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SPATIAL MODELING AND EPIDEMIOLOGICAL ASSESSMENT OF HEPATITIS C VIRUS (HCV) PREVALENCE AND SOCIO-DEMOGRAPHIC RISK FACTORS IN UPPER BUNER, KHYBER PAKHTUNKHWA, PAKISTAN

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Abstract

This study investigates the spatial patterns and demographic determinants of Hepatitis C Virus (HCV) infections in the Upper Buner region, specifically focusing on the Gadezai and Dagger tehsils. Utilizing registration data from the District Headquarter Dagger, Buner, alongside field questionnaires and Global Positioning System (GPS) tracking, a total of 844 registered patients across 29 villages were analyzed. The epidemiological assessment revealed a higher prevalence among males (51.54%) compared to females (48.45%) , with a predominant concentration of cases among married individuals (86.6%). The age group of 31–45 years

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was identified as the most severely affected cohort across both tehsils. Spatial analysis demonstrated that HCV distributions are highly clustered within larger villages, forming notable epidemiological hot spots in Dokaddah, Torwarsak, Geraray, Anghapur, Bazargai, Kalakheela, and Bampoha. Major risk factors fueling the local epidemic include low regional education and awareness , intra-familial sharing of personal items (needles, miswak, dandasa) , reliance on unhygienic barber shops , disease importation by overseas workers , contaminated stream-fed drinking water networks , and substandard practices among informal general practitioners and dental technicians. Prompt public health campaigns, mandatory pre-marital testing, structural water infrastructure repairs, and targeted spatial interventions are urgently required to mitigate further transmission.

1. INTRODUCTION

Infectious diseases exhibit distinct spatial and temporal patterns driven by environmental variations, cultural habits, and regional socio-demographic structures. Hepatitis C Virus (HCV) remains a critical public health challenge globally and regionally, demanding precise geographical tracking to maximize the efficacy of local interventions. This research evaluates the spatial patterns of Hepatitis C and its key demographic determinants within Upper Buner.

The target study area is administratively bifurcated into two primary tehsils: Gadezai and Dagger. Together, these tehsils comprise 29 distinct villages holding a documented burden of 844 registered HCV patients. Despite the growing burden, existing local healthcare systems suffer from structural deficits, and the populace demonstrates critical deficiencies in disease awareness. This paper maps the geographical hot spots of the infection, measures demographic variations across age, gender, and marital status, isolates major environmental and behavioral risk factors, and provides actionable policy frameworks to curb the disease footprint.

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2. Materials and Methods

2.1 Data Collection and Source

The baseline dataset for this study comprised 844 registered HCV patients. Residential addresses and medical records were procured directly from the District Headquarter (DHQ) in Dagger, Buner. These addresses served as the foundational registry to systematically track and locate patients within their respective villages.

2.2 Field Survey and Spatial Mapping

To evaluate explicit behavioral indicators and household dynamics, a detailed field survey was executed. A total of 254 detailed questionnaires were administered directly to adult patients, consisting of 160 male and 94 female respondents.

Concurrently, spatial field mapping was performed by recording the exact geographic coordinates (X-Y data points) of patient households using Global Positioning System (GPS) receivers. These coordinate data points were subsequently integrated into Geographic Information Systems (GIS) and statistical software to generate spatial distribution models, identify point clusters, and map regional disease hot spots.

3. Results and Analysis

3.1 Overall Socio-Demographic Summary

Of the total 844 registered HCV patients across the study area, 437 (51.78%) were male and 407 (48.22%) were female. Marital stratification showed an overwhelming concentration among married individuals, accounting for 731 cases (86.61%), whereas unmarried patients comprised only 113 cases (13.39%).

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3.2 Comparative Analysis of Tehsils

The burden of disease is unevenly distributed between the two administrative sub-units, with Gadezai tehsil carrying the vast majority of the documented cases.

Tehsil Metrics	Gadezai Tehsil DOCX+ 2	Dagger Tehsil DOCX+ 2	Total Combined DOCX+ 2
Male Patients	320 (51.12%)	117 (53.67%)	437
Female Patients	306 (48.88%)	101 (46.33%)	407
Married Patients	542 (86.58%)	189 (86.70%)	731
Unmarried Patients	84 (13.42%)	29 (13.30%)	113
Total Patient Population	626 (74.17%)	218 (25.83%)	844

3.3 Age Cohort Vulnerabilities

Age stratification across both tehsils revealed that the age group of **31–45 years** is highly affected by HCV. This cohort represents the primary active working demographic within the local communities, experiencing greater physical exposure across domestic, agricultural, and commercial settings. The age brackets of 16–30 years and 46–60 years were categorized as moderately affected.

3.4 Spatial Distribution and Hot Spot Identification

The macro spatial distribution of Hepatitis C across Upper Buner is structurally categorized as **random** on a regional level, yet strongly **clustered** on a local scale:

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- **Small Villages:** In localities such as Kingergali, Nansir, Leganay, Charay, Char, Salarzomaira, and Kalay, cases are scattered and display low-density spatial patterns.
- **Large Villages (Epidemiological Hot Spots):** High-density clusters are found within heavily populated zones. The definitive hot spots identified across the study region are:
  - **Dokaddah:** Positioned in the extreme north, this village is the single most severely affected locality in the entire study area, containing 115 patients (with a gender split of 53% male and 47% female). Multiple cases (3 to 5 patients) are frequently concentrated within single shared households.
  - **Torwarsak:** Situated in the south, Torwarsak records 110 cases (alternatively noted in preliminary text as 63 cases with 52% male and 48% female composition), marking it as the second most severely infected village in Upper Buner.
  - **Kalakheela:** Located centrally, holding 48 cases (43% male, 57% female), with infections densely packed near the village center.
  - **North-West Cluster (Bazargai, Geraray, Bampoha):** Notable high-prevalence villages. **Bazargai** registers 93 cases. **Geraray** registers 58 cases, showing a unique inversion with a higher female infection burden (41% male vs. 59% female). **Bampoha** documents 44 cases with an equal 50% gender split.
  - **Anghapur and Shanay:** Located in the south. Anghapur tracks 58 cases (62% male, 38% female or alternate field sample of 36 males and 22 females). Shanay records 47 cases (51% male, 49% female).
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4. Discussion and Risk Factors

4.1 Behavioral and Cultural Transmission Dynamics

The higher vulnerability of males (51.54%) across Upper Buner is strongly correlated with occupational exposure and commercial socialization. A primary vector for male transmission is the

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widespread practice of receiving shaves at local barber shops rather than grooming at home, which exposes clients to unsterilized razors and shared blades.

Conversely, female infections (48.45%) are deeply exacerbated by localized illiteracy and lack of clinical awareness regarding viral transmission. Culturally, local females encounter high intra-familial risk due to the sharing of contaminated cosmetic and personal items during routine household activities. Specifically, the sharing of a single unsterilized needle for ear and nose piercing within the family unit is very common.

4.2 Familial Structures and Marital Vulnerabilities

The stark variance between married (86.61%) and unmarried (13.39%) cohorts stems from several systemic socio-cultural practices:

1. **Consanguinity and Household Systems:** A high reliance on the joint family system and marriages within close extended families facilitates rapid viral transmission across immediate relatives.
2. **Absence of Pre-Marital Screening:** Couples routinely wed without undergoing screening for HCV, resulting in direct transmission between spouses and an elevated risk of vertical transmission to newborns.
3. **Broadened Life Exposure:** Married adults manage expanded agricultural, domestic, and economic tasks, increasing their contact with external risk factors.

4.3 Environmental Vectors: Water Contamination

In localized hot spots like Geraray, environmental vectors amplify behavioral risks. The primary drinking water supply is drawn from open streams running through nearby hills. Due to poor maintenance, water supply pipelines are broken at multiple points and run adjacent to or directly through open village drains. This architectural flaw allows raw sewage and contaminated wastewater to infiltrate the drinking supply, driving broader public health degradation.

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4.4 Exogenous Factors: Disease Importation

In Dagger tehsil, male infections are further driven by transnational labor migration. A substantial segment of the male workforce travels to and settles in South East Asian nations such as Malaysia, Brunei, and Thailand. Contracting the virus overseas results in the continuous importation of HCV strains back into local households upon their return.

4.5 Healthcare Delivery Vectors

The transmission cycle is further accelerated by informal healthcare providers within rural areas. Approximately 85% of the local population relies on village general practitioners (GPs) and informal dental technicians for primary medical treatment during illness. Substandard sterilization protocols, reused clinical instruments, and poor injection safety among these practitioners act as primary structural transmission vectors.

5. Conclusion and Recommendations

The spatial analysis confirms that Hepatitis C virus prevalence in Upper Buner is heavily concentrated within dense village clusters and is driven by an intersection of low public awareness, unsafe medical and grooming practices, and fragile public infrastructure. To suppress transmission dynamics, the following multi-sectoral interventions are recommended:

1. **Targeted Public Awareness Campaigns:** Launch sustained public health information campaigns via media and educational institutions. In particular, mandates should require all barber shops to display visual banners printed in the Pashto language illustrating viral transmission risks to inform illiterate patrons.
2. **Mandatory Pre-Marital Screening:** Institute mandatory pre-marital HCV screening for couples to prevent cross-infection between life partners and halt vertical transmission to infants.

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3. **Hygiene Reform and Instrument Regulation:** Encourage transition to home shaving using personal razors. Enforce strict regulations banning the sharing of piercing needles, toothbrushes, miswak, and dandasa among family members.

4. **Sanitation and Water Infrastructure Overhaul:** Order immediate infrastructure repairs by local municipal authorities to replace damaged water pipelines, separating drinking lines from open sewerage drains.

5. **Healthcare Standardization and Decentralization:** Establish specialized Hepatitis control cells within existing Rural Health Centers (RHCs) to improve diagnostic access. Enforce strict sterilization monitoring for local general practitioners and dental technicians.

6. **GIS-Driven Mobile Interventions:** Utilize spatial disease maps and GIS software to implement geographically targeted risk-control policies. Prioritize high-density hot spot zones on an emergency basis by dispatching mobile medical teams to deliver vaccines, diagnostic resources, and direct doorstep counseling.

7. **Global and National Advocacy:** Elevate the local epidemiological data to national and international forums to secure technical and financial assistance from organizations such as the World Health Organization (WHO).