Social Science & Medicine 308 (2022) 115201

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Domesticating cleaner cookstoves for improved respiratory health: Using approaches from the sanitation sector to explore the adoption and sustained use of improved cooking technologies in Nepal

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ARTICLE INFO

Keywords:
Backsliding
Behavioural settings theory
Domestication analysis
Household air pollution
IBM-WASH
Improved cookstoves
Nepal
Stacking

ABSTRACT

Drawing on village-based data from Nepal, this paper explores the transferability of the Integrated Behavioural Model for Water, Sanitation and Hygiene (IBM-WASH) to the clean cooking sector and its potential to elucidate how barriers to improved cookstove adoption and sustained use intersect at different scales. The paper also explores the potential of IBM-WASH, behaviour settings theory and domestication analysis to collectively inform effective behaviour change techniques and interventions that promote both adoption and sustained use of health-promoting technologies. Information on cookstove use in the community since 2012 enables valuable insights to be gained on how kitchen settings and associated cooking behaviour were re-configured as homes and stoves were re-built following the April 2015 earthquake. The methodological approach comprised of semi-structured interviews, focus group discussions, direct observation and household surveys. The findings indicated that the IBM-WASH framework translated well to the improved cookstove sector, capturing key influences on clean cooking transitions across the model's three dimensions (context, psychosocial and technology) at all five levels. Understandings gained from utilising IBM-WASH were enhanced – especially at the individual and habitual levels – by domestication analysis and settings theory which elucidated how different cooking technologies were incorporated (or not) within physical structures, everyday lives and routine behaviour. The paper concludes that this combination of approaches has potential applicability for initiatives seeking to promote improved environmental health at community-wide scales.

Credit author statement

Sarah Jewitt: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft, Writing – Review and Editing, Visualisation, Supervision. **Matthew Smallman-Raynor**: Interpretation, Writing – Original Draft, Writing – Review and Editing, Visualisation. **Binaya KC**: Investigation, Supervision, Review and editing. **Benjamin Robinson** Investigation, Formal Analysis, Review and editing. **Pushpanjali Adhikari**: Investigation, Supervision, Review and editing. **Catrin Evans**: Investigation, Methodology, Supervision, Review and editing. **Biraj Karmacharya**: Supervision. **Charlotte E. Bolton**: Funding acquisition, Supervision, Review and editing. **Ian P. Hall**: Funding acquisition, Supervision, Review and editing.

1. Introduction

With approximately 40% of the global population relying on inefficient, biomass-fuelled 'traditional' stoves used indoors for cooking and heating purposes, household air pollution (HAP) resulting from inefficient combustion is a major global public health concern. HAP causes

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https://doi.org/10.1016/j.socscimed.2022.115201
Received 22 November 2021; Received in revised form 19 May 2022; Accepted 5 July 2022
Available online 9 July 2022

around 2.5 million premature deaths annually and is a leading cause of pneumonia in children, exacerbates cardiovascular and pulmonary disease in adults and contributes to black carbon emissions (Ravindra and Smith, 2018; Clasen and Smith, 2019; International Energy Agency, 2022).

Recognising this, Sustainable Development Goal 7 target 7.1.2 is dedicated to promoting 'universal access to clean fuels and technologies for cooking' while many low/middle income country governments have promoted improved cookstoves (ICS) with subsidy policies and supply chain improvements (Sesan et al., 2018). Despite these efforts, ICS uptake has been slow (International Energy Agency, 2022). A key difficulty is that, even when households adopt ICS, they often continue to use, or revert to, biomass-fuelled cooking systems which are more fully embedded within their everyday social practice (Shove et al., 2012). These phenomena are known as 'stacking' (using multiple technologies simultaneously) and 'backsliding' (reversion to prior technologies) and often reflect households' diverse cooking requirements and preferences along with their need to minimise fuel costs or risks linked to a lack of sustained access to modern fuels (Masera et al., 2000; Van der Kroon et al., 2013; Ruiz-Mercado and Masera, 2015; Jewitt et al., 2020). A need has therefore been identified to understand context-specific user requirements and multi-scale barriers to the adoption and habitual use of improved (particularly clean) cookstoves (Jagadish and Dwivedi, 2018; Jürisoo et al., 2018; Rosenthal et al., 2018) or clean*er* fuel/stove combinations (Jewitt et al., 2020).

Implementation science and behaviour change approaches have received limited attention from clean cooking proponents (Goodwin et al., 2015; Clasen and Smith, 2019; Furszyfer Del Rio et al., 2020). The water, sanitation and hygiene (WASH) sector, by contrast, has long used behaviour change theories and models that offer potential transferability (Sesan et al., 2018; Clasen and Smith, 2019) and possibilities for integrating WASH and HAP initiatives (Goodwin et al., 2015; Ravindra and Smith, 2018; Sesan et al., 2018; Clasen and Smith, 2019). There are also opportunities to integrate *behaviour settings theory* which is gaining traction within the WASH sector (Curtis et al., 2019) and *domestication analysis* (Haddon, 2011) which explores the adoption, incorporation and objectification of information and communication technologies within people's homes and everyday routines. To explore these potential synergies, this paper draws on research with different cookstove stakeholders in Nepal to identify barriers to, and enablers for, HAP reduction through the uptake of improved stoves in a remote mountainous region. Information on cookstove use in the study site since 2012 provides insights into how kitchen settings and associated cooking behaviour were re-configured as homes were re-built following damage in the April 2015 Nepal earthquake.

Our aim is to use data from Nepal to explore the transferability of the Integrated Behavioural Model for Water, Sanitation, and Hygiene (IBM-WASH) (Dreibelbis et al., 2013) to the cookstove sector and its potential to elucidate how barriers to ICS adoption and sustained use intersect at different scales. The significance of the research lies in the potential of an 'IBM-WASH plus' model - integrating elements of behaviour settings theory (Curtis et al., 2019) and domestication analysis (Haddon, 2011) - to inform behaviour change interventions promoting sustained use as well as initial uptake of health-promoting technologies. We begin by reviewing similarities between the cookstove, water, sanitation and hygiene sectors and potential transferability between them (Section 2). We then introduce the fieldwork site and methodological approach (Section 3), before summarising the study findings which are structured according to the IBM-WASH model (Section 4). We conclude by suggesting that there are significant benefits in the HAP and WASH sectors working more closely together to promote improved environmental health at a community level in remote rural and low/middle income contexts (Section 5).

2. Literature review

There are many parallels between the environmental health impacts associated with barriers to addressing poor ICS and WASH access and use in low/middle income countries. Globally, air pollution ranks as the fourth leading risk factor for death in both men and women, while the combined category of unsafe water, sanitation and handwashing ranks eleventh and thirteenth for women and men respectively (GBD, 2019 Risk Factors Collaborators, 2020). Both sets of risk factors are often found in the same resource-poor populations and interventions to address them historically focused on top-down subsidy-led approaches to disseminate improved technologies (Clasen and Smith, 2019). Both HAP and WASH initiatives have grappled with low demand from users whose existing practices (gathering biomass to fuel home-built stoves and open defecation) are largely cost-free (Sesan et al., 2018; Clasen and Smith, 2019). Moreover, difficulties in linking of HAP- and WASH-related risks to illness – especially in populations with limited health-related knowledge – have hampered information, communication and education campaigns (Clasen and Smith, 2019).

A broad range of cultural, behavioural and environmental factors contribute to cookstove, fuel and sanitation stacking (Stanistreet et al., 2014; Jewitt et al., 2018). Recognition of this, along with a need to stimulate user demand for improved cooking/sanitation systems, contributed to a gradual shift from technology-focused initiatives to approaches informed by behaviour change theories. Still more recently, attention has focused on sustained use (Sesan et al., 2018) as the public health implications of 'stacking' and 'backsliding' remain significant unless everyone uses improved cookstoves and sanitation consistently (Satterthwaite et al., 2015; Clasen and Smith, 2019). Consequently, attention has been given to identifying barriers to the correct, habitual and exclusive use of ICS and WASH technologies and behaviour change techniques for addressing them (Clark et al., 2015; Sesan et al., 2018; Venkataraman et al., 2018; Clasen and Smith, 2019).

These similarities highlight the importance of multi-level, rather than individual scale, HAP and WASH interventions and calls for closer coordination are now gaining traction (Ravindra and Smith, 2018; Clasen and Smith, 2019). Despite recent use of social marketing and behaviour change techniques in ICS initiatives (Goodwin et al., 2015; Furszyfer Del Rio et al., 2020) there are few examples of shared approaches (Rhodes et al., 2014; Namagembe et al., 2015). Opportunities may therefore have been missed to build on the WASH sector's experience in developing behaviour change models and also to design approaches that target HAP and WASH-related environmental health burdens simultaneously and seek common solutions (Ravindra and Smith, 2018; Clasen and Smith, 2019). Many social marketing and information, communication and education approaches used within WASH initiatives are underpinned by behavioural theory (Jenkins and Scott, 2007) while behavioural determinants linked to opportunity, ability/capability and motivation underpin a range of health-related behaviour change frameworks including SaniFOAM (Devine, 2009).

In a systematic review of behaviour change frameworks and models used in WASH-related literature, Dreibelbis, et al. (2013) found that, while numerous studies identified behavioural determinants that influenced the adoption and sustained use of WASH, only eight presented a behavioural framework or model. Three key limitations of these existing behavioural frameworks or models were identified. Firstly, the focus on individual behaviour neglected multi-scale influences, including the role of the physical and natural environment. Secondly, limited attention was given to habitual use compared to initial uptake of WASH technologies. Thirdly there was a tendency to neglect such broader influences on WASH behaviour as gender, age, resource availability and socio-economic status (Dreibelbis et al., 2013).

To overcome these latter limitations, Dreibelbis, et al. (2013) developed the Integrated Behavioural Model for Water, Sanitation, and Hygiene (Table 1). The model sets out three intersecting dimensions (or 'factors') that influence WASH behaviour: contextual; psychosocial; and

Table 1
The integrated behavioural model for water, sanitation, and hygiene (IBM-WASH).

Level	Contextual factors	Psychosocial factors	Technology factors
Societal/ Structural	Policy and regulations, climate and geography	Leadership/advocacy, cultural identity	Manufacturing, financing, and distribution of the product; current and past national policies and promotion of products
Community	Access to markets, access to resources, built and physical environment	Shared values, collective efficacy, social integration, stigma	Location, access, availability, individual vs. collective ownership/access, and maintenance of the product
Household/ interpersonal	Roles and responsibilities, household structure, division of labour, available space	Injunctive norms, descriptive norms, aspirations, shame, nurture	Sharing of access to product, modelling/demonstration of use of product
Individual	Wealth, age, education, gender, livelihoods, employment	Self-efficacy, knowledge, disgust, perceived threat	Perceived cost, value, convenience, and other strengths and weaknesses of the product
Habitual	Favourable environment for habit formation, opportunity for and barriers to repetition of behaviour	Existing water and sanitation habits, outcome expectations	Ease/effectiveness of routine use of product

Source: Dreibelbis et al. (2013, Table 3, p. 6).

technology. The 'contextual' dimension seeks to capture elements that influence the adoption and sustained use of an intervention but are often omitted from existing models and frameworks. Behavioural determinants related to opportunity, ability/capability and motivation are included in the 'psychosocial' dimension, whilst the 'technology' dimension focuses on specific characteristics of the product being promoted. Intersecting these dimensions are four levels (structural/societal, community, household and individual) that enable multi-scale influences on WASH behaviour to be identified. A fifth level focuses on factors affecting habitual use.

Providing links between habitual use and the role of the physical environment, Curtis, et al. (2019) explore how the 'behaviour settings' in which everyday WASH activities take place can be disrupted and re-configured to promote improved WASH routines and habits. *Behaviour settings theory* emphasises how habits are shaped by physical structures and objects (termed 'stage', 'infrastructure' and 'props') combined with 'roles', 'routines', 'competencies' and 'norms' that meet particular objectives (Curtis et al., 2019). When these settings are disrupted, desirable habitual behaviour (e.g. improved handwashing) can be created and reinforced. Complementing this work, a recent WASH-related study by Gaybor (2019) draws on *domestication analysis* (Haddon, 2011) to understand the symbolic, cognitive and functional roles by which reusable menstrual technologies become integrated ('domesticated') into everyday life. Related concepts of 'de-domestication' and 're-domestication' explore how relationships with old technologies are assessed and reassessed. These complement IBM-WASH by providing more nuanced understandings of why technology stacking and backsliding occur and how this affects habitual ICS use. To date, domestication research has largely been conducted in high income contexts with a "lack of reflection upon cultural context" (Haddon, 2011:315) being identified as a limitation.

Given the similarities between the ICS and WASH sectors, we used data from Nepal to determine whether IBM-WASH captured multi-scale barriers and enablers for ICS adoption and sustained use. At the same time, we saw an opportunity to help 'de-Westernise' domestication analysis (Haddon, 2011) by focusing on catalysts for adopting and habitually using ICS in low-income contexts, exploring cultural norms and social practice surrounding cooking technology and how ICS can empower or disempower their users. Behaviour settings theory meanwhile offers insights into how kitchen settings shape and reinforce everyday cooking behaviours and routines and how their disruption (e.g. by the 2015 earthquake) may promote HAP reduction. The value of doing so is to explore the contribution of an 'IBM-WASH plus' approach to understanding and evaluating cookstove interventions and consider its potential to provide a multi-level framework for integrating HAP, WASH and possibly other health-focused initiatives in low and middle income contexts.

3. Methodology

The research formed part of an interdisciplinary project focused on Improving Respiratory Health in Nepal and involving researchers at the University or Nottingham (UK), Kathmandu University (Nepal) and Dhulikhel Hospital Kathmandu University Hospital (Dhulikhel Hospital). It draws on data collected as part of a work package focused on identifying effective interventions for reducing the risk of developing respiratory disease.

3.1. Data and methods

Fieldwork was conducted in Majhifeda village, in Ward 3 of Chaurideurali Rural Municipality, Kavrepalanchok District, between February and May 2019 and in April 2021 (Fig. 1). Majhifeda was purposively selected as the site of a Dhulikhel Hospital outreach clinic. As part of a Dhulikhel Hospital Department of Community Programs initiative, all households were offered an improved double-burner mud-built cookstove with a chimney in 2012–13 (Fig. 2) and baseline data were available for the numbers installed. As around 95% of homes were damaged by the 2015 earthquake (K C, 2019), Majhifeda was ideal for exploring how kitchen settings and cooking practices were re-configured following this disruption. Many post-earthquake homes have been constructed with separate outbuildings that house biomass-fuelled ICS or traditional cookstoves (Fig. 2E and F).

Majhifeda is located at an altitude of 1800 m in Nepal's Hill region with access by poor-quality roads that become impassable following snowfall and heavy rain. There are 840 households in the village with some 80% belonging to the Tamang community and the majority of the remainder to the Brahmin community. Livelihoods among community members comprise mainly of agriculture and animal husbandry. An overview of the socio-economic and demographic characteristics of Chaurideurali Rural Municipality and constituent wards is provided in Nepal Archives (2022). Additional information on Majhifeda is presented in Section 4.1 which discusses multi-scale contextual influences on cookstove use.

The paper draws primarily on qualitative data drawn from focus groups (FG) and semi-structured interviews (SSI) held in Majhifeda in 2019 and conducted in both Nepali (Majhifeda) and English (Kathmandu). Five focus groups were selected on the basis of sex, age and type of cookstove used (*FG-1–5*). Participants were encouraged to explain how decisions regarding household energy use reflected their lived experiences, preferences and priorities. *Semi-structured interviews* were conducted with five female community members who used ICS (*SSI-1–5*), two who did not use ICS (*SSI-6–7*) and 10 key informants. The latter consisted of three community-based health professionals (*SSI-8–10*), three traditional healers (*SSI-11–13*), a village leader (*SSI-14*), two community forest representatives (*SSI-15–16*) and a microfinance coordinator (*SSI-17*). These interviewees were selected purposively based on roles and knowledge of issues relevant to the study. To broaden

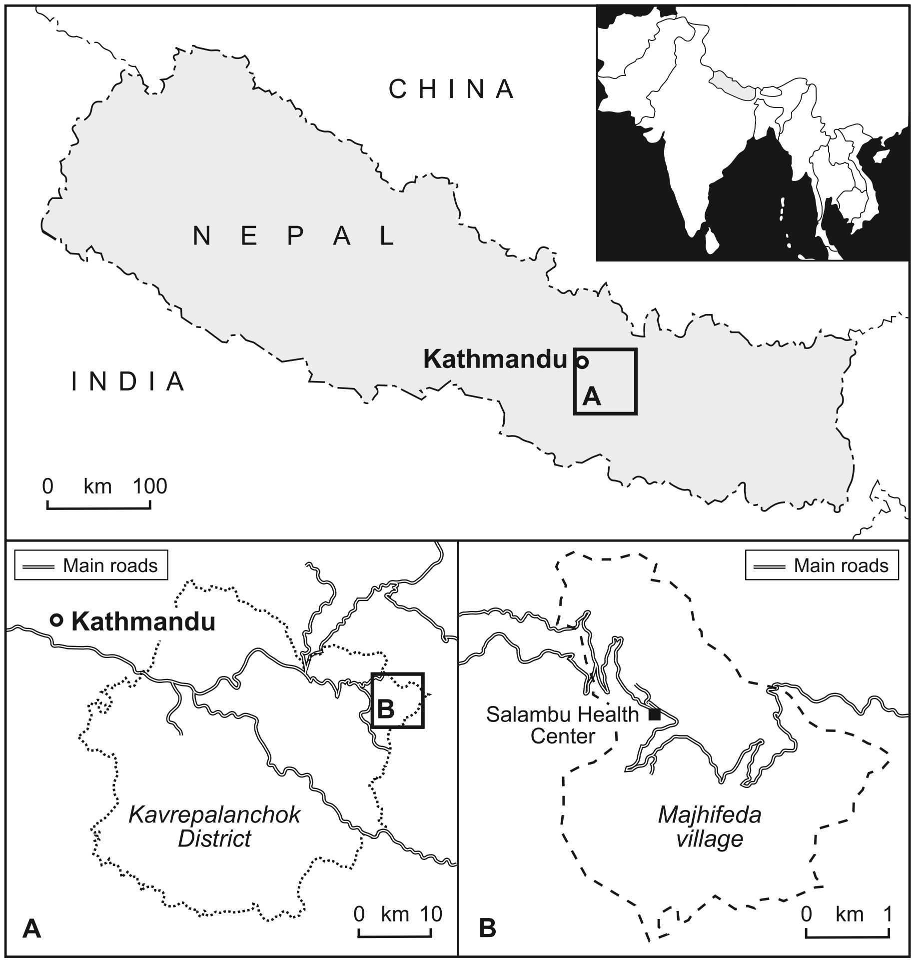

Fig. 1. Location map of study site. The upper map shows the location ('A') of Kavrepalanchok District within Nepal. The lower maps show Kavrepalanchok District (map A) and the location ('B') of Majhifeda village and Salambu Health Centre (map B).

the evidence base, an additional five semi-structured interviews were held in Kathmandu with ICS stakeholders at the Alternative Energy Promotion Centre (*SSI-18*), the Centre for Rural Technology (*SSI-19*), Dhulikhel Hospital Department of Community Programs (*SSI-20*), Kathmandu University *(SSI-21*) and Practical Action Nepal (*SSI-22*).

To contextualise the qualitative data and enable changes in the use of different cooking systems to be identified at a village-wide scale as post-earthquake house reconstruction progressed, surveys of at least 12% of households in Majhifeda were undertaken in 2019 (104 households) and 2021 (101 households). Given the absence of an accurate sampling frame for the community post-earthquake, households for the 2019 survey were selected purposively to obtain good coverage of the full range of stoves and fuels used in the village. To do this, we drew on stove installation data from the Department of Community Programs team and guidance from the village Chairperson who had good knowledge of cooking systems in the community. The survey gathered information on house construction (including ventilation and chimneys), seasonal and annual energy use and costs, and cookstove use (including priorities, preferences and maintenance). In 2021, fieldwork took place prior to the second COVID-19 wave in Nepal and ended before the national lockdown in late April. While we were able to re-visit many of the same households, changes to community members' work, migration and residence patterns linked to COVID-19 and ongoing house reconstruction necessitated the inclusion of some alternative respondents. With help from the village Chairperson, we surveyed households nearby with similar characteristics. To identify changes in behaviour settings, we collected additional information regarding pre-and post-earthquake housing, cooking systems and cooking locations.

Qualitative data from the focus groups and interviews were recorded, transcribed and, as necessary, translated, checked and verified by multiple team members before being coded and analysed thematically with assistance from NVivo version 12. Inductive coding was undertaken initially to allow themes to emerge from the data. Deductive coding using IBM-WASH as a framework (as intended by Dreibelbis et al., 2013) was subsequently undertaken to explore the model's relevance for ICS adoption and sustained use. The results in Section 4 are structured according to the IBM-WASH dimensions and levels. Household survey data were analysed using simple descriptive statistics. Ethical clearance was obtained from Kathmandu University School of Medical Sciences.

3.2. Study limitations

Key methodological limitations include researcher positionality, discrepancies between the qualitative and survey data and the potential loss of nuance and meaning in translation from Nepali to English. Efforts to mitigate against social desirability bias (Sovacool et al., 2018), especially when discussing the Department of Community Programs, included periods of residence in the community to develop trust and to triangulate data collected during household surveys with qualitative data and direct observation. These measures revealed that household survey responses tended to over-report transitions to cleaner cooking solutions and to under-report continued traditional cookstove use and the stacking of multiple stove technologies. This may reflect social

Fig. 2. Cooking facilities in Majhifeda. (A) An improved cookstove with chimney installed as part of Dhulikhel Hospital's ICS project. (B) A traditional cookstove. (C) A double burner LPG stove in a newly built house. (D) A charcoal-fuelled '*gol*' stove. (E), (F) New homes with adjacent buildings housing traditional cookstoves.

desirability bias, misinterpretation of survey questions or priority given to the principal technologies used. Finally, the inability to survey the same households in 2019 and 2021 created gaps in data on some respondents' stove/fuel transitions.

Table 2
Types of stove reported in the household surveys.[1]

	Primary stove	Secondary stove	Tertiary stove	Total
Improved cookstove (ICS)				
pre-2015	69	24	0	93
2019	28	15	2	45
2021	57	14	0	71
Traditional cookstove				
pre-2015	31	46	0	77
2019	61	14	5	79
2021	26	3	0	29
Liquefied Petroleum Gas (LPG) stove				
pre-2015	0	1	0	1
2019	11	17	4	32
2021	16	42	2	59

Notes: [1]Classification of primary, secondary and tertiary stoves is based on regularity of use. All figures are expressed as a percentage proportion of households surveyed.

4. Results and discussion

To contextualise the qualitative findings, Table 2 summarises the results of the 2019 and 2021 household surveys in relation to the types of cookstove used. As noted in Section 3.1, all households were offered an improved double-burner mud-built cookstove with a chimney in 2012–13 (Fig. 2A). The village Chairperson estimated that around 690 'Dhulikhel Hospital improved cookstoves' (DH-ICS) were installed and the household survey data indicated that 93% of households had used them prior to 2015. Whilst 45% of sample households were still using them in 2019, 17 households reported backsliding to (or 're-domesticating') traditional cookstoves following damage from the 2015 earthquake. Reflecting ongoing house reconstruction, 71% of households reported using ICS by 2021, but the use of liquefied petroleum gas (LPG) stoves also increased from just 1% (prior to 2015) to 59% (2021). A high degree of cookstove stacking was observed, with 46% and 11% of respondents respectively reporting the regular use of secondary and tertiary stoves in 2019 and 59% and 2% reporting this in 2021.

Framed by these insights, Table 3 is structured according to the analytical framework of the IBM-WASH model (Table 1) and summarises the results of our thematic analysis of focus group and interview materials. We consider the evidence for each dimension (contextual, psychosocial and technology) in turn.

Table 3
Summary of contextual, psychosocial and technology influences on cooking practices in Majhifeda, Nepal.

Level[1]	Contextual factors	Psychosocial factors	Technology factors
Societal/ Structural	Renewable Energy Subsidy Policy, promotion of biomass energy technologies and post-earthquake aid. Seasonality of poor lung health and stove use (e.g. for winter heating). Mountainous terrain limits energy infrastructure, altitude influences HAP, earthquake influenced cooking practices.	Government-led information, communication and education initiatives targeting ICS, smoking cessation and HAP reduction, cultural preferences for biomass cooking.	Government policy promoting ICS manufacturing, testing, financing (via subsidies) and product distribution with higher subsidies available for remote and high-altitude regions. Traditional biomass use supported by National Rural and Renewable Energy Program.
Community	Poor access to stove markets and LPG cylinders, zero or low cost firewood from farm land or community forests, earthquake-related changes to the built environment and cooking systems.	Shared cooking-related cultural norms, widespread ICS adoption, use and maintenance, adherence to caste-based cooking practices/restrictions.	Access to clean energy and transport infrastructure, availability of zero or low cost firewood from individual or community woodland, availability of materials/artisans to maintain/repair ICS.
Household/ interpersonal	Cooking practices influenced by gendered social norms, family size, access to firewood on farmland and post-earthquake changes to living and cooking practices.	Caste-specific cooking restrictions, descriptive norms (and shame) surrounding sooty kitchens/ pots, aspirations for clean-burning stoves, concern about HAP-related ill-health.	Effective initial communication and promotion of DH-ICS including training to build and maintain ICS but lack of continued access to technical support undermines sustained use.
Individual	Unaffordability of clean cooking systems. Cooking preferences vary by age and gender. Education influences cooking preferences and concern about HAP. Livelihoods affect lung health.	Varying knowledge of causes of lung ill-health, concern about HAP-based health threats and health-seeking behaviour or adoption and maintenance of ICS. Distaste for soot-blackened kitchens and pots.	Traditional cookstoves and DH-ICS are cheap to construct and fuel. LPG perceived as expensive when biomass fuel is freely available and often used sparingly. Cooking system choices influenced heavily by specific stove attributes. The need for space heating and large quantities of food (e.g. for animals) favours continued use of traditional cookstoves.
Habitual	DH-ICS embedded within households' cooking routines and re-built post-earthquake. Expense and access constraints limit sustained and exclusive LPG use.	DH-ICS used habitually but not exclusively with irregular maintenance undermining HAP reduction. Frequent repair/maintenance requirements plus aspirations for clean burning stoves stimulated LPG adoption but not exclusive use.	Evidence of sustained DH-ICS use but regular maintenance required to sustain HAP reduction benefits. LPG convenient and easy to use but regular use limited by affordability and irregular access to LPG refills. A lack of alternatives for key attributes provided by traditional cookstoves (e.g. space heating or cooking large volumes) challenges sustained/exclusive clean cookstove use.

Notes: [1] See Table 1 for level descriptors associated with each of the three factors. Note that the descriptor for psychosocial factors (habitual) has been adapted here for 'existing cooking habits'.

4.1. Contextual influences

The contextual dimension in Table 3 underscores the multi-level effects of the 2015 earthquake on cooking practices and systems. Alongside the physical, social and economic impacts of the earthquake, considerations of national energy policy, access to resources and markets, affordability of technology, gendered social norms, cooking preferences, and concerns over lung health and HAP have tended to promote the stacking of traditional and cleaner cooking technologies.

4.1.1. Societal/structural

Several interlocking policies and regulations have succeeded in promoting biomass-fuelled ICS. Nepal's Renewable Energy Subsidy Policy provides financial support to eligible households for ICS that comply with government regulations (Ministry of Population and the Environment, 2016). The Ministry of Population and Environment (2017) recognises biomass as an important ingredient in Nepal's short- and medium-term energy mix, while the Fourteenth Plan (National Planning Commission, 2016) focuses on promoting forest enterprises and controlling deforestation. This, coupled with the exclusion of LPG from Nepal's Renewable Energy Subsidy Policy, irregular electricity supply and the Indian fuel blockade's impact on LPG access in September 2015 (Robinson et al., 2021) promoted transitions to 'cleaner' rather than clean cooking solutions. The blockade prompted people to 'foreground' (Jewitt et al., 2020) fuel insecurity risks and prioritise fuel stacking with many LPG users 're-domesticating' biomass fuels:

> During the blockade the demand for improved cookstoves was very high … Because there was no LPG gas … you need something to cook. Firewood was easily available … (*SSI-21*).

Geography and climate are important societal/structural factors that influenced stove choices. Nepal's mountainous terrain, combined with poorly-developed transport and distribution networks, influenced access to energy infrastructure. Geography also influenced eligibility for, and the costs of, subsidised stoves (Robinson et al., 2021):

> there is a price that is fixed but it depends on transportation … Subsidy is not for all the houses … Whose house … is above 2000m sea level and … above 1500m sea level and north facing … are qualified for metallic ICS subsidy … those who do not fit this criteria even if they are in cold place, they might not get (*SSI-21*).

Seasonality and the need for winter space heating also influenced stove choices, with households favouring traditional stoves over ICS in cold weather:

> Once it gets colder outside they use traditional stoves with firewood to warm themselves … we cannot warm ourselves with an improved cookstove (*SSI-8*).

The greater $PM_{2.5}$ concentrations and CO exposure associated with traditional cookstoves (K C, 2019) served to promote a strong seasonal dimension to respiratory health problems *(SSI-9)* when combined with wintertime respiratory infections plus the high prevalence of lung disease in rural areas and among those exposed to HAP (Ekezie et al., 2021).

Although largely absent from the ICS literature, natural hazards were another important geographical influence on cookstove choices in Nepal. The 2015 earthquake, in particular, caused significant damage to homes and consequent disruption of cooking-related behaviour settings:

> before the earthquake every household had an improved cookstove … but after it, all of the old houses … were destroyed … along with those cookstoves (*SSI-15*).

Post-earthquake aid packages were distributed to stricken communities. These included unfamiliar ICS, including solar stoves, some of which were 'domesticated' (*SSI-5;FG-4*). In addition, the Nepal Reconstruction Association provided funds to rebuild damaged houses. This stimulated the reconfiguration of cookstove behaviour settings, with cleaner stoves often being domesticated or re-domesticated:

> those who have damaged their house, they need to install new cookstoves … After they have prepared their house it's an opportunity to have a new cookstove design (*SSI-21*).

4.1.2. Community

Many of the societal/structural influences also played out at the community scale (Table 3). Poor access to infrastructure and markets was cited as a major barrier to ICS (especially LPG) adoption *(SSI-9)*. Access to natural resources also had a significant, often negative, influence on ICS transitions. Post-earthquake, access to Majhifeda's community forest for materials to re-build houses provided a source of fuelwood *(SSI-4)*, whilst earthquake-related changes to physical structures and living arrangements prompted changes in cooking practices:

> we cannot use the old kitchen as it is about to fall down … (*P3:FG-5*)

4.1.3. Interpersonal/household

At the interpersonal/household level, family size and gendered cultural norms influenced stove adoption and incorporation, with smaller households favouring DH-ICS and LPG as they could easily accommodate their cooking requirements and the fuel expenditure was manageable:

> those with small households will use gas … but large families can't due to financial constraints (*SSI-15*).

Gendered cooking practices often promoted stacking, with men using traditional outdoor wood-fuelled stoves for brewing alcohol and during festivals while women did everyday cooking indoors (*SSI-1*). Access to natural resources also influenced the wider behaviour settings within which cooking technology domestication took place with little incentive to use cleaner fuels for people with free access to firewood:

> we have our own jungle … we don't need to pay for wood … we … only use wood (*SSI-7*).

As already noted, cooking behaviour settings and routines were disrupted and re-configured post-earthquake with ongoing financial constraints or a lack of technical expertise prompting traditional cookstove re-domestication *(SSI-5)*. But backsliding from ICS was often temporary. As families re-built their homes, some re-domesticated their existing ICS and incorporated new technologies including LPG (Table 2). This stimulated changes to local cooking behaviour settings:

> we have a separate gas stove room … the [new] home is built differently (*P1:FG-4*)

4.1.4. Individual

Individual-level barriers and enablers to ICS adoption are well documented and include wealth, education, age and gender (Rehfuess et al., 2014; Stanistreet et al., 2014). Echoing this, affordability was widely reported, along with access, as barriers to exclusive LPG use. Village healthcare workers linked stove choices to age and education-related differences with younger, more educated villagers favouring ICS. Some who had spent time in Kathmandu had domesticated LPG:

> they [daughters-in-law] only cook with LPG … if they encounter a smoky stove they say "it makes my eyes water … I cannot come inside" … [they] … have been born and brought up in Kathmandu (*SSI-6*).

4.1.5. Habitual

The Dhulikhel Hospital stove programme has successfully promoted habitual use of its mud-built ICS since 2012–13, with 71% of households reporting ICS use in 2021 (Table 2). Although DH-ICS are often used alongside traditional cookstoves, LPG and *gol* (charcoal-fuelled clay or metal stoves – Fig. 2D), their fixed location has facilitated incorporation within local kitchen behaviour settings. There were also indications of ICS 'conversion' and 're-domestication' with many accounts of respondents' rebuilding them post-earthquake:

> I have destroyed that house and made a new one … and now I have made a separate kitchen … I have made an improved stove like that [DH-ICS] … it is not a very good one … but at least the smoke is going outside (*P3:FG-2*).

The earthquake had unanticipated consequences for HAP reduction by exposing households to ICS infrastructure and props that they continued to use, albeit not exclusively (*SSI-5*). This included the rapid incorporation and objectification of LPG within homes and cooking routines (*P1:FG-4*), although rarely as the primary fuel. As sustained and habitual LPG use continues to be limited by affordability and access constraints, it tends to complement rather than displace traditional cookstoves. These, in turn, have become even more firmly incorporated and objectified within cooking behaviour settings and everyday routines as adjoining buildings have been constructed to house them (Fig. 2E and F). This is particularly true for households with access to free firewood or that cook food for their animals.

4.1.6. Context dimension summary

The context domain of the IBM-WASH framework translated well to the ICS sector, capturing key influences on clean cooking transitions at all five levels (Table 3). The main difference was the greater importance of environmental influences (seasonality, climate, altitude, natural resources and hazards) across the different levels for ICS. This may simply reflect the geographical characteristics of Majhifeda, or it may indicate a need to integrate these dimensions more fully for HAP and, potentially, other interventions where environmental influences are likely to be significant. Domestication analysis and settings theory added additional insights on how post-earthquake house designs and kitchen settings were re-configured and cleaner cooking technologies were incorporated (or re-domesticated) and objectified within habitual cooking practices.

4.2. Psychosocial factors

The psychosocial dimension in Table 3 captures the deeply-rooted cultural dimensions of cooking preferences, along with knowledge of (and concerns over) HAP-related respiratory health and the role of stove maintenance in the choice of cooking technologies.

4.2.1. Societal/structural

Nepal has many policies and programmes aimed at promoting ICS adoption (Section 4.1.1) and the dissemination of information on HAP-related health problems and biomass energy efficiency. Consequently, awareness about ICS is high although potential end-users are not necessarily well-informed about their health benefits.

4.2.2. Community

Issues relating to cultural identity were expressed in terms of shared values that shaped cooking behaviour settings and stove domestication, although some were caste- or time-specific. Among the numerically dominant Tamang, outdoor cooking is quite common:

> Mainly in Tamang society they cook outside … they have improved cookstoves … but they do not always use them (*SSI-8*).

Amongst Brahmins, women are expected to segregate during menstruation and sometimes use different stoves to cook for themselves:

> [during menstruation] I cook on that solar stove which came at the time of the earthquake (*P2:FG-1*).

Caste-specific restrictions on taking pork inside the house, meanwhile, can necessitate the use of outdoor stoves *(SSI-2)*. With regard to collective efficacy, Dhulikhel Hospital's ICS programme had raised the community's awareness of HAP, with Table 2 indicating sustained (although not exclusive) ICS use by a high proportion of villagers pre-earthquake.

4.2.3. Interpersonal/household

Just as community-scale shared values and a desire for social integration or avoiding stigma can encourage stove stacking, injunctive and descriptive norms (and accompanying concerns about shame) often reinforce this at household/interpersonal scales. Cultural norms concerning household cleanliness (or a sense of shame in not demonstrating this) also influenced stove choices, domestication and 'conversion' as respondents sought to reduce the drudgery of cleaning soot-blackened pots and stoves:

> We need to polish [the DH-ICS with mud] … if not then it will become blackened (laugh) (*P1*). We polish ours daily (*P2*) (*FG-3*).

This was often linked to a desire for LPG stoves that would make kitchen settings tidier and streamline everyday cooking routines. LPG was widely used when visitors were present as it was quick, largely smoke-free and conveyed a degree of prestige *(SSI-3)*. Nurture also influenced decisions to use cleaner stoves with health benefits being referred to both directly and indirectly:

> Dust and smoke from cookstoves … cannot escape. These children will inhale this smoke and dust … which will eventually affect them internally (*SSI-3*)

4.2.4. Individual

Poor knowledge of HAP-related health problems, and how ICS can address these, have been identified as important barriers to ICS adoption (Rehfuess et al., 2014; Stanistreet et al., 2014). Among healthcare staff, community members were perceived as having limited knowledge of the causes of lung-related ill health (*SSI-10*) yet, qualitative data indicated that messages disseminated by the DH-ICS programme on the efficiency and health benefits of ICS had been received and understood by some:

> we had that [DH-ICS] before where all the smoke used to go outside directly and only two to four pieces of wood was needed … it is good for people who are cooking inside … good for health' (*SSI-7*).

A minority of respondents, however, remained sceptical of the potential health impacts of HAP (*P2:FG-4*). Rather, they were concerned about alternative threats, including agricultural dust, cold weather, diet and destiny. Most indicated self-efficacy in seeking healthcare (whether it be the health centre or a traditional healer), whilst self-efficacy in reducing HAP was also evident as respondents spoke of women being trained to make ICS and of households repairing earthquake-damaged ICS (*P2:FG-1*). Some households, however, lacked the requisite expertise:

> we should construct improved cookstoves, and we had that improved cookstove previously but who will make for us? … we don't know how to make (*P1:FG-4*).

As disgust is a lesser influence on HAP-related behaviour than WASH-related behaviour (Table 1), it appeared only in the context of menstruation-related cooking restrictions (Section 4.2.2) and the cleanliness of kitchens and cooking paraphernalia (Section 4.2.3).

4.2.5. Habitual

Cleaner-burning stoves were an aspirational element of post-earthquake home refurbishments. At the same time, disrupted cooking behaviour settings helped to embed habitual use of cleaner cooking stacks (Jewitt et al., 2020), with households re-domesticating ICS, incorporating LPG and creating separate covered spaces for traditional cookstoves:

> when we construct a new house … it might get black inside … so we are planning to transfer the ICS to the new house (*SSI-3*)

On the other hand, challenges to sustained DH-ICS use included frustration at its maintenance requirements and the lack of trained installers/repairers:

> now … the stove's damaged and smoke will certainly come … we have even sent [for the installers] to rebuild it … they said we don't have enough time … (*P1:FG-2*).

Under such circumstances, aspirations for cleaner kitchens, combined with post-earthquake disruption to kitchen behaviour settings, made LPG increasingly attractive.

4.2.6. Psychosocial dimension summary

The psychosocial domain of the IBM-WASH framework effectively captured most themes in our data (Table 3). Moreover, the intersection of levels served to emphasise the importance of a multi-level framework for this dimension. Examples include advocacy which can be more effective if reinforced at community as well as societal/structure levels. Likewise, community-level stigma can manifest as shame at the interpersonal level or disgust at the individual level. While some aspects of cultural identity apply country-wide, others align more closely to social integration, shared values and aspirations and have more community- or caste-based significance that intersects community and interpersonal levels. At the habitual level, domestication analysis and settings theory added valuable insights into how aspirational factors (and to a lesser extent disgust) facilitated the incorporation and re-domestication of cleaner cooking systems in post-earthquake kitchen settings.

4.3. Technology factors

The technology dimension in Table 3 highlights the critical importance of culturally-rooted preferences for particular stove attributes. These preferences, alongside the availability of zero or low-cost firewood and issues associated with ongoing DH-ICS maintenance, represent substantial challenges to the sustained and exclusive use of cleaner cooking technologies.

4.3.1. Societal/structural

ICS have been promoted by a range of national policies, beginning in the 1950s and expanding in the 1980s under the Community Forestry Development Project which sought to reduce deforestation (ESMAP, 2014). Further momentum was gained with the launch of Nepal's Alternative Energy Promotion Centre Energy Sector Assistance Program in the late 1990s and the National ICS Program Biomass Energy Support Program in 2007. The Alternative Energy Promotion Centre has continued to promote ICS under the Biomass Energy Sub-Component of the National Rural and Renewable Energy Program. Traditional biomass is seen as a key source of cooking and heating energy in Nepal's energy strategy (ESMAP, 2014) with higher subsidies available for remote areas, specific beneficiary groups and metallic ICS in high altitude regions. Stoves were also distributed after the 2015 earthquake as part of national and NGO-led disaster relief and recovery programs.

4.3.2. Community

The technologies used for cooking and space heating are influenced by community scale, context-related factors that include easy access to low (or zero) cost firewood with sustained and exclusive LPG use hindered by constraints around the ready availability of supplies in the village (*SSI-3*). This is especially true in the rainy season, and in winter following snowfall, when roads often become impassable. DH-ICS stoves, by contrast, present few resource-related difficulties although, as noted in Section 4.2.5, access to trained installers sometimes proved difficult.

4.3.3. Interpersonal/household

The loss of access to ICS installers undermined the DH-ICS project's efforts to enhance sustainability at the household/interpersonal level by training local community members in stove building and maintenance and facilitating access to technical support. The installation of DH-ICS stoves in 93% of sample households in 2012–13, and near-universal awareness of them, indicated that the project successfully communicated knowledge about HAP and the benefits of DH-ICS; if not directly, then by word of mouth and observation.

4.3.4. Individual

The cost of mud-built ICS was not a barrier to adoption as participants only contributed locally-available materials (*SSI-1*). Despite receiving no financial support for LPG stoves, rising 'appropriation' levels were observed (Table 2), indicating that initial stove cost was not a significant barrier to adoption. LPG stoves had been widely incorporated within their owners' cooking-related behaviour settings and were highly valued and proudly used in the presence of guests ('conversion'), but their sustained and exclusive use was hindered by fuel costs, irregular cylinder access and ready access to free or cheap fuelwood:

> 'that improved cookstove is what we been using. We can use wood [on it]. Gas is convenient but we are careful as once it runs out, we cannot get it easily and who will give us gas in the village?' (*SSI-3*).

Cooking system choices were influenced by preferences for specific stove attributes, with particular value attached to convenience, ease of use, cooking speed and reduced smoke. The DH-ICS was particularly liked for its capacity to accommodate two pots with different cooking temperatures (*I2*). Respondents with LPG often contrasted its convenience with wood-fuelled stoves:

> … if I feel lazy I cook food with gas and eat (*P6*) … now I cannot carry wood … for cooking food I brought gas (*P5*) … gas is easy … we don't have to blow the fire, we don't need to sit idle there, we can cook by just lighting the flame … rice will be cooked while [we're] cutting vegetables (*P1:FG-4*)

Traditional cookstoves were valued for space heating (*SSI-8*) and the option to leave them unattended (*SSI-6*). In addition, they were considered more robust than DH-ICS which are unable to support heavy cooking pots and require regular maintenance to prevent cracking and ensure smoke removal:

> if the smoke outlet is blocked then we remove that … As soon as it … gets black, we mud paste it. We don't let it crack. We check the chimney once a week (*SSI-3*).

Some respondents clearly found this maintenance to be burdensome with one reporting that it prompted her to incorporate LPG into her cooking stack:

> … all is about to break, the more you try to paste it the more cracks … sometimes I want to break it and throw it (*SSI-1*).

> smoke will go after cleaning … but again it gets blocked. That's why I bought gas (*P1:FG-3*).

There was no clear agreement regarding cooking speed. Some respondents favoured traditional cookstoves as they could add plenty of wood to create a large flame:

> In … rainy season need to go to the fields so it will be easy to cook with a traditional stove as we can insert firewood from all sides, and food will be cooked quickly (*SSI-8*).

Others favoured DH-ICS, while many LPG users said they would use gas when short of time (*SSI-3;P2:FG-5*). Gas was also liked for burning cleanly which respondents associated with health benefits and reduced labour from cleaning sooty kitchens and pots. In a similar way, DH-ICS and *gol* were valued for reducing smoke (*SSI-5,P1:FG-4*). Some respondents switched stoves seasonally, using outdoor traditional cookstoves in the rainy season when wet fuelwood produced excessive smoke. Kerosene had been widely de-domesticated on account of its smokiness and smell.

Taste preferences also influenced stove and fuel choices. Some respondents disliked the taste of meals cooked on LPG or were concerned that they would be improperly cooked if the gas supply ran low:

> … don't like gas … food is uncooked … gas may finish … try to save gas and the food remains uncooked (*SSI-3*).

For cooking rice, many preferred *gol* and used DH-ICS or gas stoves for water, curries and vegetables (*SSI-3*) while Tamang households often prepared alcoholic drinks outside on traditional cookstoves to accommodate large pots and long periods of slow cooking (*SSI-10*). Traditional cookstoves were also widely used to prepare food for livestock as this requires large cooking pots and significant quantities of firewood (*P3: FG-2*).

4.3.5. Habitual

Although DH-ICS have remained popular, and there is evidence of the rising acquisition and sustained use of LPG stoves, exclusive use of clean cooking technologies remains uncommon (Table 2). Post-earthquake adjustments to cooking settings, including the construction of adjoining covered spaces for traditional cookstoves in rebuilt homes, appeared to facilitate their continued use by reducing smoke and soot deposits within the house.

Although the maintenance requirements of DH-ICS prompted some households to incorporate LPG into their cooking behaviour settings, this rarely reduced stacking as different stoves were favoured for particular tasks (Section 4.3.4). Nevertheless, there were indications that some preferences could be accommodated with cleaner stacks comprised of DH-ICS, LPG and *gol*, with a desire for ease of use, convenience and smoke reduction being important themes in the qualitative data:

> before … while cooking food in [traditional] stove … eye irritation was caused, more tears will come … now in improved cookstove no smoke will come … it's been 5 years … we have been using improved cookstove.' (*SSI-1*)

4.3.6. Technology dimension summary

Given the strong, culturally-rooted preferences for particular technology attributes, end-user perspectives usually have a major influence on the uptake and sustained use of clean cooking technologies (Sesan et al., 2018; Stanistreet et al., 2019) that are well captured by the IBM-WASH framework (Table 3). This is important given the tendency of ICS and, to some extent, WASH initiatives and associated literatures to neglect user-based attitudes towards technologies in preference for a focus on behavioural determinants (Dreibelbis et al., 2013). At the habitual and individual levels especially, domestication analysis and behaviour settings theory provide IBM-WASH with valuable additional insights into technology- and settings-related barriers to ICS adoption and sustained use. In particular they shed light on what different cooking stack components mean to local people, how they fit within kitchen-related behaviour settings and routines and why particular technologies may be rejected, de-domesticated and re-domesticated as circumstances and settings change.

5. Conclusion

Information from Majhifeda offers valuable insights into how cooking-related behaviour settings were disrupted and reformed following the earthquake in 2015. A desire for different kitchen designs in new homes helped to encourage the re-building of DH-ICS, the retention of *gol* and the incorporation of LPG, with almost 70% of households reporting transitions to cleaner cooking stacks (Jewitt et al., 2020). This rarely represented a complete shift, however, as all families possessed at least one biomass stove, hindering sustained HAP reduction at both household and community scales. Resistance to fully de-domesticating traditional cookstoves stemmed from the need for seasonal heating and a desire to prepare multiple dishes simultaneously, cook food quickly, feed livestock and leave stoves unattended. Efforts to minimise cost and fuel insecurity (Jewitt et al., 2020) were important drivers for stacking biomass with LPG.

The different domains and levels of the IBM-WASH model effectively captured the intersecting factors underpinning stove and fuel stacking in Majhifeda and highlighted key barriers to sustained and exclusive ICS use. These understandings were enhanced – especially at the individual and habitual levels – by domestication analysis (Haddon, 2011) and settings theory (Curtis et al., 2019) which elucidated the processes, contexts, constraints and wider aspirations surrounding the use of cooking technologies and their incorporation (or otherwise) within physical structures, everyday lives and routine behaviour. This combination of approaches provided more holistic insights into multi-scale influences on how and why people adopt particular technology combinations, use them in particular ways and form symbolic or emotional attachments to them.

Although exclusive use of clean cooking solutions is unlikely to occur in Majhifeda very soon, these insights provide a useful basis for considering how transitions to the habitual use of clean*er* stove and fuel combinations might be promoted to reduce HAP in the short to medium term. Possibilities for further exploration include village-level training on constructing and repairing DH-ICS, initiatives to facilitate year-round LPG access in remote areas and information/communication campaigns promoting cost/fuel-saving approaches for LPG users such as using pan lids or 'wonderbags' for finishing rice or dal.

Given increasing concern about the slow progress towards Sustainable Development Goal 7's target of universal access to clean cooking fuels and technologies (International Energy Agency, 2022), IBM-WASH informed by domestication analysis and settings theory has potential to inform, support and evaluate interventions targeting sustained HAP reductions well beyond our study area. Its transferability from WASH to ICS also indicates a capacity to inform multi-sector interventions operating at multiple scales. As Clasen and Smith (2019) argue, there are significant benefits in the HAP and WASH sectors working more closely together to address common problems and promote improved environmental health at a community-wide scale. We suggest that an 'IBM--WASH plus' approach could facilitate this as well has having broader applicability for community-scale health-focused interventions.

Acknowledgements

This work was supported through an interdisciplinary GCRF grant 'Improving Respiratory Health in Nepal' (project 631169) with additional support from the Energy for Life/EPSRC Global Challenges Research Fund Pump-Priming Call (project code EP/P510993/1). CEB and IPH are supported through the NIHR Nottingham BRC. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health. We would like to express our thanks to Maneesha Shrestha Makaju, Sneha Shrestha and Kanchan Acharya for their role in data collection, transcription and translation and to Yakubu Salifu, Mohsen Gul, Teju Limbu and Holly Jewitt Maurice for assistance with the initial data analysis and checking. We would also like to express our gratitude to our respondents in Majhifeda, without whose assistance the research would not have been possible and to Elaine Watts for producing Fig. 1. We are very grateful to the anonymous reviewers whose comments and suggestions were extremely useful in improving the paper.

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