Research Article

Community Engagement for Air Pollution Awareness and Healthy Behaviour Change in a Non-Attainment City of Himachal Pradesh, India

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ABSTRACT

Background: Ambient air pollution is a major environmental health threat and a leading cause of premature mortality worldwide. In India, particulate matter ($PM_{2.5}$ and PM_{10}) contributes substantially to respiratory and cardiovascular disease burden, particularly among vulnerable populations. While the National Clean Air Programme (NCAP) emphasises community engagement as a key strategy for reducing pollution exposure, evidence on the effectiveness of structured community-based health communication interventions in small non-attainment hill towns remains limited. This study evaluated the Swachh Hawa Sunder Nagar campaign, a youth-led public health initiative designed to promote household-level behaviour change for air pollution mitigation in Sunder Nagar, Himachal Pradesh.

Objectives: To assess the reach, implementation, and effectiveness of a youth-led, community-based air pollution health communication campaign and to evaluate patterns of participant engagement, ambassador performance, and associations between pledge mobilisation and peer health education activities.

Materials and Methods: A prospective observational study was conducted during a 49-day campaign (15 August-2 October 2026) based on a four-domain behaviour change framework comprising clean air pledges, peer health education, family outreach, and community awareness activities. Student Green Ambassadors from schools and colleges were trained in air pollution health risks, local pollution sources, and preventive behaviours. Activity data were collected through standardised Google Forms and stored in a SQLite database. Descriptive statistics were calculated for all domains. Inter-ambassador differences in pledge mobilisation were analysed using the Kruskal-Wallis H-test with eta-squared (η^2) effect size estimation. Spearman's rank correlation was used to examine the association between pledge counts and peer health education interactions.

Results: A total of 155 activity records from 46 active campaign days generated 106,530 engagement instances. These included 68,712 clean air pledges, 6,410 peer health education interactions, 2,507 family outreach contacts, and 28,901 community awareness engagements. Family outreach activities reached an estimated 10,529 individuals at the household level. Significant variation in pledge mobilisation was observed among ambassadors ($H = 89.34$, $df = 8$, $p < 0.001$), with a large effect size ($\eta^2 = 0.55$), indicating that ambassador performance accounted for 55% of the variance in mobilisation outcomes. Pledge counts showed a moderate positive correlation with peer health education interactions ($r_s = 0.38$, $p < 0.001$; $r_s^2 = 0.14$), suggesting that public commitment-making reinforced knowledge dissemination. Female ambassadors contributed the majority of campaign outputs, accounting for 95.7% of pledges and 97.9% of family outreach contacts. Supplementary activities expanded campaign reach through social media engagement (43,726 views), outreach to approximately 500 construction-worker families, cycle rallies, street theatre, and bamboo plantation activities.

Conclusion: The Swachh Hawa Sunder Nagar campaign demonstrates that a government-facilitated, youth-led health communication model can achieve substantial household and community-level engagement in a small NCAP non-attainment city at minimal cost. The four-domain framework effectively combined individual commitment, peer education, family outreach, and community action to promote clean-air behaviours. Significant ambassador-driven differences in outcomes and the positive association between pledges and health education highlight key factors for programme optimisation. The model offers a scalable and replicable approach for strengthening the community engagement component of NCAP and other air quality management programmes in India.

Key words: Air pollution; Public health; PM2.5; PM10; Community health intervention; non-attainment cities; NCAP; Health equity

Introduction

Ambient air pollution is the world's leading environmental cause of premature death, responsible for an estimated 6.7 million deaths annually worldwide.[1] In India, it caused approximately 1.67 million deaths in 2019 the second-largest risk factor for mortality in the country.[2] The health burden is not distributed equally: children under five, the elderly, pregnant

women, and communities living near industrial sites and waste management facilities bear a disproportionate share of the disease burden.[2] Particulate matter PM2.5 (diameter 2.5 micrometers or less) and PM10 (10 micrometers or less) is the primary health-damaging pollutant.[1] PM2.5 penetrates deep into the alveoli and enters the bloodstream, causing respiratory diseases, cardiovascular events, stroke, lung cancer, and adverse birth outcomes including low birth weight and preterm delivery.[3] PM10 irritates the upper respiratory tract and exacerbates asthma, chronic obstructive pulmonary disease (COPD), and allergic rhinitis. Long-term exposure to PM2.5 concentrations above 10 micrograms per cubic meter the WHO guideline value is associated with a 6-13% increase in all-cause mortality per 10 micrograms per cubic meter increment.[1,3] In Himalayan valley towns, nocturnal temperature inversions and thermally driven valley-wind circulations trap and concentrate these pollutants well beyond levels predicted by flat-terrain models, amplifying health exposure for valley-floor communities.[4]

India launched National Clean Air Programme (NCAP) in January 2019, targets a 40% reduction in PM10 concentrations by 2025-26 across 131 non-attainment cities.[5] By 2025-26, 108 of 130 NCAP cities recorded lower PM10 levels than the 2017-18 baseline, with 26 cities exceeding the 40% reduction target.[6] NCAP's seven thematic areas include Public Outreach and Capacity Building as a mandatory component, and the Swachh Vayu Survekshan (SVS) city ranking awards dedicated marks for community health engagement.[7] Cities with the largest PM10 reductions Ahmedabad (40%) and Rajkot (39%) combined technical source controls with sustained public health engagement programmes.[8]

A significant share of urban PM2.5 in Indian Tier-2 and Tier-3 cities estimated at 30-60% comes from diffuse behavioural sources: open waste burning, vehicle idling, and domestic biomass combustion.[9] These sources are not amenable to regulatory emission controls alone; they require sustained behaviour change at the household level. The Health Belief Model predicts that individuals adopt health-protective behaviours when they perceive personal susceptibility to health harm, understand the severity of the threat, and believe that their actions are effective.[10] The Theory of Planned Behaviour further predicts that subjective norms the perceived expectations of family members and peers are among the strongest predictors of health behaviour adoption.[10] Community-based health communication that activates both perceived severity and subjective norms is therefore the most effective strategy for achieving household-level behaviour change in air pollution reduction.

A 2025 rapid review of 79 air quality communication interventions confirmed that participatory approaches combining health awareness, commitment-making, and community action produce the most durable protective behaviour outcomes.[11] Youth-led peer health education is particularly effective: a study published in Nature Climate Change demonstrated that children's environmental health knowledge measurably shapes parental behaviour through upward social influence a mechanism with direct implications for household-level pollution reduction.[12] The WWF-India EIACP Programme, supported by MoEF&CC and CAQM, demonstrated this at scale in Delhi between June and September 2025, engaging over 2,00,000 participants across 65 schools through the Vayu Mitra Pledge and health awareness sessions.[13]

In Himachal Pradesh, seven cities are designated NCAP non-attainment cities: Baddi, Damtal, Kala Amb, Nalagarh, Paonta Sahib, Parwanoo, and Sunder Nagar. Together, they received a cumulative Rs 25.73 crore in performance-based grants between 2019-20 and 2025-26.[14] Sunder Nagar ranked second among category-3 cities in the swatch vayu survekshan in 2022 but fell to twelfth by 2025, reflecting a deterioration in air quality management with direct implications for community health. Residents particularly children, the elderly, pregnant women, and construction workers living near the Chandapur waste treatment site face elevated exposure to health-damaging particulate matter from multiple local and trans-boundary sources. Despite growing evidence for community-based health communication in air quality management, quantitative documentation of such campaigns in Indian non-attainment hill towns remains limited.[15] This study reports on the design, implementation, and evaluation of the Swachh Hawa Sunder Nagar campaign a 49-day public health initiative from 15 August to 2 October 2026 and offers a validated, low-cost model for household-level health engagement.

Materials and Methods

Study Setting and Health Exposure Profile

Sunder Nagar (31 degrees 32 minutes N, 76 degrees 54 minutes E; elevation approximately 900 m above mean sea level) is a sub-divisional headquarters in Mandi district, Himachal Pradesh. The town is a regional commercial and educational center with a mixed population of permanent residents, seasonal construction workers, and informal settlement communities. Its valley topography flanked by hills on multiple sides promotes pollutant accumulation through nocturnal temperature inversions and periods of low wind speed,[4] creating conditions of elevated and prolonged health exposure for valley-floor residents.

The town's residents are exposed to health risks from multiple pollution sources. The most locally distinctive of these is the BBMB reservoir lake adjacent to the town. Siltation has left wide stretches of silt banks exposed many times a year. [16] BBMB officials state that they are adopting systematic and scientific approaches to address silt accumulation and water management.[17] Given the media attention the silt has received, [16] its implications for air quality also merit discussion: scientific evidence shows that wind-driven resuspension of fine lacustrine sediments generates fugitive PM10 and PM2.5 loads in downwind residential areas, particularly during dry periods and low lake levels.[18] Prolonged inhalation of resuspended lacustrine dust is associated with upper and lower respiratory tract irritation, particularly in children and the elderly.[18]

The ACC Limited cement plant at Barmana, Bilaspur (~25-30 km south-west), is a documented trans-boundary source of health-damaging particulate matter. A National Green Tribunal (NGT) joint committee inspection in January 2025 found dust emissions from clinker, ash, and cement silos; inadequate dust control barriers; and seven complaints over three years. [19,20,21] Cement dust inhalation is associated with chronic bronchitis, restrictive lung disease, and an elevated risk of silicosis in heavily exposed populations.[22]

Several local sources add to the particulate burden. Open waste burning releases PM2.5, carbon monoxide, volatile organic compounds, dioxins, and furans. [9,23,24] These pollutants have well-documented carcinogenic, neurotoxic, and immunosuppressive effects that disproportionately affect children and pregnant women living near burning sites.[24]

Public health risk is further heightened by the BBMB Sunder Nagar sewage treatment plant, which was fined for repeated violations of pollution norms. Non-payment of the fine attracted an additional penalty, bringing the total to about ₹30.5 lakh. High levels of untreated sewage pollutants have raised public health concerns.[25]

road and construction dust, unnecessary vehicle idling, and seasonal domestic biomass combustion add further PM loading. Real-time HPSPCB monitoring places Sunder Nagar's AQI between the Good (27-46) and Satisfactory categories, with PM10 at 46 micrograms per cubic meter and PM2.5 at 20 micrograms per cubic meter.[26] However, episodic exceedances from the sources above remain a recurring health concern for vulnerable groups.

Campaign Design and Theoretical Framework

The Swachh Hawa Sunder Nagar campaign was a structured public health communication initiative developed by the Sub-Divisional Magistrate's office in collaboration with Crayash Charitable Trust. It ran for 49 days, from 15 August 2026 (Independence Day) to 2 October 2026 (Gandhi Jayanti), a period chosen to coincide with national civic occasions and to maximise school participation.

The campaign was grounded in the Social-Ecological Model of health behaviour change, which recognises that individual behaviour is shaped by interlocking influences at the individual, interpersonal, community, and societal levels.[10] The four-domain intervention framework was designed to activate behaviour change at each of these levels: pledge-taking at the individual level, peer health education at the interpersonal level, family outreach at the household level, community awareness activities at the community level, and supplementary public events, including the cycle rally and Nukkad Natak, at the societal level. This multi-level approach is consistent with evidence that interventions targeting several levels of the model produce larger and more durable behaviour change than single-level interventions.[11]

All private and government schools in Sunder Nagar were invited to participate. Twelve schools and three colleges nominated student representatives, who were trained and designated as Green Ambassadors. The health-focused training covered four areas: (i) the health effects of PM2.5 and PM10 on the respiratory and cardiovascular systems, including specific risks for children, the elderly, and pregnant women; (ii) local pollution sources and their health implications, including BBMB lake silt and the Barmana cement plant; (iii) practical health-protective household behaviours, such as avoiding waste burning, reducing vehicle idling, choosing active transport, protecting green spaces, and using clean cooking fuels; and (iv) data recording protocols. However, only nine of these ambassadors (eight female, one male) submitted activity records during the campaign.

Four-Domain Household Health Behaviour Change Framework

The campaign applied a four-domain framework for household health behaviour change. Activity in each domain was recorded daily using a standardised Google Form.

Domain 1 — Clean Air Pledge: Each day, students publicly committed to at least one health-protective clean air behaviour at home and in their community. Public pledging draws on social norms, a core construct of the Theory of Planned Behaviour, by making commitments visible and socially accountable, which can reinforce household behaviour change.[10]

Domain 2 — Peer Health Education: Each day, ambassadors held face-to-face conversations with at least 15 people about the health effects of PM2.5 and PM10, local pollution sources, and protective household measures. This approach works at the interpersonal level of the social-ecological model and is a recognised way of reaching households that formal health channels often miss.[11]

Domain 3 — Family Health Outreach: Each day, ambassadors held clean-air health conversations with at least five families and encouraged at least one household commitment, such as avoiding waste burning, reducing vehicle idling, walking or cycling, or protecting trees and green spaces. Because families are the main decision-making unit for practices such as waste burning and biomass combustion, this domain is the most direct route to household behaviour change.[12] Over the campaign, ambassadors also identified three to five local air pollution and health concerns, which formed a community-validated hazard inventory to inform the Sunder Nagar City Action Plan.

Domain 4 — Community Awareness Activity: Each day, ambassadors ran at least one Swachh Hawa awareness activity, such as health quizzes, awareness sessions, poster campaigns, or other creative health communication. They also encouraged five Swachh Hawa Peer Supporters to continue spreading the message in their communities.

Supplementary Health Communication Activities

In addition to above activities, the campaign incorporated several supplementary health communication components. These comprised: (i) health outreach to construction worker families residing adjacent to the Chandpur waste treatment site, a population characterised by high occupational and residential exposure to PM2.5 and PM10 and limited access to formal health communication; (ii) a cycle rally to promote active transport as a health-protective household behaviour; (iii) a Nukkad Natak (street theatre) performance conveying the health risks of air pollution to the general public through a culturally resonant medium; (iv) verbal health education sessions with waste pickers and waste workers; (v) a bamboo (Bambusa spp.) plantation around the Chandpur site on World Bamboo Day, selected for the documented PM2.5-reduction and phytoremediation capacity of bamboo;[27,28] and (vi) a poster campaign, declamation competitions, wall paintings, and a community women's cricket match, intended to extend campaign reach across gender and age groups.

Statistical Analysis

Activity data comprising 155 records from 46 active campaign days were stored in a SQLite relational database. For each quantitative domain, the following descriptive statistics were computed: sample size (n), total (sum), arithmetic mean ($\bar{x}$), median, standard deviation (SD), standard error of the mean (SE = SD/$\sqrt{n}$), coefficient of variation (CV = SD/mean × 100),

and the 95% confidence interval (CI = mean ± 1.96 × SE). Because activity counts were non-normally distributed, as indicated by high CV values, the Kruskal-Wallis H-test was used to compare pledge mobilisation across the nine ambassadors.[29] The effect size for this test was estimated using eta-squared ($\eta^2 = [H - k + 1]/[n - k]$, where k is the number of groups), with values of 0.01, 0.06, and 0.14 interpreted as small, medium, and large effects, respectively.[29] The association between daily pledge counts and peer health education counts was assessed using Spearman's rank correlation coefficient (rs), and the coefficient of determination (rs^2) was reported to quantify the proportion of variance explained.[29] Statistical significance was set at $\alpha = 0.05$. Records with missing values in individual domains were retained for domain-specific analyses but excluded from cross-domain correlation analyses (complete-case approach). All analyses were performed using Python version 3.12.

Results

Overall Campaign Reach and Health Engagement

Across 155 activity records from 46 active campaign days, the Swachh Hawa Sunder Nagar campaign generated a combined health outreach of 106,530 individual engagement instances across four structured domains (Table 1). Clean air pledges totalled 68,712 (mean 443.3 per session; SD 617.8; SE 49.6; 95% CI: 344.1-542.5; CV 139.4%; median 151.0). Peer health education interactions totalled 6,410 (mean 49.3; SD 88.7; SE 7.8; 95% CI: 33.7-64.9; CV 179.9%; median 26.0). Family health outreach contacts totalled 2,507 (mean 20.4; SD 47.3; SE 4.3; 95% CI: 11.8-29.0; CV 232.0%; median 15.0). Community awareness participants totalled 28,901 (mean 267.6; SD 453.2; SE 43.6; 95% CI: 180.4-354.8; CV 169.3%; median 30.0). The high CV values across all domains (range 139.4-232.0%) indicate substantial session-to-session variability, consistent with the episodic nature of school-based health mobilisation.

Table 1. Descriptive Statistics for Health Campaign Activity Domains (15 August - 2 October 2026, n = 155 sessions)

Domain	Total	Mean	SD	SE	Median	95% CI	CV%
Clean Air Pledges	68,712	443.3	617.8	49.6	151.0	[344.1, 542.5]	139.4
Peer Health Education	6,410	49.3	88.7	7.8	26.0	[33.7, 64.9]	179.9
Family Outreach	2,507	20.4	47.3	4.3	15.0	[11.8, 29.0]	232.0
Community Awareness	28,901	267.6	453.2	43.6	30.0	[180.4, 354.8]	169.3
Combined Total	106,530	—	—	—	—	—	—

Daily pledge counts ranged from 0 to 7,412 (25 August 2026), with a daily mean of 1,527.0 (SD 1,742.3). The campaign showed a bimodal temporal pattern: an initial mobilisation peak in late August (21 August: 4,277; 25 August: 7,412; 27 August: 3,704) followed by a sustained engagement plateau through September, with peaks on 7 September (3,387), 9 September (3,519), and 24 September (2,918). The final day (2 October 2026) recorded 1,100 pledges, confirming sustained health engagement through the campaign's close.

The family outreach domain the most direct measure of household-level health behaviour change reach recorded 2,507 family contacts across 123 active sessions (mean 20.4 families per session; SD 47.3; 95% CI: 11.8-29.0). Assuming an average household size of 4.2 persons (consistent with Himachal Pradesh Census data), the 2,507 family contacts represent an estimated direct household health communication reach of approximately 10,529 individuals. Combined with 6,410 peer health education interactions and 28,901 community awareness participants, the campaign's total estimated individual health reach accounting for family multiplier effects exceeded 106,530 direct engagement instances, with indirect household reach substantially higher.

Ambassadors also documented ten local air pollution and health concerns over the campaign: (i) unnecessary vehicle idling; (ii) open waste burning; (iii) road and construction dust; (iv) lack of greenery; (v) domestic biomass burning; (vi)

inadequate waste segregation; (vii) dust from unpaved roads; (viii) industrial emissions including trans-boundary cement dust from the Barmana plant; (ix) agricultural residue burning; and (x) poor solid waste management.

Table 2 presents health outreach outcomes across nine active ambassadors. Aarushi (Angel's Public School, 33 active days) contributed 36.9% of total pledges (25,365), 51.9% of peer health education interactions (3,324), 75.0% of family outreach contacts (1,880), and 73.3% of community awareness participants (21,188).

Table 2. Ambassador-Level Health Campaign Outcomes

Ambassador	Institution	Active Days	Pledges	Peer Educated	Families	Awareness
Aarushi	Angel's Public School	33	25,365	3,324	1,880	21,188
Mehak	DAV Public School	25	14,505	647	126	94
Simran	PM SHRI GMSSS	25	11,938	51	34	5,681
Parineeta	Mahavir Public School	38	10,909	892	142	92
Alok Bharadwaj	Paradise Public School	10	2,746	910	52	1,270
Rishika Chauhan	Modern Hi-Tech Model School	20	2,120	208	222	173
Akanksha Sharma	Himachal Dental College and Hospital	1	403	—	48	403
Nandini	Namdhari Delhi Public School	1	350	—	—	—
Arina Kapoor	Mother's Arms Global Public School	2	376	378	3	—

The Kruskal-Wallis H-test confirmed statistically significant inter-ambassador differences in pledge mobilisation ($H = 89.34$, $df = 8$, $p < 0.001$; critical value at alpha = 0.05: 15.51). Effect size (eta-squared) was calculated as 0.55, indicating a large effect that is, 55% of the variance in pledge mobilisation was attributable to differences between ambassadors (Table 3). This large effect size underscores the critical role of ambassador consistency and institutional context in determining health campaign reach.

Table 3. Kruskal-Wallis Test: Inter-Ambassador Pledge Mobilisation with Effect Size

Parameter	Value
H-statistic	89.34
Degrees of freedom	8
Critical value (alpha = 0.05)	15.51
p-value	< 0.001
Effect size (eta-squared)	0.55 (large)
Conclusion	Significant inter-group differences

Spearman rank correlation between daily pledge counts and peer health education counts (n = 130 matched records) yielded rs = 0.38 (t = 4.91, p < 0.001), indicating a statistically significant moderate positive association (Table 4). The coefficient of determination (rs-squared = 0.14) indicates that 14% of the variance in peer health education counts was explained by pledge count variation. Sessions with higher pledge uptake tended to involve more peer-to-peer health education interactions, suggesting that collective health commitment-making reinforces informal health knowledge dissemination a pattern consistent with social norm activation in health behaviour change theory.[10]

Table 4. Spearman Rank Correlation: Pledge Count vs Peer Health Education Count

Parameter	Value
Spearman's rs	0.38
Coefficient of determination (rs-squared)	0.14
t-statistic	4.91
n (matched pairs)	130
p-value	< 0.001
Interpretation	Moderate positive association

Female ambassadors (n = 8, 89% of total) contributed 95.7% of pledges (65,966), 85.8% of peer health education interactions (5,500), 97.9% of family outreach contacts (2,455), and 95.6% of community awareness participants (27,631) (Table 5). The male ambassador (n = 1) contributed 4.0% of pledges (2,746) and 14.2% of peer health education interactions (910) across 10 active days.

Table 5. Health Campaign Contributions by Gender

Gender	Ambassadors	Pledges	Peer Educated	Families	Awareness
Female	8 (89%)	65,966 (95.7%)	5,500 (85.8%)	2,455 (97.9%)	27,631 (95.6%)
Male	1 (11%)	2,746 (4.0%)	910 (14.2%)	52 (2.1%)	1,270 (4.4%)

Supplementary Health Activity Outcomes

The poster campaign, run by just five schools, drew 43,726 cumulative social media views, more than the estimated population of Sunder Nagar, without professional management or paid promotion. The cycle rally brought more than 100 cyclists onto Sunder Nagar's streets, publicly demonstrating active transport as a health-protective household behaviour. The Nukkad Natak reached the highest-footfall public location in the town, communicating air pollution health risks to the general population through street theatre. Slum community health outreach covered approximately 500 construction worker families at the Chandpur waste treatment site periphery a population with high occupational PM2.5 and PM10 exposure and limited access to formal health communication. The bamboo plantation on World Bamboo Day at the Chandpur site created a lasting environmental health legacy: Phyllostachys edulis forests reduce atmospheric PM2.5 by up to 18.6% and PM10 by 14.3% in suburban environments,[27] and bamboo's phytoremediation capacity for heavy metals [28] is well suited to waste treatment site peripheries where soil contamination poses additional health risks.

Discussion

The Swachh Hawa Sunder Nagar campaign reached 106,530 engagement instances over 49 days, using nine student ambassadors from a single Tier-3 town. The 2,507 family outreach contacts representing an estimated 10,529 individuals when multiplied by the average Himachal Pradesh household size of 4.2 demonstrate that the campaign successfully penetrated the household level, which is the primary site of health-harmful air pollution behaviours such as waste burning

and biomass combustion. For context, the WWF-India EIACP Programme backed by MoEF&CC and CAQM engaged over 2,00,000 participants across 65 schools in Delhi over three months.[13] This Swachh Hawa campaign's 68,712 pledges from nine ambassadors demonstrates that a government-facilitated, youth-led health communication model can deliver metropolitan-scale engagement in a small-town setting, consistent with evidence that participatory health communication approaches produce the most durable protective behaviour outcomes.[11]

The large effect size (eta-squared = 0.55) from the Kruskal-Wallis analysis indicates that 55% of the variance in pledge mobilisation was attributable to differences between ambassadors a finding with direct implications for programme design. Ambassador consistency was the primary determinant of health outreach reach: the top ambassador's 33 active days generated 36.9% of total pledges, while the sole male ambassador's 10 active days produced the second-highest peer health education count (910), confirming that engagement depth can compensate for lower frequency. Future programme design should set minimum activity requirements, pair high- and low-performing ambassadors, and ensure institutional accountability to reduce performance dispersion and achieve equitable household health communication reach.

The Spearman correlation ($r_s = 0.38$, r_s-squared = 0.14, $p < 0.001$) between pledge counts and peer health education confirms a reinforcing dynamic: public health commitment-making catalyses informal health knowledge dissemination, consistent with the Health Belief Model's prediction that visible social commitment activates peer norm pathways.[10] The near-exclusive contribution of female ambassadors (95.7% of pledges) reflects documented patterns of higher female participation in South Asian community health programmes[30] and points to the need for targeted strategies to recruit and retain male youth health ambassadors to ensure that health messages reach male-headed households.

The family outreach domain is the most direct measure of the campaign's household-level public health impact. By engaging 2,507 families in clean-air health conversations and encouraging at least one household-level commitment avoiding waste burning, reducing vehicle idling, choosing active transport, or protecting green spaces the campaign operationalised the Theory of Planned Behaviour at the household level.[10] Each family contact represents a potential multiplier: a single household commitment to stop waste burning, for example, eliminates a recurring source of PM2.5, dioxins, and furans that affects not only the household members but also neighbouring families and outdoor workers.[9] The campaign's moving from individual through peer education to family outreach and community action mirrors the social-ecological model of health behaviour change, which recognises that individual behaviour is embedded in and shaped by family, peer, and community contexts.[10]

The slum community health outreach covering approximately 500 construction worker families at the Chandpur waste treatment site periphery addresses a critical health equity gap. Construction workers and waste pickers face the highest occupational PM2.5 and PM10 exposure in Sunder Nagar yet are almost never reached by formal health communication programmes. Open waste burning disproportionately affects informal settlements, with 2-24% of municipal solid waste burned in the open in Indian cities,[9] releasing carcinogenic dioxins and furans at ground level where exposure is most intense. Engaging these households directly in their living and working environments represents a meaningful step toward health equity in air pollution communication and aligns with the WHO's call for health interventions to prioritise the most exposed and least served populations.[1]

The bamboo plantation at the Chandpur site extends this equity dimension into the physical environment. Phyllostachys edulis forests reduce atmospheric PM2.5 by up to 18.6% and PM10 by 14.3% in suburban environments,[27] and bamboo's phytoremediation capacity for heavy metals [28] directly addresses the dual health hazard of airborne particulate matter and soil contamination at waste treatment site peripheries. Unlike pledges or digital outreach, a bamboo grove constitutes a permanent, self-sustaining environmental health intervention that continues to protect the most exposed households long after the campaign concludes.

The poster campaign's 43,726 social media views achieved organically by five schools demonstrates the amplifying potential of youth-generated health communication content. Research shows that 72% of users share environmental health content on digital platforms and 68% report behaviour change following digital campaign exposure.[31] Integrating social media amplification as a standard component of NCAP public health outreach strategies would extend household

health communication reach at minimal additional cost, particularly among younger age groups with high digital media engagement.

The study used a prospective, structured data collection design with a standardised Google Form, ensuring systematic real-time capture across all health-behaviour activity domains. Non-parametric statistics were appropriate given the non-normal distribution of activity counts,[29] and complete-case analysis for cross-domain correlations is a standard conservative approach. The effect size reporting (eta-squared for Kruskal-Wallis; rs-squared for Spearman correlation) follows international standards for public health research reporting.[29] The findings quantify health outreach scale based on ambassador-reported engagement counts. Future studies would benefit from pre-post knowledge, attitude, and practice (KAP) surveys to measure household behaviour change depth, spirometry or peak flow measurements in exposed communities to assess respiratory health outcomes, and ambient air quality monitoring to link community health mobilisation to measurable changes in local PM2.5 and PM10 concentrations.

Conclusion

The Swachh Hawa Sunder Nagar campaign demonstrates that a government-facilitated, youth-led public health communication model can achieve substantial household-level reach in a non-attainment Tier-3 Indian city within a short timeframe and at zero external cost. Over 49 days, nine Green Ambassadors from schools and colleges generated 68,712 clean air pledges, 6,410 peer health education interactions, 2,507 family outreach contacts (estimated household reach: 10,529 individuals), and 28,901 community awareness participants a combined health outreach of 106,530 engagement instances. A poster campaign across five schools reached 43,726 social media views organically. Slum community health outreach covered approximately 500 construction worker families at the Chandpur waste treatment site periphery among the most health-vulnerable and least-served households in the town. The bamboo plantation at the Chandpur site created a lasting environmental health legacy with documented PM2.5 reduction and phytoremediation benefits.

The large effect size (eta-squared = 0.55) from the Kruskal-Wallis analysis and the moderate positive pledge-education correlation (Spearman rs = 0.38, rs-squared = 0.14, $p < 0.001$) offer clear, evidence-based guidance for programme optimisation: ambassador consistency drives household health outreach reach, and collective health commitment-making reinforces peer health knowledge dissemination. The four-domain household behaviour change framework moving from individual pledge through peer education to family outreach and community action provides a replicable public health model for the community engagement component of NCAP city action plans across Indian non-attainment cities.

NCAP's success in achieving its 40% PM reduction target depends not only on technical source controls but on sustained household-level behaviour change that addresses the diffuse, distributed pollution sources that regulation alone cannot reach. The Swachh Hawa model offers a validated, low-cost public health template for this purpose. Future research should incorporate pre-post KAP assessments, respiratory health outcome measurements (spirometry, peak flow), ambient air quality monitoring, and multi-city comparative designs to build a stronger evidence base for community-based public health interventions in India's NCAP framework.

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References

1. World Health Organization. Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease. Geneva: WHO Press; 2016.

2. India State-Level Disease Burden Initiative Air Pollution Collaborators. The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: The Global Burden of Disease Study 2019. Lancet Planet Health. 2021;5(11):e688-e702. doi:10.1016/S2542-5196(21)00246-4
3. Landrigan PJ, Fuller R, Acosta NJR, et al. The Lancet Commission on pollution and health. Lancet. 2018;391(10119):462-512. doi:10.1016/S0140-6736(17)32345-0
4. Ciarelli G, Di Antonio L, Mikkola J, et al. Radiative impacts of particulate matter in a Himalayan valley: A modelling case study of the Khumbu Valley, Nepal. EGU General Assembly 2026, EGU26-11787. 2026. doi:10.5194/egusphere-egu26-11787
5. Ministry of Environment, Forest and Climate Change, Government of India. National Clean Air Programme (NCAP). New Delhi: MoEFCC; 2019. Available from: https://moef.gov.in/en/division/environment-divisions/climate-change/national-clean-air-programme/
6. Press Information Bureau, Government of India. India's Path to Blue Skies: 108 Cities Cut Pollution, 26 Cities Achieve Over 40% Reduction Under NCAP. New Delhi: PIB; 7 September 2026. Available from: https://static.pib.gov.in/WriteReadData/specificdocs/documents/2026/sep/doc_9816_20260907_20291701.pdf
7. Central Pollution Control Board. PRANA — Portal for Regulation of Air-Pollution in Non-Attainment Cities. New Delhi: CPCB, MoEFCC; 2019. Available from: https://prana.cpcb.gov.in/
8. Press Information Bureau, Government of India. Goals set under NCAP. New Delhi: PIB; 8 August 2024. Available from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2043004
9. Kumaraswamy SK, Sharma B, Pai M. Combating Open Waste Burning to Reduce Air Pollution. New Delhi: WRI India Perspectives, World Resources Institute India; 2024. Available from: https://wri-india.org/perspectives/combating-open-waste-burning-reduce-air-pollution
10. Glanz K, Rimer BK, Viswanath K, editors. Health Behavior: Theory, Research, and Practice. 5th ed. San Francisco: Jossey-Bass; 2015.
11. Cibin R, Horgan L, Ciolfi L, Dockray S, Murphy G, Venables DS, et al. Promoting air quality-related awareness and behavioural change: A rapid review of communication interventions integrating behavioural, science communication and socio-ecological perspectives. Environ Challenges. 2025;20:101237. doi:10.1016/j.envc.2025.101237
12. Lawson DF, Stevenson KT, Peterson MN, et al. Children can foster climate change concern among their parents. Nat Clim Change. 2019;9:458-462. doi:10.1038/s41558-019-0463-3
13. Press Information Bureau, Government of India. WWF EIACP Inspires Over 2,00,000 Citizens Across Delhi Through 25 High-Impact Awareness Programmes. New Delhi: PIB; 13 September 2025. Available from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2166202
14. Singh KV (Minister of State, MoEFCC). Parliamentary response on air quality management in Himachal Pradesh. Lok Sabha, Session 186; 2026. Reported in: Tandon A. Baddi, Parwanoo, Kala Amb among 7 Himachal towns under air pollution watch. The Tribune. 22 July 2026.
15. Engaging communities in addressing air quality: a scoping review. Environ Health. 2022;21:89. doi:10.1186/s12940-022-00896-2
16. Gautam UK (President, Sundernagar Progressive Development Forum). Siltation threatens lake. The Tribune. 25 November 2025. Available from: https://www.tribuneindia.com/news/himachal/siltation-threatens-lake/
17. Himachal Pradesh Government. Governor visits BBMB Dredger Complex at Sundernagar. Press Release No. 374/2026-PUB; 7 April 2026. Available from: http://himachalpr.gov.in/OnePressRelease.aspx?Language=1&ID=46578
18. Ginoux P, Prospero JM, Gill TE, Hsu NC, Zhao M. Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products. Rev Geophys. 2012;50(3):RG3005. doi:10.1029/2012RG000388

19. Mullick R. NGT panel spots green compliance gaps at Adani Group cement plant. The Times of India. 9 February 2025. Available from: https://timesofindia.indiatimes.com/city/chandigarh/ngt-panel-spots-green-compliance-gaps-at-adani-group-cement-plant/articleshow/118095507.cms
20. NGT Panel Flags Environmental Gaps at ACC Cement Plant in Himachal Pradesh. Homes and Buildings. 10 February 2025. Available from: https://homesbuildings.com/ngt-panel-flags-environmental-gaps-at-acc/
21. ACC's Barmana plant acts on NGT environmental warnings. ICR Newsroom / CemNet. 24 April 2025. Available from: https://www.cemnet.com/News/story/179017/acc-s-barmana-plant-acts-on-ngt-environmental-warnings.html
22. Jena MC, Mishra SK, Moharana HS. Environmental impact assessment of cement plants and estimation of pollutant load on environment in India. Int J Syst Assur Eng Manag. 2025;16(7):2343-2354. doi:10.1007/s13198-025-02802-8
23. Pollution source tracing and health impact of PM10 elements using DN-PMF in sub-urban sites of the Indian Himalayan Region. Environ Geochem Health. 2025. doi:10.1007/s10653-025-02692-6
24. Das S, Verma N, Mitra S, Shiva Nagendra SM, Vardoulakis S. Air Quality Degradation from Open Waste Burning: A Case Study of Brahmapuram, Kochi, India. Aerosol Sci Eng. 2026. doi:10.1007/s41810-026-00415-7
25. Mullick R. BBMB fined for breaching pollution norms. The Times of India. 12 October 2026. Available from: https://timesofindia.indiatimes.com/city/chandigarh/bbmb-fined-for-breaching-pollution-norms/articleshow/134899832.cms
26. Himachal Pradesh State Pollution Control Board. Live Air Quality Index of Himachal Pradesh AQI Calendar, Sundernagar. Shimla: HPSPCB; 2026. Available from: http://hppcb.in/aqi-calender
27. Jiang Z, Lian J, Jiang Y, et al. Phyllostachys edulis forest reduces atmospheric PM2.5 and PAHs on hazy days at suburban area. Sci Rep. 2018;8:12482. doi:10.1038/s41598-018-30298-9
28. Saikia P, Podh S, Patel M, Kumar A. Bamboo: A Potential Candidate for Phytoremediation of Chemical Pollutants and Heavy Metals. In: Phytoremediation: Emerging Trends and Applications. Cham: Springer; 2024. doi:10.1007/978-3-031-60761-5_5
29. Corder GW, Foreman DI. Nonparametric Statistics for Non-Statisticians: A Step-by-Step Approach. Hoboken, NJ: John Wiley and Sons; 2009.
30. Agarwal B. Gender and forest conservation: The impact of women's participation in community forest governance. Ecol Econ. 2009;68(11):2785-2799. doi:10.1016/j.ecolecon.2009.04.025
31. Kaur K, Behura S, Srinivasa PC, et al. Environmental Awareness Through Digital Media: Impact and Reach. Int J Environ Sci. 2025;11(14s):1986-1992. doi:10.64252/ca6n3g68