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Review Paper

Effectiveness of behaviour change interventions to reduce the risk of faecal contamination in urban irrigated vegetable value chains – applying the COM-B behavioural framework

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ABSTRACT

In low- and middle-income countries, inadequate sanitation results in faecal contamination of the water used by urban farmers for irrigation. Consumers of raw contaminated vegetables run the risk of developing diarrhoeal diseases and helminth infections, which are a leading cause of under-five mortality and impact the well-being and productivity of millions of adults. This review identifies the evidence base for assessing which factors determine the success and/or failure of interventions that aim to manage the risk of faecal contamination in the urban irrigated vegetable value chain. We carried out a systematic search of the literature from the perspective of the COM-B behaviour framework (Capability + Opportunity + Motivation = Behaviour). Our results reveal that most interventions address stakeholders' opportunity or capability to adopt safe practices without adequately considering their motivation. Interventions often focus on one sector rather than on the whole value chain (sanitation, agriculture, trade, consumption). To effectively change hygiene and food safety practices in the urban irrigated vegetable value chain, stakeholders' intrinsic motivations need to be identified. Where WHO's multi-barrier approach is the best option, we recommend building on local multistakeholder platforms and adopting a behaviour change framework to support the largely technical change from farm to fork.

Key words: behaviour change, food safety, informal sector, motivation, participatory governance

HIGHLIGHTS

- Adopting safe practices from farm to fork can reduce the risk of faecal contamination of urban irrigated vegetables.
- Adopting safe practices depends on stakeholders' opportunity, capability, and motivation to do so.
- Stakeholders' motivations are often neglected.
- Persuasion (i.e., leverage stakeholders' values and norms), environmental restructuring, and role modelling can stimulate stakeholders' motivations.

INTRODUCTION

Most leafy vegetables consumed in cities of low- and middle-income countries (LMICs) are grown locally (Orsini *et al.* 2013). Urban and peri-urban agriculture enhances urban livelihoods, food sovereignty, recycling of organic waste, greening cities, and limiting floods (FAO 2012). However, the urban water systems most often used to irrigate these vegetables are contaminated with faecal, chemical, and emerging contaminants due to lagging sanitation. It is estimated that urban farmers practice *de facto* indirect wastewater reuse on 30 million hectares of farmland, supplying fresh vegetables to 800 million people globally (Thebo *et al.* 2017), and these figures are likely to increase (Raschid-Sally & Jayakody 2008; Figuié 2019).

Exposure to contaminated water and consuming raw contaminated vegetables are the two major pathways to contracting enteric, acute respiratory, and parasitic diseases (Hoffmann *et al.* 2017; Raj *et al.* 2020). Faecal pathogens (bacteria, protozoa, and viruses) can provoke diarrhoeal diseases (including cholera), acute respiratory infections (e.g., tuberculosis from breathing sprinklers droplets), as well as other water- and food-borne invasive infectious (e.g., hepatitis, typhoid fever) and parasitic diseases (e.g., helminth infections such as *Taenia* and *Ascaris*). Exposure to contaminated water caused about 1.4 million deaths and the loss of 74 million disability-adjusted life years (DALYs) in LMICs in 2019 (Wolf *et al.* 2023). The consumption of contaminated food caused over 220,000 deaths and the loss of 17 million DALYs in LMICs in 2010, mainly in Africa and Southeast East Asia (WHO 2015). Even though these mostly preventable diseases primarily affect children under 5 years, they also impact the well-being and productivity of all age groups and impose a heavy economic burden (Hutton & Haller 2004; WHO 2015).

The World Health Organization (WHO) proposes a multiple-barrier approach adapted to LMICs to reduce health risks from using wastewater (WHO 2006, 2022). It suggests public authorities set appropriate health-based targets, working with primary stakeholders (farmers, vegetable traders, street food vendors, and consumers) to combine safe practices from 'farm to fork' to protect workers' and consumers' health. Where possible, sanitation is counted as the first barrier. Amoah *et al.* (2011) demonstrated the cost-effectiveness of adopting low-cost irrigation practices on farms, safe vegetable handling, and washing methods in markets (including street food restaurants) and households. Increasing uptake of these practices remains challenging (Drechsel *et al.* 2022) and should be considered a priority (Prain *et al.* 2022).

To date, there has been no systematic analysis of the factors that result in the success or failure of interventions to change stakeholder hygiene and food safety practices in the urban irrigated vegetable value chains of LMICs. This research responds to that gap and proposes modifications for more successful interventions. The COM-B behavioural model (Capability + Opportunity + Motivation = Behaviour) developed by Michie *et al.* (2011), explained in the following section, was used to structure a review of the range of approaches used to address the risk of faecal contamination in the value chain. This provides a basis for explaining why safe practices are not more widely adopted.

METHODS

This review systematically appraises the impact of interventions on stakeholders' adoption of good hygiene and food safety practices in the urban irrigated value chains of LMICs.

Search strategy

The systematic search of the literature ensured comprehensive conceptual coverage by querying the titles, abstracts, and keywords in the Scopus, Web of Science, and ProQuest-Social Science Premium Collection against the Boolean combination of five queries as follows:

#1 (the presence of human excreta through 16 terms including faeces, faecal sludge or wastewater)
AND
#2 (the occurrence of oro-faecal diseases through 25 terms including water-borne, diarrhoea or helminth)
AND
[#3 (irrigated vegetable production through 11 terms including farmer, horticulture or
crop)
OR
#4 (vegetable trading through 21 terms including produce, trader and consumer)]
AND
#5 (low- and middle-income countries through terms such as Global South or developing countries and a list of LMICs countries).

Query #5 was adapted from Liverpool-Tasie *et al.* (2020) and is based on the World Bank classification of economies from 2021. The detailed terms of the search are available in Table 3 in the Supplementary Material.

Inclusion and exclusion criteria

The search was limited to articles focusing on LMICs published in English between 1 January 2000 and 1 August 2022. Furthermore, the Context–Intervention–Mechanism–Outcome (CIMO) logic proposed by Denyer & Tranfield (2009) was adopted to develop the inclusion and exclusion criteria as follows:

- Context: the study relates to the urban irrigated vegetable value chain in LMICs.

  Excluded: high-income countries, rural settings, health facilities, schools, focus on drinking water or groundwater, and food products other than vegetables or non-faecal contaminants.

- Intervention: the study reports an initiative aiming to manage the risk of faecal contamination rather than assess the risk.

  Excluded: risk assessments.

- Mechanisms: the study reports a risk management mechanism other than conventional effluent treatment.

  Excluded: conventional onsite or centralised wastewater or sludge treatment.

- Outcomes: the study reports a reduction of contamination or a change of practices.

  Excluded: absent results.

Records were screened using Rayyan (https://rayyan.ai/), and those not meeting eligibility and inclusion criteria were excluded. The remaining articles were included for qualitative analysis. Relevant information was systematically identified: authors, publication year, and country of implementation; sector of intervention (farm and/or market and/or household-consumer); mechanism of intervention; and whether the intervention targets stakeholders' opportunities, capabilities, and/or motivations (see Table 1).

Conceptual framework

We hypothesised that many WASH interventions follow top-down designs that primarily focus on providing stakeholders with an innovation (such as a technology, service, or technique), sometimes supported by education or training. They often, however, fail to account for stakeholders' perceptions and willingness to integrate the innovation into their practices. Assessing interventions against a robust theoretical behavioural framework helps identify which factors promote or hinder the success of the cases reviewed. The COM-B behavioural framework (Michie *et al.* 2011) was selected for its accessibility and robust theoretical foundation, unifying several theories and models. Numerous studies build on this model to explain behaviours or promote changes in contexts ranging from informing the British government's behaviour change policies (Michie & West 2013) to improving hand and food hygiene behaviours in LMICs (Wodnik *et al.* 2018).

The COM-B model posits that adopting a behaviour depends on stakeholders having the Capability (C), Opportunity (O), and Motivation (M) to perform this Behaviour (B), hence the COM-B acronym (see Figure 1). The model defines the 'Capability' component as the physical and psychological ability within an individual (e.g., through training and education) to perform a behaviour. Opportunity is the physical and socio-economic possibility of performing a behaviour (e.g., access to tangible and intangible resources, including regulations, technology, or services). Motivation refers to the 'brain processes that energise and direct behaviour', (Michie *et al.* 2011, p. 4) whether automatic (e.g., feelings) or reflexive (e.g., conscious planning).

Deficits in Capability, Opportunity, and/or Motivation can be addressed through nine functions (see Table 2): restricting opportunities for competing behaviours, restructuring the physical or social environment, enabling, educating, training, incentivising, persuading, coercing, and modelling (Michie *et al.* 2011). One intervention function can address more than one behavioural component and can incorporate functions. Enablement is understood broadly as providing the means to make it easier to enact a behaviour innovation to reduce barriers or improve the opportunity (beyond environmental restructuring) or the capability (beyond education and training). Examples include providing physical or social support and material or financial resources. These interventions are promoted by different types of policy: legislation, service provision, communication, or marketing campaigns. Michie *et al.* (2011, 2014) recommend diagnosing what people need to adopt recommended behaviour by identifying intervention functions and policy categories adapted to foster change, then selecting the behaviour change technique and mode of delivery that best serves the intervention function.

The results presented and discussed below are structured around the intervention functions described in the records under review and clustered around the related Opportunity, Capability, and Motivation components of the COM-B model (see Table 2).

RESULTS AND DISCUSSION

Searching the published literature for 'farm to fork' experiences aimed at improving hygiene and safety in urban irrigated vegetable value chains in LMICs yielded 630 unique records. Of these, 597 were excluded during screening and eligibility assessment. The remaining 33 studies were included in the qualitative analysis (see Figure 2). They mention a range of

Table 1 | Included articles and their association with sectors of the value chain and components of behaviour change

				Integration across sectors of the value chain				Integration across the three sources of behaviour		
	Authors	**Country of study**	**Focus**	**Sanitation**	**Farmers**	**Food vendors**	**Households**	**Opportunity**	**Capability**	**Motivation**
1	Amoah *et al.* (2007)	West Africa	Sanitary vegetable washing methods			X	X	X		
2	Amoah *et al.* (2011)	West Africa	Low-cost options to reduce contamination from farm to fork		X	X	X	X		
3	Asirifi *et al.* (2021)	Ghana	Biochar		X			X		
4	Borghi *et al.* (2002)	Burkina Faso	Hygiene promotion				X	X		
5	Cuenca-Adame *et al.* (2001)	Mexico	Wastewater irrigation of onion and decontamination by disinfectant		X			X		
6	Davis *et al.* (2011)	Tanzania	Informational interventions				X		X	
7	De Buck *et al.* (2017)	LMICs	Promote handwashing and sanitation behaviour change				X			X
8	Donkor (2009)	Ghana	Food handling			X			X	
9	Googoolee *et al.* (2020)	Mauritius	Water cress cultivation and washing practices		X			X		
10	Hirai *et al.* (2016)	Indonesia	Handwashing with soap				X			X
11	Idowu & Rowland (2006)	Nigeria	Personal hygiene			X				
12	Keraita *et al.* (2007)	Ghana	Effect of low-cost wastewater irrigation methods on lettuce contamination		X			X		
13	Keraita *et al.* (2007)	Ghana	Effect of wastewater irrigation cessation on lettuce contamination		X			X		
14	Knopp *et al.* (2010)	Tanzania	Patterns and risk factors of helminthiasis				X			
15	Kragić Kok *et al.* (2020)	Ethiopia	Serious games to promote water recycling and hygiene practices				X			X
16	Luchesi *et al.* (2016)	Brazil	Washing of leafy vegetables with chlorinated water			X[a]		X		
17	Mihrshahi *et al.* (2009)	Viet Nam	Deworming				X[b]			
18	Morse *et al.* (2019)	Malawi	Changing WASH and food hygiene practices (using the RANAS method)				X			X
19	Moya *et al.* (2019)	Kenya	Barriers to the use of human excreta-derived fertiliser by horticultural export farmers		X			X		X
20	Musa & Akande (2002)	Nigeria	Routine medical examination of school food vendors			X				

(*Continued.*)

Table 1 | Continued

				Integration across sectors of the value chain				Integration across the three sources of behaviour		
	Authors	**Country of study**	**Focus**	**Sanitation**	**Farmers**	**Food vendors**	**Households**	**Opportunity**	**Capability**	**Motivation**
21	Ngowi *et al.* (2017)	Burkina Faso	Health education (using the PHAST method) to control taeniasis and cysticercosis among pig growers		X				X	
22	Nondlazi *et al.* (2017)	South Africa	Onsite greywater treatment		X[c]			X		
23	Reddi *et al.* (2016)	India	Hand hygiene				X			
24	Salamandane *et al.* (2020)	Mozambique	Fresh vegetable handling			X		X		
25	Samadi *et al.* (2009)	Iran	Fresh vegetable washing with disinfectants			X[d]		X		
26	Sarter & Sarter (2012)	Madagascar	Promoting a culture of food safety (using disgust, social norms and accountability)			X				X
27	Silverman *et al.* (2014)	Ghana	On-farm wastewater treatment for vegetable irrigation		X			X		
28	Traoré *et al.* (2020)	Mali	Lettuce washing		X			X		
29	Tripathi *et al.* (2019)	India	Micro-irrigation with wastewater		X			X		
30	Udert *et al.* (2016)	South Africa	Nutrient recovery from urine	X				X		
31	Winkler *et al.* (2017)	Multiple	Sanitation safety planning	X	X			X		
32	Woldetsadik *et al.* (2017)	Ethiopia	Lettuce washing		X[e]			X		
33	Yihenew *et al.* (2014)	Ethiopia	Cooperative social organization to control malaria and parasitosis				X		X	

[a]Supermarkets/lab.
[b]Women of reproductive age/lab.
[c]Gardens/lab.
[d]Markets and retails stores/lab.
[e]Farms/lab.

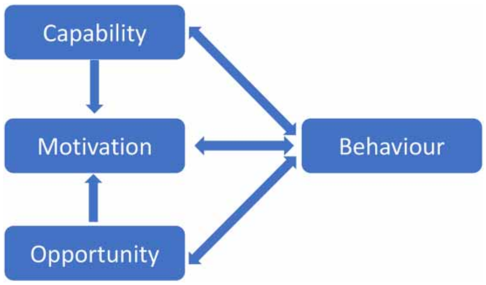

Figure 1 | The COM-B framework. *Source*: adapted from Michie *et al.* (2011).

Table 2 | Intervention functions, definitions, and the behaviour change component(s) addressed

Intervention functions	Definitions	Opportunity (physical)	Opportunity (social)	Capability (physical)	Capability (psychological)	Motivation (reflexive)	Motivation (automatic)
Restriction	Using rules to reduce the opportunity to engage in the target behaviour or increase the target behaviour by reducing the opportunity to engage in competing behaviours	✓	✓				
Environmental restructuring	Changing the physical/social context	✓	✓				✓
Enablement	Increasing means/reducing barriers to increase capability or opportunity beyond training, education, or environmental restructuring	✓	✓	✓	✓		✓
Education	Increasing knowledge or understanding				✓	✓	
Training	Imparting skills			✓	✓		
Incentivisation	Creating expectation of reward					✓	✓
Persuasion	Using communication to induce positive or negative feelings or stimulate action					✓	✓
Coercion	Creating expectation of punishment or cost					✓	✓
Modelling	Providing an example for people to aspire to or imitate						✓

Source: Adapted from Michie *et al.* (2011), pp. 7–8.

approaches with the potential to complement conventional treatment systems in reducing contamination risk. Their outcomes, often qualitative, are presented below, structured around the COM-B model, clustered by the mechanism (i.e. intervention function) they build on, and grouped under the main need they aim to address (i.e., Opportunity, Capability, or Motivation). These outcomes are discussed in relation to the broader literature. As this relatively small sample primarily represents interventions in sub-Saharan Africa, this may make our findings more representative of this area.

Opportunities

The COM-B framework suggests that physical (e.g., equipment and infrastructure) or social (e.g. services) opportunity needs are best addressed by restricting the opportunities to perform competing behaviours, restructuring the physical and/or social environment, and enablement interventions.

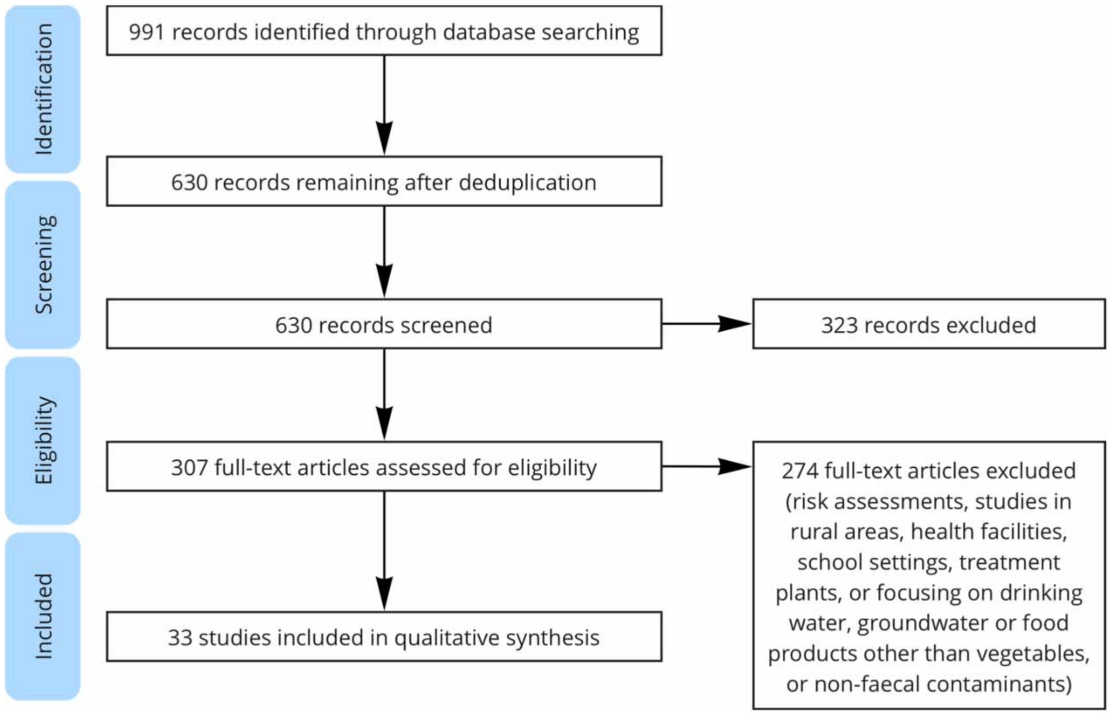

Figure 2 | Flow diagram of the search strategy.

Restriction: bans and regulations

Regulations on wastewater reuse in LMICs reflect different political priorities. To address water scarcity, Mexico and several countries in the Middle East/North Africa and other arid/semi-arid regions promote formal irrigation schemes using treated wastewater (Shoushtarian & Negahban-Azar 2020). Countries including Ghana, India, Jordan, Mexico, Morocco, Tunisia, and Vietnam, however, have officially banned the use of untreated wastewater with mixed success. Regulations around wastewater reuse for irrigation are inadequate or missing in many LMICs, including Southeast Asia (Winkler *et al.* 2017). Regulations that aim to protect public health from faecal pathogens in other sectors can also be unclear or inconsistent (see Moya *et al.* (2019) on the use of excreta-derived fertilisers in Kenya and Okoruwa & Onuigbo-Chatta (2021) on food safety regulations in Nigeria).

The lack of enforcement of regulations to effectively control stakeholders' practices limits the effectiveness of restriction (and coercion) interventions. Examples include Cuenca-Adame *et al.* (2001) for wastewater irrigation in Mexico, Musa & Akande (2002) for routine medical examination of food vendors in Nigeria, and Salamandane *et al.* (2020) for food markets in Mozambique. The lack of coordination among public agencies, the resulting poor regulatory coherence, and weak enforcement capability also exacerbate the problem (Okoruwa & Onuigbo-Chatta 2021). As largely informal food value chains, characterised by a multitude of small-scale farmers and mobile vendors, are challenging to control, most administrations focus on the formal/export sectors in capital cities (Antwi-Agyei *et al.* 2016; Nordhagen *et al.* 2022). The lack of understanding of microbial risk among urban farmers and vegetable and street food vendors, and their limited access to water, sanitation, or cold storage, make compliance with regulations particularly difficult (Keraita *et al.* 2014; Salamandane *et al.* 2020). When non-compliance is detected, sanctions are not always proportionate or dissuasive. Sanctions that are absent or too light entice stakeholders to ignore good practices (Seleman *et al.* 2020).

Ad hoc regulations and adequate enforcement can lead to more sustainable changes than temporary educational or promotional interventions (Idowu & Rowland 2006; Keraita *et al.* 2014). Mobilising the political will to develop adequate policies and secure funding sufficient to enforce resulting regulations is challenging, as local data on the prevalence of food-borne diseases are scarce and public authorities rarely prioritise the informal sector (Jaffee *et al.* 2019). Regulations are more likely to change behaviours if they avoid mimicking international standards they do not have the capability to implement (Mdee & Harrison 2019) and, instead, adapt them into national standards that account for the local context (Keraita & Drechsel 2015).

Environmental restructuring: certification and access to premium markets

Certifying vegetable safety to give access to premium channels should motivate urban farmers to adopt safe practices (Keraita & Drechsel 2015). Most domestic food safety management systems, however, consist primarily of controls in the formal sector, overlooking the informal sector despite it serving the largest proportion of the population and accounting for the majority of the food disease burden in LMICs (Figuié 2019; Henson *et al.* 2023).

Effectively developing standards and enforcing controls seems to be a feature of the export-oriented private sector rather than governments (Moya *et al.* 2019). Certified farmers adhere to standards developed with little or no participation from their end (González & Nigh 2005), including record-keeping and controlling the quality of the water used for irrigation and washing. Most smallholder farmers, however, are unable to sustain the high certification costs or emulate these practices, and the food safety of domestic markets remains unaffected (Henson *et al.* 2023).

Third-party certification schemes have recently started to serve domestic markets, adopting requirements more accessible to smallholder farmers. The Ghanaian Ministry of Food and Agriculture and Standards Authority and cooperation partners instigated the Ghana Green Label in 2014 (GhanaGreenLabel.Org 2015). High costs and low domestic demand for certified vegetables limit the supply to a handful of packing houses and high-end outlets in Accra. As of 2022, about 700 farmers are certified nationally, including a few dozen urban and peri-urban farmers. Similarly, since 2016, the supermarket chain SPAR-South Africa has developed Localg.a.p. (for Local Good Agricultural Practices), a programme adapted from the European Farm Assurance Programme GlobalG.A.P. (GLOBALG.A.P./FoodPLUS GmbH 2023), which builds smallholder farmers' capability to comply with good hygiene and safety practices and supply its local supermarkets (SPAR 2021). Both these programmes allow farmers to use a potentially polluted source of irrigation water, provided they supply a water analysis demonstrating they took the necessary steps to ensure the water quality complies with 'accepted [water] standards' (Ghana Green Label) or the WHO (2006) Guidelines (SPAR/Localg.a.p.). Unfortunately, the principles of health-based targets and the multi-barrier approach are overlooked in both cases.

Participatory guarantee systems (PGSs) are an alternative to private third-party certification, consisting of farmers, consumers, and other interested stakeholders agreeing on good practices and working conditions adapted to socio-ecological contexts. Networks of local farmers and consumers assess compliance (Nelson *et al.* 2010), which can help address food safety issues in value chains where quality management is limited (Moustier *et al.* 2023) and distrust exists between stakeholders (Antwi-Agyei *et al.* 2016). More than 1.2 million producers are involved in over 240 PGSs cultivating 900,000 hectares globally, mostly in the Global South (Anselmi & Moura e Castro 2022). PGSs also provide platforms to reduce farmers' costs through collective buying, marketing, and logistics, exchanging good practices and locally adapted seeds (Home *et al.* 2017). PGSs, however, often suffer from a lack of recognition by institutions and struggle to convince consumers to allocate time and resources to maintain the certification process. Consequently, they are subject to tension among stakeholders (Kaufmann *et al.* 2023).

Enablement: developing and testing alternatives to conventional wastewater treatment

Several on-farm techniques can reduce the transmission of pathogens to the crop. Biochar proved ineffective in eliminating pathogens from the soil of farms in northern Ghana (Asirifi *et al.* 2021). On-farm fly ash/lime filters reduce faecal coliforms by 0.5 log units in domestic greywater, which can then be used for irrigation (Nondlazi *et al.* 2017). The focus on technical performance, however, often leaves aside cost efficiency, sustainability, and user acceptability, which shape stakeholders' capability and motivation to use them. The project 'Valorisation of Urine Nutrients in Africa' included a multi-disciplinary team to better account for economic viability, seek authorities' support, and explore users' attitudes towards the reuse of urine and dehydrated faeces, recognising that adoption is the users' decision (Udert *et al.* 2016). Sedimentation ponds and filtration techniques (Silverman *et al.* 2014; Tripathi *et al.* 2019) can help farmers reduce pathogen concentration in irrigation water, especially helminth eggs. Some Ghanaian urban farmers use small ponds but are not interested in maintaining their sedimentation properties (Silverman *et al.* 2014). Moreover, the risk of these ponds becoming reservoirs for malaria-transmitting mosquitoes needs to be considered, particularly with the expansion of *Anopheles stephensi*, which can develop in urban polluted waters (Drechsel *et al.* 2006; Sinka *et al.* 2020).

Various irrigation practices impact pathogen exposure differently. The most effective are drip irrigation systems (especially subsurface ones; see Tripathi *et al.* 2019), but most urban farmers are not willing to accommodate the filtration, pressurisation, and distribution equipment, and reduced cropping density they require (Keraita *et al.* 2007a). Contrary to the overhead flow and splashing on watering cans, flood and furrow irrigation limit the pathogen transfer to the aerial parts of vegetables but further expose farmers who work barefoot. Sprinklers and spray irrigation produce droplets that transfer pathogens to crops, farmers, passers-by, and farm neighbours (Keraita *et al.* 2007a). Stopping irrigation a few days before harvest for pathogens to die off naturally is acceptable under temperate climates where crops are only irrigated every few days (Drechsel & Keraita 2014), but not in hot climates like in Ghana, where it results in wilting and revenue loss (Keraita *et al.* 2007b). Optimising irrigation to reduce soil moisture during and after the growing season also reduces pathogen concentration (Cuenca-Adame *et al.* 2001; Tripathi *et al.* 2019) but is beyond most farmers' capability. Selecting crops that require cooking increases safety but is unattractive due to their lower market value. Switching to safer water sources is often constrained by piped water being too expensive or landlords forbidding farmers to drill boreholes on their land (Amoah *et al.* 2011).

Sanitary vegetable washing methods can also reduce the level of pathogenic contamination. Washing vegetables in basins, with or without the addition of salt or vinegar, is common in markets and households but less effective at removing pathogens than washing under running water or in water with added chlorine, permanganate potassium, or another disinfectant (Amoah *et al.* 2007; Googoolee *et al.* 2020; Traoré *et al.* 2020). As washing vegetables does not prevent the occupational exposure of farmers and vendors (Woldetsadik *et al.* 2017), nor is sufficient to protect consumers (Amoah *et al.* 2007; Samadi *et al.* 2009; Luchesi *et al.* 2016; Googoolee *et al.* 2020), it is essential to address both on-farm and post-harvest contamination.

Medical examinations and deworming (chemotherapy) of street food vendors can limit contamination. The effectiveness of medical examination to prevent transmission of helminth eggs depends on whether the drug used targets all relevant parasites (Idowu & Rowland 2006) and the enforcement is sufficient to ensure results are reported and post-convalescence examinations performed (Musa & Akande 2002). Regular deworming left high levels of contamination in Nigeria as the limited campaign coverage and insufficient access to safe water and toilets did not prevent re-infection (Idowu & Rowland 2006; Knopp *et al.* 2010). In contrast, Sri Lanka has almost eliminated morbidity due to worm infections thanks to mass deworming (Montresor & Mupfasoni, 2019) and higher access to at least basic urban water and sanitation services (JMP 2022). Education activities should complement deworming campaigns to address low-risk awareness, which is exacerbated by the infection remaining asymptomatic for extended periods (Idowu & Rowland 2006; Mihrshahi *et al.* 2009; Knopp *et al.* 2010).

Capabilities

The COM-B framework suggests that a physical, psychological (emotional or cognitive) capability deficit within an individual's realm is best addressed by education, training, and enablement interventions.

Education and training: hygiene promotion and training for good practices

Interventions often consider education and training together or even interchangeably. From the perspective of the COM-B framework, however, they serve different purposes and should be differentiated. Education increases knowledge or understanding by providing information, thus improving psychological capability or reflexive motivation. Training imparts skills to increase physical or psychological capabilities (Michie *et al.* 2011).

Providing opportunities to adopt safe practices needs to be complemented with education and guidance to increase stakeholders' awareness of microbial risks (Luchesi *et al.* 2016; Reddi *et al.* 2016; Woldetsadik *et al.* 2017; Salamandane *et al.* 2020). Education intervention also aims to change their attitudes (Moya *et al.* 2019) and motivate them to act (Kragić Kok *et al.* 2020).

Indeed, throughout Africa, many urban residents do not link food-borne diseases to a lack of hygiene (Salamandane *et al.* 2020), with some claiming that 'stomach aches result from consuming food that the worms do not like' (Idowu & Rowland 2006, p. 163) or that speaking of contaminated vegetables only aims to hurt others' businesses (Abass *et al.* 2017).

Education is a major health determinant (Mihrshahi *et al.* 2009; Ngowi *et al.* 2017). Methods, such as PRECEDE (Predisposing, Reinforcing, and Enabling Constructs in Educational Diagnosis and Evaluation) or PHAST (Participatory Hygiene and Sanitation Transformation), help practitioners structure interventions to more effectively increase participants' knowledge appropriation (Ngowi *et al.* 2017). However, Information–Education–Communication (IEC) interventions alone offer mixed results, especially if they misunderstand the context in which the behaviour is to be performed or the recipient's perception of the cost and benefits of the behaviour (De Buck *et al.* 2017). Individuals' choices are not purely rational and based on knowledge (Scott *et al.* 2007). Rather, they rely on shortcuts and cue associations, such as the credibility of the person conveying the information or the attractiveness of the medium (Glanz *et al.* 2008).

The profile and legitimacy of the educator, their interpersonal communication skills, and their attention to the gender sensitivity of some behaviours (Salamandane *et al.* 2020) are as important as their knowledge of the topic (Borghi *et al.* 2002; Winkler *et al.* 2017). Equally important is the quality and availability of educational material, as well as the duration and frequency of the interventions (De Buck *et al.* 2017). Co-designing the content with intended recipients and fieldworkers helps ensure it is appropriate (Amoah *et al.* 2009). Knowledge can be conveyed through plays, world cafés, and road shows that follow the pathogen pathway from farm to fork (Amoah *et al.* 2009), radio spots (Borghi *et al.* 2002), movies, and comic booklets (Ngowi *et al.* 2017) or educational games (Kragić Kok *et al.* 2020). Such community-based education involving experiential, empowering exchanges are more effective than one-way approaches, such as sharing health messaging, especially in the long-term (De Buck *et al.* 2017), but is more challenging to upscale.

Training often completes education interventions (Musa & Akande 2002; Donkor 2009; Salamandane *et al.* 2020). Training strengthens recipients' self-efficacy, i.e., 'I know I can do it' (Ngowi *et al.* 2017) by allowing them to observe and practise in a controlled environment the behaviour to be performed. Training food handlers is a widely applied strategy to increase food safety (FAO 2003). Urban farmers, however, receive little training to address the health risks of wastewater irrigation (Amoah *et al.* 2011). In many cases, extension officers can only offer urban farmers training developed for rural farmers, even though the crops and practices differ, reflecting the lack of recognition and marginality of urban agriculture (Keraita & Drechsel 2015). Even when tailored to recipients' needs, training requires refresher interventions (Salamandane *et al.* 2020) and is challenging to upscale (Grace 2015).

Motivation

The COM-B framework suggests that stakeholder automatic (e.g., wants, needs, emotions) and reflexive (i.e., conscious planning, beliefs about good and bad) motivation is best stimulated by persuasion, incentivisation, or coercion interventions. In addition, education can stimulate reflexive motivation, while automatic motivation responds to environmental restructuring, modelling, and enablement.

Incentivisation and coercion: market incentives

Incentivisation is one of the functions that intervention designers rely on the most to stimulate stakeholders' motivation to improve sanitation services (Moya *et al.* 2019) or increase the adoption of safe practices among farmers and traders (Amoah *et al.* 2011). Designers mostly think of market incentives, such as premium prices for safer vegetables, cash transfers, governmental subsidies, access to microcredit, or other forms of monetary incentives (Karg *et al.* 2010; De Buck *et al.* 2017).

Implementing viable market incentives by stimulating demand is challenging (Amoah *et al.* 2011). Studies suggest that stakeholders' returns need to increase by at least 30% for them to adopt a new practice (Karg *et al.* 2010). This accounts for often underestimated intangible costs, such as cultural resistance, perceived control, opportunity cost, and other psychological costs (Keraita & Drechsel 2015), but not necessarily for quality monitoring costs (Karg *et al.* 2010). Most customers of informal markets are unaware of the risk (Keraita & Drechsel 2015), and not interested in knowing (Nordhagen *et al.* 2022) or paying for safer vegetables. The demand from hotel restaurants, supermarkets, and other premium outlets that serve customers willing to pay such premiums is limited. Decision-makers could stimulate the offer of safe vegetables through coercion through fines, fees, taxes, or other disincentives (Karg *et al.* 2010). Funding the required monitoring of farmers' and food handlers' practices would require policymakers to have a clearer understanding of the return on investment (Keraita & Drechsel 2015).

Other monetary and explicit incentives do not always reach their goal (De Buck *et al.* 2017), as decision-makers sometimes misunderstand stakeholders' values and preferences. The existence, nature, size, and framing of the incentive convey either positive or negative signals to stakeholders. Too small an incentive may suggest that policymakers think the behaviour is unimportant, whereas if too high it can suggest policymakers consider the behaviour too complicated for stakeholders or that they are only self-interested (Gneezy *et al.* 2011). Thus, poorly designed incentives can reduce stakeholders' willingness to adopt a safe practice, even once it is removed. Incentives are more effective when framed in a way that preserves stakeholders' feelings of trust and autonomy rather than through control or challenging social norms, image concerns, and other social motivations (Gneezy *et al.* 2011) as illustrated by Bahraseman *et al.* (2024).

Non-monetary incentives are also a possibility, including dedicated support from extension officers, 'best farmer' awards or compliance certificates, good media publicity, and new marketing channels (Karg *et al.* 2010; Keraita *et al.* 2014). The study by Morse *et al.* (2019) is one of the few to actually report leveraging implicit incentives that mobilise stakeholders' desire for social recognition to align their practices with their personal values and ethics, autonomy, and control. Experts often underestimate farmers' sensitivity to jeopardising consumer health and assume farmers are more interested in explicit incentives, such as being provided with free or subsidised seeds, fertilisers, or other inputs (Keraita *et al.* 2014).

Environmental restructuring, modelling, and persuasion

Interventions that cater to stakeholders' motivations are seldom articulated in the screened literature. Morse *et al.* (2019) suggests restructuring the social environment by advertising that many households are already performing the recommended hygiene-related behaviours, which are becoming the social norm. Improving farmers' land-tenure security would increase their willingness to adopt safe practices (Amponsah *et al.* 2016). Others leverage traditional beliefs such as '*tody*' (similar to Buddhist and Hinduist karma) to convince Malagasy food vendors to avoid making their customers sick (Sarter & Sarter 2012). Role models motivating the uptake of good health practices by those around them have also been highlighted (Yihenew *et al.* 2014). Opinion leaders or other individuals respected by their community can champion behaviour change (De Buck *et al.* 2017; Winkler *et al.* 2017). Modelling through serious games can also stimulate the adoption of good practices (Kragić Kok *et al.* 2020). Davis *et al.* (2011) generated personalised information by testing the water quality in homes to persuade households to adopt risk-reducing strategies; Hirai *et al.* (2016) identified the desire to smell nice as a powerful intrinsic motivation to wash hands with soap, while Kragić Kok (2020) leveraged social learning through games.

Further reflections

Adopting a robust behavioural framework, such as the COM-B framework, helps intervention designers consider all relevant factors and establish a thorough diagnosis and theory of change instead of relying on assumptions and familiar go-to functions. The framework also helps articulate the functions (e.g., sharing information is not training) and objectives of the intervention (e.g., whether education is to strengthen capabilities and/or reinforce reflexive motivation) and align its content and delivery. It is helpful to consider which practices present the best combination of Acceptability, Practicability, Effectiveness, Affordability, Spill-over or Side-effects, and Equity (the APEASE criteria, see Michie *et al.* 2014) when selecting the ones to promote.

Changing the practices and attitudes of all stakeholders involved in the value chain has coordination and governance implications. Food safety and public health are public goods whose production is one of the sovereign duties of governments. A challenge governments face is to recognise and enable informal businesses to produce and distribute safer vegetables by providing them with information, support, and incentives, rather than just control and sanctions, to comply with minimum food safety standards (Karg *et al.* 2010; Henson *et al.* 2023). Henson *et al.* (2023) also recommended that governments integrate food safety in urban planning and other relevant policies and guide local multisectoral collective action at the municipal level.

LIMITATIONS

This review focuses on LMICs where the multi-barrier approach, as recommended by WHO (2006), remains the accepted procedure. Each country can adopt its own trajectory, especially in relation to enforcing water quality standards and food safety regulations (Drechsel *et al.* 2023). This review examines the contamination of vegetables primarily through irrigation with water contaminated with faecal matter. Faecal contamination introduced through food handlers' poor personal hygiene and food practices was also accounted for. Other contaminants, such as heavy metals and contaminants of emerging concerns that might require source control or other solutions not mentioned here, might also need to be considered. Experiences of adoption of organic farming practices, which also depend on premiums for 'safer' food, have not been included since these topics are extensively covered in the literature.

CONCLUSIONS

This review uses the COM-B behavioural framework to synthesise experiences with different approaches adopted to reduce the health risks associated with the use of wastewater contaminated with faecal pathogens in informal vegetable value chains in LMICs. It shows how most interventions focus on enabling the adoption of good practices by providing stakeholders with opportunities or strengthening their capabilities. Fewer interventions aim to stimulate stakeholder motivation to adopt safe practices, and those that do often simply convey their designers' rationales or struggle to identify sustainable monetary or other explicit incentives. Technical innovation, regulations, education, training, and explicit incentives are helpful and may be necessary but are often not sufficient. This review suggests that intervention designers should consider less-used strategies, including implicit incentivisation, promoting good examples to emulate, and persuasion, which can reinforce and complement technical and management controls and increase their impact. It is equally important not to consider behaviour change approaches as a shortcut to transferring responsibilities to primary stakeholders without investing in the required infrastructure or services. To improve their impact, hygiene and food safety interventions should address the opportunity, capability, and motivation needs of both primary stakeholders (farmers, vendors, and/or consumers) and secondary stakeholders, such as supporting institutions. More participatory approaches that include stakeholders early in the design process would likely increase their buy-in and the sustainability of the intervention. This aligns with the WHO recommendation that governments recognise that public agencies, farmers, food business associations, consumers, and community representatives are interdependent (WHO 2018). We suggest that where the multi-barrier approach remains the best option, urban farmers, vegetable traders, street food vendors, and consumer representatives should be encouraged to contribute to existing multistakeholder platforms to develop a shared vision of the value chain that ensures all their opportunities, capabilities, and motivations are catered for.

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AUTHOR CONTRIBUTIONS

DG conceptualised the study; carried out the search, analysis, and interpretation; and drafted the review. RES and KVG supervised the study, reviewed the search, and edited the manuscript. PD and BEE reviewed and critiqued the manuscript for clarity and coherence.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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