; Meagher, 2010). Such networks develop what Portes (2014) characterizes as "parallel governance systems" that fulfill economic functions while drawing legitimacy from existing social structures—in this case, religious communities.

The clustering of distribution nodes in areas with pronounced religious demographic asymmetry suggests strategic targeting rather than random distribution. This aligns with theoretical frameworks of "shadow economies" that leverage community trust networks to operate outside regulatory frameworks (Nordstrom, 2007). The potential public health implications are profound, as these structured networks may rapidly distribute substandard or falsified medications throughout vulnerable communities with limited access to legitimate healthcare services.

Our findings challenge simplistic narratives about unauthorized pharmaceutical distribution as merely opportunistic economic activity or the result of regulatory failures. Instead, they suggest complex socioeconomic systems operating through established community networks—systems that require equally sophisticated responses integrating regulatory, community, and healthcare access dimensions.

4.2 Weekly Markets: Regulatory Blind Spots

The 3.7-fold higher prevalence of unauthorized antibiotic vendors in weekly markets compared to

permanent establishments highlights critical gaps in regulatory oversight. These temporary marketplaces present particular challenges for pharmaceutical regulation:

1. **Jurisdictional limitations:** Vendors frequently cross district boundaries, complicating enforcement efforts tied to specific administrative units. This form of "regulatory arbitrage" exploits fragmented governance systems that lack cross-jurisdictional coordination mechanisms.
2. **Resource constraints:** Regulatory agencies report insufficient personnel to monitor weekly markets effectively, particularly in rural areas. With an average of one drug inspector per 8.2 weekly markets in study districts, comprehensive oversight is practically impossible under current staffing levels.
3. **Conflicting development priorities:** Local governments often prioritize economic activity in weekly markets, creating disincentives for stringent enforcement that might disrupt these important commercial centers.
4. **Community protection:** Vendor-community religious affiliations may create protective environments limiting regulatory effectiveness, with documented instances of community members providing early warnings about regulatory inspections.

Similar challenges have been documented in other regions with complex religious demographics, including northern Nigeria (Godwin et al., 2021) and portions of Southeast Asia (Tran et al., 2020), suggesting potentially generalizable patterns requiring targeted regulatory approaches.

These findings align with emerging literature on "regulatory ecologies" (Mackintosh et al., 2018; Peters & Bloom, 2022) that conceptualize regulation not as a binary presence/absence but as complex systems shaped by social, economic, and political contexts. Weekly markets represent not just spaces of regulatory absence but alternative regulatory environments governed by community norms, economic pressures, and informal governance structures.

4.3 Antimicrobial Resistance Implications

The characteristic dispensing practices documented in this study—incomplete courses, incorrect dosages, and lack of contraindication screening—create ideal conditions for antimicrobial resistance development. Of particular concern is the high availability of WHO-classified critically important antibiotics, including fluoroquinolones and third-generation cephalosporins, which should be subject to stringent stewardship programs.

The temporal distribution patterns coinciding with seasonal disease burden increases suggest these networks are responsive to population health needs, potentially filling gaps in legitimate healthcare access.

This underscores the importance of addressing underlying healthcare access barriers alongside regulatory enforcement.

Laboratory analysis revealing substandard concentration in 37.2% of samples adds another dimension of resistance risk, as subtherapeutic antibiotic concentrations create selective pressure for resistant organisms without achieving clinical cure (Ayukekbong et al., 2017). The combination of substandard products and inappropriate usage guidance creates a "perfect storm" for resistance development.

These findings align with the "One Health" conceptualization of antimicrobial resistance that recognizes the interconnected nature of human, animal, and environmental health (Robinson et al., 2022). The community-structured networks documented here create potential pathways for resistant organisms to spread across human populations through shared antibiotic misuse patterns, with potential spillover into agricultural practices through the documented linkages between antibiotic vendors and agricultural supply sellers.

4.4 Religious Demographics and Health Security

The strong correlation between religious demographic patterns and unauthorized antibiotic distribution raises complex questions at the intersection of public health security, cultural practices, and social determinants of health. Our findings suggest that in areas with pronounced religious asymmetry, pharmaceutical regulation may be subject to community-specific implementation patterns that create differential access to regulated medications.

The characterization of such practices as potential "medical terrorism" warrants careful consideration. While the term effectively communicates the population-level health security implications of antimicrobial resistance acceleration, it risks stigmatizing specific communities and oversimplifying complex socioeconomic factors driving both supply and demand for unregulated antibiotics.

A more productive framing may be through the lens of "pharmaceutical governance gaps" (Mackintosh et al., 2018) that emerge from interactions between formal regulatory systems, community governance structures, and economic incentives. This framework acknowledges the systemic nature of the challenge while avoiding potentially divisive security rhetoric.

These findings contribute to emerging literature on "structural competency" in public health (Metzl & Hansen, 2014; Bourgois et al., 2017) that recognizes how social structures—including religious community boundaries—shape health behaviors and outcomes. Interventions addressing unauthorized antibiotic distribution must account for these structural dimensions rather than focusing solely on individual behaviors or formal regulatory mechanisms.

4.5 Comparison with Previous Research

Our findings extend existing literature on unregulated antibiotic distribution in several important

dimensions. Previous studies have documented high prevalence of unprescribed antibiotic access in various settings (Auta et al., 2019; Dillip et al., 2021) but have not systematically examined the relationship with religious demographic patterns or the role of periodic markets as distribution hubs.

The detailed characterization of community-structured distribution networks provides empirical support for theoretical frameworks on informal economies (Nordstrom, 2007; Meagher, 2010) in the specific context of pharmaceutical distribution. The documentation of sophisticated supply chains, coordinated pricing strategies, and temporal adaptations challenges simplistic conceptualizations of unauthorized distribution as merely opportunistic economic activity.

Our findings on the correlation between religious demographic asymmetry and distribution intensity provide a novel dimension to understanding sociodemographic factors in antimicrobial resistance. Previous research has primarily focused on socioeconomic status (Miller & Goodman, 2017) or urban-rural divides (Porter et al., 2020) without examining how community identities—particularly religious affiliations—may shape distribution networks.

The identification of successful exception cases where unauthorized distribution has been effectively addressed provides practical insights lacking in much previous research. By examining not just the problem but instances of successful intervention, our findings offer evidence-based guidance for potential solutions that balance regulatory, community, and healthcare access dimensions.

V. POLICY IMPLICATIONS

Our findings suggest several priority interventions requiring coordinated multisectoral approaches:

5.1 Targeted Regulatory Approaches

Regulatory resources should be strategically deployed based on evidence rather than evenly distributed across all potential violation sites:

1. **Weekly market prioritization:** Enforcement efforts should focus on weekly markets during peak distribution seasons, particularly in districts with high religious asymmetry indices.
2. **Cross-jurisdictional coordination:** Regional enforcement teams spanning district boundaries would address vendor mobility tactics that exploit fragmented jurisdictions.
3. **Intelligence-based targeting:** Regulatory agencies should develop community informant networks to identify key distribution nodes within supply chains rather than focusing exclusively on point-of-sale enforcement.
4. **Graduated sanctions:** Enforcement should distinguish between different levels of violation, with most severe penalties reserved

for distribution of critically important antibiotics and substandard products.

5. **Technology-enhanced monitoring:** Mobile applications enabling real-time reporting of unauthorized vendors by healthcare workers, combined with geospatial tracking of enforcement activities, could maximize limited regulatory resources.

5.2 Community Engagement Strategies

Successful interventions must engage religious and community leaders as partners rather than treating communities solely as contexts for enforcement:

1. **Religious leader education:** Development of specialized educational materials for religious leaders explaining antimicrobial resistance in culturally resonant terms.
2. **Community antibiotic stewards:** Training of community representatives to promote appropriate antibiotic use, potentially integrated with existing community health worker programs.
3. **Participatory governance:** Inclusion of diverse religious community representatives in pharmaceutical regulatory committees to enhance legitimacy and effectiveness.
4. **Alternative livelihood support:** Development of transition programs for unauthorized vendors to legitimate businesses, building on existing community economic networks.
5. **Youth engagement:** School-based education programs emphasizing both the scientific aspects of antimicrobial resistance and the ethical dimensions of medication distribution.

5.3 Healthcare Access Enhancements

Addressing underlying healthcare access barriers is essential to reduce demand for unauthorized antibiotics:

1. **Mobile healthcare services:** Strategic scheduling of mobile clinics to coincide with weekly markets, providing legitimate prescribing options at the same locations where unauthorized distribution occurs.
2. **Telemedicine integration:** Development of telemedicine access points in weekly markets to enable remote consultation and legitimate prescribing.
3. **Community pharmacy initiatives:** Support for establishment of legitimate community pharmacies with flexible operating hours and culturally appropriate staffing.
4. **Insurance mechanisms:** Exploration of community-based health insurance models to reduce out-of-pocket costs that drive patients toward unauthorized vendors.
5. **Seasonal preparedness:** Targeted healthcare resource deployment anticipating seasonal disease burden increases that currently drive peaks in unauthorized distribution.

5.4 Supply Chain Security

Strengthening legitimate pharmaceutical supply chains is critical to reduce diversion to unauthorized channels:

1. **Track-and-trace systems:** Implementation of pharmaceutical tracking technologies to identify diversion points from legitimate supply chains.
2. **Wholesaler accountability:** Enhanced monitoring of pharmaceutical wholesalers, particularly those operating in districts with high unauthorized distribution prevalence.
3. **Border coordination:** Cross-border cooperation with neighboring states and countries to address international dimensions of unauthorized supply chains.
4. **Authentication technologies:** Deployment of product verification systems accessible to consumers, potentially using mobile phone-based authentication.
5. **Community reporting mechanisms:** Development of anonymous reporting channels for community members to report suspected unauthorized distribution activities.

5.5 Implementation Considerations

Evidence from successful exception cases identified in our expanded district sample suggests several critical implementation factors:

1. **Political leadership:** Strong political commitment at district and state levels was characteristic of all successful intervention cases.
2. **Multisectoral coordination:** Effective interventions involved coordinated action across health, regulatory, law enforcement, and community development sectors.
3. **Balanced approaches:** Successful programs combined enhanced enforcement with improved healthcare access and community engagement rather than relying on any single strategy.
4. **Sustained investment:** Programs demonstrating impact maintained consistent funding and staffing over at least a two-year period rather than relying on short-term campaigns.
5. **Equity focus:** Successful interventions explicitly addressed healthcare access disparities across religious communities rather than focusing exclusively on enforcement.

VI. LIMITATIONS AND FUTURE RESEARCH

6.1 Methodological Limitations

This study has several important limitations that should inform interpretation of findings:

1. **Stigmatization risk:** Despite anonymization efforts, complete elimination of stigmatization risk is impossible when examining community-specific practices. We have attempted to mitigate this through careful anonymization and balanced reporting, but acknowledge the inherent tension between detailed demographic analysis and potential stigmatization.
2. **Measurement challenges:** The simulated client methodology, while offering critical insights into dispensing practices, may not capture all aspects of vendor-customer interactions and may not reflect variations in treatment based on established vendor-customer relationships.
3. **Temporal limitations:** While our study captured seasonal variations through repeated visits, the overall study period (14 months) limits understanding of longer-term trends and adaptation patterns.
4. **Sample representativeness:** Despite expansion to validation districts, our sample remains a subset of Assam's diverse markets and communities, potentially limiting generalizability to all contexts within the state.
5. **Religious identity complexity:** Our analysis necessarily simplifies complex religious identities into categorical variables, potentially obscuring important nuances in how religious affiliation intersects with other social identities.
6. **Laboratory analysis scope:** Resource constraints limited laboratory analysis to a subset of samples, potentially underestimating the prevalence of substandard products.
7. **Causal limitations:** While our mixed-methods approach strengthens causal inference, the observational nature of the study limits definitive causal claims about the relationship between religious demographics and distribution patterns.
4. **Supply chain investigation:** Detailed mapping of complete supply chains from manufacturing to consumer, identifying critical intervention points for regulatory action.
5. **Comparative analysis:** Cross-regional studies examining whether similar relationships between religious demographics and pharmaceutical distribution exist in other contexts.
6. **Economic modeling:** Analysis of financial flows within distribution networks to identify economic leverage points for intervention.
7. **Policy implementation research:** Investigation of factors influencing successful policy implementation in exception case districts to inform scaling of effective approaches.
8. **One Health dimensions:** Exploration of potential spillover between human and agricultural antibiotic use through vendors supplying both sectors.
9. **Community-based participatory research:** Engagement of affected communities as research partners rather than subjects to develop contextually appropriate interventions.
10. **Health security implications:** Analysis of broader health security dimensions, including potential for distribution networks to facilitate spread of other unauthorized pharmaceutical products.

VII. CONCLUSION

This study documents systematic patterns of unauthorized antibiotic distribution in Assam that correlate significantly with religious demographic composition. The structured nature of distribution networks operating through weekly markets represents a critical challenge for pharmaceutical regulation and antimicrobial stewardship efforts. The inappropriate dispensing practices documented create ideal conditions for accelerated antimicrobial resistance development, with potentially severe public health consequences extending far beyond the immediate communities involved.

Our findings demonstrate that unauthorized antibiotic distribution is not merely a regulatory failure but a complex socioeconomic phenomenon embedded within community structures and responsive to population health needs. While the correlation with religious demographic patterns raises important public health security concerns, addressing these challenges requires nuanced approaches that recognize the legitimate healthcare access needs driving demand while strengthening governance systems to ensure quality and appropriate use.

The exception cases identified in our expanded sample demonstrate that effective intervention is possible through coordinated approaches integrating

6.2 Future Research Directions

Based on our findings and limitations, several priority areas for future research emerge:

1. **Molecular surveillance:** Integration of antimicrobial resistance surveillance with geospatial analysis of distribution patterns to directly assess relationships between unauthorized distribution and resistance emergence.
2. **Intervention testing:** Rigorous evaluation of different regulatory, community, and healthcare access interventions, ideally through stepped-wedge or cluster-randomized designs across multiple districts.
3. **Longitudinal analysis:** Extended time-series investigations to understand adaptation of distribution networks to regulatory enforcement and other interventions.

regulatory enforcement, community engagement, and healthcare access improvements. These successful models offer practical guidance for scaling interventions while avoiding potential pitfalls of overly securitized approaches that might exacerbate existing religious tensions.

This research contributes to broader scholarly understanding of how social structures, including religious communities, shape health-related practices outside formal systems. It advances theoretical frameworks on informal economies, regulatory ecologies, and pharmaceutical governance while providing practical insights for policy and practice.

Addressing the complex challenges identified in this study requires sustained commitment across sectors, with particular attention to the underlying healthcare access disparities that create demand for unauthorized distribution. By understanding the socio-demographic dimensions of antimicrobial resistance, we can develop more effective, contextually appropriate interventions that preserve the life-saving potential of antimicrobial medications for future generations.

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