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Occupational Safety and Health and Healthy Housing: A Review of Opportunities and Challenges

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ABSTRACT

Purpose: Occupational safety and health (OSH) risks in construction of healthy housing (HH) have not been examined and collaboration between HH and OSH professionals is inadequate. The World Health Organization is developing international HH guidelines and the International Labour Organization is working to improve OSH in construction globally.

Methods: We searched for exemplary reports (including gray literature) on construction hazards; preventive measures for occupants and workers; OSH frameworks, laws, and regulations; definitions; and HH.

Results: Healthy housing construction typically improves ventilation, moisture and mold, pest control, injury hazards, cleanability, maintenance, accessibility, thermal conditioning, and avoidance of toxic building materials. To date, this work is done without explicit requirements for worker health. Construction is among the most hazardous sectors around the globe, although protective measures are well known, including engineering and administrative controls and provision of personal protective equipment. Residential construction, renovation, repair, and maintenance are fragmented, consisting mostly of small companies without proper OSH training, equipment, and knowledge of HH principles. Residential construction is often undertaken by informal or unauthorized workers, putting them at high risk. Reduced exposure to toxic building materials is an example of a benefit for both workers and occupants if OSH and HH collaboration can be improved. By recognizing that homes under new construction or renovation are both a workplace and a residence, HH and OSH initiatives can apply public health principles to occupants and workers simultaneously. This article publishes key definitions, hazards and interventions common to both fields.

Conclusions: A global increase in residential construction and renewed global interest in HH poses both risks and opportunities for primary prevention. Policy and practice interventions can benefit the health of occupants and those who work on their homes. Improvements in legislation, regulation, and international frameworks are needed to maximize OSH and HH collaboration and realize significant cobenefits. Occupational safety and health and HH standards should include requirements to protect both workers and occupants. Because homes can also be workplaces, both workers and housing occupants will receive important cobenefits when OSH and HH standards use proven interventions to protect workers and occupants.

KEY WORDS: building code, construction, healthy housing, housing, occupational safety and health

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Responsibility for creating healthy housing (HH) is fragmented and diffuse, placing both workers and occupants at risk of preventable disease and injury. In part, this is because such responsibility is typically shared by owners, occupants, designers, architects, engineers, financial institutions, workers (who construct, renovate, repair, demolish, and maintain homes), and others. Indeed, both workers and occupants have a shared need to ensure that homes are safe and healthy because homes under new construction or renovation are both a workplace and a residence. It makes little sense to build healthy homes to promote occupant health and safety if those who work on such homes are placed at needless risk of injury and disease. This article identifies existing international interventions that, if widely implemented,

promise to support the health of both occupants and the workers who construct or renovate their homes.

Some of the world's earliest laws dating back to 3000 BCE (Code of Hammurabi) included prohibitions of inadequate housing construction, for example, "If a builder has built a house for a man and his work is not strong, and if the house he has built falls in and kills the householder, that builder shall be slain."[1] Although the penalty is drastic compared with today's norms, the importance of housing clearly has a legacy that still resounds today. Indeed, today's housing codes had their origins in the sanitation movement that began in England around the 1830s and spread to the United States in the latter part of the 1800s with the publication of Jacob Riis' book *How the Other Half Lives*; the sanitation movement is credited with improved housing ventilation, reduced crowding, and other conditions related to tuberculosis, typhoid, and cholera.[2,3]

Although the connection between health and housing is still not well recognized, recent international developments have sought to reinvigorate the issue. The World Health Organization (WHO) is developing international HH guidelines.[4] In 2014, the National Healthy Housing Standard (an update of the 1985 Basic Housing Standard) was released in the United States.[5] Great Britain has implemented a National Healthy Housing Rating System in 2006[6] and New Zealand has implemented the HH index around 2007[7] among others. The International Labour Organization (ILO) has also recently developed initiatives to improve occupational safety and health (OSH) in the construction sector.[8]

Yet despite this long history and clear common interests, collaboration between OSH and HH professionals is limited. Occupational safety and health is defined as

> the science of the anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment.[9]

Clearly, "surrounding communities" includes housing occupants. Similarly, the definition of HH is

> A house that is located, designed, built, renovated, and maintained in ways that support the health of both its residents and the workers who labor to create and maintain that home, providing moisture control, ventilation and thermal conditioning, pest control, physical safety from injuries, avoidance of building materials with toxic materials (eg, lead-based paint, formaldehyde), accessibility and security, and cleanability.

See Supplemental Digital Content Table 1, available at http://links.lww.com/JPHMP/A362, for key definitions of terms common to both HH and OSH.

Yet no HH standards contain explicit OSH requirements, and residential construction requirements for OSH contain no provisions for protecting housing occupants. This is also reflected in the "green building" standards such as LEED or Enterprise Community Standards, none of which have explicit OSH elements, despite the belief that "green" is innately "healthy."[10] In short, the housing sector has limited awareness about OSH and similarly the OSH field has limited awareness of HH methods and standards, although each has goals and concepts in common. This is exacerbated by the fact that virtually all building codes and housing laws are local, not national, in contrast to overarching environmental and public health regulations.

The aim of this article is to identify common concepts in both the OSH and HH fields by (1) elucidating key definitions of terms used by both construction and HH professionals (see Supplemental Digital Content Table 1, available at http://links.lww.com/JPHMP/A362); (2) identifying populations that are at risk from either their work or from their unhealthy housing; (3) assessing data on the global residential construction sector; and (4) reviewing international and national frameworks, laws, and regulatory authorities for both OSH and HH. This article also provides recommendations and information on both hazards and interventions for those implementing HH guidelines to ensure both worker and occupant health. (Supplemental Digital Content Table 2, available at http://links.lww.com/JPHMP/A363, lists specific construction tasks, trades, and associated OSH hazards and interventions in housing generally, and Supplemental Digital Content Table 3, available at http://links.lww.com/JPHMP/A364, lists specific HH work tasks and associated interventions.)

Methods

We identified international data on construction activity, injuries and illnesses, model interventions, as well as typical HH principles and work. We also reviewed selected ILO OSH programs, existing norms, regulations, laws, standards, and recommendations, and assessed feasibility and implementation barriers. A literature search in PubMed using the key words "occupational safety and health" and "healthy housing" yielded only 39 articles, and none were a review of *both* OSH and HH. Therefore, we undertook a

qualitative assessment of construction activity, injuries and illnesses, and interventions employed in both the OSH and healthy homes fields, including reports from the WHO and the ILO. The articles we examined were identified through key word searches and on WHO and ILO Web sites. The goal of this initial examination is intended to lay the foundation for more systematic collaboration between the 2 fields and research projects that examine both HH and OSH holistically.

Findings

This section discusses international frameworks (eg, laws, regulations, international conventions, and best practices), current trends in housing construction, injury and disease burden, and interventions. Implementation is examined in the "Discussion" section.

Frameworks

The ILO Global Action for Prevention program includes construction as one of the high-risk sectors.[8] But legal frameworks of laws, regulations, codes, or guidelines in building construction (in general) and housing construction (in particular) vary widely around the globe. Enforcement of such frameworks is widely viewed as deficient in both developing and developed economies.[11,12]

These local frameworks involve (1) permitting from governmental bodies (which can include review and approval of whether housing should be constructed at a given location; whether its design, durability, and sustainability are adequate; compliance with codes, construction, and/or rehabilitation specifications; and listing of materials and procedures); (2) purchase of insurance (workers' compensation and public liability); (3) contractual agreements (between housing owners and the contracting company and between the contracting company and the workers) that specify responsibilities and terms of payment; (4) OSH oversight; and (5) requirements for trained and specialized workforces.

There are also international frameworks for OSH. For example, the Seoul Declaration on Safety and Health at Work called on governments to develop a "national preventive safety and health culture" to systematically improve safe workplace performance and to provide an enforceable health standard.[13] Several ILO frameworks are noteworthy (Table 1). The WHO Global Plan of Action on workers' health[14] recommended establishing national policies for all workers that include interventions and basic occupational health services for the primary prevention of work-related diseases and injuries. That plan identified universal coverage for all working people, adaptation to local conditions, affordability, and employer and public sector collaboration to ensure universal coverage.

TABLE 1
International Labour Organization Frameworks and Conventions

Framework Number	Title
C155	Occupational Safety and Health Convention, 1981
R164	Occupational Safety and Health Recommendation, 1981
C187	Promotional Framework for Occupational Safety and Health Convention, 2006
R197	Promotional Framework for Occupational Safety and Health Recommendation, 2006
C161	Occupational Health Services Convention, 1985
C167	Safety and Health in Construction Convention, 1988
R175	Safety and Health in Construction Recommendation, 1988
C162	Asbestos Convention, 1986
R172	Asbestos Recommendation, 1986
R171	Occupational Health Services Recommendation, 1985

Frameworks may also include Occupational Exposure Limits[15] or Threshold Limit Values[16] or others for chemical, physical, and biological agents and are sometimes promulgated and enforced by individual governments. However, in many cases, the legal limits are outdated or do not exist at all for the many chemicals and other hazardous agents typically found on construction sites. For example, the US Occupational Safety and Health Administration's Permissible Exposure Limits were mostly established in the 1970s and are widely perceived to be out of date and not protective.

Importantly, no international frameworks have been codified for HH, which is the gap that the WHO International Healthy Housing Guidelines will attempt to fill.

Current trends in housing construction

Although data on the magnitude of global construction and surveillance of its injuries and illnesses are limited and need updating, the following trends are clear[17]:

- Expansion in total construction output and employment, despite the recent economic downturn.
- Expansion in the residential sector due in part to a backlog of unmet housing needs, especially in developing countries.
- Increasing prevalence of small firms.

Total construction output worldwide will likely grow from $7.4 trillion in 2010 to $10.3 trillion in 2020 (2010 US$).[18] Global construction demand is predicted to increase until at least 2030.[19] China, India, and the United States together could make up 60% of all global construction growth. Construction activity in emerging markets may make up about 63% of total construction profits by 2025 and about 75% of construction workers are in developing countries.[17] In short, construction is an indicator of investment and economic growth.[20,21]

Residential work is a large percentage of all construction activity due to increasing demand and a shortage of affordable housing. Supplemental Digital Content Figure 1, available at http://links.lww.com/JPHMP/A365, shows that in the United States new construction of homes and home improvement made up about 52% of the total dollar value in 2015. Supplemental Digital Content Figure 2, available at http://links.lww.com/JPHMP/A365, shows that in 2012 the percentage of workers in construction involved in the residential sector varied from about 10% to 66%, depending on the trade involved.[22]

The need for additional housing construction is currently, and will continue to be, large. By 2030, about 3 billion people will need proper housing and water, sanitation, power, and other systems. UN Habitat estimates that up to 80% of the population lives in slums in some cities and 55 million new slum dwellers have appeared since 2000. The data are startling: Sub-Saharan Africa has a slum population of 199.5 million, South Asia has 190.7 million, East Asia has 189.6 million, Latin America and the Caribbean has 110.7 million, Southeast Asia has 88.9 million, West Asia has 35 million, and North Africa has 11.8 million.[23] In 2010, an estimated 828 million people lived in urban areas.[24] In short, providing adequate and healthy housing, particularly in developing nations, will continue to be a major development problem.

Injury and disease burden in construction

Construction is among the most hazardous of sectors, with approximately 1 in 6 fatal accidents reported globally and 60 000 fatalities per year.[17] Injury and disease burden in construction is directly related to the skill level of the workforce. Low skill workers such as general laborers tend to have more hazardous exposures and less knowledge, but specialized trades are, by definition, populated by workers with experience and training in their work. Generally, the construction industry provides employment for those with low educational attainment as well as immigrants who are often unauthorized to work. Workers who are employed directly and permanently are the core workers of general contractors and public sector construction. Lower education and immigrant status mean that employment arrangements are more precarious, which have demonstrated negative health effects.[25]

Disease and injury burden is exacerbated by reductions in the directly employed workforce and increases in those employed temporarily and casually by subcontractors. These work arrangements often fail to create a health and safety culture, typically manifested by not providing information on new materials; not training the workforce on health and safety; inhibiting injury and illness reporting; and shifting cost and risk to the workers themselves and to public safety nets.[26] Construction work often provides a way of entering the labor market for migrant and low-skilled workers. Half of migrant workers on construction sites in Beijing, China, have received no more than primary education with at least 10% illiterate.[27] Globally, 15% of the world's 100 million labor migrants work in construction,[28] with skirting of laws around formal employment; skills, knowledge, and language limitations; and disincentives for employers to follow labor and OSH regulations, particularly on training and provision of safety equipment.

In developed countries, construction workers are 3 to 4 times more likely than other workers to die from work-related accidents, with higher rates of occupational health problems, including respiratory disease, musculoskeletal disorders (especially back disorders), noise-induced hearing loss, and skin problems (see Supplemental Digital Content Figures 3 and 4, available at http://links.lww.com/JPHMP/A365).[22] In developing countries, construction work is 3 to 6 times more hazardous than that in developed countries.[28] This may be due in part to the more fragmented nature of residential construction; in the United States, about 80% of construction companies had 1 to 9 employees, 12% used day laborers, 22% of employer firms had no full-time employees, and 8% hired temporary workers (see Supplemental Digital Content Figure 5, available at http://links.lww.com/JPHMP/A365).[22]

The number of fatalities and injuries in construction, overall, is high and even higher in residential construction (Table 2). In 2012, nonfatal injury and illness rates involving days away from work in residential construction were 177 injuries per 10 000 employees versus 147 injuries per 10 000 employees for the construction industry as a whole. From 1992 to 2010, 44% of construction deaths occurred in workplaces with less than 11 employees.[30] Falls, overexertion, and contact with objects together caused more than 90% of nonfatal construction injuries in the United States in 2015 (see Supplemental Digital

TABLE 2
Fatal and Nonfatal Injuries in US Construction by Trade, 2013[a]

	Fatalities		Nonfatal Injuries With Days Away From Work	
Trade	No. Workers	Rate/100 000 FTE	No. Workers	Rate/10 000 FTE
Laborer/helper	200	15	17 510	156.3
Carpenter	73	4.8	8950	143.2
Roofer	70	35	1680	121.9
Electrician	57	3.9	6490	150.7
Foreman	17	1	3940	99.5
Power line installer	14	50	1020	390.5
Ironworker	10	22	650	211.5
Welder	10	10	890	107.3
Painter	8	0.7	3150	105.6
Plumber	6	0.5	6870	207.2

Abbreviation: FTE, full-time equivalent worker.
[a] *Adapted from Wang et al.*[29]

Content Figure 4, available at http://links.lww.com/JPHMP/A365).[22] Construction hazards can also cause respiratory disease from inhaling dust (including silica from cutting stone tiles and other construction materials), cancer (including asbestos and radon), neurological and other toxic effects (from exposure to lead, volatile organic compounds, and other substances in glues, paints, and other products), musculoskeletal disorders, noise-induced hearing loss, skin problems, injuries, and deaths associated with transportation of (and other work with) construction materials.

Organizational and logistical factors common in construction include shift work, outdoor work in the elements, site congestion, multiple employers on one site, time pressure, and others; these are all recognized risk factors, but because they are not the proximate cause of an accident on a construction site, they are not well studied.[31]

Although hazards are prevalent throughout the construction sector, the groups most vulnerable include

- women workers;
- child workers;
- new workers without experience and training;
- workers in small firms and the self-employed;
- workers with preexisting illnesses and injuries;
- those workers or volunteers responding to a disaster who may not be adequately trained;
- those without the necessary protective equipment; and
- so-called "do-it-yourselfers" (amateurs) or occupants who undertake repair, renovation, or construction projects for which they have inadequate experience or training.

Injury and disease burden in housing

The burden of disease for occupants associated with inadequate housing has been estimated by WHO for dampness, mold, crowding, lead, radon, noise, injuries, and other housing-related factors. For Europe alone, this totals more than 2 million disability-adjusted life years. Such estimates are needed for other regions. The report identifies children, the elderly, those with preexisting health conditions, and other populations who spend more time in the home environment and states, "to realize the large health potential associated with adequate, safe and healthy homes, joint action of health and non-health sectors is required."[32] Low-income housing and racial and ethnic disparities also contribute to higher rates of housing-related diseases and injuries for occupants.[33] A series of articles previously published in this journal reviews the literature on housing-related diseases and injuries, such as (but not limited to) fire-related fatalities from absence of smoke alarms, increased asthma from pests and other triggers, mold-induced illness from dampness, cancer from radon, and injuries from falls.[34-37]

Interventions

Supplemental Digital Content Table 2, available at http://links.lww.com/JPHMP/A363, identifies examples of interventions to improve OSH in housing construction, renovation, and repair by trade. Supplemental Digital Content Table 3, available at http://links.lww.com/JPHMP/A364, identifies examples of HH interventions and associated OSH hazards and interventions. To our knowledge, this is the first

time that interventions in the 2 fields (OSH and HH) have been published together. The interventions include some that can be expected to benefit both workers and occupants. For example, avoiding the use of wood cabinets with added formaldehyde will benefit both. Similarly, installing railings on stairways and eliminating uneven surfaces will help reduce falls and trip hazards for both workers and occupants. A current database for owners, contractors, and workers of construction work hazards, trades, tasks, and practical control measures to reduce or eliminate hazards is available at http://www.cpwrconstructionsolutions.org/. The evidence base for HH interventions has been systematically reviewed previously in this journal.[34-37]

Healthy housing work can include design, development, codes, specifications, and underwriting standards. For example, the Healthy Housing Rating System in Great Britain[6] and the National Healthy Housing Standard in the United States[5] contain elements of these, but neither has explicit OSH requirements.

Surveillance of housing construction–related diseases and injuries, as well as surveillance of inadequate housing at the national and global levels would help target interventions but is lacking especially in the developing countries. Surveillance data should be included in the next UN World Population and Housing Census program (see http://unstats.un.org/unsd/demographic/sources/census/2010_PHC/default.htm).

Another key intervention is to minimize the use of toxic chemicals and agents in materials to construct HH. For example, at least 45 countries are still manufacturing lead-based paint, which has spawned the Global Alliance to End Lead Paint, chaired by WHO and the United Nations Environment Program. The ILO was among the first to ban the use of lead in residential paint in 1924, an example of how collaboration between OSH and housing sectors can produce benefits for each.[38]

The Figure shows a few of the key healthy homes interventions.

Discussion

Integration

Incorporation of OSH into HH guidelines and standards (and vice versa) is likely to result in improved health for both workers and occupants, but barriers are significant. Integration of OSH and HH will mitigate fragmentation,[39] which has hampered both HH and construction standard development and OSH. Unlike other environmental media such as air and water, most housing is privately owned and thus not part of the "shared commons" that is the foundation of most environmental regulations. This means that virtually all building codes and housing laws are local, not national, in contrast to environmental and public health regulations. National housing or building codes are the exception, not the rule. Labor frameworks, codes, regulations, and laws also exist, but they typically do not contain specific HH issues. This fragmentation means that consistent outreach, training, hazard recognition, and hazard control standards and guidelines are needed for both HH and OSH.

Overcoming such fragmentation may be difficult, but there are programs that address it. For example, the ILO Safety and Health in Construction Convention of 1988, No. 167 includes[40]

- promoting cooperation between employers and workers in making workplaces safe and healthy;
- ensuring that all parties including designers and planners of a construction contract have responsibilities;
- ensuring that the prime (principal) contractor is responsible for coordinating OSH requirements, with each subcontractor responsible for his or her own workers; and
- giving workers the duty to report risks and their right to remove themselves from a dangerous situation.

The Convention includes inspections and penalties. Beyond that, the European Union has gone further than ILO Convention No. 167, with duties for the client, which could be the occupant or housing provider.

Better integration could also be achieved through collaboration of health institutions and OSH. For example, a Thailand pilot project[41] integrated primary health care units (PCU) with the Bureau of Occupational and Environmental Diseases. The project promoted worker initiative in improving occupational health; linked occupational health issues with food and product quality; provided risk assessment and advice on workplace health and safety; conducted surveillance of work-related and chronic diseases and education; and provided safety equipment.

Enforcement

Integration of OSH into HH guidelines could also stimulate increased policing by both labor and housing inspectors. For example, Malaysia developed a "stop work order" on projects deemed unsafe, with a report that contractors quickly responded to safety advice when threatened with a shutdown.[42]

Inspectors are few, especially in housing where the number of sites requiring inspection can be very large. And housing inspectors and labor inspectors are

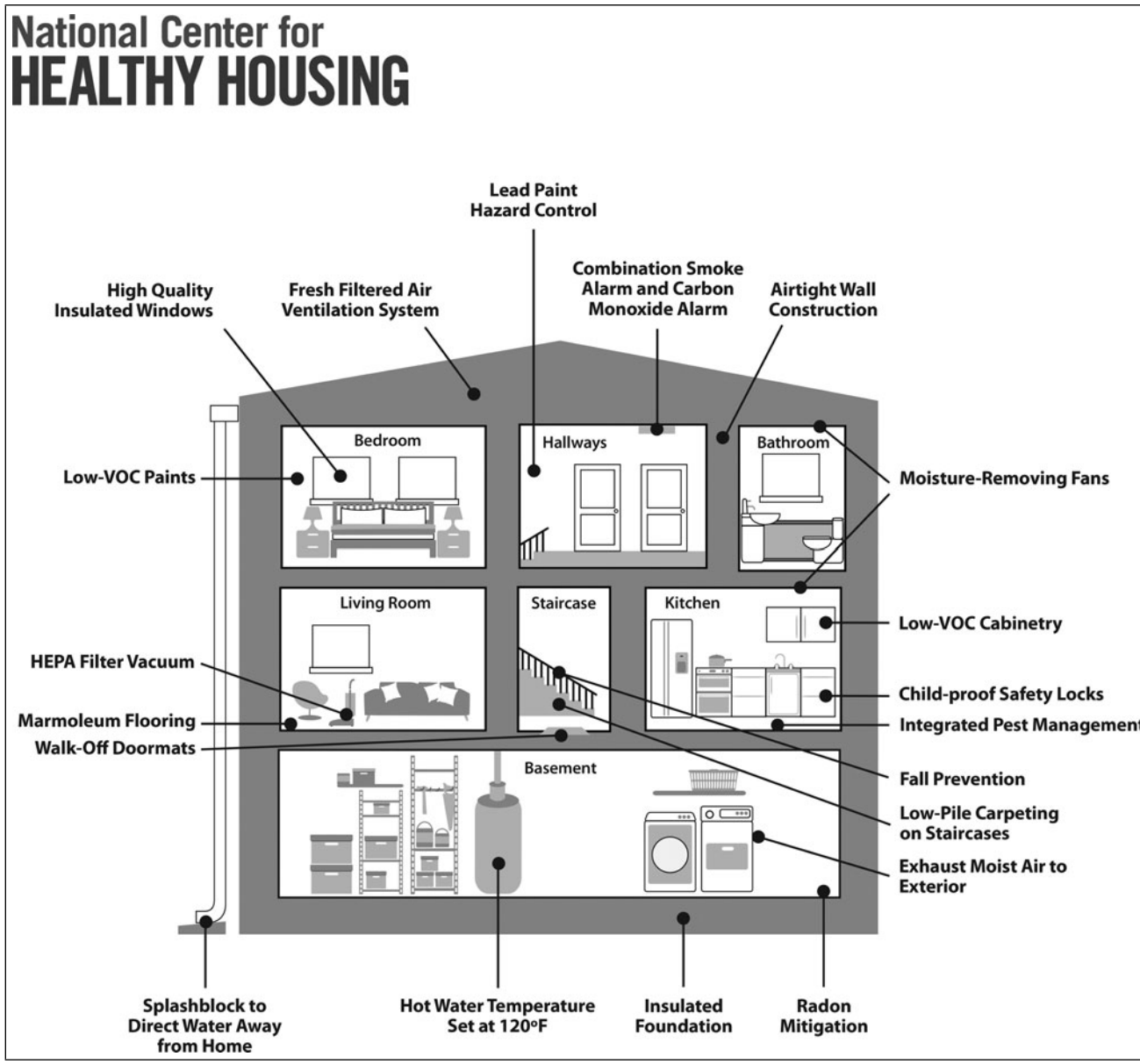

FIGURE Summary of Selected Healthy Homes Interventions.
Abbreviations: HEPA, high efficiency particle air; VOC, volatile organic compounds.

usually located in entirely different organizations with little or no opportunity for collaboration. Large firms are increasingly expected to "police" themselves in compliance with ISO 9000 requirements. Mentoring of small firms by large ones can be particularly effective, for example, as part of contracting between financial institutions that fund housing construction and housing construction firms.

Labor and housing inspectors can help inform workers, employers, and occupants in prevention. The causes of most injuries and ill health in the construction industry and in housing are both known and preventable (see Supplemental Digital Content Tables 2 and 3, available at http://links.lww.com/JPHMP/A363 and available at http://links.lww.com/JPHMP/A364). With appropriate training, inspections could also be performed by trade unions and community groups (such as tenants' unions) interested in increasing the supply of HH.

Some countries are now experimenting with "safety cards," which could become a requirement in HH standards. For example, Malaysia makes every construction worker take a 1-day safety and health course to get a "green card." Those without the card may not enter worksites. In addition, contractors must train their management. A similar system operates

in Singapore, Australia, Ireland, and the United States.[20]

Underwriting standards present another intervention opportunity to increase collaboration between OSH and HH. Such standards typically carry the force of law because they are part of the contract or insurance policy. Of course, this would require housing contractors to purchase insurance, which is required in most developed countries but not necessarily in developing nations.

Training

Insurance can also be used to stimulate training by offering a lower premium for reduced claims through improved training or an increase on higher-cost claims where training did not occur. This system is in place in Switzerland and Germany.[17] In countries where insurance is less developed, the costs of OSH training could be required in bids for construction projects or contract costs.[43]

To be effective, training should be required, desired, and feasible. Markets, occupants, employers, and workers must all demand and value OSH and HH. Training should be focused on key players. One project examined which entities were most influential in the view of workers, NGOs, industry, and researchers; it identified project owners, workers' compensation insurance, government, and inspectors.[30]

Perversely, the cost of a death, injury, or illness on a construction site is sometimes built into the prime bid for the job, while costs of prevention are not included.[44] Some employers may perceive OSH requirements such as training to increase the cost of housing construction, without careful examination of the offset experienced through reduced costs from avoided medical treatment and death benefits. Training and outreach costs are generally a tiny fraction of the cost of construction; indeed, if financial institutions require the use of trained workers, incremental costs can be folded into long-term financing.

Construction skills are often acquired through an informal apprenticeship system in developing countries instead of using more formal training operations.[20] This suggests that OSH and HH training should be an adjunct to (not a replacement of) apprenticeship programs. In the Philippines and Egypt, an estimated 95% and 85%, respectively, of construction workers are in informal apprenticeship programs.[45] Vocational training schools exist in many countries, but compensation for training time is not well established. High turnover of workers poses a considerable barrier to training. Options include putting training costs into contractor bids and/or to finance training publicly.

Implications for Policy & Practice

- OSH and HH standards should include requirements to protect both workers and occupants.
- Residential construction, renovation, repair, and maintenance work are widespread but also fragmented, consisting mostly of small companies that lack proper OSH training and equipment. This results in a high burden of disease and injury worldwide for both workers and occupants that is preventable.
- Improvements in legislation, regulation, and international frameworks are needed to maximize collaboration in both fields and realize the cobenefits each field offers.
- The supply of HH is inadequate and needs to be expanded. This expansion should be accompanied by proven interventions for both OSH and HH that are enforced. The production and preservation of HH can be maximized by a trained, equipped, and safe workforce because there will be less time lost to avoidable injury and disease.
- Both workers and occupants are likely to realize important cobenefits of integrating HH and OSH. Further research is needed to enable both sectors to increase collaboration and maximize those benefits.

Workforce housing

The connection between HH and workforce housing is seen in some types of housing construction where employers provide housing on-site for workers and migrants.[46,47] In China, where much of the construction workforce is from rural areas, housing and other facilities are required to be made available on-site. However, there are reports that such housing is often dirty and overcrowded; is infested by mosquitoes, rats, and other pests; is poorly ventilated or heated; has no eating areas; and has high levels of settled and airborne dust.[27]

Similarly, 82% of foreign workers in Malaysia were found to live in worksite buildings that were overcrowded, lacked basic sanitation, had poor water drainage and inadequate trash disposal, and reportedly led to dengue fever.[42] In industrialized countries such as the United States, such housing is also linked to negative mental and physical health outcomes of residents and is often crowded; infested with mold, mildew, and other allergens; is contaminated with pesticides; and has structural deficiencies.[46]

Research needs

Research needs in both the OSH and HH fields are numerous. A systematic review of OSH[48] examined

13 studies and found only limited, low-quality evidence that a multifaceted safety campaign and a multifaceted drug workplace program reduces nonfatal injuries among construction workers. Another review [49] found "… a need to invest in more in-depth evaluation of [research to practice (r2p)] efforts that gauge audience reach, adoption, and implementation in addition to safety and health impact." Observational studies can provide evidence about the prevalence of workplace hazards, the injuries associated with them, and likely strategic directions for injury prevention and hazard reduction.

There have been systematic reviews of HH interventions,[34-37] but these are now outdated and not linked to the OSH systematic reviews.

Global surveillance of both housing quality and occupational disease and injury in the residential and HH setting is needed, as are more systematic reviews of interventions. This is particularly important for emerging issues such as nanomaterials used in construction materials, which can release dust during building and demolition. Construction processes that contain nanomaterials have begun to be listed, but more work is needed, especially on interventions.[50]

References

1. Code of Hammurabi. Circa 3000 B.C. (Section 229). https://legacy.fordham.edu/halsall/ancient/hamcode.asp. Accessed November 5, 2016.
2. Stein L. A study of respiratory tuberculosis in relation to housing conditions in Edinburgh; the pre-war period. *Br J Soc Med*. 1950;4:143-169.
3. Centers for Disease Control and Prevention and U.S. Department of Housing and Urban Development. Healthy housing reference manual. http://www.hud.gov/offices/lead/library/hhi/HealthyHousingReferenceManual.pdf. Published 2006. Accessed November 5, 2016.
4. World Health Organization. Healthy housing experts call for international guidelines. http://www.who.int/hia/housing/en/. Published 2010. Accessed November 5, 2016.
5. National Center for Healthy Housing and American Public Health Association. National healthy housing standard. http://www.nchh.org/Policy/NationalHealthyHousingStandard.aspx. Published 2014. Accessed November 5, 2016.
6. Department for Communities. United Kingdom. Housing health and safety rating system (HHSRS) guidance. https://www.gov.uk/government/collections/housing-health-and-safety-rating-system-hhsrs-guidance. Published 2006. Accessed November 5, 2016.
7. New Zealand He Kainga Oranga, the Housing and Health Research Programme. The health housing index. http://www.healthyhousing.org.nz/research/current-research/healthy-housing-index/#overview. Accessed November 5, 2016.
8. International Labour Organization. Introduction to the ILO's programme: global action for prevention on occupational safety and health. http://www.ilo.org/global/about-the-ilo/how-the-ilo-works/WCMS_495278/lang--en/index.htm. Published 2016. Accessed November 5, 2016.
9. Alli BO. *Fundamental Principles of Occupational Health and Safety*. Geneva, Switzerland: International Labour Organization; 2008. http://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms_093550.pdf. Accessed April 18, 2017.
10. Jacobs DE, Ahonen E, Dixon SL, et al. Moving into green healthy housing. *J Public Health Manag Pract*. 2015;21(4):345-354.
11. Santos F. 2005. Study finds lax safety standards at construction sites. New York Times. October 18. http://www.nytimes.com/2005/10/18/nyregion/study-finds-lax-safety-standards-at-construction-sites.html?_r=0. Accessed November 5, 2016.
12. Watterson A. Global construction health and safety—what works, what does not, and why? *Int J Occup Environ Health*. 2007;13(1):1-4.
13. Finish Institute of Occupational Health. From risks to vision zero. Helsinki. Proceedings of the International Symposium on Culture of Prevention—Future Approaches. http://www.ttl.fi/en/international/conferences/culture_of_prevention/Documents/proceedings_cupre_2013.pdf. Published 2014. Accessed November 5, 2016.
14. World Health Organization. Workers health: global plan of action. http://www.who.int/occupational_health/publications/global_plan/en/. Published 2007. Accessed 5 June, 2017.
15. European Agency for Safety and Health at Work. Occupational exposure limits. https://oshwiki.eu/wiki/Occupational_exposure_limit_values. Published 2016. Accessed 5 June, 2017.
16. American Conference of Governmental Industrial Hygienists. Threshold limit values. TLV® chemical substances. http://www.acgih.org/tlv-bei-guidelines/tlv-chemical-substances-introduction. Published 2016. Accessed November 4, 2016.
17. International Labour Organization. Good practices and challenges in promoting decent work in construction and infrastructure projects. Issues paper for discussion at the Global Dialogue Forum on Good Practices and Challenges in Promoting Decent Work in Construction and Infrastructure Projects (Geneva). http://www.ilo.org/wcmsp5/groups/public/—ed_dialogue/—sector/documents/publication/wcms_416378.pdf. Published 2015. Accessed November 5, 2016.
18. Newswire PR. Global construction market worth $10.3 trillion in 2020 (50 largest, most influential markets). http://www.prnewswire.com/news-releases/global-construction-market-worth-103-trillion-in-2020-50-largest-most-influential-markets-292235961.html. Published 2015. Accessed November 5, 2016.
19. Global Construction Perspectives and Oxford Economics. Global Construction 2030: a global forecast for the construction industry to 2030. https://www.pwc.se/sv/entreprenad/assets/global-construction-2030.pdf. Published 2015. Accessed 5 June, 2017.
20. International Labour Organization. *The Construction Industry in the Twenty First Century: Its Image, Employment Prospects and Skill Requirements*. Geneva, Switzerland: Tripartite Meeting on the Construction Industry in the Twenty-first Century; 2001. http://www.ilo.org/public/english/standards/relm/gb/docs/gb283/pdf/tmcitr.pdf. Published 2001. Accessed November 5, 2016.
21. Bon R, Crosthwaite D. *The Future of International Construction*. London: Thomas Telford. European Construction Economics Research Unit, Department of Construction Management & Engineering, University of Reading; 2000.
22. CPWR (Center for Construction Research and Training). 2013. *The Construction Chart Book*. 6th ed. Silver Spring, MD: Center for Construction Research and Training. Forthcoming.
23. United Nations Habitat. Housing and slum upgrading. http://unhabitat.org/urban-themes/housing-slum-upgrading/. Published 2012. Accessed November 5, 2016.
24. United Nations Habitat. State of the world's cities 2010/2011. http://unhabitat.org/?mbt_book=state-of-the-worlds-cities-20102011-cities-for-all-bridging-the-urban-divide. Published 2010. Accessed November 5, 2016.
25. Benach J, Muntaner C. Precarious employment and health: developing a research agenda. *Epidemiol Community Health*. 2007;61(4):276-277.
26. Gillen M, Gittleman J. Path forward: emerging issues and challenges. *J Safety Research*. 2010;41:301-306.

27. Lu Y, Fox PW. The construction industry in the 21st century: Its image, employment prospects and skill requirements: case study from China. https://www.researchgate.net/publication/242494768_THE_CONSTRUCTION_INDUSTRY_IN_CHINA_ITS_IMAGE_EMPLOYMENT_PROSPECTS_AND_SKILL_REQUIREMENTS. Published 2001. Accessed November 5, 2016.
28. Martin P. Recession and migration: a new era for labor migration? *Int Migr Rev*. 2009;43(3):671-691.
29. Wang X, Largay JA, Dong XS. Fatal and nonfatal injuries among construction trades between 2003 and 2014. http://www.cpwr.com/sites/default/files/publications/Third%20Quarter%20QDR%20final_2.pdf. Accessed 5 June, 2017.
30. CPWR (Center for Construction Research and Training). Reaching and influencing small residential contractors' safety and health practices. http://www.cpwr.com/sites/default/files/publications/Reaching%20and%20Influencing%20Residential%20Contractors.pdf. Published 2014. Accessed November 5, 2016.
31. Manu PA, Ankrah NA, Proverbs DG, Suresh S. Investigating the multi-causal and complex nature of the accident causal influence of construction project features. *Accid Anal Prev*. 2012;48:126-133.
32. Braubach M, Jacobs DE, Ormandy D eds. *Environmental Burden of Disease Associated With Inadequate Housing: A Method Guide to the Quantification of Health Impacts of Selected Housing Risks in the WHO European Region*. Geneva, Switzerland: World Health Organization; 2011. http://www.euro.who.int/__data/assets/pdf_file/0003/142077/e95004.pdf. Accessed February 28, 2017.
33. Jacobs DE. Environmental health disparities in housing. *J Am Public Health Assoc*. 2011;101(suppl 1):S115-S122.
34. Jacobs DE, Brown MJ, Baeder A, et al. A systematic review of housing interventions and health: introduction, methods, and summary findings. *J Public Health Manag Pract*. 2010;16(5 suppl):S5-S10.
35. DiGuiseppi C, Jacobs DE, Phelan KJ, Mickalide AD, Ormandy D. Housing interventions and control of injury-related structural deficiencies: a review of the evidence. *J Public Health Manage Pract*. 2010;16(5 suppl):S34-S43.
36. Krieger J, Jacobs DE, Ashley PJ, et al. Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence. *J Public Health Manag Pract*. 2010;16(5 suppl):S11-S20.
37. Sandel M, Baeder A, Bradman A, et al. Housing interventions and control of health-related chemical agents: a review of the evidence. *J Public Health Manage Pract*. 2010;16(5 suppl):S24-S33.
38. International Labour Organization. 1921. C013—White Lead (Painting) Convention, 1921 (No. 13). http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_INSTRUMENT_ID:312158. Accessed November 5, 2016.
39. Jacobs DE. Healthy housing standards: fragmentation or harmonization? Keynote Address. In: Proceedings of the 5th Warwick Healthy Housing Conference, University of Warwick; 2008; Coventry, United Kingdom.
40. International Labour Organization. Information system on International Labour Standards. NORMLEX. http://www.ilo.org/dyn/normlex/en/f?p=1000:12000:::NO:::. Accessed November 5, 2016.
41. International Labour Organization. Asia-Pacific Working Paper Series. Promoting occupational health services for workers in the informal economy through primary care units Somkiat Siriruttanapruk, Koji Wada, Tsuyoshi Kawakami. http://www.ilo.org/wcmsp5/groups/public/@asia/@ro-bangkok/@sro-bangkok/documents/publication/wcms_114237.pdf. Published 2009. Accessed November 5, 2016.
42. Abdul-Aziz A-R. Foreign workers and labour segmentation in Malaysia's construction industry. *Construction Manage Econ*. 2001;19(8):789-798.
43. Department for International Development. *The Social Aspects of Construction Study (SAC): Briefing Paper*. London: Department for International Development; 2001.
44. Hendrickson C. *Project Management for Construction Fundamental Concepts for Owners, Engineers, Architects and Builders*. Pittsburgh, PA: Carnegie Mellon University; 2008. Version 2.2. Section 8.2 risk allocation, worker health and safety.
45. Assaad R. Formal and informal institutions in the labor market, with applications to the construction sector in Egypt. *World Dev*. 1993;21(6):925-939.
46. Arcury TA, Jacobs IJ, Ruiz V. Farmworker housing quality and health. *New Solut*. 2015;25(3):256-262.
47. International Labour Organization. R115—workers' housing recommendation, no. 115. http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_INSTRUMENT_ID:312453. Published 1961. Accessed November 5, 2016.
48. van der Molen HF, Lehtola MM, Lappalainen J, et al. Interventions to prevent injuries in construction workers. *Cochrane Database Syst Rev*. 2012;12:CD006251.
49. Chapman LJ. *Literature Review and Environmental Scan for Better Translation of Research to Practice in Residential Construction*. Silver Spring, MD: Center for Construction Research and Training; 2013. http://www.cpwr.com/sites/default/files/publications/residential_construction_r2p_literature_review_chapman.pdf. Accessed November 5, 2016.
50. CPWR (Center for Construction Research and Training). Construction Nanomaterial Inventory. elCOSH Nano. http://nano.elcosh.org/. Published 2016. Accessed November 5, 2016.