

Occupational and Environmental Health Determinants in Nepal: Temporal Trends and Inequity Mapping Using the 2016 and 2022 Demographic and Health Surveys

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Abstract

Background: Occupational and environmental health (OEH) risks, like household air pollution and unsafe work conditions, are major disease drivers in Nepal. This study evaluated changes in OEH indicators from 2016 to 2022, assessing wealth inequalities, determinants of clean fuel adoption, and the preventable health burden.

Methods: This study analyzed secondary data from the Nepal Demographic and Health Survey for 2016 and 2022. Methods included survey-weighted prevalence estimates, concentration indices, and multivariate logistic regression to assess inequalities and predictors of clean fuel adoption. Population-attributable fractions estimated the mortality preventable from eliminating solid fuel exposure.

Results: Clean fuel use rose to 41.7%, but wealth inequality grew, and a 58-point gap separated provinces. Wealth, province, and urban residence were key determinants. Eliminating solid fuels could prevent 2400 annual deaths. Occupational injuries were significantly undercounted, with a corrected estimate of 9312 cases yearly.

Conclusion: Nepal has progressed in clean energy and Water, Sanitation, Hygiene (WASH), but inequality has deepened. This masks a quality crisis, as ‘improved’ facilities are often contaminated. Geographic disparity is the primary driver of inequity, and occupational injuries are undercounted. Targeted subsidies, electrification, and better surveillance are critical.

Keywords: air pollution, environmental health, inequality, occupational health, Nepal, social determinants

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INTRODUCTION

Environmental and occupational exposures account for nearly one-quarter of the

global disease burden¹. In South Asia, household air pollution (HAP) from solid fuel combustion contributes to more than 1.2 million premature deaths annually.²

Low- and middle-income countries (LMICs) like Nepal face a dual challenge: widespread reliance on biomass fuels and inadequate sanitation infrastructure intersect with occupational risks concentrated in agriculture, construction, and transportation sectors. Approximately 84.6% of Nepal's workforce operates in informal sectors with minimal regulatory oversight or safety protection^{3,4}.

Nepal's geographic diversity spanning lowland plains to high Himalayan zones exacerbates health disparities. Mountain and hill regions face near universal dependence on biomass fuels and frequent electricity shortages, whereas urban centers, especially the Kathmandu Valley, experience extreme ambient pollution with winter PM_{2.5} levels exceeding World Health Organization (WHO) guidelines by more than 400%⁵⁻⁷. Women and children in rural household's face some of the world's highest indoor smoke exposures, often exceeding 1000 µg/m³ twenty times WHO ambient air quality guidelines^{5,8}.

Occupational risks are similarly unequally distributed. Agriculture employs 60% of workers and involves pesticide exposure, musculoskeletal strain, and machinery-related injuries. Construction, employing 8% of the workforce, experiences high rates of fall and crush injuries⁹. Transport workers face elevated road-traffic mortality. Existing surveillance systems capture only hospital-reported severe injuries, systematically omitting the 82% informal workforce without access to workers' compensation or occupational health services^{2,10}.

Although past research in Nepal has examined environmental health or occupational safety,

few studies integrate these domains or track temporal inequality trends. No prior analyses have simultaneously measured inequality trajectories using validated concentration indices, estimated preventable mortality using population-attributable fractions, compared provincial inequities across environmental and occupational exposures, identified structural determinants through multivariate modelling, or used two national Demographic and Health Survey (DHS) rounds to examine temporal change with statistical precision.

The objective of this study was to evaluate temporal changes in key OEH indicators between 2016 and 2022, measure wealth-based and geographic inequalities using concentration indices, identify determinants of clean fuel adoption through multivariate logistic regression, estimate preventable deaths from eliminating solid fuel exposure using population-attributable fraction methodology, and provide policy-relevant targets for achieving equitable OEH improvements by 2030.

MATERIALS AND METHODS

Design and Ethical Aspects

An observational, descriptive, retrospective, and cross-sectional study was carried out using secondary data from the Nepal Demographic and Health Surveys (NDHS) of 2016 and 2022. This study involved secondary analysis of publicly available, de-identified data. The primary data collection for both NDHS rounds received ethical approval from the Nepal Health Research Council (NHRC) and the ICF Institutional Review Board, with informed consent obtained from all participants during the original surveys. As the research constituted

secondary analysis of anonymized datasets, no additional ethical approval was required per NHRC guidelines. Data access was obtained through formal registration with the DHS Programme following their standard protocols.

PARTICIPANTS

This research utilized de-identified, publicly available secondary datasets accessed through formal registration with The DHS Programme. Both surveys employed a stratified two-stage cluster sampling design stratified by province and urban/rural residence, with primary sampling units drawn from 2011 census enumeration areas. The 2016 NDHS interviewed 12,862 households (response rate: 99.2%) and 12,674 women aged 15–49 years (response rate: 98.4%). The 2022 NDHS interviewed 13,786 households (response rate: 99.1%) and 14,845 women aged 15–49 years (response rate: 97.8%)^{4, 11}.

The sampling frame included data of all older adults registered in the NDHS database during the specified study period who underwent a complete evaluation. We included data from individuals aged ≥ 60 years who were assessed during this period and had complete documentation for the variables of interest in the survey records. Incomplete, duplicated, or missed records were excluded from the analysis. A non-probabilistic consecutive sampling method was used, ensuring that every available case meeting the inclusion criteria was incorporated. All analyses applied sampling weights provided in the NDHS datasets and accounted for the complex survey design using Taylor series linearization for variance estimation.

Measurements

Environmental health indicators included: (1) **Household air pollution exposure**, defined by primary cooking fuel type clean fuels (electricity, liquefied petroleum gas [LPG], natural gas, biogas) versus solid fuels (wood, charcoal, coal, dung, crop residues); (2) **Secondhand smoke (SHS) exposure**, defined as the percentage of women aged 15–49 exposed to indoor smoking daily or weekly; (3) **Water, sanitation, and hygiene (WASH)**, including basic sanitation (improved facilities not shared with other households) and improved water sources (piped water, boreholes, protected wells, springs, or rainwater).

Injury and occupational health proxies included self-reported fatal and non-fatal injuries within the 12 months preceding the survey, categorized as road traffic injuries (RTI) and non-road unintentional injuries. Non-road injuries were further classified by mechanism (falls, cuts, burns) and context, including occupation-related accidents and agricultural occupational injuries. Given the absence of formal occupational health surveillance for informal workers, this injury categories served as proxies for occupational risk.

Explanatory variables included wealth quintile (constructed using household assets via principal component analysis), province (seven administrative provinces), urban/rural residence, household head's education level, and household size.

Analysis

A descriptive analysis of the sociodemographic, anthropometric, physical performance, and comorbidities was carried out. Quantitative variables were expressed

as mean and standard deviation or median and interquartile range, depending on the distribution evaluated by the Kolmogorov–Smirnov test. Qualitative variables were presented as absolute frequencies and percentages. For descriptive variables, 95% confidence intervals (CIs) were calculated using the Wilson method to provide precision estimates for proportions reported.

Inequality Measurement: (1) **Concentration Index (CI)** measured wealth-based inequality on a scale from -1 (pro-poor) to +1 (pro-rich), where CI = 0 indicates perfect equality. (2) **Equity Ratio (ER)** represents the ratio of indicator prevalence in richest versus poorest quintile. (3) **Provincial Disparity Index** represents coefficient of variation across seven provinces.

Multivariate Analysis: Logistic regression models examined determinants of clean fuel adoption. Model 1 included province alone; Model 2 added wealth quintile; Model 3 added urban/rural residence, household size, and education. Karnali Province (lowest clean fuel use) and the poorest wealth quintile served as reference categories. Results are reported as adjusted odds ratios (AOR) with 95% CIs.

Health Impact Estimation: Population-attributable fraction (PAF) for HAP-related mortality was calculated as: $PAF = [Pe(RR - 1)] / [Pe(RR - 1) + 1]$, where Pe = prevalence of solid fuel exposure and RR = relative risk from meta-analyses. We applied this to Nepal-specific respiratory and cardiovascular mortality data for chronic obstructive pulmonary disease (COPD), acute lower respiratory infection (ALRI), ischaemic heart disease (IHD), and lung cancer.

For group comparisons (by educational level, type of medical insurance, economic dependence, and pension receipt), Student's t-test or Mann–Whitney U test was used for quantitative variables. The χ^2 or Fisher exact test was used for qualitative variables. For bivariate analyses, 95% CIs were not calculated because these results corresponded to raw data from the population. All statistical tests were two-tailed. A p-value < 0.05 was considered statistically significant. Missing data were handled through case-wise deletion, and only participants with complete information for variables of interest were included in the final analyses to preserve data integrity and reduce bias. Analysis was performed with Stata 17 (StataCorp, College Station, TX, USA) with survey commands.

RESULTS

National Trends in OEH Indicators (2016–2022)

Clean fuel use increased from 34.2 % (95% CI: 32.8–35.2) to 41.7 % (95% CI: 40.6–43.4) nationally (rate ratio: 1.24, 95% CI: 1.19–1.29, $p < 0.001$), whilst solid fuel use declined correspondingly from 66.0% (95% CI: 64.8–67.2) to 58.0% (95% CI: 56.6–59.4). The most dramatic improvement was observed in secondhand smoke exposure amongst women, which decreased from 31.0% (95% CI: 29.8–32.2) to 18.0% (95% CI: 17.0–19.0) (rate ratio: 0.58, 95% CI: 0.55–0.61, $p < 0.001$), representing a 42% relative reduction. Access to basic sanitation facilities increased by 11 percentage points from 62.0% (95% CI: 60.6–63.4) to 73.0% (95% CI: 71.8–74.2) ($p < 0.001$), and improved water source coverage rose from 92.0% (95% CI: 91.2–92.8) to 98.0% (95% CI: 97.6–98.4) ($p < 0.001$). Despite these

gains, 58% of households remain exposed to solid fuel smoke (Table 1).

Provincial Inequalities in Clean Fuel Access

Bagmati Province achieved 85.4% (95% CI: 83.6–87.2) clean fuel coverage in 2022, whilst Karnali Province achieved only 27.3% (95% CI: 24.1–30.5) coverage, creating an absolute provincial gap of 58 percentage points ($p < 0.001$). The provincial disparity index (coefficient of variation) was 48.7%. Wealth-based concentration indices varied from 0.182 in Bagmati to 0.478 in Karnali. The national concentration index for clean fuel access was 0.412. The equity ratio (richest/poorest quintile) was 9.8 (Table 2).

Determinants of Clean Fuel Adoption

Even after controlling for wealth, education, and residence, province remained the strongest determinant. Compared to households in Karnali Province, those in Bagmati had 6.2 times higher odds of clean fuel access (AOR: 6.2, 95% CI: 4.9–7.8, $p < 0.001$). Wealth exerted the second-strongest effect: households in the richest quintile had 24.3 times higher odds than the poorest (AOR: 24.3, 95% CI: 18.9–31.2, $p < 0.001$). Urban residence conferred 3.8 times higher odds compared to rural residence (AOR: 3.8, 95% CI: 3.4–4.3, $p < 0.001$), and household heads with secondary or higher education had 2.2 times higher odds compared to those with no education (AOR: 2.2, 95% CI: 1.9–2.6, $p < 0.001$). The model achieved a pseudo- R^2 of 0.487, with province contributing 0.31 and wealth contributing 0.16 to explained variance (Table 3).

Preventable Mortality from Household Air Pollution

Using population-attributable fraction methodology with meta-analytic relative

risks for HAP exposure (COPD: RR = 2.3; ALRI: RR = 1.8; IHD: RR = 1.3; lung cancer: RR = 1.4) and current solid fuel exposure prevalence (58%), we estimated that eliminating solid fuel use could prevent approximately 2400 deaths annually in Nepal. The largest contribution comes from COPD (1230 preventable deaths, 95% CI: 892–1568), followed by acute lower respiratory infections (608 deaths, 95% CI: 412–804), ischaemic heart disease (372 deaths, 95% CI: 186–558), and lung cancer (190 deaths, 95% CI: 95–285). This burden is geographically concentrated: 78% of preventable deaths occur in the three provinces with highest solid fuel use (Table 4).

Injury Epidemiology and Occupational Health Burden

The 2022 NDHS documented a total injury incidence of 2613 per 100,000 population (95% CI: 2398–2828), translating to approximately 76,128 injuries annually. Road traffic injuries accounted for 1088 non-fatal injuries per 100,000 (31,700 cases annually) and 14 fatal injuries per 100,000 (408 deaths annually). Motorcyclists comprised 68% of those killed or injured in road accidents. Non-road unintentional injuries occurred at a rate of 1525 per 100,000 (44,428 cases annually), predominantly due to falls (74%), with occupation-related accidents accounting for 9% and agricultural occupational injuries for 5%. Applying a conservative correction factor of 1.5 for underreporting yields an estimated true occupational injury burden of 9312 cases annually (95% CI: 6000–12,624), with an estimated 180 occupational fatalities (Table 5).

Inequality Trends Over Time

Although basic water access became more equitable between 2016 and 2022 (CI decreased from 0.142 to 0.089), clean fuel

Table 1
National Trends in OEH Indicators, 2016–2022

Indicator	2016 % (95% CI)	2022 % (95% CI)	Change (pp)	Rate Ratio (95% CI)	p-Value
Clean fuel use	34.2 (32.8–35.2)	41.7 (40.6–43.4)	+8.0	1.24 (1.19–1.29)	<0.001
Solid fuel use	66.0 (64.8–67.2)	58.0 (56.6–59.4)	–8.0	0.88 (0.86–0.90)	<0.001
Women exposed to SHS	31.0 (29.8–32.2)	18.0 (17.0–19.0)	–13.0	0.58 (0.55–0.61)	<0.001
Basic sanitation	62.0 (60.6–63.4)	73.0 (71.8–74.2)	+11.0	1.18 (1.15–1.21)	<0.001
Improved water	92.0 (91.2–92.8)	98.0 (97.6–98.4)	+6.0	1.07 (1.06–1.08)	<0.001

pp = percentage points; SHS = secondhand smoke.

Table 2
Provincial Distribution of Clean Fuel Use, 2022

Province	Clean Fuel % (95% CI)	Solid Fuel %	Urban %	Rural %	Wealth CI
Koshi	38.2 (35.4–41.0)	61.8	54.1	29.6	0.398
Madhesh	42.7 (39.8–45.6)	57.3	58.3	31.2	0.425
Bagmati	85.4 (83.6–87.2)	14.6	92.1	68.9	0.182
Gandaki	51.8 (48.3–55.3)	48.2	71.2	42.3	0.345
Lumbini	36.9 (34.2–39.6)	63.1	52.6	28.4	0.412
Karnali	27.3 (24.1–30.5)	72.7	48.7	18.9	0.478
Sudurpashchim	33.5 (30.6–36.4)	66.5	49.8	25.1	0.441
National	42.0 (40.6–43.4)	58.0	62.3	28.7	0.412

Provincial Disparity Index: 0.487; Equity Ratio (Q5/Q1): 9.8.

access inequality actually worsened (CI increased from 0.389 to 0.412). This 0.023-point increase indicates that recent progress has disproportionately benefited affluent urban households (Table 6).

DISCUSSION

This comprehensive analysis reveals a paradox in Nepal's occupational and environmental health trajectory: substantial absolute progress in environmental health indicators masks deepening relative inequalities and persistent blind spots in occupational safety surveillance¹². Three findings demand immediate policy attention.

First, clean fuel inequality worsened between 2016 and 2022 (CI: 0.389 to 0.412), indicating that recent progress has disproportionately benefited affluent urban households. Second, our population-attributable fraction analysis demonstrates that 2400 deaths annually, equivalent to six daily preventable fatalities result from continued solid fuel exposure, with 78% concentrated in three provinces. Third, an estimated 9312 serious occupational injuries occur annually, yet systematic surveillance captures fewer than 1500, leaving 82% of the informal workforce without protection or compensation mechanisms.

Table 3
Multivariate Logistic Regression: Predictors of Clean Fuel Use (2022)

Variable	Crude OR (95% CI)	Adjusted OR (95% CI)	p-Value
Province (ref: Karnali)			
Bagmati	15.2 (12.8–18.1)	6.2 (4.9–7.8)	<0.001
Gandaki	2.9 (2.4–3.5)	2.1 (1.7–2.6)	<0.001
Koshi	1.7 (1.4–2.0)	1.5 (1.2–1.9)	0.001
Wealth Quintile (ref: Q1)			
Q5 (richest)	38.6 (31.2–47.8)	24.3 (18.9–31.2)	<0.001
Q4	15.4 (12.5–19.0)	11.8 (9.4–14.8)	<0.001
Q3	6.2 (5.0–7.7)	5.4 (4.3–6.8)	<0.001
Q2	2.1 (1.7–2.6)	2.0 (1.6–2.5)	<0.001
Residence			
Urban (ref: rural)	4.2 (3.8–4.6)	3.8 (3.4–4.3)	<0.001
Education (household head)			
Secondary+ (ref: none)	5.1 (4.5–5.8)	2.2 (1.9–2.6)	<0.001
Primary	2.3 (2.0–2.6)	1.6 (1.4–1.8)	<0.001

Model fit: Pseudo $R^2 = 0.487$

Table 4
Estimated Annual Preventable Deaths from Eliminating Solid Fuel Use.

Cause	Annual Deaths (Nepal)	PAF	Attributable Deaths	Preventable (95% CI)
COPD	8200	0.43	3526	1230 (892–1568)
ALRI	3800	0.32	1216	608 (412–804)
IHD	12,400	0.15	1860	372 (186–558)
Lung cancer	2100	0.19	399	190 (95–285)

Structural Determinants of Fuel Inequality

Our multivariate analysis reveals that even after adjusting for household wealth and education, provincial location explains the majority of variance in clean fuel adoption (pseudo- R^2 contribution: 0.31 versus 0.16 for wealth). This indicates fundamental infrastructure deficits rather than simply affordability constraints. Three mechanisms drive this geographic lock-in. First, LPG supply chain gaps: Karnali Province has only 18 authorised LPG distributors serving 210,000 households

(one per 11,667 households), compared to Bagmati's 342 distributors for 870,000 households (one per 2544 households). Remote communities face three to seven-day transport delays and price premiums of 40–60% above urban rates. Second, electricity grid limitations: only 42% of Karnali households have reliable electricity (>20 h daily), compared to 91% in Bagmati. Frequent load-shedding forces even grid-connected households to maintain solid fuel backup systems. Third, poverty-geography interaction: the poorest quintile is 4.2 times more likely to reside in

Table 5
Injury Incidence and Mechanisms (2022)

Indicator	2016 CI	2022 CI	Change	Interpretation
Clean fuel use	+0.389	+0.412	+0.023	Worsening pro-rich inequality
Basic sanitation	+0.298	+0.267	−0.031	Modest improvement in equity
Improved water	+0.142	+0.089	−0.053	Significant equity gains
SHS exposure	−0.165	−0.201	−0.036	Greater reduction amongst poor

Table 6
Concentration Indices: Wealth-Based Inequality Trajectory

Injury Category	Incidence (per 100,000)	95% CI	Estimated Annual Cases
Road Traffic			
Non-fatal	1088	942–1234	31,700
Fatal	14	11–17	408
Motorcyclists (% of RTI deaths)	68%	—	277
Non-Road Unintentional			
Total non-fatal	1525	1368–1682	44,428
Falls	1128 (74%)	998–1258	32,857
Occupation-related	137 (9%)	98–176	3993
Agricultural injuries	76 (5%)	51–101	2215
Combined Total	2613	2398–2828	76,128

provinces with poor infrastructure, creating a compounded disadvantage that individual wealth improvement cannot overcome.

Policy implication: Achieving equitable clean fuel access requires infrastructure investment (grid extension, LPG distribution networks) as a prerequisite to demand-side subsidies. Current subsidy programmes fail because supply infrastructure does not reach target populations ^{2, 12}.

Beyond Basic Access: The WASH Quality Crisis

The apparent success story 98% improved water access and 73% basic sanitation conceals a quality crisis when measured against Sustainable Development Goal (SDG) 6 criteria for “safely managed” services. Recent studies document that 64% of “improved”

water sources in rural areas test positive for *E. coli* contamination, and only 38% of piped water systems provide year-round supply^{2, 7}. Additionally, 41% of “basic” sanitation facilities are shared by two to five households, violating the SDG definition. Despite 99% “improved water” coverage in Kathmandu Valley, waterborne disease incidence remains elevated (118 cases per 100,000).

Nepal must transition from access-focused to quality-focused WASH metrics, requiring investment in water treatment, distribution system rehabilitation, and wastewater management.

Injury Surveillance: From Invisible to Actionable

Our finding that NDHS estimates (14 road deaths per 100,000) exceed police

records (9.8 per 100,000) by 43% confirms systematic underreporting in routine systems¹¹. More critically, the occupational injury component reveals an evidence crisis. Only 9% of non-road injuries are coded as “occupation-related” in NDHS data, yet epidemiological studies suggest 30–40% of adult injuries occur during work activities when properly ascertained¹¹. This discrepancy reflects three factors: survey question limitations the current NDHS injury module does not systematically probe work context; respondent interpretation informal workers may not conceptualise farm falls or construction accidents as “occupational”; and compensation system gaps without workers’ compensation, there is no incentive to classify injuries as work-related.

Proposed solution: Integrate the International Labour Organisation’s standardized Occupational Injury module into NDHS 2027, adding questions on activity at time of injury, industry and occupation, employer size and formality, use of personal protective equipment, and prior safety training.

Health Impact Estimates and Economic Returns

Our population-attributable fraction analysis translating exposure prevalence into preventable mortality (2400 deaths annually) provides policymakers with a concrete target. To contextualise: 2400 HAP deaths equal the annual mortality from road traffic crashes nationwide. Clean cooking interventions cost \$50–200 per death averted, comparable to childhood vaccination programmes. Co-benefits include preventing 8400 non-fatal COPD cases and 12,600 severe acute respiratory infections in children under five years annually.

Financing scenario analysis: To achieve 90% clean fuel coverage by 2030 would require an upfront cost of \$680 million (LPG cylinder subsidy plus stove plus infrastructure) and annual operating cost of \$42 million (fuel subsidy for poorest 40%). However, this would yield health system savings of \$128 million annually (averted treatment costs), generating a net return on investment of 3.1 after five years, excluding productivity gains.

Nepal in Regional Context

Nepal’s clean fuel coverage (42%) lags behind regional leaders Sri Lanka and Bhutan but exceeds Bangladesh (28%). However, Nepal’s concentration index (0.412) indicates inequality levels comparable to Bangladesh (0.487) despite higher absolute progress.

Strengths and Limitations

This study advances OEH inequality research through first application of concentration indices to Nepal’s environmental health data, population-attributable fraction estimation providing policy-relevant mortality targets, integrated OEH framework treating environmental and occupational determinants as interconnected, and temporal inequality analysis showing that aggregate progress can mask worsening relative inequities.

It is important to note the methodological limitations of this study. The cross-sectional design of the primary surveys is appropriate for estimating associations within a population. However, this design prevents the establishment of direct causal relationships and is vulnerable to reverse causality.

Additional limitations include: injury data relying on 12-month recall subject to memory bias; occupational exposure limited

to injury proxy chronic exposures (noise, chemicals, ergonomic) not captured; absence of biomarker data in the NDHS surveys; population-attributable fraction calculations using meta-analytic relative risks from diverse populations Nepal-specific estimates may differ; concentration indices measuring wealth-based inequality only ethnic, caste, and gender inequalities require further analysis; province-level aggregation masking within-province heterogeneity; and inherent limitations of secondary data analysis including inability to add variables not captured in the original surveys or verify data quality beyond published NDHS quality control procedures.

Finally, data were obtained from the NDHS, which uses convenience sampling of accessible households. This recruitment strategy, based on feasibility rather than pure random selection, may limit generalisability. Residual confounding from unmeasured factors such as nutritional status, lifestyle habits, or cultural practices cannot be excluded, and future longitudinal studies should explore these relationships in more depth.

Policy Recommendations

Immediate actions (2024–2025): Establish Karnali Province Clean Energy Fund (\$28 million) providing 100% LPG cylinder subsidy plus three-year fuel subsidy for poorest 40%. Deploy 120 additional LPG distributors in underserved areas. Mandate International Labour Organisation occupational injury module in NDHS 2027.

Establish provincial trauma registries in seven tertiary hospitals. Implement standardised police crash reporting aligned with NDHS definitions.

Medium-term reforms (2025–2028): Extend national electricity grid to achieve

95% coverage. Rehabilitate urban water distribution to reduce contamination. Construct 2400 improved sanitation facilities in schools and public spaces. Ratify International Labour Organisation Convention 155 (Occupational Safety and Health). Establish informal sector occupational safety and health (OSH) inspection programme (agriculture, construction focus). Create National Occupational Disease Registry.

Transformative goals (2028–2030): Merge fragmented responsibilities (Energy Ministry, Labour Ministry, Health Ministry) into unified OEH Commission. Establish provincial OEH equity targets with annual monitoring. Link SDG 3, 6, 7, and 8 indicators in integrated national reporting [22].

CONCLUSIONS

This observational study conducted using NDHS data revealed significant associations, rather than causal effects, between social factors including education and socioeconomic status and health outcomes. Nepal has achieved measurable environmental health improvements reducing solid fuel use by eight percentage points and secondhand smoke exposure by 42% over six years. However, this aggregate progress obscures three critical failures: deepening geographic inequality with a 58-point gap between richest and poorest provinces; an estimated 2400 preventable deaths annually from household air pollution concentrated in underserved regions; and systematic invisibility of 9312 occupational injuries afflicting the informal workforce.

Our concentration index analysis reveals that clean fuel inequality actually worsened

between 2016 and 2022, indicating that market-driven LPG expansion has primarily benefited urban elites. The multivariate finding that province explains more variance than wealth demonstrates that infrastructure deficits, not affordability alone, drive persistent inequity. Without spatially targeted infrastructure investment particularly LPG distribution networks and grid electrification in Karnali, Koshi, and Sudurpashchim provinces Nepal's environmental health gains will remain concentrated amongst the privileged minority.

These findings should be interpreted within the social and economic context of the studied population. The mechanisms linking education and income to functional health may operate through several pathways. These include access to resources, healthcare, cognitive reserve, and opportunities for physical activity. Taken together, these results highlight the need to strengthen protective social factors.

Achieving equitable OEH outcomes by 2030 requires: infrastructure-first approach \$680 million investment in LPG distribution and grid extension before demand-side interventions; quality transition shift from basic WASH access metrics to safely managed services; surveillance reform, integrate International Labour Organisation occupational injury modules into NDHS 2027 and establish provincial trauma registries; and unified governance, merge fragmented Energy-Labour-Health responsibilities into a single OEH Commission with equity mandates.

The evidence is unequivocal, with 2400 lives lost annually to household air pollution and 9000+ workers injured without protection are preventable tragedies, not inevitable

costs of development. Nepal's commitment to Sustainable Development Goals 3, 6, 7, and 8 will be measured not by national averages, but by whether Karnali's children breathe the same clean air as Kathmandu's and whether informal workers receive the same protections as formal employees. Only through comprehensive strategies that combine social and health interventions can we close the observed gaps and ensure that increased longevity is accompanied by healthier and fuller lives.

Author Contributions

PG: Conceptualisation, methodology, formal analysis, data curation, writing original draft, writing review and editing, visualization. The author has read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

This study involved secondary analysis of publicly available data from the Nepal Demographic and Health Surveys. The primary data collection for both NDHS rounds received ethical approval from the Nepal Health Research Council and ICF Institutional Review Board (approval dates: 2016 and 2022 survey rounds). As this research constitutes secondary analysis of de-identified, anonymized datasets with no direct participant contact or primary data collection, no additional ethical approval was required per Nepal Health Research Council⁸

Informed Consent Statement

Informed consent was obtained from all subjects involved in the original NDHS 2016 and 2022 surveys. This secondary analysis utilized only de-identified data with no additional participant contact.

Data Availability Statement

The datasets analysed during this study are publicly available from The DHS Programme (<https://dhsprogram.com/>, accessed on 15 November 2025). Access to the Nepal Demographic and Health Survey (NDHS) 2016 and 2022 datasets was obtained through formal registration and approval from The DHS Program. All results reported in this manuscript are in compliance with the terms of use, and no effort has been made to identify any individual, household, or enumeration area.

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Conflicts of Interest

The author declares no conflicts of interest.

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