AIVC TN68: Technical Briefing on Residential Ventilation & Health Implications

Executive Summary

AIVC Technical Note 68 (TN68) provides a comprehensive synthesis of the evidence linking residential ventilation, indoor air quality (IAQ), and occupant health. It identifies key indoor pollutants, quantifies their relative health impacts using a 'harm-based' methodology (DALYs), and evaluates control strategies, emphasising ventilation's crucial role.

Key findings highlight the significant health burden posed by pollutants like PM2.5 and Radon, demonstrating that current ventilation standards and practices may not always be sufficient to achieve health-based targets. TN68 advocates for performance-based approaches, integrating source control and effective ventilation, to guide building performance regulations, public health policy, and professional practice towards creating healthier indoor environments.

This briefing summarises the core technical findings and policy-relevant conclusions of TN68.

Introduction & Context

- **Source:** AIVC Technical Note 68 (TN68), published February 2016 by the Air Infiltration and Ventilation Centre (AIVC), the IEA's Energy in Buildings and Communities Programme (EBC) information centre on energy-efficient ventilation.
- **Purpose:** To review and synthesise the scientific evidence concerning **residential ventilation** practices and their impact on occupant health via changes in **indoor air quality (IAQ)**.
- **Scope:** Focuses on residential buildings, common indoor air pollutants, associated health outcomes, **pollutant prioritisation** methodologies, and the effectiveness of control strategies, particularly ventilation.
- **Authorship:** Developed through international expert collaboration, edited by W. Borsboom (TNO), W. De Gids (VentGuide), J. Logue & M. Sherman (LBNL), and P. Wargocki (DTU).
- **Relevance:** Provides foundational knowledge for policymakers, building professionals (designers, engineers, installers), researchers, and public health officials involved in **building performance** standards, housing policy, and health protection.

The Residential Indoor Air Quality (IAQ) Challenge

- **Significance:** Indoor air can be significantly more polluted than outdoor air, particularly in energy-efficient, airtight homes where **pollutant mitigation** via natural air exchange is reduced. As people spend the majority of their time indoors, residential IAQ is a major determinant of overall pollutant exposure and associated **health impacts**.
- **Key Pollutants Covered in TN68:** The note reviews a wide range of chemical and biological contaminants commonly found in homes, including:
  - *Particulate Matter (PM2.5):* From combustion (cooking, smoking, heating), outdoor air penetration.
  - *Radon:* Naturally occurring radioactive gas entering from soil; levels vary geographically (significant in Ireland).
  - *Volatile Organic Compounds (VOCs):* e.g., Formaldehyde (building materials, furniture), Benzene (attached garages, ETS), Acrolein (cooking), Naphthalene (moth repellents).
  - *Nitrogen Dioxide (NO2):* Primarily from unvented gas appliances (stoves, heaters), outdoor sources.
  - *Carbon Monoxide (CO):* From incomplete combustion.
  - *Environmental Tobacco Smoke (ETS):* A Complex mixture from smoking.
  - *Ozone (O3):* Primarily from outdoor air, some indoor sources (e.g., office equipment - less common in homes).
  - *Biological Contaminants:* Mould/dampness indicators, allergens (dust mites, pets).
- **Sources:** Pollutants originate from both:
  - *Indoor Sources:* Building materials, furnishings, consumer products, combustion appliances, occupant activities (cooking, cleaning, smoking, breathing), biological growth (mould).
  - *Outdoor Sources:* Penetration of ambient air pollution (PM2.5, NO2, O3), soil gas intrusion (Radon).
- **Concentration Levels:** TN68 summarises studies showing that indoor concentrations of many key pollutants frequently exceed health-based guidelines or outdoor levels.

Health Impacts & Burden Assessment

- **Range of Effects:** Exposure to common indoor pollutants is linked to a wide spectrum of adverse **health impacts**:
  - *Respiratory:* Asthma development/exacerbation, allergies, respiratory infections (pneumonia, bronchitis), Chronic Obstructive Pulmonary Disease (COPD), lung cancer (Radon, ETS, PM2.5).
  - *Cardiovascular:* Ischemic heart disease, congestive heart failure (linked strongly to PM2.5).
  - *Neurological:* Headaches, fatigue, potential developmental effects (some VOCs, lead).
  - *Cancer:* Lung cancer (Radon, ETS, PM2.5, Formaldehyde, Benzene).
  - *Other:* Irritation (eyes, nose, throat), odours, impacts on sleep quality and cognitive function (emerging research).
- **Quantifying Health Burden:** TN68 utilises the concept of Disability-Adjusted Life Years (DALYs) – a measure combining years of life lost due to premature mortality and years lived with disability. This allows for:
  - Comparing the overall population health burden across different pollutants.
  - Quantifying the potential health benefits (DALYs averted) of interventions like improved ventilation or source control.
  - Providing a basis for cost-benefit analysis of different **IAQ** improvement strategies.

Pollutant Prioritisation: The Harm-Based Approach

- **Rationale:** Not all pollutants contribute equally to the overall health burden from poor IAQ. A 'harm-based approach', central to TN68, prioritises mitigation efforts by focusing on pollutants causing the greatest health damage (highest DALYs).
- **Methodology:** Combines:
  - *Exposure Assessment:* Measured or modelled indoor concentrations of pollutants.
  - *Health Impact Assessment:* Dose-response functions linking exposure levels to specific health outcomes, quantified in DALYs per unit exposure or concentration.
- **Key Prioritization Findings (TN68 Summary):** While results vary by region, housing stock, and assumptions, common findings include:
  - **PM2.5:** Frequently identified as a major contributor to the indoor air health burden due to strong links with cardiovascular and respiratory mortality/morbidity. Both

indoor (cooking, smoking) and outdoor sources penetrating indoors are significant.
    - **Radon:** A leading cause of lung cancer (second only to smoking). Its contribution is highly dependent on local geology and building characteristics. Crucial in Radon-prone areas.
    - **Formaldehyde:** Classified as a human carcinogen, often contributes significantly to the DALY burden, primarily from building materials and furnishings.
    - **Other Significant Contributors:** Depending on the study/location, pollutants like Acrolein (respiratory irritant from cooking), Benzene (carcinogen), NO2 (respiratory effects), and dampness/mould indicators also rank highly.
- **Policy Relevance:** This approach moves beyond simple compliance with concentration limits (which may not correlate directly with overall harm) towards strategies demonstrably reducing the *total health burden* from indoor air pollution. It enables targeted and potentially more cost-effective interventions.

Control Strategies for Healthier Indoor Air

TN68 emphasises a combined approach to manage indoor pollutants effectively:

- **Source Control:** Preventing or reducing pollutant emissions at the source. Often the most effective first step.
    - *Examples:* Selecting low-emission building materials and furnishings (VOCs, Formaldehyde), prohibiting smoking indoors (ETS), using electric instead of gas cooking appliances (NO2, CO, PM2.5), proper maintenance of combustion appliances, Radon mitigation systems (sub-slab depressurisation), managing moisture to prevent mould.
    - *Policy Levers:* Material/product standards, building codes mandating source control measures (e.g., Radon barriers), public awareness campaigns.
- **Ventilation:** Diluting and removing indoor pollutants by exchanging indoor air with outdoor air. Essential for pollutants that cannot be easily controlled at source or have outdoor origins.
    - *Types:*
        - *Natural Ventilation:* Relies on pressure differences (wind, temperature) via openings (windows, vents). Performance is variable and weather-dependent.
        - *Mechanical Extract Ventilation (MEV):* Fans extract air from specific areas

(kitchens, bathrooms). Common, but effectiveness depends on system design and adequate air inlets.
        - *Hybrid Extract Ventilation (HEV):* Fans that can operate naturally or mechanically depending on weather, extract air from wet areas (kitchen, bathrooms). Effectiveness depends on system design and adequate air inlets.
        - *Mechanical Supply Ventilation:* Fans supply filtered outdoor air, often to living areas/bedrooms.
        - *Balanced Mechanical Ventilation with Heat Recovery (MVHR):* Supplies and extracts air at equal rates, often with heat exchange to save energy. Provides controlled ventilation rates but requires proper design, installation, commissioning, and maintenance.
    - *Effectiveness: Depends critically on the actual airflow rate achieved relative to indoor volume and pollutant generation rates. Higher ventilation generally reduces concentrations but has energy implications. TN68 highlights that simply meeting minimum code ventilation rates may not be sufficient to address health risks from specific pollutants like PM2.5 or Radon in some situations.*
- **Air Cleaning:** Using devices to remove pollutants from indoor air.
    - *Particle Filtration: Effective for removing PM2.5 (e.g., high-efficiency filters in HVAC systems or portable air cleaners). Efficiency rated by MERV (US) or ISO 16890 (Europe).*
    - *Gas-Phase Filtration: Uses sorbents (e.g., activated carbon) to remove specific VOCs or ozone. Effectiveness varies by pollutant and filter type/capacity.*
    - *Role: Generally considered supplementary to source control and ventilation, particularly useful for targeting specific pollutants (e.g., PM2.5) or for occupants with sensitivities.*

Ventilation Standards & Performance Metrics

- **Traditional Approach:** Many **ventilation standards** have historically been prescriptive (specifying fixed airflow rates based on floor area or occupancy) or focused primarily on odour/moisture control and perceived air quality, rather than explicit health outcomes.
- **Shift Towards Performance:** TN68 supports the move towards performance-based

ventilation standards, where ventilation rates are designed to achieve specific **IAQ** targets or health-based outcomes. This allows for flexibility in design, encourages innovation and facilitates the use of energy efficient systems.

- **Influence on Standards:** The harm-based approach and evidence synthesised in TN68 have influenced updates to key standards:
  - *ASHRAE 62.2 (US Residential Ventilation): Introduced pathways considering health-based metrics, moving beyond simple airflow requirements.*
  - *European Standards (e.g., EN 16798 series, EPBD): Increasing emphasis on IAQ and health alongside energy performance. The revised Energy Performance of Buildings Directive (EPBD) explicitly requires consideration of "optimal indoor environmental quality".*
- **Challenges:** Defining appropriate health-based performance targets, accounting for pollutant mixtures, and developing practical compliance verification methods remain ongoing challenges.

Key Findings & Recommendations Summary (from TN68)

- Indoor air pollution in residences poses a significant public health burden.
- PM2.5, Radon, and Formaldehyde are frequently identified as priority pollutants based on health harm (DALYs).
- Effective control requires a combination of source management and adequate ventilation.
- Existing minimum ventilation rates in standards may not suffice to protect against health risks from all key pollutants in all situations.
- Performance-based approaches, considering health impacts, are needed to optimize ventilation strategies and standards.
- Further research is needed on pollutant mixtures, specific ventilation system effectiveness in real-world conditions, and long-term **health impacts**.

Policy & Practice Implications

- **Building Codes & Regulations:** Need regular updates reflecting current **IAQ** science (e.g., TN68 findings). Consider incorporating performance-based pathways, requirements for source control (low-emission materials), specific **pollutant**

mitigation (Radon zones), and ensuring ventilation systems are properly installed, commissioned, and maintained.

- **Public Health:** Integrate **IAQ** into public health strategies and guidance. Raise awareness among homeowners and tenants about risks and solutions. Provide specific advice for vulnerable populations.
- **Professional Practice:** Enhance training for architects, engineers, builders, and installers on **IAQ** principles, ventilation system design/installation, and the health implications of their work. Emphasize commissioning and maintenance.
- **Product Standards & Labeling:** Strengthen standards for low-emitting materials and consumer products. Improve labeling for ventilation equipment and air cleaners regarding performance against key health-relevant pollutants.
- **Research & Development:** Continued investment needed to fill knowledge gaps identified in TN68 and translate research into practical guidance and innovative solutions.

Further Information

This briefing provides a high-level summary. For comprehensive details, refer to:

- AIVC Technical Note 68: Residential Ventilation and Health (February 2016)
- AIVC Ventilation Information Paper 43: Residential ventilation and health (July 2021) - *Official Summary*
- https://tn68-aivc.com/