

The Role of Health Security in Fire Prevention Strategies

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Abstract

A health security framework improves the design of fire prevention strategies by explicitly linking health with fire, fostering a preventive approach that emphasizes risk reduction before ignition occurs. Attention to fire-related health impacts is increasingly important as the threat landscape evolves. At least 18 chemical and biological agents and various psychosocial hazards associated with fire and smoke exposure adversely affect human health and well-being (Taylor et al., 1970) and incur substantial direct and indirect costs (Al-Hajj et al., 2022). Fire and health hazards often co-occur, with 65% of the U.S. population residing within one mile of at least one location posing both physical fire and health risks. Climate change exacerbates health-threat and fire-hazard intersections, alongside the accelerating spread of technologies, perspectives, and materials that can ignite fires or promote their proliferation.

Key Words: Health security, fire prevention, safety strategies, risk management, emergency preparedness, public health, occupational safety, hazard mitigation.

1. Introduction

Health security principles enhance fire prevention, marking an urgent shift from reactive to proactive approaches. Infectious disease threats—including emerging pathogens, conversion of endemic diseases, and post-viral syndromes—elevate fire vulnerability through increased social gatherings, confinement spaces, and mental strain. Wildfire smoke exposure, weak ventilation systems, and heightened flammability of interior materials pose additional challenges. Urban design, service delivery, and law enforcement considerations intersect with both health and fire domains to deepen systemic risk.

Health security comprises protection against threats to human health that jeopardize social and economic stability. Fire prevention embraces measures that avert, impede, or mitigate the impact of fire events, centrally concerned with the protection of people, property, and the environment. Historical, epidemiological, and technological connections bind these fields, while synergies extend beyond fire prevention to preparedness and response.

1.1. Context and Relevance

Public health threats have become pervasive worldwide (R. Campbell, 2011). Addressing these current and emerging threats—from infectious diseases to noncommunicable diseases, pollution, natural disasters, and climate change—has risen to the top of global governance agendas. Such threats can also amplify the risk of fires and flammable materials, which are associated with chemical exposure, airborne disease, or heat stress that can strain health-care systems (Kostova et al., 2021). Consequently, aligning health security with fire prevention is critical for safeguarding public safety, especially in dense urban areas.

Streamlining preventive, preparatory, and reactive measures across the health and fire sectors can reduce hazardous exposure, improve emergency evacuation timeliness, and strengthen planning for fire-related health populations. A distinctive definition of health security and fire prevention further refines the common threads, ensuring consistency throughout the analysis.

1.2. Defining Health Security and Fire Prevention

In December 2022, an apartment fire in the community of East in Yerevan, Armenia, claimed the lives of 16 people, including multiple young children. The deadly incident received extensive media coverage locally, regionally, and internationally, exposing the extent to which devastating fires occur in urban areas globally. Health security can contribute to fire-prevention strategies and mitigate the public health impacts (Kumar Chattu & Kevany, 2019). Health security adopts multidisciplinary, multisectoral, cross-agency approaches to monitoring, prevention, preparedness, and response to diverse factors threatening physical and mental well-being (Wenham, 2019).

Despite its humanitarian and health imperative, contemporary fire risk is growing worldwide, particularly in informal, densely populated urban centres. Established fire-risk factors intersect with climate change, evolving psychosocial conditions, new patterns of urbanization, and emerging infectious diseases, creating converging hazards (R. Campbell, 2011). Awareness of health and fire-security interplay fluctuates cyclically, but existing analysis tends to focus narrowly on health-sector responsibilities. In practice, health provisions influence every stage of fire-prevention policy and practice; the health security concept provides a pragmatic organizing framework for assessing interventions and partnerships at the health–fire nexus.

2. Historical Intersections Between Health Security and Fire Safety

Throughout history, public health officials have recognized fire safety as a crucial intervention to safeguard community wellbeing. Despite considerable risk mitigation progress, fire remains a major urban hazard. The COVID-19 pandemic underscored the global salience and interconnectedness of health and security, drawing attention to how health security principles can bolster fire prevention measures.

The epidemiological profile of urban fires remains a pressing public health issue. Fires injure or kill over 500,000 people annually (Kumar Chattu & Kevany, 2019). The direct health impacts of fires increase the burden on health systems. Recent research across metropolitan areas—including Los Angeles, Houston, and London—indicates that smoke from wildfires and structural fires heightens morbidity and mortality from respiratory, cardiovascular, and other diseases (McCoy et al., 2023). Fires also exert psychosocial strain, affecting anxiety levels, substance use, and domestic violence. These public health stressors compound across multiple disasters, and health information can yield insights to reduce exposure, incident frequency, and societal harm.

Health-focused fire safety strategies have been successfully implemented in various cities. Building fire and safety codes frequently reference public health indicators, yet political frameworks and governance arrangements impede integrated decision-making. Audits promoted by the World Health Organization's Healthy Cities initiative in multiple countries—Thailand, Malaysia, Egypt, Morocco, and others—have shown how cities can leverage environmental health data to identify housing and urban planning improvements that enhance community wellbeing and lower health, fire, and hazard risks simultaneously. Advising cities to invest in

environmental health improvement, the initiative emphasizes the substantial co-benefits that accompany enhanced social, economic, and urban physical environments.

2.1. Epidemiology of Fire-Related Health Impacts

Fires present significant ongoing health risks, leading to the spread of disease, toxicity from inhalation, and other harms. These threats are heightened by contemporary issues ranging from unregulated fuel sources to increasing opportunities for burn injuries from development projects and climate change effects, such as prolonged droughts that trigger expansive wildfires. As with bioterrorism, a coordinated public health approach helps mitigate threats across the full threat spectrum. The volume and acuity of health-system loads from fire hazards influence overall health security levels and thus guide the prioritization of mitigating measures. Addressing fire risks may reduce overall morbidity and mortality levels and therefore strengthen the overall health security of urban populations (Liu et al., 2015).

Fire events may proliferate as climate change affects severity and duration of droughts, precipitation, and temperature. Various influences cause remote fires in forests and other areas to expand in frequency or to begin more easily. Characteristics of the built environment, available fuel, a more mobile youth demographic, and the proliferation of fire as a low-cost method of protest or social disruptor further signify that, overall, widespread and interconnected fire hazards continue to emerge as a prevailing public health challenge.

2.2. Case Studies in Public Health-Driven Fire Mitigation

Two urban case studies illustrate the contribution of health security principles to fire prevention. In both examples, health data are closely integrated with fire-mitigation measures, informing the characterization of fire hazards and the design of health-promoting intervention options.

The program implemented by the City of Boston supports local organizations in installing smoke alarms. Elevating the protection of vulnerable households to a public health priority reflects an explicit connection between fire risk and community-wide health. Vulnerable groups include older adults who face elevated morbidity and mortality risk from smoke exposure (Al-Hajj et al., 2022). Data on household characteristics and health status collected during the initial outreach phase support informed targeting of smoke-alarm installations.

Community-wide wildland-urban-interface fuels management in the San Francisco Bay Area targets the reduction of hazardous fuels from structures, landscaping, and vegetation to mitigate air quality impacts from wildland fires. Research demonstrates that airborne particles released during wildfires are linked to increases in respiratory hospital visits. In response to this association, the quantitative health-request-for-service database and a related analysis interrogate where hazardous-fuels conditions, air-quality impacts, and exposure-responsiveness equity converge (Bowman et al., 2018).

3. Threat Landscapes and Risk Assessment

Across the globe, fires threaten people's health and health systems. Smoke from wildfires, fire-suppressant chemicals, and even the fire itself can cause respiratory and other illnesses. These have economic, social, and health security consequences—not only for the individuals immediately affected but also for their families, communities, and local economies. Locations with higher pollution levels or limited access to health care have greater vulnerability to the health impacts associated with fires. Managing fire risk has become multifaceted, involving urban planning, social services, health-care architecture, and zoning, in order to delineate safety zones, specify building materials, manage land-use change, and protect population health.

Health-related fire hazards can be chemical—e.g., from the burning of plastics, chemicals, and flammable liquids; biological—e.g., from pathogens or toxins; and psychosocial—e.g., chaos, fear, and anxiety. Emerging global fire trajectories in several countries and major urban centers have introduced new hazards and vulnerability characteristics. Cross-sector collaboration between health, fire, and urban-planning services can yield joint science-based strategies for identifying hazardous chemicals in and around buildings, mapping hazardous networks and materials, and modelling vulnerability and hazard estimation (May Collins, 2018). Epidemiological and crowdsource data on infectious diseases, injuries, and deaths can be integrated with fire-outbreak information through machine-learning and big-data approaches to quantify fire-associated health impacts in real time, estimate the burden of disease and health system load, and spur timely on-demand intervention resources (M. Martin et al., 2011).

To conclude, integrating health security across the fire-prevention cycle shapes more proactive, equitable, and resilient systems (Anastasis Valiantis, 2003). Programmatic measures, readiness levels, level-of-effort requirements, data sources, and enabling technologies can inform scaling to diverse urban contexts.

3.1. Identifying Health-Related Fire Hazards

The fire-related health hazards can fall into three categories: chemical, biological, and psychosocial. Chemical risk factors include numerous elements like fire/smoke exposure and hazardous materials. Biological hazards include myriad pathogenic agents and toxigenic biological material. The psychosocial risk factors represent another enormous domain. They encompass not only psychological disorders/disease but also numerous stress-inducing factors (e.g., gender-based violence, community disorder) that may foster such psychological conditions as depression and anxiety. These multiple health risk factors may affect, directly as well as indirectly, the propensity of fire occurrence or the severity/impact of fire events. An array of national and international data sources can be leveraged in this analytical framework, such as national health surveys, census (demographic/household composition) data, health-related datasets from catastrophe (fires, flooding, hurricanes) events, hazard/pollution databases and uniform crime reports.

The fire hazard-landscape analysis that follows maps the prominent health–fire hazard associations that apply to diverse settings across the globe, thereby extending the insights of (DANZI et al., 2017) and (Glauberman & Qureshi, 2021). Further details on the ways in which health conditions, fire hazards, housing environment, and care infrastructure jointly affect overall vulnerability and resilience appear within Section 5.2 “Vulnerability and Resilience Modeling,” which cross-references this section.

3.2. Vulnerability and Resilience Modeling

Wildfires threaten numerous communities across the western United States and internationally, elevating the risk of damaging urban conflagrations, significant property loss, and high casualty rates. Health security influences fire mitigation strategies where direct health impacts from fires and smoke, including immediate and chronic morbidity, mortality, and mental health disruptions, substantially burden health-care capacity and resources (Mahmoud & Chulawat, 2018). Efforts to limit fire size, frequency, and spread can significantly reduce these health risks and are further motivated by equity concerns, as vulnerable populations are frequently located in fire-prone areas and face heightened wildfire risk, and fire safety infrastructure and services are often inequitable (Modaresi Rad et al., 2023).

Vulnerability and resilience frameworks systematically examine the interactions between health hazards and the built environment, identifying concordant fire risks and protecting both health and fire outcomes (Jimenez Alonso et al., 2015). Vulnerability to fire hinges on the character of a fire incident, the pre-existing health status of the exposed population, and the degree of exposure. Accessibility and accessibility of health and emergency services impact resilience by shaping timely responses to fires and mitigating adverse health effects, loss of life, and related damages through early detection, treatment, and action.

4. Preventive Frameworks and Policies

Preventive frameworks and policies aim to reduce fire incidents, injuries, and deaths. Smoke-alarm installation combined with fire-safety education and community involvement has increased safety-behaviour adoption. Environmental modifications and home visits by public-health professionals, community partners, and firefighters have shown positive effects on safety and behaviour change, especially among vulnerable populations. Education and environmental interventions are cost-effective and relevant for Indigenous communities, as evidenced by a study in New Zealand that showed reduced injury hospitalisation rates. Existing fire-safety laws and regulations, such as mandatory smoke-alarm installation, have led to significant reductions in fire incidents, injuries, and mortality in countries like Germany and Australia. Some legislation, such as fire-safe-clothing laws in New Zealand, decreased child injuries, but others, like the fire-safe-cigarette law, showed limited or null effects. Fire interventions that involve community engagement, discussions, simulations, and hands-on training are also part of preventive strategies (Al-Hajj et al., 2022).

Emergency preparedness programs should bring together health departments with health systems to clarify community needs both daily and during emergencies. Dedicated staff should focus on routine work to improve health and equity, building readiness for disasters. Public-health leaders must renew efforts to earn community trust, counter misinformation, and strengthen partnerships with community organizations through increased funding and transparency. Connecting preparedness to core public-health capacities is essential; without them, efforts are ineffective. Modern data systems enable timely understanding of threats, helping responses adapt quickly. Improving workforce diversity, communication, and community partnerships increases trust. Public-health agencies should collaborate across sectors to address root causes of health inequity, making communities more resilient to emergencies. Local agencies should engage with schools, police, and housing authorities to use data for innovative solutions to longstanding problems, reducing vulnerability to health threats (M. SHARFSTEIN & LURIE, 2023).

4.1. Integrating Health Security into Fire Codes

To enhance the coherence and clarity of fire prevention strategies, urban fire codes can explicitly incorporate health security elements through cross-referenced standards. These fire codes, prepared by national and international technical organizations in collaboration with fire departments, define technical criteria for fire safety and their implementation. By systematically introducing principles of health security and emphasizing alignment across codes, a wide array of standards—from structural and non-structural measures to evacuation policies—can be integrated without fundamentally altering policy frameworks or requiring extensive stakeholder engagement (Glauberma & Qureshi, 2021).

Fire-risk hazards at the health–fire nexus include biological, chemical, and psychosocial stressors, all of which increase the likelihood of fires and complicate prevention and mitigation efforts. To identify hazards and evaluate preventive actions, regions can conduct public-health–risk assessments in tandem with systematic urban-fire–risk assessments. Such assessments draw on diverse datasets tracking issues as wide-ranging as disease outbreaks, vector influxes, and hospital admissions to monitor the emergence of health-related fire hazards. Models gauging vulnerability, resilience, and exposure during different scenarios rely on indicators of health status, housing conditions, and access to care that provide critical insights for policy and program design to strengthen fire-prevention frameworks.

4.2. Non-Structural and Structural Interventions

In the context of housing design, zoning ordinances may enhance occupant health and determine the scale of residential building fires. While fire departments typically assess risk through the lens of circumstances and materials involved, local health departments collect and manage extensive data on the health status of neighbourhoods, individuals, and communities, which can shed light on underlying vulnerabilities that exacerbate fire hazards. The mapping of expectancy duration, residential surveys, and indicators of egress capacity can reveal egress-related vulnerabilities (Al-Hajj et al., 2022).

The built environment affects aerosol dispersion and exposure concentration during fire events. Ventilation restrictions in naturally ventilated dwellings may increase exposure concentrations and health impacts from smoke and fire-related chemical exposure during such events (Al-Hajj et al., 2023). After establishing a clear understanding of fire development and occupant vulnerability, specific approaches may be identified to enhance occupant health and safety. Community/public health nurses may contribute to fire risk assessments by participating in multifactorial exploration of residential design features that may impede occupant mobility, sensory awareness, and cognitive capacity during a fire emergency (Glauberma & Qureshi, 2021).

5. Public Health Preparedness and Emergency Response

Surveillance rapidly informs fire-related actions. Data-sharing mechanisms between health and fire services enable timely detection of unusual health indicators signaling heightened fire risk (Singh Bedi et al., 2021). Well-characterized fire hazards inform preventive measures. Chemical exposure from hazardous materials, biological events like anthrax, and psychosocial conditions—such as the connections between living arrangements, mental health, and occupancy—are critical considerations. Extensive data frameworks support hazard identification. Reducing fire risk during evacuation necessitates planning for medical surge, shelter, and transit needs. Analysis of health-system surge capacity helps estimate the number of additional occupants that facilities can accommodate, guiding evacuation strategies. Transport networks, temporal dynamics, and jurisdictional boundaries shape both evacuation flows and shelter placement, determining potential concurrent demands. Up-to-date shelter-location information is vital. Precise, risk-based evacuation strategies are particularly valuable when conventional fire codes do not meet alternative-construction-performance standards. With COVID-19 underscoring the significance of messaging, effective communication during a fire involves conveying risk, establishing trust, and ensuring cultural appropriateness.

5.1. Surveillance and Early Warning Systems

Timely detection of elevated health-related fire risk and the communication of warnings are critical for reducing adverse outcomes. Health surveillance systems can contribute to these functions by providing information on factors such as the emergence of burn injuries, respiratory infection spikes, airborne chemical levels, and severe weather, which in turn influence the risk of health-threatening fires. Public health and fire services share a common mandate to protect, and twinning their systems can improve performance.

Recent years have witnessed an alarming rise in the number of forest fires occurring worldwide and in the burden of respiratory diseases associated with inhalation of smoke. As these phenomena intensify due to climate change and increased wildfire activity, increasing attention is being directed to their effects on public health. Yet, even in urban settings, many of these infections remain poorly understood and underreported. Municipalities need to support their health departments in the establishment of prompt disease notification systems that serve as early warning indicators for increased disease risk, as the timely disclosure of any abrupt rise in burn injuries and

respiratory diseases—especially in younger patients and low-income housing clusters, who are usually the most affected—enables fire departments to initiate precautionary measures to reduce further health damages.

5.2. Medical Surge Capacity and Evacuation Planning

During catastrophic fires, public health facilities can experience extensive damage, operational interruption, and overwhelming demand. To ensure timely and safe evacuation and continued operations for healthcare services, hospitals and clinics increasingly prepare dedicated evacuation plans that outline scenarios, on-site resources, daily operations, and institutional collaboration (Goniewicz et al., 2020).

Addressing medical surge capacity comprises identifying metropolitan indicators and thresholds that trigger shelter-in-place or evacuation strategies, planning how to rapidly establish temporary healthcare facilities, checking sufficient disposable supply stocks, confirming security for closed facilities, and periodically training on evacuation procedures. Recent pandemics provide lessons on health-protection messaging regarding mask, distance, and hygiene, critical pre-evacuation advisories that protect shelters from smoke and contagion, and scientifically sound promotion of vaccine and post-exposure prophylaxis regimens (D. Kirsch et al., 2017).

5.3. Communication and Community Engagement

Effective risk communication focuses on guiding individuals' understandings of the threats and practices necessary to prevent fire-related hazards, while fostering trust among the community and authorities. During crisis, rapid dissemination of accurate and useful information enable individuals to appropriately and effectively react to protect themselves. Community engagement can strengthen fire safety efforts by working collaboratively on shared issues and maintaining open dialogue with community members on informal decisions that shape official plans. Community-driven discussions and initiatives are more culturally appropriate, facilitating co-development of actions tied to local experiences and needs. Facilitating practical discussions on specific community issues lays the foundation for engaging with broader field.

Risk communication approaches are more effective in preventing and limiting further dissemination of the fire-related information. Conducting focus groups enables the authority to specifically diagnose existing understanding and coverage of fire risk and prevention framework of the community.

6. Technologies and Innovations

Fire-related health burdens derive from both direct injuries and smoke inhalation; the latter accounts for over 80% of global deaths across the socioeconomic spectrum. Contaminants entering buildings increase exposure even during indoor fires. Disparate pre-fire health conditions dramatically shape outcomes, with obstruction in access to services hindering response options and amplifying risk. Fires regularly overwhelm medical systems, exacerbating pre-existing health intricacies. Forward-thinking cities gather both fire risk and health impact intelligence to guide reduction efforts.

Health security principles fundamentally reshape, expand, and elevate fire prevention policy and practice across diverse urban settings, especially for marginalized populations. Health security encompasses proactive strategies to prevent, detect, and mitigate biological, chemical, and radionuclear threats—ranging from epidemics to hazardous chemicals—to safeguard individual health (B. Dalton, 2017). Fire prevention emphasizes proactive measures to reduce ignition, fuel, and rapid-fire spread, along with emergency response. These two security domains converge post-ignition and pre-extinguishment. By facilitating actionable information that guides proactivity and resource allocation, health security tools sharpen the impact and integration of fire prevention efforts.

6.1. Early Detection and Monitoring Tools

Air quality sensors, smart smoke and chemical detectors, and public health monitoring systems advance early detection and support cross-sector collaboration between health and fire emergency response services.

Fire incidents release harmful fire effluents and particulate matter into the built environment and the surrounding air. Early fire detection systems that are coupled with air quality sensors can prompt the activation of appropriate extinguishing systems (Stikova et al., 2010). Improvements in the design of smoke and chemical detection systems that include input from health service agencies and air quality data enhance the performance of these systems.

Beyond the immediate physical danger posed by fires, they are also health hazards that can compromise human and community well-being (R. Cameron et al., 2020). Collecting real-time information on injury patterns and health-related effects from both fire incidents and smoke exposure aids equipment design, contributes data to fire planning models, and influences health-oriented fire prevention action.

6.2. Smart Infrastructure and Building Design

In the drive to promote health security principles in fire safety, researchers and practitioners increasingly recognize that building and infrastructure design shape occupant exposure to harmful conditions. Incorporating health criteria into the design process—such as emissions from materials, building circulation patterns, and proximity to ambulance services—has become commonplace in the broader context of smart cities and healthy buildings (Askaripoor et al., 2016). Such criteria directly influence fire-related risk factors, including the likelihood of a building fire, the severity of smoke exposure for residents, and the capacity of the health system to accommodate extra demand. Integrating health considerations across zoning, building codes, and land-use regulations could therefore mitigate fire risk while advancing objectives for climate change, active transport, and public health. Enhancing the links between health security and fire prevention can support broader implementation of fire-related guidance in public health.

6.3. Personal Protective Measures and Medical Readiness

Protective clothing and equipment standards, first-aid capacity in public shelters, fire-related health education programs, and fire-fighter medical surveillance demonstrate a commitment to safeguarding public health before, during, and after fire events (Institute for Occupational Safety and Health, 1970).

Individuals exposed to hazardous materials during fire-fighter duties, and residents at risk from smoke, chemicals, and evacuation, represent two distinct groups requiring preventive health measures.

7. Cross-Sector Collaboration

Collaborative approaches yield better outcomes across complementary fields like fire safety and health security (Zhu et al., 2019). Public health, fire services, and urban planning interact with health sector data to inform more targeted mitigation strategies. The private sector also contributes through voluntary national standards and local corporate responsibility efforts (Allen et al., 2022).

7.1. Public Health, Fire Services, and Urban Planning

Public health intersects with fire safety through both formal and informal governance mechanisms involving fire services and urban planning. Health surveillance of fire-related injuries, illness, and conditions enables proactive prevention action. Health-related data are used to assess fire-related vulnerability and resilience across urban areas. Health insights guide the development of building codes supporting indoor containment and reducing the overall fire risk. These principles are illustrated through zoning decisions that mitigate the secondary health impacts of smoke exposure (Glaubergerman & Qureshi, 2021).

Both fire services and urban planning play crucial roles in public health—an often-overlooked dimension of collaborative efforts at the intersection of health security and fire prevention. The health system bears a dual burden: supporting fire prevention, preparedness, and response while safeguarding vulnerable urban populations from the associated secondary effects of fire hazards (F. Ceñido et al., 2019). The organizational structure of the fire service often leverages public health expertise to evaluate community risks and formulate appropriate protective measures.

7.2. Private Sector Roles and Community Partners

Many private-sector roles can bolster community fire prevention efforts. Residential smoke detectors made by participating manufacturers and distributed through the Community Action Program in Flagstaff, Arizona, complement the installation of dual-carbon indoor detectors by the Fire Department. Insurance companies offer loss prevention inspections and grant incentives to encourage implementation of local fire-safety standards and initiatives. Scheduling state-responsible timber sales under Arizona's Forest Improvement Program promotes landowners' compliance with state and local fire-control regulations. Such steps do not violate the anti-industry provision of the state constitution because the state acts in the public interest. Advice from numerous stakeholders contributes to loss prevention statewide (Flagstaff Forests Partnership & Fire Advisory Council, 2004).

8. Economic and Social Considerations

Contemporary prevention strategies must center on economic and social considerations, which remain critical to the successful realization of health security approaches to fire risk mitigation. Cost and access factors pervade the prevention planning landscape; therefore, cost-effectiveness analyses sensitive to health outcomes and broader fire risk reduction benefits are essential to garnering support for proposed interventions (Al-Hajj et al., 2022). Equity considerations also merit special attention in the design and deployment of fire prevention measures. The absence of a cohesive health security strategy results in ongoing inequities in access to the protective infrastructure and preventive services necessary to break the fire-health cycle.

8.1. Cost-Benefit of Health-Driven Fire Prevention

The effectiveness of smoke alarms in preventing fires and associated injuries hinges on their proper installation and maintenance (Al-Hajj et al., 2022). Providing public mechanical ventilation systems remains relatively uncommon. While many building codes mandate substantial egress provisions for alternative escaping routes, the psychological need for a ‘versatile escape route’—a secondary avenue of egress that occupants employ repetitively, leading them toward the exits through familiar neighbouring rooms—has remained underexplored. Safety codes addressing health and built environments must also consider shared spaces, anchoring exit-door propensity toward the individual’s own compartment (Taylor et al., 1970).

8.2. Equity and Access in Protective Infrastructure

Preventive strategies for safeguarding lives and properties from damaging fires must address equity in access to protective infrastructure. African American and Hispanic populations—especially the elderly and low-income households—face a greater risk of death and property damage from residential fires. Societal disturbances such as demonstrations against racial inequality and justice elsewhere in the United States during the summer of 2020 underscored the inequities experienced by these groups. Equity in access to preventive services is also paramount for communities exposed to the growing wildfire threat. Recent Southern California studies identify decreasing property values in previously fire-affected areas and highlight some communities of color, low-income, and elderly populations’ disproportionate burden. Vulnerability considerations surrounding fire protection and emergency evacuation thus need to embrace broader socioeconomic dimensions and distributional impacts (Pollack et al., 2024).

Disparate access to mitigation resources and adaptive capacity under extreme weather constrain even outreach efforts to engage underrepresented communities. California wildfires and resulting emergency power shutoffs during 2014–2022 further showcase the societal configurations at stake. Denial of prerequisites such as running water and the lingering impact of historical redlining artificially exacerbate the inequitable distribution of access to relevant infrastructure. Enhanced cross-area collaboration—across both public organizations and private businesses—can earmark investments directed toward vulnerable segments and facilitate proactive dialogue and capacity-building preparation in event of an emergency. Addressing such socioeconomic considerations in fire protection planning constitutes an integral element for equitable allocation of protective investments and property safeguards against wildfire-induced threats (Jennings et al., 2021).

9. Evaluation and Accountability

Reinforcing the connection between health security and fire prevention involves a commitment to evaluation and learning. While fire services typically measure smoke alarm and detector installation rates to gauge effectiveness, the approach carries limitations. Successful systems map a comprehensive range of fire and health outcomes onto the performance of both health security and fire prevention measures; metrics reinforce the case for joint action (Al-Hajj et al., 2023).

Comprehensive approaches permit quantification of both fire and health impacts through indicators tracking prevalence of sleeping with lit cigarettes, fire-damaged housing units, visits for smoke inhalation, and respiratory emergency department presentations. Joint preventive measures—such as maintaining installed smoke detectors, targeting high-risk populations, and conducting thorough home safety checks—further align the two sectors (Taylor et al., 1970). Feedback loops for policy reform ensure that fire codes, plans, and training adapt in response to changing hazards, vulnerabilities, and contemporary knowledge.

9.1. Metrics for Success

The assessment of fire prevention strategies can be based on injuries and deaths sustained in fire incidents (Taylor et al., 1970) ; on the perceived ability of individuals to carry out their daily activities; and on the alleviation of pain and psychological distress caused by fire incidents. Evaluation of effectiveness is typically performed through a pre- and post-intervention comparison of incident rates. This assessment often lacks consideration of socio-economic circumstances and does not employ control groups to improve the clarity of the results. When multiple strategies are undertaken, determining the effect of any particular strategy is especially difficult. Cost-effectiveness analyses should also be performed to ensure that the greatest benefit is obtained from investment of fixed public agency budgets. Follow-up evaluations of performance by fire and rescue agencies can examine both service delivery outcomes and the financial sustainability of operations (Al-Hajj et al., 2023). Consequently, efficient targeting of resources towards groups at elevated risk, such as the aged, disabled, and those with greater internal and external fire hazards, can enhance community safety. Greater understanding of fire risk perception helps formulate appropriate educational strategies, and enhanced clarity of whether fire incidents of any kind are expected or unexpected assists in refining communication efforts. Measurement of the performance of service delivery in fire prevention remains challenging and invites continued investigation. Prioritisation of fire prevention strategy requires careful analysis, incorporation of central issues, and exploration of a range of fire and risk variables.

9.2. Policy Reform and Institutional Learning

Despite the existence of building codes, land-use planning, regulations for premises and equipment, and public alerts, fires continue to threaten public health in urban centers worldwide. The degree of risk varies critically across neighborhoods, and the disruptions caused by wildfires raise the possibility of emergencies within emergencies. Yet, lessons from New Zealand's Port Hills fires demonstrate that institutional learning remains a major challenge—even when fires occur regularly, well-documented concerns are not addressed, and changes to fire management systems are recommended (L. Montgomery, 2018). The persistence of common themes and ongoing reliance on unlearned lessons highlight widespread gaps in translating insights into practice. Similarly, investigations into wildfire risk reduction in the United States indicate that crucial normative aspects, such as the management of risk, remain poorly codified in state-level policies and rules (Anastasis Valiantis, 2003). These experiences underscore the importance of mechanisms to update urban-fire codes and related plans, procedures, and training whenever significant fires expose new relevant hazards, vulnerabilities, or opportunities for prevention.

Systematic processes can facilitate the identification of emergent safety or health issues, the consideration of associated responses, and the integration of learning across different scales into policies, legislation, and institutional arrangements. Such processes have previously guided improvements to hazard-management and flood-control policies, flood-management regimes, and the promotion of urban-integrated development in response to major flooding in Bangladesh, Canada, and Queensland, respectively. Similar approaches for coordinating and updating fire-management codes, plans, and practices would enhance resilience against health-related fire threats.

10. Conclusion

The integration of health security principles reshapes fire prevention toward proactive, equitable, and resilient systems. The innovation required involves simpler approaches, applicable in diverse urban contexts, that better characterize hazards and vulnerabilities related to health. Cross-cutting policy frameworks, supported by more systematic coordination of technical assistance and community engagement, enhance implementation. Enhanced pre-post surveillance can quantify health security interventions that mitigate fire risks.

References:

- [1] Taylor, M. J., Appleton, D., Keen, G., & Fielding, J. (1970). Assessing the effectiveness of fire prevention strategies. [PDF]
- [2] Al-Hajj, S., Desapriya, E., Pawliuk, C., Garis, L., & Pike, I. (2022). Interventions for Preventing Residential Fires in Vulnerable Neighbourhoods and Indigenous Communities: A Systematic Review of the Literature. ncbi.nlm.nih.gov
- [3] R. Campbell, J. (2011). Human Health Threats and Implications for Regional Security in Southeast Asia. ncbi.nlm.nih.gov
- [4] Kostova, D., Richter, P., Van Vliet, G., Mahar, M., & L. Moolenaar, R. (2021). The Role of Noncommunicable Diseases in the Pursuit of Global Health Security. ncbi.nlm.nih.gov
- [5] Kumar Chattu, V. & Kevany, S. (2019). The need for health diplomacy in health security operations. ncbi.nlm.nih.gov
- [6] Wenham, C. (2019). The oversecuritization of global health: changing the terms of debate. [PDF]
- [7] McCoy, D., Roberts, S., Daoudi, S., & Kennedy, J. (2023). Global health security and the health-security nexus: principles, politics and praxis. ncbi.nlm.nih.gov
- [8] Liu, J., Pereira, G., Uhl, S., Bravo, M., & Bell, M. (2015). A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. [PDF]
- [9] Bowman, D. M. J. S., Daniels, L. D., Johnston, F. H., Williamson, G. J., Jolly, W. M., Magzamen, S., Rappold, A. G., Brauer, M., & Henderson, S. B. (2018). Can air quality management drive sustainable fuels management at the temperate wildland-urban interface?. [PDF]
- [10] May Collins, K. (2018). Fire prevention treatments to mitigate wildfire risk. [PDF]
- [11] M. Martin, I., E. Martin, W., & B. Raish, C. (2011). A Qualitative and Quantitative Analysis of Risk Perception and Treatment Options as Related to Wildfires in the USDA FS Region 3 National Forests. [PDF]
- [12] Anastasis Valiantis, M. (2003). Influences on state-level policies for wildfire risk reduction. [PDF]
- [13] DANZI, E. N. R. I. C. O., MARMO, L. U. C. A., & Luca, F. (2017). A parametric fire risk assessment method supporting performance based approaches application to health-care facilities in northern Italy. [PDF]
- [14] Glauberman, G. & Qureshi, K. (2021). Community/Public Health Nurses' Awareness of Residential High-Rise Fire Safety issues. ncbi.nlm.nih.gov
- [15] Mahmoud, H. & Chulahwat, A. (2018). Unraveling the Complexity of Wildland Urban Interface Fires. ncbi.nlm.nih.gov
- [16] Modaresi Rad, A., T. Abatzoglou, J., Fleishman, E., H. Mockrin, M., C. Radeloff, V., Pourmohamad, Y., Cattau, M., Michael Johnson, J., Higuera, P., J. Nauslar, N., & Sadegh, M. (2023). Social vulnerability of the people exposed to wildfires in U.S. West Coast states. ncbi.nlm.nih.gov
- [17] Jimenez Alonso, W., Joseph James McCormick, B., A. Miller, M., Schuck-Paim, C., & R. Asrar, G. (2015). Beyond crystal balls: crosscutting solutions in global health to prepare for an unpredictable future. ncbi.nlm.nih.gov
- [18] M. SHARFSTEIN, J. O. S. H. U. A. & LURIE, N. I. C. O. L. E. (2023). Public Health Emergency Preparedness After COVID-19. ncbi.nlm.nih.gov

- [19] Al-Hajj, S., Thomas, L., Morris, S., Clare, J., Jennings, C., Biantoro, C., Garis, L., & Pike, I. (2023). Community Fire Risk Reduction: Longitudinal Assessment for HomeSafe Fire Prevention Program in Canada. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [20] Singh Bedi, J., Vijay, D., Dhaka, P., Paul Singh Gill, J., & B. Barbuddhe, S. (2021). Emergency preparedness for public health threats, surveillance, modelling & forecasting. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [21] Goniewicz, K., Misztal-Okońska, P., Pawłowski, W., M. Burkle, F., Czerski, R., J. Hertelendy, A., & Goniewicz, M. (2020). Evacuation from Healthcare Facilities in Poland: Legal Preparedness and Preparation. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [22] D. Kirsch, T., Schlegelmilch, J., Strauss-Riggs, K., E. Chandler, T., & E. Redlener, I. (2017). Regions Respond to Catastrophes. [PDF]
- [23] B. Dalton, C. (2017). Enablers of innovation in digital public health surveillance: lessons from Flutracking. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [24] Stikova, E., Gjorgjev, D., & Karadzovski, Z. (2010). Strengthening the Early-Warning Function of the Surveillance System: The Macedonian Experience. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [25] R. Cameron, A., Meyer, A., Faverjon, C., & Mackenzie, C. (2020). Quantification of the sensitivity of early detection surveillance. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [26] Askaripoor, T., Shirali, G. A., Yarahmadi, R., & Kazemi, E. (2016). The Role of the Implementation of National Building Regulations in the Fire Safety Improvement of Industrial Structures. [PDF]
- [27] Institute for Occupational Safety and Health, N. (1970). Preventing firefighter fatalities due to heart attacks and other sudden cardiovascular events. [PDF]
- [28] Zhu, X., Weigel, P., Baloh, J., Nataliansyah, M., Gunn, N., & Mueller, K. (2019). Mobilising cross-sector collaborations to improve population health in US rural communities: a qualitative study. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [29] Allen, P., Walsh-Bailey, C., Hunleth, J., J. Carothers, B., & C. Brownson, R. (2022). Facilitators of Multisector Collaboration for Delivering Cancer Control Interventions in Rural Communities: A Descriptive Qualitative Study. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [30] F. Ceñido, J., Freeman, C., & Bazargan-Hejazi, S. (2019). Environmental Interventions for Physical and Mental Health: Challenges and Opportunities for Greater Los Angeles. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [31] Flagstaff Forests Partnership, G. & Fire Advisory Council, P. (2004). Community wildfire protection plan for Flagstaff and surrounding communities in the Coconino and Kaibab National Forests of Coconino County, Arizona. [PDF]
- [32] Pollack, M., Piansky, R., Gupta, S., Kody, A., & Molzahn, D. (2024). Equitably allocating wildfire resilience investments for power grids: The curse of aggregation and vulnerability indices. [PDF]
- [33] Jennings, V., E. Reid, C., & H. Fuller, C. (2021). Green infrastructure can limit but not solve air pollution injustice. [ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov)
- [34] L. Montgomery, R. (2018). The Port Hills fire and the rhetoric of lessons learned. [PDF]