



- **News**
- **Evaluating Different Financing Packages for Mobile Home HVAC**
Evaluating Different Financing Packages for Mobile Home HVAC **Budgeting Monthly Payments for Mobile Home Heating Projects** **Reviewing Interest Options for Mobile Home AC Installations** **Setting Up Installment Plans for Mobile Home Furnace Upgrades** **Comparing Credit Requirements for Mobile Home HVAC Financing** **Investigating No Payment Period Deals for Mobile Home Cooling** **Combining Rebates with Financing for Mobile Home AC Purchases** **Checking Eligibility for Income Based Mobile Home HVAC Loans** **Aligning Payment Strategies with Seasonal Needs in Mobile Home Heating** **Exploring Collaboration with Utility Incentive Programs for Mobile Homes** **Scheduling Payments for Large Scale Mobile Home HVAC Replacements** **Simplifying Approval Steps for Mobile Home HVAC Financing**
- **Exploring Major Brands for Mobile Home Furnace Installations**
Exploring Major Brands for Mobile Home Furnace Installations **Aligning System Specifications with Mobile Home AC Requirements** **Evaluating Carrier Options for Mobile Home Air Conditioning** **Navigating Trane Models for Mobile Home Heating** **Selecting Goodman Units for Reliable Mobile Home Climate Control** **Verifying Rheem Specifications in Mobile Home HVAC Retrofits** **Identifying Compatible Parts Across Multiple Mobile Home Brands** **Adapting Different Brand Coils and Compressors for Mobile Home Use** **Maintaining Uniform Performance with Mixed Brand Components** **Comparing Equipment Sizes to Mobile Home Square Footage** **Assessing Future Upgrade Paths for Mobile Home AC Brand Choices** **Checking Warranties Offered by Various Mobile Home HVAC Brands**
- **About Us**



Exploring Collaboration with Utility Incentive Programs for Mobile Homes

Overview of HVAC needs specific to mobile homes

Exploring collaboration with utility incentive programs for mobile homes opens a promising avenue for enhancing energy efficiency and reducing costs for residents. Mobile homes, often overlooked in energy efficiency discussions, face unique challenges due to their construction and typically lower insulation standards. However, they also present significant opportunities for improvement through targeted interventions supported by utility incentive programs.

Utility incentive programs are designed to encourage energy conservation by providing financial assistance or rebates to consumers who invest in energy-efficient appliances or home improvements. These programs benefit utilities by helping manage demand and delay the need for costly infrastructure upgrades, while consumers enjoy lower energy bills and improved comfort.

Properly sealed ductwork prevents energy loss in mobile home HVAC systems **mobile home hvac systems prices** wall.

For mobile home residents, participating in these programs can be transformative. Many mobile homes were built before modern energy codes were established, making them inherently less efficient than traditional houses. Utility incentives can help offset the initial cost of upgrading insulation, replacing single-pane windows with double-glazed ones, or installing more efficient HVAC systems—all of which can significantly reduce energy consumption.

Collaboration is key to maximizing the impact of these programs on mobile homes. Utilities can partner with local governments and non-profit organizations to reach out to mobile home communities, educate residents about available incentives, and simplify the application process. Tailored outreach efforts ensure that residents are aware of the

benefits and how they can access them.

Moreover, collaboration can extend beyond just residential upgrades. Utilities might consider working with manufacturers to promote better building practices for new mobile homes or offering incentives that encourage builders to integrate renewable energy sources such as solar panels into their designs.

The benefits of such collaborations are manifold. For utilities, promoting energy efficiency helps stabilize the grid and reduces peak demand pressures. For residents of mobile homes—who often belong to low-income demographics—the savings from reduced utility bills can have a substantial impact on household finances while simultaneously improving living conditions through enhanced indoor air quality and temperature regulation.

In conclusion, exploring collaboration with utility incentive programs offers an effective strategy for advancing energy efficiency in mobile homes. By leveraging partnerships between utilities, government bodies, manufacturers, and community organizations, it's possible to create a more sustainable future that includes everyone—regardless of housing type—in its vision for a greener tomorrow. The potential savings on both an individual and systemic level underscore the importance of integrating these collaborative efforts into broader sustainability initiatives.

In today's rapidly evolving energy landscape, the partnership between mobile home owners and utility companies has emerged as a pivotal factor in addressing energy efficiency and sustainability challenges. This collaboration is particularly critical in the context of exploring utility incentive programs, which can significantly benefit mobile home communities. The importance of this synergy cannot be overstated, as it holds the potential to not only enhance living conditions but also promote environmental stewardship and economic savings.

Mobile homes, often characterized by their unique construction and placement, face distinct energy efficiency challenges compared to traditional housing. These challenges include less insulation, older appliances, and a general lack of access to modern energy-saving technologies. As a result, mobile home residents frequently encounter higher utility costs relative to their income levels. Utility companies, on the other hand, are continuously seeking ways to promote sustainability and reduce energy consumption across all sectors. By collaborating with mobile home owners through targeted incentive programs, these companies can address both environmental goals and consumer needs effectively.

Utility incentive programs designed for mobile homes typically focus on areas such as upgrading insulation, installing efficient heating and cooling systems, replacing outdated appliances with Energy Star-rated models, and incorporating renewable energy solutions. By participating in these programs, mobile home owners can significantly reduce their energy consumption and lower utility bills while simultaneously contributing to broader environmental goals such as reducing carbon footprints.

The benefits of collaboration extend beyond mere cost savings. For utility companies, engaging with mobile home communities presents an opportunity to expand their customer base for new technologies like smart meters or community solar projects. Moreover, these partnerships enable utilities to gather valuable data on energy usage patterns within this demographic segment, which can inform future program development and policy decisions.

For mobile home owners, working closely with utility companies not only provides immediate financial relief through rebates or subsidies but also fosters a sense of empowerment. Being active participants in choosing sustainable solutions cultivates a stronger sense of community ownership over environmental outcomes. Additionally, educational initiatives that often accompany these programs help residents understand how they can further optimize their energy usage independently.

However, successful collaboration requires overcoming certain barriers such as awareness gaps about available incentives or logistical challenges related to implementing upgrades in older units. Effective communication channels must be established between utilities and residents to ensure that information about available programs reaches those who need it most. Furthermore, tailored approaches that consider the specific needs and constraints of each community will enhance participation rates and overall program success.

In conclusion, fostering collaboration between mobile home owners and utility companies through well-designed incentive programs presents a win-win scenario for all parties involved. Such partnerships pave the way for increased energy efficiency within this crucial housing sector while supporting larger sustainability objectives at both local and national levels. By prioritizing communication and education alongside technical improvements, we can ensure that these collaborations yield long-lasting benefits for individuals and the environment alike.

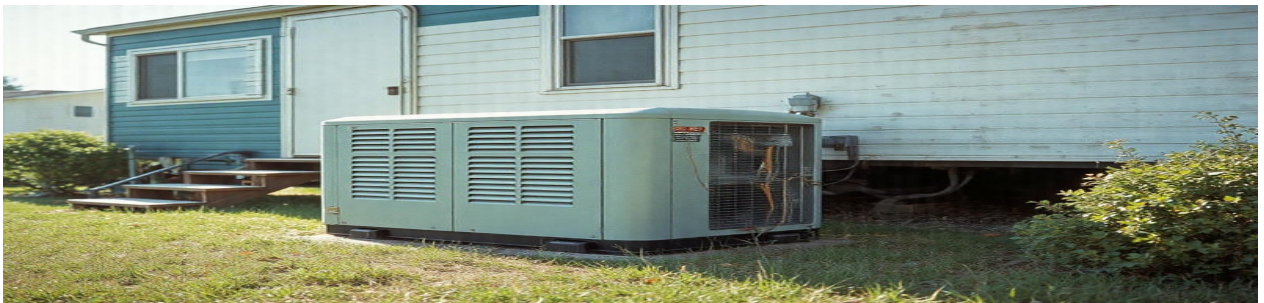
Affordable Payment Plans for Upgrading Mobile Home AC Systems



Choosing the right payment plan for upgrading your mobile home AC system is a crucial decision that can significantly impact your financial stability and comfort at home.. With numerous options available, it's essential to consider several factors to ensure you select a plan that aligns with your needs and budget. Firstly, assess your financial situation.

Posted by on 2024-12-30

Aligning Equipment Compatibility with Financing Options in Mobile Homes



In the dynamic world of mobile homes, aligning equipment compatibility with financing options is a crucial element that can significantly impact the success of any project.. The process involves ensuring that the equipment used in mobile home construction or renovation is not only technically suitable but also financially feasible.

Posted by on 2024-12-30

Benefits of Payment Plans Tailored for Mobile Home HVAC Upgrades



When contemplating upgrades to your mobile home's HVAC system, choosing the right payment plan is as crucial as selecting the equipment itself.. As energy efficiency and comfort become increasingly important, many homeowners are considering tailored payment plans that make these enhancements more accessible.

Posted by on 2024-12-30

Understanding Financing Options for Mobile Home HVAC

Exploring collaboration with utility incentive programs for mobile home communities presents an intriguing opportunity to improve energy efficiency and sustainability in a sector that often faces unique challenges. Mobile home residents frequently contend with higher energy costs due to less efficient construction and insulation compared to traditional homes. Thus, engaging these communities in incentive programs offered by utilities can be a mutually beneficial strategy, helping reduce energy consumption while easing financial burdens on residents.

To effectively engage mobile home communities in these incentive programs, it is essential to employ strategies tailored specifically to their needs and circumstances. One of the foundational elements is education. Many residents may not be aware of the available incentives or how they can benefit from them. Organizing community workshops or informational sessions can demystify the application process and highlight the potential savings on utility bills. These sessions could be facilitated by community leaders or representatives from utility companies who understand the intricacies of both mobile home living and energy programs.

Another critical strategy is fostering trust within the community. Mobile home residents might have reservations about participating in utility programs due to past experiences or perceived complexities. Establishing trust requires consistent communication and demonstrating tangible benefits through pilot projects or testimonials from fellow community members who have successfully participated in such programs.

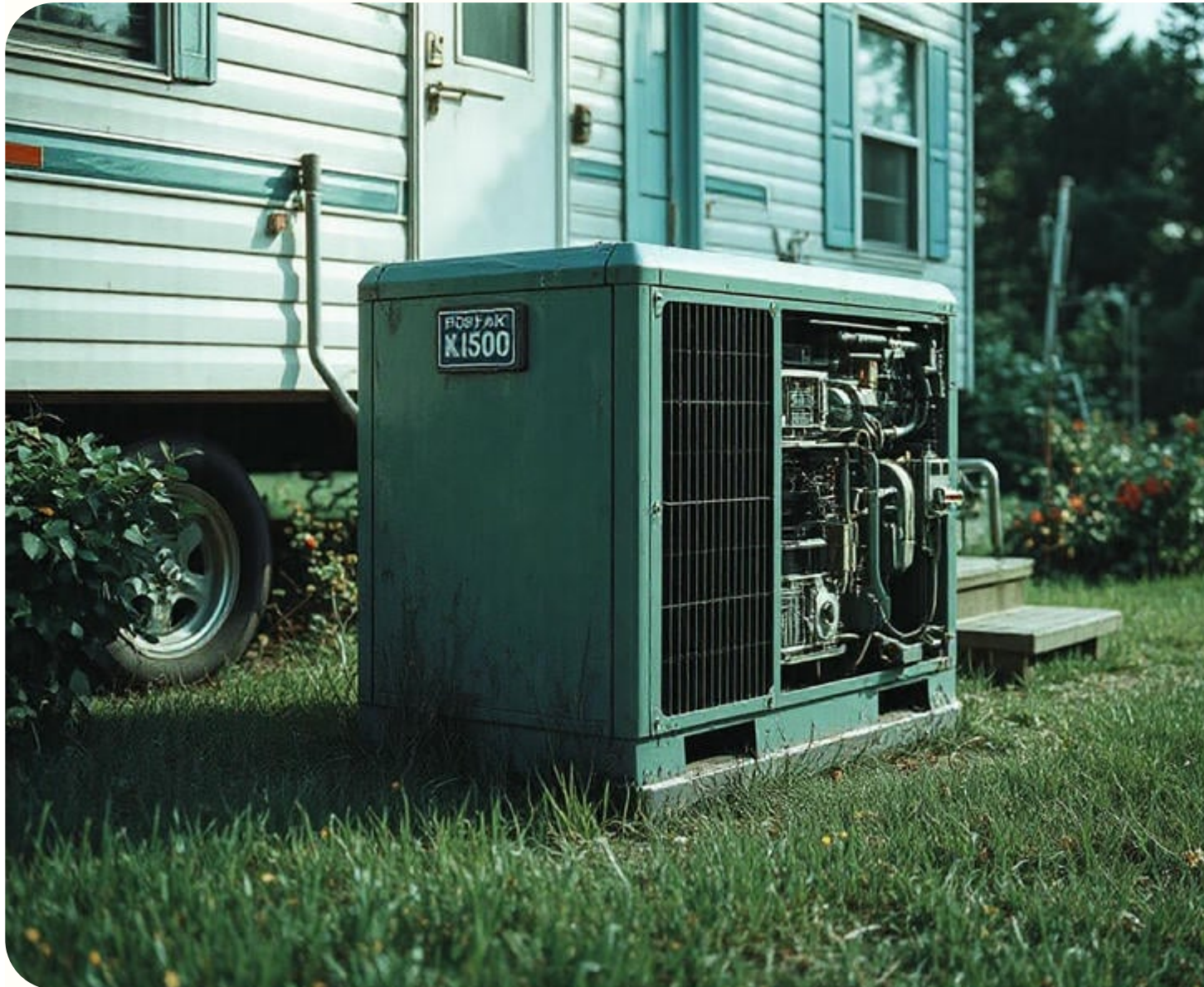
Partnerships play a significant role as well. Collaborating with local nonprofits, advocacy groups, and government agencies can bolster outreach efforts. These organizations might already have established relationships within mobile home communities and can act as intermediaries between residents and utility providers, ensuring that information is accurately conveyed and any concerns are addressed promptly.

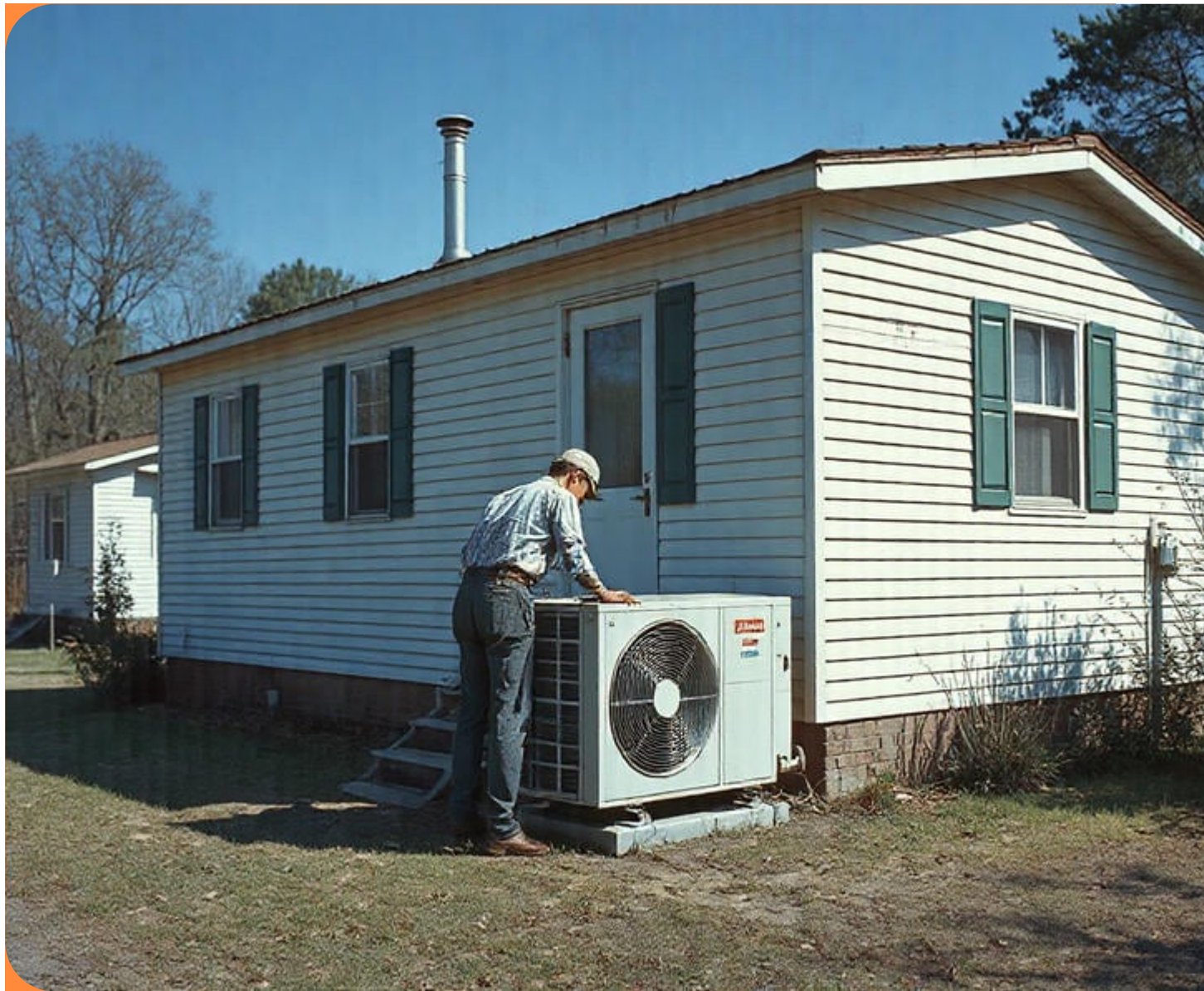
Moreover, tailoring incentive structures specifically for mobile homes can enhance participation rates. Utilities could consider offering rebates for upgrades that are particularly beneficial to mobile homes, such as improved skirting for better insulation or energy-efficient heating systems designed for smaller spaces. Simplifying rebate applications or providing upfront discounts rather than post-purchase reimbursements could also make these incentives more accessible.

Additionally, leveraging technology can streamline engagement efforts. Mobile apps or online platforms that allow residents to easily track their energy usage, apply for incentives, and receive personalized recommendations based on their specific needs could significantly increase participation rates.

Finally, recognizing the diversity within mobile home communities is crucial. These neighborhoods often consist of various demographics including seniors, low-income families, and immigrants who might face language barriers or other obstacles in accessing information about incentive programs. Tailored communication strategies that consider these diverse backgrounds will ensure inclusivity and maximize program reach.

In conclusion, exploring collaboration with utility incentive programs offers a promising pathway toward enhancing energy efficiency in mobile homes while supporting financially vulnerable populations. By focusing on education, building trust through partnerships, customizing incentives to meet specific needs, utilizing technology efficiently, and embracing diversity within these communities, stakeholders can create an environment where sustainable practices flourish alongside improved quality of life for residents.





Explanation of common financing packages available

Exploring the realm of utility incentive programs for mobile homes brings to light a tapestry of successful collaborations that not only enhance energy efficiency but also offer substantial economic benefits to homeowners. These case studies serve as a testament to how strategic partnerships can drive positive change in communities, particularly those residing in mobile

homes, who often face unique challenges regarding energy consumption and cost savings.

One exemplary case study involves the partnership between a local utility company and a nonprofit organization dedicated to improving living conditions in low-income areas. By focusing on mobile home parks, this collaboration aimed to reduce energy costs through comprehensive retrofitting programs. The project involved upgrading insulation, installing energy-efficient windows, and replacing outdated heating systems with modern, efficient alternatives. The result was a remarkable reduction in energy bills for residents, sometimes by as much as 30%. This not only relieved financial pressure on families but also contributed to environmental sustainability by lowering overall energy consumption.

Another notable example is the initiative taken by a state government working alongside utilities and manufacturers of mobile homes. This tripartite collaboration focused on integrating smart technology into new mobile home designs. By incorporating smart thermostats and LED lighting systems directly into the construction process, these homes were equipped with built-in mechanisms for reducing electricity usage from day one. Homeowners reported significant decreases in their monthly utility bills while enjoying enhanced comfort levels due to better temperature regulation throughout their living spaces.

Moreover, an inspiring story comes from an innovative program where utility companies offered rebates and incentives for mobile home owners who participated in educational workshops about energy conservation practices. These workshops empowered residents with knowledge about simple yet effective measures such as sealing air leaks or optimizing appliance usage patterns. In return for attending these sessions and implementing learned strategies, homeowners received financial incentives that further motivated them towards sustained behavioral changes.

Such case studies underscore the powerful impact that well-coordinated collaborations can have when leveraging utility incentives aimed at mobile homes. They illustrate how partnerships across various sectors-governmental bodies, nonprofits, private enterprises-can yield tangible benefits for individuals while fostering wider societal gains like reduced carbon footprints and heightened awareness around sustainable living practices.

In conclusion, exploring collaborations with utility incentive programs offers promising pathways towards creating more energy-efficient communities within mobile home settings. These successful case studies highlight not only the potential cost savings but also the broader implications of such initiatives: improved quality of life for residents coupled with meaningful contributions towards environmental stewardship-a win-win scenario made possible through collaborative effort and shared vision among stakeholders committed to

Key factors to consider when choosing a financing option

Exploring collaboration with utility incentive programs for mobile homes presents a significant opportunity to enhance energy efficiency and affordability for residents. However, potential barriers to participation often impede the seamless integration of mobile home communities into these beneficial programs. Identifying and addressing these barriers is crucial to ensuring that all residents can reap the benefits of reduced energy costs and improved living conditions.

One of the primary barriers is the lack of awareness among mobile home residents about available utility incentive programs. Many residents may not be informed about the existence of such programs or how they can benefit from them. This lack of awareness can stem from insufficient outreach efforts by utilities or a general disconnect between program administrators and mobile home communities. Overcoming this requires targeted communication strategies, including community meetings, informational flyers, and partnerships with local organizations that have established trust within these communities.

Financial constraints present another significant barrier. While incentives aim to reduce costs, initial investments are often required for improvements such as insulation upgrades or energy-efficient appliances. Many mobile home residents may live on fixed or low incomes, making it difficult for them to afford upfront expenses even if they are eventually reimbursed through incentives. Addressing this issue might involve offering no-cost initial assessments and providing financing options that allow costs to be spread out over time or integrated into utility bills.

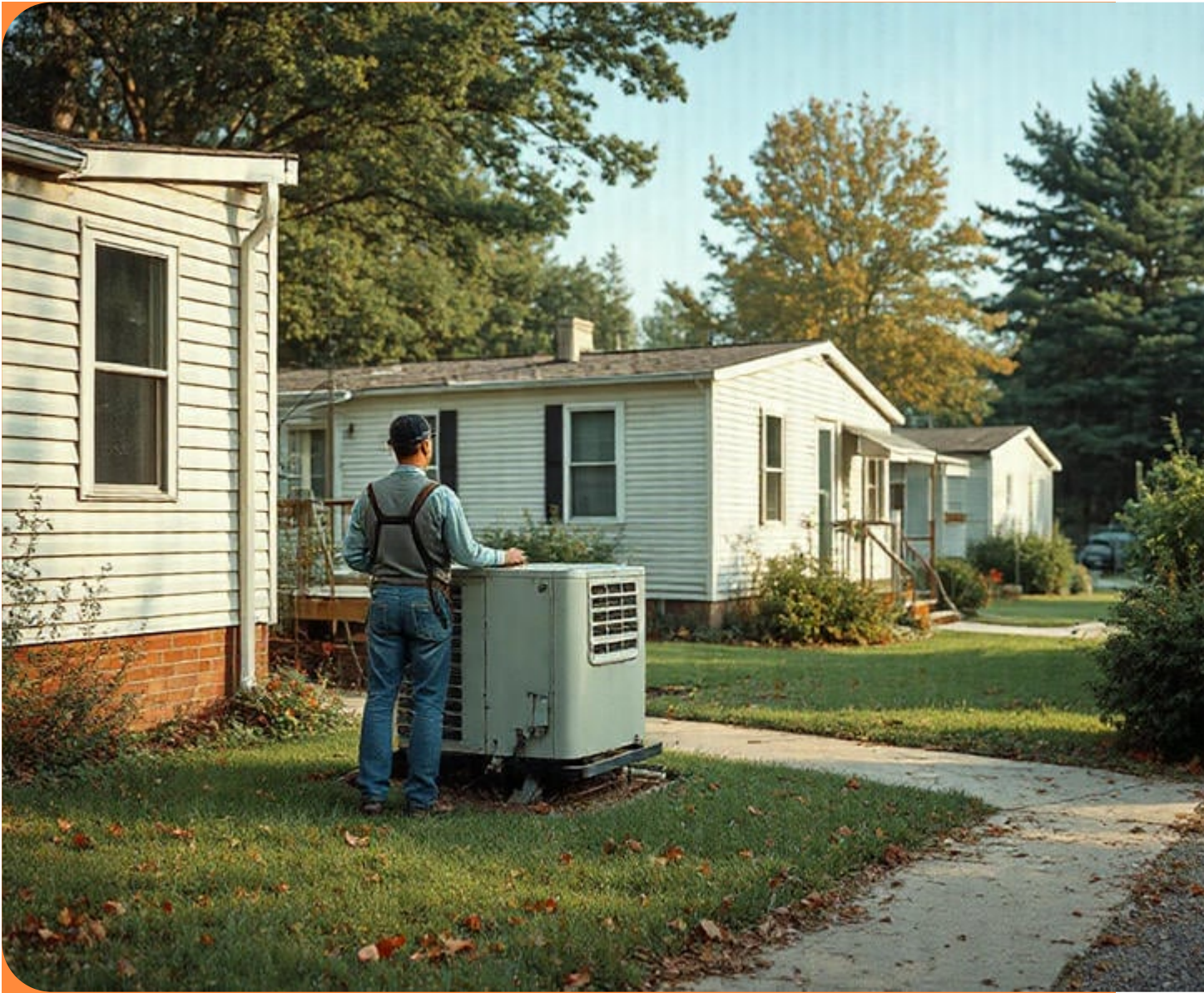
The physical nature of mobile homes themselves can also pose challenges. Older models may not be compatible with certain energy efficiency upgrades due to structural limitations. In some cases, implementing upgrades could require significant modifications that are costly or impractical. To overcome this barrier, utilities could offer specialized solutions tailored to older

mobile homes or provide technical assistance to identify feasible improvements.

Furthermore, regulatory hurdles can complicate participation in utility incentive programs for mobile home communities. Zoning laws and land ownership issues sometimes limit what changes can be made without extensive bureaucratic processes. Collaborating with local governments to streamline regulations and facilitate smoother implementation of energy-saving measures can be an effective strategy here.

Lastly, there is often a sense of mistrust towards utility companies among some residents due to past experiences or perceived inequities in service provision. Building trust is essential for successful collaboration; therefore, utilities should engage in transparent communication practices and demonstrate genuine commitment to improving conditions for mobile home residents. Establishing feedback loops where residents can voice concerns and suggest improvements will foster a more inclusive environment.

In conclusion, while potential barriers exist when exploring collaboration with utility incentive programs for mobile homes, they are not insurmountable. By increasing awareness through targeted outreach, providing financial assistance options, addressing physical limitations specific to mobile homes, simplifying regulatory processes, and building trust within communities, stakeholders can ensure broader participation in these valuable programs. Ultimately, overcoming these obstacles will lead to enhanced energy efficiency and economic benefits for one of society's most vulnerable demographics: those living in mobile homes.



Personal Loans for HVAC Systems

As we navigate the complexities of a rapidly changing energy landscape, the need for enhanced energy efficiency in mobile homes has never been more pressing. Mobile homes, often overlooked in traditional energy conservation strategies, present a unique opportunity for substantial improvements in energy consumption and cost savings. One promising avenue to explore is collaboration with utility incentive programs, which can play a pivotal role in advancing energy efficiency for these homes.

Historically, mobile homes have faced significant challenges concerning energy efficiency due to their construction characteristics and often limited access to resources. These homes typically possess less insulation compared to conventional houses and may rely on older heating and cooling systems that are not as efficient. This results in higher utility bills and increased environmental impact due to excessive energy use. However, by leveraging utility incentive programs, we can address these issues head-on.

Utility companies have recognized the importance of integrating mobile homes into their broader energy efficiency initiatives. These programs often provide financial incentives for homeowners to upgrade their appliances, improve insulation, or install more efficient HVAC systems. By partnering with utilities, stakeholders can ensure that mobile home residents have greater access to these benefits.

One future trend likely to gain traction is the customization of incentive programs specifically tailored for mobile home communities. Utilities could develop targeted campaigns that focus on common inefficiencies found within these dwellings, such as poor sealing around windows and doors or outdated water heaters. By offering rebates or financing options for specific improvements that align with the needs of mobile home residents, utilities can help reduce barriers associated with initial costs.

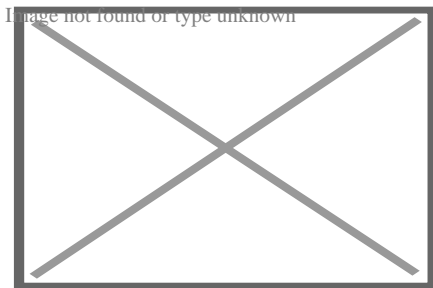
Another promising aspect is the potential integration of smart technologies through utility partnerships. Smart thermostats and advanced metering infrastructure can empower residents by giving them greater control over their energy usage while simultaneously allowing utilities to manage demand more effectively. By incentivizing the adoption of smart technology solutions within mobile homes, utility companies can foster an environment where both consumers and providers benefit from reduced peak loads and improved grid reliability.

Education will also play a crucial role in maximizing the effectiveness of these collaborations. Utility companies could partner with local organizations or community groups to offer workshops that educate mobile home residents about available programs and teach them how simple changes can lead to significant savings. By fostering a sense of community

engagement around energy efficiency efforts, utilities can ensure sustained participation from residents who see tangible benefits from program involvement.

In conclusion, exploring collaboration with utility incentive programs presents an exciting pathway toward achieving greater energy efficiency in mobile homes-an area ripe for improvement yet too often neglected. Through customized incentives focused on specific inefficiencies common among these residences along with educational outreach initiatives promoting awareness about available resources-utility companies stand poised at the forefront driving positive change within this sector thereby ensuring sustainable living conditions today while safeguarding our environment tomorrow.

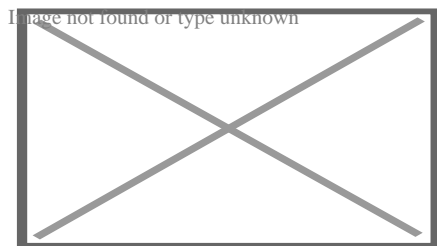
About Indoor air quality



An air filter being cleaned

- v
- t
- e

Part of a series on



Air pollution from a factory

Air

- Acid rain
- Air quality index
- Atmospheric dispersion modeling
- Chlorofluorocarbon
- Combustion
- Exhaust gas
- Haze
- Global dimming
- Global distillation
- Indoor air quality
- Non-exhaust emissions
- Ozone depletion
- Particulates
- Persistent organic pollutant
- Smog
- Soot
- Volatile organic compound

Biological

- Biological hazard
- Genetic
- Illegal logging
- Introduced species
 - Invasive species

Digital

- Information

Electromagnetic

- Light
 - Ecological
 - Overillumination
- Radio spectrum

Natural

- Ozone
- Radium and radon in the environment
- Volcanic ash
- Wildfire

Noise

- Transportation
- Health effects from noise
- Marine mammals and sonar
- Noise barrier
- Noise control
- Soundproofing

Radiation

- Actinides
- Bioremediation
- Depleted uranium
- Nuclear fission
- Nuclear fallout
- Plutonium
- Poisoning
- Radioactivity
- Uranium
- Radioactive waste

Soil

- Agricultural
- Land degradation
- Bioremediation
- Defecation
- Electrical resistance heating
- Illegal mining
- Soil guideline values
- Phytoremediation

Solid waste

- Advertising mail
- Biodegradable waste
- Brown waste
- Electronic waste
- Foam food container
- Food waste
- Green waste
- Hazardous waste
- Industrial waste
- Litter
- Mining
- Municipal solid waste
- Nanomaterials
- Plastic
- Packaging waste
- Post-consumer waste
- Waste management

Space

- Space debris

Thermal

- Urban heat island

Visual

- Air travel
- Advertising clutter
- Overhead power lines
- Traffic signs
- Urban blight
- Vandalism

War

- Chemical warfare
- Herbicidal warfare
 - Agent Orange
- Nuclear holocaust
 - Nuclear fallout
 - Nuclear famine
 - Nuclear winter
- Scorched earth
- Unexploded ordnance
- War and environmental law

Water

- Agricultural wastewater
- Biosolids
- Diseases
- Eutrophication
- Firewater
- Freshwater
- Groundwater
- Hypoxia
- Industrial wastewater
- Marine
- Monitoring
- Nonpoint source
- Nutrient
- Ocean acidification
- Oil spill
- Pharmaceuticals
- Freshwater salinization
- Septic tanks
- Sewage
- Shipping
- Sludge
- Stagnation
- Sulfur water
- Surface runoff
- Turbidity
- Urban runoff
- Water quality
- Wastewater

Topics

- History
- Pollutants
 - Heavy metals
 - Paint

Misc

- Area source
- Brain health and pollution
- Debris
- Dust
- Garbology
- Legacy
- Midden
- Point source
- Waste
 - Toxic

Lists

- Diseases
- Law by country
- Most polluted cities
- Least polluted cities by PM2.5
- Treaties
- Most polluted rivers

Categories

- By country

 [Environment portal](#)

 [Ecology portal](#)

Indoor air quality (IAQ) is the air quality within buildings and structures. Poor indoor air quality due to **indoor air pollution** is known to affect the health, comfort, and well-being of building occupants. It has also been linked to sick building syndrome, respiratory issues, reduced productivity, and impaired learning in schools. Common pollutants of indoor air include: secondhand tobacco smoke, air pollutants from indoor combustion, radon, molds and other allergens, carbon monoxide, volatile organic compounds, legionella and other bacteria, asbestos fibers, carbon dioxide,^[1] ozone and particulates.

Source control, filtration, and the use of ventilation to dilute contaminants are the primary methods for improving indoor air quality. Although ventilation is an integral component of maintaining good indoor air quality, it may not be satisfactory alone.^[2] In scenarios where outdoor pollution would deteriorate indoor air quality, other treatment devices such as filtration may also be necessary.^[3]

IAQ is evaluated through collection of air samples, monitoring human exposure to pollutants, analysis of building surfaces, and computer modeling of air flow inside buildings. IAQ is part of indoor environmental quality (IEQ), along with other factors that exert an influence on physical and psychological aspects of life indoors (e.g., lighting,

visual quality, acoustics, and thermal comfort).[4]

Indoor air pollution is a major health hazard in developing countries and is commonly referred to as "household air pollution" in that context.[5] It is mostly relating to cooking and heating methods by burning biomass fuel, in the form of wood, charcoal, dung, and crop residue, in indoor environments that lack proper ventilation. Millions of people, primarily women and children, face serious health risks. In total, about three billion people in developing countries are affected by this problem. The World Health Organization (WHO) estimates that cooking-related indoor air pollution causes 3.8 million annual deaths.[6] The Global Burden of Disease study estimated the number of deaths in 2017 at 1.6 million.[7]

Definition

[edit]

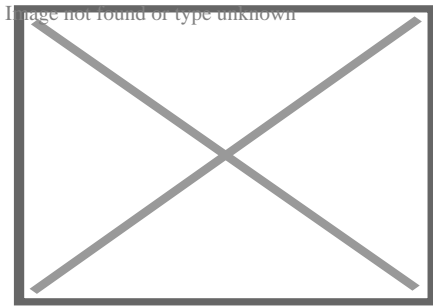
For health reasons it is crucial to breathe clean air, free from chemicals and toxicants as much as possible. It is estimated that humans spend approximately 90% of their lifetime indoors[8] and that indoor air pollution in some places can be much worse than that of the ambient air.[9][10]

Various factors contribute to high concentrations of pollutants indoors, ranging from influx of pollutants from external sources, off-gassing by furniture, furnishings including carpets, indoor activities (cooking, cleaning, painting, smoking, etc. in homes to using office equipment in offices), thermal comfort parameters such as temperature, humidity, airflow and physio-chemical properties of the indoor air.[citation needed] Air pollutants can enter a building in many ways, including through open doors or windows. Poorly maintained air conditioners/ventilation systems can harbor mold, bacteria, and other contaminants, which are then circulated throughout indoor spaces, contributing to respiratory problems and allergies.

There have been many debates among indoor air quality specialists about the proper definition of indoor air quality and specifically what constitutes "acceptable" indoor air quality.

Health effects

[edit]



Share of deaths from indoor air pollution. Darker colors mean higher numbers.

IAQ is significant for human health as humans spend a large proportion of their time in indoor environments. Americans and Europeans on average spend approximately 90% of their time indoors.^{[11][12]}

The World Health Organization (WHO) estimates that 3.2 million people die prematurely every year from illnesses attributed to indoor air pollution caused by indoor cooking, with over 237 thousand of these being children under 5. These include around an eighth of all global ischaemic heart disease, stroke, and lung cancer deaths. Overall the WHO estimated that poor indoor air quality resulted in the loss of 86 million healthy life years in 2019.^[13]

Studies in the UK and Europe show exposure to indoor air pollutants, chemicals and biological contamination can irritate the upper airway system, trigger or exacerbate asthma and other respiratory or cardiovascular conditions, and may even have carcinogenic effects.^{[14][15][16][17][18][19]}

Poor indoor air quality can cause sick building syndrome. Symptoms include burning of the eyes, scratchy throat, blocked nose, and headaches.^[20]

Common pollutants

[edit]

Generated by indoor combustion

[edit]

Main article: Household air pollution

Further information: Energy poverty and cooking

a 3-stone stove

Image not found or type unknown

A traditional wood-fired 3-stone stove in Guatemala, which causes indoor air pollution

Indoor combustion, such as for cooking or heating, is a major cause of indoor air pollution and causes significant health harms and premature deaths. Hydrocarbon fires cause air pollution. Pollution is caused by both biomass and fossil fuels of various types, but some forms of fuels are more harmful than others.

Indoor fire can produce black carbon particles, nitrogen oxides, sulfur oxides, and mercury compounds, among other emissions.^[21] Around 3 billion people cook over open fires or on rudimentary cook stoves. Cooking fuels are coal, wood, animal dung, and crop residues.^[22] IAQ is a particular concern in low and middle-income countries where such practices are common.^[23]

Cooking using natural gas (also called fossil gas, methane gas or simply gas) is associated with poorer indoor air quality. Combustion of gas produces nitrogen dioxide and carbon monoxide, and can lead to increased concentrations of nitrogen dioxide throughout the home environment which is linked to respiratory issues and diseases.^[24]^[25]

Carbon monoxide

[edit]

Main article: Carbon monoxide poisoning

One of the most acutely toxic indoor air contaminants is carbon monoxide (CO), a colourless and odourless gas that is a by-product of incomplete combustion. Carbon

monoxide may be emitted from tobacco smoke and generated from malfunctioning fuel burning stoves (wood, kerosene, natural gas, propane) and fuel burning heating systems (wood, oil, natural gas) and from blocked flues connected to these appliances.^[26] In developed countries the main sources of indoor CO emission come from cooking and heating devices that burn fossil fuels and are faulty, incorrectly installed or poorly maintained.^[27] Appliance malfunction may be due to faulty installation or lack of maintenance and proper use.^[26] In low- and middle-income countries the most common sources of CO in homes are burning biomass fuels and cigarette smoke.^[27]

Health effects of CO poisoning may be acute or chronic and can occur unintentionally or intentionally (self-harm). By depriving the brain of oxygen, acute exposure to carbon monoxide may have effects on the neurological system (headache, nausea, dizziness, alteration in consciousness and subjective weakness), the cardiovascular and respiratory systems (myocardial infarction, shortness of breath, or rapid breathing, respiratory failure). Acute exposure can also lead to long-term neurological effects such as cognitive and behavioural changes. Severe CO poisoning may lead to unconsciousness, coma and death. Chronic exposure to low concentrations of carbon monoxide may lead to lethargy, headaches, nausea, flu-like symptoms and neuropsychological and cardiovascular issues.^[28]^[26]

The WHO recommended levels of indoor CO exposure in 24 hours is 4 mg/m^3 .^[29] Acute exposure should not exceed 10 mg/m^3 in 8 hours, 35 mg/m^3 in one hour and 100 mg/m^3 in 15 minutes.^[27]

Secondhand tobacco smoke

[edit]

Main article: Passive smoking

Secondhand smoke is tobacco smoke which affects people other than the 'active' smoker. It is made up of the exhaled smoke (15%) and mostly of smoke coming from the burning end of the cigarette, known as sidestream smoke (85%).^[30]

Secondhand smoke contains more than 7000 chemicals, of which hundreds are harmful to health.^[30] Secondhand tobacco smoke includes both a gaseous and a particulate materials which, with particular hazards arising from levels of carbon monoxide and very small particulates (fine particulate matter, especially PM2.5 and PM10) which get into the bronchioles and alveoles in the lung.^[31] Inhaling secondhand smoke on multiple occasions can cause asthma, pneumonia, lung cancer, and sudden infant death syndrome, among other conditions.^[32]

Thirdhand smoke (THS) refers to chemicals that settle on objects and bodies indoors after smoking. Exposure to thirdhand smoke can happen even after the actual cigarette smoke is not present anymore and affect those entering the indoor environment much

later. Toxic substances of THS can react with other chemicals in the air and produce new toxic chemicals that are otherwise not present in cigarettes.[³³]

The only certain method to improve indoor air quality as regards secondhand smoke is to eliminate smoking indoors.[³⁴] Indoor e-cigarette use also increases home particulate matter concentrations.[³⁵]

Particulates

[edit]

Atmospheric particulate matter, also known as particulates, can be found indoors and can affect the health of occupants. Indoor particulate matter can come from different indoor sources or be created as secondary aerosols through indoor gas-to-particle reactions. They can also be outdoor particles that enter indoors. These indoor particles vary widely in size, ranging from nanomet (nanoparticles/ultrafine particles emitted from combustion sources) to micromet (resuspended dust).[³⁶] Particulate matter can also be produced through cooking activities. Frying produces higher concentrations than boiling or grilling and cooking meat produces higher concentrations than cooking vegetables.[³⁷] Preparing a Thanksgiving dinner can produce very high concentrations of particulate matter, exceeding 300 $\mu\text{g}/\text{m}^3$.[³⁸]

Particulates can penetrate deep into the lungs and brain from blood streams, causing health problems such as heart disease, lung disease, cancer and preterm birth.[³⁹]

Generated from building materials, furnishing and consumer products

[edit]

See also: Building materials and Red List building materials

Volatile organic compounds

[edit]

Volatile organic compounds (VOCs) include a variety of chemicals, some of which may have short- and long-term adverse health effects. There are numerous sources of VOCs indoors, which means that their concentrations are consistently higher indoors (up to ten times higher) than outdoors.[⁴⁰] Some VOCs are emitted directly indoors, and some are formed through the subsequent chemical reactions that can occur in the gas-phase, or on surfaces.[⁴¹][⁴²] VOCs presenting health hazards include benzene, formaldehyde, tetrachloroethylene and trichloroethylene.[⁴³]

VOCs are emitted by thousands of indoor products. Examples include: paints, varnishes, waxes and lacquers, paint strippers, cleaning and personal care products, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions.^[44] Chlorinated drinking water releases chloroform when hot water is used in the home. Benzene is emitted from fuel stored in attached garages.

Human activities such as cooking and cleaning can also emit VOCs.^[45]^[46] Cooking can release long-chain aldehydes and alkanes when oil is heated and terpenes can be released when spices are prepared and/or cooked.^[45] Leaks of natural gas from cooking appliances have been linked to elevated levels of VOCs including benzene in homes in the USA.^[47] Cleaning products contain a range of VOCs, including monoterpenes, sesquiterpenes, alcohols and esters. Once released into the air, VOCs can undergo reactions with ozone and hydroxyl radicals to produce other VOCs, such as formaldehyde.^[46]

Health effects include eye, nose, and throat irritation; headaches, loss of coordination, nausea; and damage to the liver, kidney, and central nervous system.^[48]

Testing emissions from building materials used indoors has become increasingly common for floor coverings, paints, and many other important indoor building materials and finishes.^[49] Indoor materials such as gypsum boards or carpet act as VOC 'sinks', by trapping VOC vapors for extended periods of time, and releasing them by outgassing. The VOCs can also undergo transformation at the surface through interaction with ozone.^[42] In both cases, these delayed emissions can result in chronic and low-level exposures to VOCs.^[50]

Several initiatives aim to reduce indoor air contamination by limiting VOC emissions from products. There are regulations in France and in Germany, and numerous voluntary ecolabels and rating systems containing low VOC emissions criteria such as EMICODE,^[51] M1,^[52] Blue Angel^[53] and Indoor Air Comfort^[54] in Europe, as well as California Standard CDPH Section 01350^[55] and several others in the US. Due to these initiatives an increasing number of low-emitting products became available to purchase.

At least 18 microbial VOCs (MVOCs) have been characterised^[56]^[57] including 1-octen-3-ol (mushroom alcohol), 3-Methylfuran, 2-pentanol, 2-hexanone, 2-heptanone, 3-octanone, 3-octanol, 2-octen-1-ol, 1-octene, 2-pentanone, 2-nonanone, borneol, geosmin, 1-butanol, 3-methyl-1-butanol, 3-methyl-2-butanol, and thujopsene. The last four are products of *Stachybotrys chartarum*, which has been linked with sick building syndrome.^[56]

Asbestos fibers

[edit]

Many common building materials used before 1975 contain asbestos, such as some floor tiles, ceiling tiles, shingles, fireproofing, heating systems, pipe wrap, taping muds, mastics, and other insulation materials. Normally, significant releases of asbestos fiber do not occur unless the building materials are disturbed, such as by cutting, sanding, drilling, or building remodelling. Removal of asbestos-containing materials is not always optimal because the fibers can be spread into the air during the removal process. A management program for intact asbestos-containing materials is often recommended instead.

When asbestos-containing material is damaged or disintegrates, microscopic fibers are dispersed into the air. Inhalation of asbestos fibers over long exposure times is associated with increased incidence of lung cancer, mesothelioma, and asbestosis. The risk of lung cancer from inhaling asbestos fibers is significantly greater for smokers. The symptoms of disease do not usually appear until about 20 to 30 years after the first exposure to asbestos.


Although all asbestos is hazardous, products that are friable, e.g. sprayed coatings and insulation, pose a significantly higher hazard as they are more likely to release fibers to the air.^[58]

Microplastics

[edit]

Main article: Microplastics

See also: Renovation and Particulates

 This section **needs expansion** with: E.g., [1]. You can help by adding to it. (*October 2024*)

Microplastic is a type of airborne particulates and is found to prevail in air.^{[59][60][61][62]} A 2017 study found indoor airborne microfiber concentrations between 1.0 and 60.0 microfibers per cubic meter (33% of which were found to be microplastics).^[63] Airborne microplastic dust can be produced during renovation, building, bridge and road reconstruction projects^[64] and the use of power tools.^[65]

Ozone

[edit]

See also: Ground-level ozone

Indoors ozone (O₃) is produced by certain high-voltage electric devices (such as air ionizers), and as a by-product of other types of pollution. It appears in lower

concentrations indoors than outdoors, usually at 0.2-0.7 of the outdoor concentration.^[66] Typically, most ozone is lost to surface reactions indoors, rather than to reactions in air, due to the large surface to volume ratios found indoors.^[67]

Outdoor air used for ventilation may have sufficient ozone to react with common indoor pollutants as well as skin oils and other common indoor air chemicals or surfaces. Particular concern is warranted when using "green" cleaning products based on citrus or terpene extracts, because these chemicals react very quickly with ozone to form toxic and irritating chemicals^[46] as well as fine and ultrafine particles.^[68] Ventilation with outdoor air containing elevated ozone concentrations may complicate remediation attempts.^[69]

The WHO standard for ozone concentration is 60 $\mu\text{g}/\text{m}^3$ for long-term exposure and 100 $\mu\text{g}/\text{m}^3$ as the maximum average over an 8-hour period.^[29] The EPA standard for ozone concentration is 0.07 ppm average over an 8-hour period.^[70]

Biological agents

[edit]

Mold and other allergens

[edit]

Main articles: Indoor mold and Mold health issues

Occupants in buildings can be exposed to fungal spores, cell fragments, or mycotoxins which can arise from a host of means, but there are two common classes: (a) excess moisture induced growth of mold colonies and (b) natural substances released into the air such as animal dander and plant pollen.^[71]

While mold growth is associated with high moisture levels,^[72] it is likely to grow when a combination of favorable conditions arises. As well as high moisture levels, these conditions include suitable temperatures, pH and nutrient sources.^[73] Mold grows primarily on surfaces, and it reproduces by releasing spores, which can travel and settle in different locations. When these spores experience appropriate conditions, they can germinate and lead to mycelium growth.^[74] Different mold species favor different environmental conditions to germinate and grow, some being more hydrophilic (growing at higher levels of relative humidity) and other more xerophilic (growing at levels of relative humidity as low as 75–80%).^{[74][75]}

Mold growth can be inhibited by keeping surfaces at conditions that are further from condensation, with relative humidity levels below 75%. This usually translates to a relative humidity of indoor air below 60%, in agreement with the guidelines for thermal comfort that recommend a relative humidity between 40 and 60 %. Moisture buildup in

buildings may arise from water penetrating areas of the building envelope or fabric, from plumbing leaks, rainwater or groundwater penetration, or from condensation due to improper ventilation, insufficient heating or poor thermal quality of the building envelope.^[76] Even something as simple as drying clothes indoors on radiators can increase the risk of mold growth, if the humidity produced is not able to escape the building via ventilation.^[77]

Mold predominantly affects the airways and lungs. Known effects of mold on health include asthma development and exacerbation,^[78] with children and elderly at greater risk of more severe health impacts.^[79] Infants in homes with mold have a much greater risk of developing asthma and allergic rhinitis.^[80]^[71] More than half of adult workers in moldy or humid buildings suffer from nasal or sinus symptoms due to mold exposure.^[71] Some varieties of mold contain toxic compounds (mycotoxins). However, exposure to hazardous levels of mycotoxin via inhalation is not possible in most cases, as toxins are produced by the fungal body and are not at significant levels in the released spores.

Legionella

[edit]



This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (September 2024) (Learn how and when to remove this message)

Legionnaires' disease is caused by a waterborne bacterium *Legionella* that grows best in slow-moving or still, warm water. The primary route of exposure is through the creation of an aerosol effect, most commonly from evaporative cooling towers or showerheads. A common source of *Legionella* in commercial buildings is from poorly placed or maintained evaporative cooling towers, which often release water in an aerosol which may enter nearby ventilation intakes. Outbreaks in medical facilities and nursing homes, where patients are immuno-suppressed and immuno-weak, are the most commonly reported cases of Legionellosis. More than one case has involved outdoor fountains at public attractions. The presence of *Legionella* in commercial building water supplies is highly under-reported, as healthy people require heavy exposure to acquire infection.

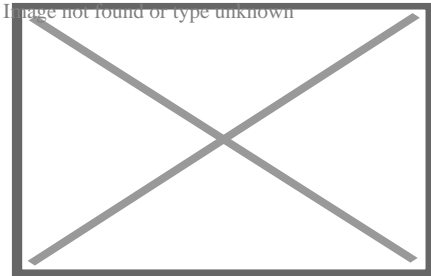
Legionella testing typically involves collecting water samples and surface swabs from evaporative cooling basins, shower heads, faucets/taps, and other locations where warm water collects. The samples are then cultured and colony forming units (cfu) of *Legionella* are quantified as cfu/liter.

Legionella is a parasite of protozoans such as amoeba, and thus requires conditions suitable for both organisms. The bacterium forms a biofilm which is resistant to chemical and antimicrobial treatments, including chlorine. Remediation for *Legionella* outbreaks in commercial buildings vary, but often include very hot water flushes (160 °F (71 °C)),

sterilisation of standing water in evaporative cooling basins, replacement of shower heads, and, in some cases, flushes of heavy metal salts. Preventive measures include adjusting normal hot water levels to allow for 120 °F (49 °C) at the tap, evaluating facility design layout, removing faucet aerators, and periodic testing in suspect areas.

Other bacteria

[edit]



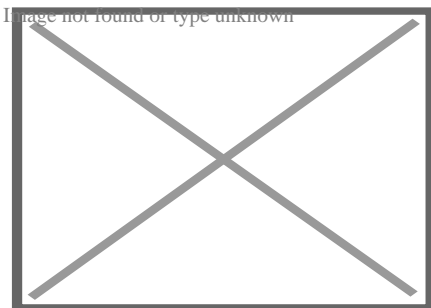
Airborne bacteria

There are many bacteria of health significance found in indoor air and on indoor surfaces. The role of microbes in the indoor environment is increasingly studied using modern gene-based analysis of environmental samples. Currently, efforts are under way to link microbial ecologists and indoor air scientists to forge new methods for analysis and to better interpret the results.^[81]

A large fraction of the bacteria found in indoor air and dust are shed from humans. Among the most important bacteria known to occur in indoor air are *Mycobacterium tuberculosis*, *Staphylococcus aureus*, *Streptococcus pneumoniae*.^[citation needed]

Virus

[edit]



Ninth floor layout of the Metropole Hotel in Hong Kong, showing where an outbreak of the severe acute respiratory syndrome (SARS) occurred

Viruses can also be a concern for indoor air quality. During the 2002–2004 SARS outbreak, virus-laden aerosols were found to have seeped into bathrooms from the bathroom floor drains, exacerbated by the draw of bathroom exhaust fans, resulting in the rapid spread of SARS in Amoy Gardens in Hong Kong.^{[82][83]} Elsewhere in Hong Kong, SARS CoV RNA was found on the carpet and in the air intake vents of the Metropole Hotel, which showed that secondary environmental contamination could generate infectious aerosols and resulted in superspreading events.^[84]

Carbon dioxide

[edit]

Humans are the main indoor source of carbon dioxide (CO₂) in most buildings. Indoor CO₂ levels are an indicator of the adequacy of outdoor air ventilation relative to indoor occupant density and metabolic activity.

Indoor CO₂ levels above 500 ppm can lead to higher blood pressure and heart rate, and increased peripheral blood circulation.^[85] With CO₂ concentrations above 1000 ppm cognitive performance might be affected, especially when doing complex tasks, making decision making and problem solving slower but not less accurate.^{[86][87]} However, evidence on the health effects of CO₂ at lower concentrations is conflicting and it is difficult to link CO₂ to health impacts at exposures below 5000 ppm – reported health outcomes may be due to the presence of human bioeffluents, and other indoor air pollutants related to inadequate ventilation.^[88]

Indoor carbon dioxide concentrations can be used to evaluate the quality of a room or a building's ventilation.^[89] To eliminate most complaints caused by CO₂, the total indoor CO₂ level should be reduced to a difference of no greater than 700 ppm above outdoor levels.^[90] The National Institute for Occupational Safety and Health (NIOSH) considers that indoor air concentrations of carbon dioxide that exceed 1000 ppm are a marker suggesting inadequate ventilation.^[91] The UK standards for schools say that carbon dioxide levels of 800 ppm or lower indicate that the room is well-ventilated.^[92]

Regulations and standards from around the world show that CO₂ levels below 1000 ppm represent good IAQ, between 1000 and 1500 ppm represent moderate IAQ and greater than 1500 ppm represent poor IAQ.^[88]

Carbon dioxide concentrations in closed or confined rooms can increase to 1,000 ppm within 45 minutes of enclosure. For example, in a 3.5-by-4-metre (11 ft × 13 ft) sized office, atmospheric carbon dioxide increased from 500 ppm to over 1,000 ppm within 45 minutes of ventilation cessation and closure of windows and doors.^[93]

Radon

[edit]

Main article: Radon

Radon is an invisible, radioactive atomic gas that results from the radioactive decay of radium, which may be found in rock formations beneath buildings or in certain building materials themselves.

Radon is probably the most pervasive serious hazard for indoor air in the United States and Europe. It is a major cause of lung cancer, responsible for 3–14% of cases in countries, leading to tens of thousands of deaths.^[94]

Radon gas enters buildings as a soil gas. As it is a heavy gas it will tend to accumulate at the lowest level. Radon may also be introduced into a building through drinking water particularly from bathroom showers. Building materials can be a rare source of radon, but little testing is carried out for stone, rock or tile products brought into building sites; radon accumulation is greatest for well insulated homes.^[95] There are simple do-it-yourself kits for radon gas testing, but a licensed professional can also check homes.

The half-life for radon is 3.8 days, indicating that once the source is removed, the hazard will be greatly reduced within a few weeks. Radon mitigation methods include sealing concrete slab floors, basement foundations, water drainage systems, or by increasing ventilation.^[96] They are usually cost effective and can greatly reduce or even eliminate the contamination and the associated health risks.^[citation needed]

Radon is measured in picocuries per liter of air (pCi/L) or becquerel per cubic meter (Bq m⁻³). Both are measurements of radioactivity. The World Health Organization (WHO) sets the ideal indoor radon levels at 100 Bq/m⁻³.^[97] In the United States, it is recommend to fix homes with radon levels at or above 4 pCi/L. At the same time it is also recommends that people think about fixing their homes for radon levels between 2 pCi/L and 4 pCi/L.^[98] In the United Kingdom the ideal is presence of radon indoors is 100 Bq/m⁻³. Action needs to be taken in homes with 200 Bq/m³ or more.^[99]

Interactive maps of radon affected areas are available for various regions and countries of the world.^{[100][101][102]}

IAQ and climate change

[edit]

See also: Effects of climate change on human health

Indoor air quality is linked inextricably to outdoor air quality. The Intergovernmental Panel on Climate Change (IPCC) has varying scenarios that predict how the climate will change in the future.^[103] Climate change can affect indoor air quality by increasing the level of outdoor air pollutants such as ozone and particulate matter, for example through emissions from wildfires caused by extreme heat and drought.^{[104][105]} Numerous predictions for how indoor air pollutants will change have been made.^{[106][107][108][109]}

and models have attempted to predict how the forecasted IPCC scenarios will vary indoor air quality and indoor comfort parameters such as humidity and temperature.^[110]

The net-zero challenge requires significant changes in the performance of both new and retrofitted buildings. However, increased energy efficient housing will trap pollutants inside, whether produced indoors or outdoors, and lead to an increase in human exposure.^{[111][112]}

Indoor air quality standards and monitoring

[edit]

Quality guidelines and standards

[edit]

For occupational exposure, there are standards, which cover a wide range of chemicals, and applied to healthy adults who are exposed over time at workplaces (usually industrial environments). These are published by organisations such as Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), the UK Health and Safety Executive (HSE).

There is no consensus globally about indoor air quality standards, or health-based guidelines. However, there are regulations from some individual countries and from health organisations. For example, the World Health Organization (WHO) has published health-based global air quality guidelines for the general population that are applicable both to outdoor and indoor air,^[29] as well as the WHO IAQ guidelines for selected compounds,^[113] whereas the UK Health Security Agency published IAQ guidelines for selected VOCs.^[114] The Scientific and Technical Committee (STC34) of the International Society of Indoor Air Quality and Climate (ISIAQ) created an open database that collects indoor environmental quality guidelines worldwide.^[115] The database is focused on indoor air quality (IAQ), but is currently extended to include standards, regulations, and guidelines related to ventilation, comfort, acoustics, and lighting.^{[116][117]}

Real-time monitoring

[edit]


Since indoor air pollutants can adversely affect human health, it is important to have real-time indoor air quality assessment/monitoring system that can help not only in the improvement of indoor air quality but also help in detection of leaks, spills in a work environment and boost energy efficiency of buildings by providing real-time feedback to the heating, ventilation, and air conditioning (HVAC) system(s).^[118] Additionally, there

have been enough studies that highlight the correlation between poor indoor air quality and loss of performance and productivity of workers in an office setting.^[119]

Combining the Internet of Things (IoT) technology with real-time IAQ monitoring systems has tremendously gained momentum and popularity as interventions can be done based on the real-time sensor data and thus help in the IAQ improvement.^[120]

Improvement measures

[edit]

 **This section needs expansion.** You can help by adding to it. *(November 2023)*

See also: Air purifier, Air conditioner, Air filter, Cleanroom, Particulates § Controlling technologies and measures, Pollution control, and Ventilation (architecture)

Further information: Fan (machine), Dehumidifier, and Heater

Indoor air quality can be addressed, achieved or maintained during the design of new buildings or as mitigating measures in existing buildings. A hierarchy of measures has been proposed by the Institute of Air Quality Management. It emphasises removing pollutant sources, reducing emissions from any remaining sources, disrupting pathways between sources and the people exposed, protecting people from exposure to pollutants, and removing people from areas with poor air quality.^[121]

A report assisted by the Institute for Occupational Safety and Health of the German Social Accident Insurance can support in the systematic investigation of individual health problems arising at indoor workplaces, and in the identification of practical solutions.^[122]

Source control


[edit]

 **This section is empty.** You can help by adding to it. *(September 2024)*

HVAC design

[edit]

Main articles: HVAC, Air handler, and Ventilation (architecture)

 **This section needs additional citations for verification.** Please help improve **this article** by adding citations to reliable sources in this section. Unsourced material may be challenged and removed. *(November 2019)* *(Learn how and when to remove this message)*

Environmentally sustainable design concepts include aspects of commercial and residential heating, ventilation and air-conditioning (HVAC) technologies. Among several considerations, one of the topics attended to is the issue of indoor air quality throughout

the design and construction stages of a building's life.^[citation needed]

One technique to reduce energy consumption while maintaining adequate air quality, is demand-controlled ventilation. Instead of setting throughput at a fixed air replacement rate, carbon dioxide sensors are used to control the rate dynamically, based on the emissions of actual building occupants.^[citation needed]

One way of quantitatively ensuring the health of indoor air is by the frequency of effective turnover of interior air by replacement with outside air. In the UK, for example, classrooms are required to have 2.5 outdoor air changes per hour. In halls, gym, dining, and physiotherapy spaces, the ventilation should be sufficient to limit carbon dioxide to 1,500 ppm. In the US, ventilation in classrooms is based on the amount of outdoor air per occupant plus the amount of outdoor air per unit of floor area, not air changes per hour. Since carbon dioxide indoors comes from occupants and outdoor air, the adequacy of ventilation per occupant is indicated by the concentration indoors minus the concentration outdoors. The value of 615 ppm above the outdoor concentration indicates approximately 15 cubic feet per minute of outdoor air per adult occupant doing sedentary office work where outdoor air contains over 400 ppm^[123] (global average as of 2023). In classrooms, the requirements in the ASHRAE standard 62.1, Ventilation for Acceptable Indoor Air Quality, would typically result in about 3 air changes per hour, depending on the occupant density. As the occupants are not the only source of pollutants, outdoor air ventilation may need to be higher when unusual or strong sources of pollution exist indoors.

When outdoor air is polluted, bringing in more outdoor air can actually worsen the overall quality of the indoor air and exacerbate some occupant symptoms related to outdoor air pollution. Generally, outdoor country air is better than indoor city air.^[citation needed]

The use of air filters can trap some of the air pollutants. Portable room air cleaners with HEPA filters can be used if ventilation is poor or outside air has high level of PM 2.5.^[122] Air filters are used to reduce the amount of dust that reaches the wet coils.^[citation needed] Dust can serve as food to grow molds on the wet coils and ducts and can reduce the efficiency of the coils.^[citation needed]

The use of trickle vents on windows is also valuable to maintain constant ventilation. They can help prevent mold and allergen build up in the home or workplace. They can also reduce the spread of some respiratory infections.^[124]

Moisture management and humidity control requires operating HVAC systems as designed. Moisture management and humidity control may conflict with efforts to conserve energy. For example, moisture management and humidity control requires systems to be set to supply make-up air at lower temperatures (design levels), instead of the higher temperatures sometimes used to conserve energy in cooling-dominated climate conditions. However, for most of the US and many parts of Europe and Japan, during the majority of hours of the year, outdoor air temperatures are cool enough that

the air does not need further cooling to provide thermal comfort indoors.^[citation needed] However, high humidity outdoors creates the need for careful attention to humidity levels indoors. High humidity give rise to mold growth and moisture indoors is associated with a higher prevalence of occupant respiratory problems.^[citation needed]

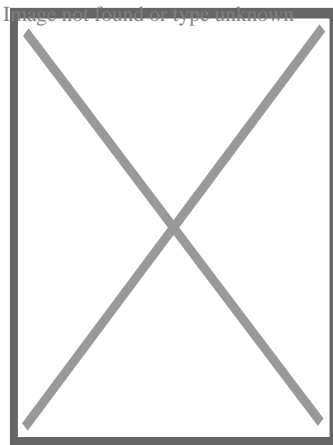
The "dew point temperature" is an absolute measure of the moisture in air. Some facilities are being designed with dew points in the lower 50s °F, and some in the upper and lower 40s °F.^[citation needed] Some facilities are being designed using desiccant wheels with gas-fired heaters to dry out the wheel enough to get the required dew points.^[citation needed] On those systems, after the moisture is removed from the make-up air, a cooling coil is used to lower the temperature to the desired level.^[citation needed]

Commercial buildings, and sometimes residential, are often kept under slightly positive air pressure relative to the outdoors to reduce infiltration. Limiting infiltration helps with moisture management and humidity control.

Dilution of indoor pollutants with outdoor air is effective to the extent that outdoor air is free of harmful pollutants. Ozone in outdoor air occurs indoors at reduced concentrations because ozone is highly reactive with many chemicals found indoors. The products of the reactions between ozone and many common indoor pollutants include organic compounds that may be more odorous, irritating, or toxic than those from which they are formed. These products of ozone chemistry include formaldehyde, higher molecular weight aldehydes, acidic aerosols, and fine and ultrafine particles, among others. The higher the outdoor ventilation rate, the higher the indoor ozone concentration and the more likely the reactions will occur, but even at low levels, the reactions will take place. This suggests that ozone should be removed from ventilation air, especially in areas where outdoor ozone levels are frequently high.

Effect of indoor plants

[edit]



Spider plants (*Chlorophytum comosum*) absorb some airborne contaminants.

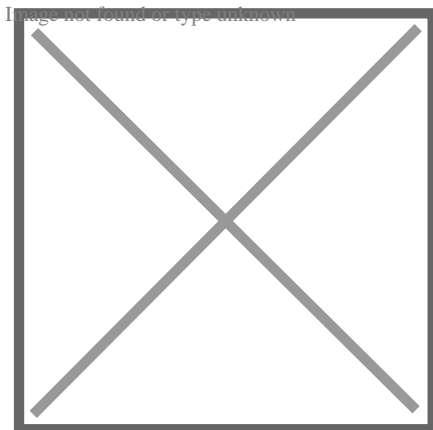
Houseplants together with the medium in which they are grown can reduce components of indoor air pollution, particularly volatile organic compounds (VOC) such as benzene, toluene, and xylene. Plants remove CO₂ and release oxygen and water, although the quantitative impact for house plants is small. The interest in using potted plants for removing VOCs was sparked by a 1989 NASA study conducted in sealed chambers designed to replicate the environment on space stations. However, these results suffered from poor replication^[125] and are not applicable to typical buildings, where outdoor-to-indoor air exchange already removes VOCs at a rate that could only be matched by the placement of 10–1000 plants/m² of a building's floor space.^[126]

Plants also appear to reduce airborne microbes and molds, and to increase humidity.^[127] However, the increased humidity can itself lead to increased levels of mold and even VOCs.^[128]

Since extremely high humidity is associated with increased mold growth, allergic responses, and respiratory responses, the presence of additional moisture from houseplants may not be desirable in all indoor settings if watering is done inappropriately.^[129]

Institutional programs

[edit]



EPA graphic about asthma triggers

The topic of IAQ has become popular due to the greater awareness of health problems caused by mold and triggers to asthma and allergies.

In the US, the Environmental Protection Agency (EPA) has developed an "IAQ Tools for Schools" program to help improve the indoor environmental conditions in educational institutions. The National Institute for Occupational Safety and Health conducts Health Hazard Evaluations (HHEs) in workplaces at the request of employees, authorized representative of employees, or employers, to determine whether any substance normally found in the place of employment has potentially toxic effects, including indoor

air quality.^[130]

A variety of scientists work in the field of indoor air quality, including chemists, physicists, mechanical engineers, biologists, bacteriologists, epidemiologists, and computer scientists. Some of these professionals are certified by organizations such as the American Industrial Hygiene Association, the American Indoor Air Quality Council and the Indoor Environmental Air Quality Council.

In the UK, under the Department for Environment Food and Rural Affairs, the Air Quality Expert Group considers current knowledge on indoor air quality and provides advice to government and devolved administration ministers.^[131]

At the international level, the International Society of Indoor Air Quality and Climate (ISIAQ), formed in 1991, organizes two major conferences, the Indoor Air and the Healthy Buildings series.^[132]

See also

[edit]

- Environmental management
- Healthy building
- Indoor bioaerosol
- Microbiomes of the built environment
- Olfactory fatigue

References

[edit]

- ^{1.} [^] *Carroll, GT; Kirschman, DL; Mammana, A (2022). "Increased CO2 levels in the operating room correlate with the number of healthcare workers present: an imperative for intentional crowd control". *Patient Safety in Surgery*. **16** (35): 35. doi:10.1186/s13037-022-00343-8. PMC 9672642. PMID 36397098.*
- ^{2.} [^] *ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, ASHRAE, Inc., Atlanta, GA, US*
- ^{3.} [^] *Belias, Evangelos; Licina, Dusan (2022). "Outdoor PM2.5 air filtration: optimising indoor air quality and energy". *Building & Cities*. **3** (1): 186–203. doi:10.5334/bc.153.*
- ^{4.} [^] *KMC Controls (September 24, 2015). "What's Your IQ on IAQ and IEQ?". Archived from the original on April 12, 2021. Retrieved April 12, 2021.^[unreliable source?]*
- ^{5.} [^] *Bruce, N; Perez-Padilla, R; Albalak, R (2000). "Indoor air pollution in developing countries: a major environmental and public health challenge". *Bulletin of the World Health Organization*. **78** (9): 1078–92. PMC 2560841. PMID 11019457.*
- ^{6.} [^] *"Household air pollution and health: fact sheet". WHO. May 8, 2018. Archived from the original on November 12, 2021. Retrieved November 21, 2020.*
- ^{7.} [^] *Ritchie, Hannah; Roser, Max (2019). "Access to Energy". *Our World in Data*. Archived from the original on November 1, 2021. Retrieved April 1, 2021. "*

According to the Global Burden of Disease study 1.6 million people died prematurely in 2017 as a result of indoor air pollution ... But it's worth noting that the WHO publishes a substantially larger number of indoor air pollution deaths.."

8. ^ Klepeis, Neil E; Nelson, William C; Ott, Wayne R; Robinson, John P; Tsang, Andy M; Switzer, Paul; Behar, Joseph V; Hern, Stephen C; Engelmann, William H (July 2001). "The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants". *Journal of Exposure Science & Environmental Epidemiology*. **11** (3): 231–252. Bibcode:2001JESEE..11..231K. doi:10.1038/sj.jea.7500165. PMID 11477521. S2CID 22445147. Archived from the original on March 28, 2023. Retrieved March 30, 2024.
9. ^ U.S. Environmental Protection Agency. Office equipment: design, indoor air emissions, and pollution prevention opportunities. Air and Energy Engineering Research Laboratory, Research Triangle Park, 1995.
10. ^ U.S. Environmental Protection Agency. Unfinished business: a comparative assessment of environmental problems, EPA-230/2-87-025a-e (NTIS PB88-127030). Office of Policy, Planning and Evaluation, Washington, DC, 1987.
11. ^ Klepeis, Neil E; Nelson, William C; Ott, Wayne R; Robinson, John P; Tsang, Andy M; Switzer, Paul; Behar, Joseph V; Hern, Stephen C; Engelmann, William H (July 1, 2001). "The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants". *Journal of Exposure Science & Environmental Epidemiology*. **11** (3): 231–252. Bibcode:2001JESEE..11..231K. doi:10.1038/sj.jea.7500165. ISSN 1559-0631. PMID 11477521. Archived from the original on November 13, 2023. Retrieved November 13, 2023.
12. ^ "Combined or multiple exposure to health stressors in indoor built environments: an evidence-based review prepared for the WHO training workshop "Multiple environmental exposures and risks": 16–18 October 2013, Bonn, Germany". World Health Organization. Regional Office for Europe. 2014. Archived from the original on November 6, 2023. Retrieved April 10, 2024.
13. ^ "Household air pollution". World Health Organization. December 15, 2023. Archived from the original on November 12, 2021. Retrieved April 10, 2024.
14. ^ Clark, Sierra N.; Lam, Holly C. Y.; Goode, Emma-Jane; Marczylo, Emma L.; Exley, Karen S.; Dimitroulopoulou, Sani (August 2, 2023). "The Burden of Respiratory Disease from Formaldehyde, Damp and Mould in English Housing". *Environments*. **10** (8): 136. doi:10.3390/environments10080136. ISSN 2076-3298.
15. ^ "Chief Medical Officer (CMO): annual reports". GOV.UK. November 16, 2023. Retrieved May 5, 2024.
16. ^ "Project information | Indoor air quality at home | Quality standards | NICE". www.nice.org.uk. Retrieved May 5, 2024.
17. ^ "The inside story: Health effects of indoor air quality on children and young people". RCPCH. Retrieved May 5, 2024.
18. ^ Halios, Christos H.; Landeg-Cox, Charlotte; Lowther, Scott D.; Middleton, Alice; Marczylo, Tim; Dimitroulopoulou, Sani (September 15, 2022). "Chemicals in European residences – Part I: A review of emissions, concentrations and health effects of volatile organic compounds (VOCs)". *Science of the Total Environment*.

839: 156201. Bibcode:2022ScTEn.83956201H.

doi:10.1016/j.scitotenv.2022.156201. ISSN 0048-9697. PMID 35623519.

19. ^ "Literature review on chemical pollutants in indoor air in public settings for children and overview of their health effects with a focus on schools, kindergartens and day-care centres". www.who.int. Retrieved May 5, 2024.
20. ^ Burge, P S (February 2004). "Sick building syndrome". *Occupational and Environmental Medicine*. **61** (2): 185–190. doi:10.1136/oem.2003.008813. PMC 1740708. PMID 14739390.
21. ^ Apte, K; Salvi, S (2016). "Household air pollution and its effects on health". *F1000Research*. **5**: 2593. doi:10.12688/f1000research.7552.1. PMC 5089137. PMID 27853506. "Burning of natural gas not only produces a variety of gases such as sulfur oxides, mercury compounds, and particulate matter but also leads to the production of nitrogen oxides, primarily nitrogen dioxide...The burning of biomass fuel or any other fossil fuel increases the concentration of black carbon in the air"
22. ^ "Improved Clean Cookstoves". *Project Drawdown*. February 7, 2020. Archived from the original on December 15, 2021. Retrieved December 5, 2020.
23. ^ WHO indoor air quality guidelines: household fuel combustion. Geneva: World Health Organization. 2014. ISBN 978-92-4-154888-5.
24. ^ "Clearing the Air: Gas Cooking and Pollution in European Homes". CLASP. November 8, 2023. Retrieved May 5, 2024.
25. ^ Seals, Brady; Krasner, Andee. "Gas Stoves: Health and Air Quality Impacts and Solutions". RMI. Retrieved May 5, 2024.
26. ^ **a b c** Myers, Isabella (February 2022). *The efficient operation of regulation and legislation: An holistic approach to understanding the effect of Carbon Monoxide on mortality (PDF)*. CO Research Trust.
27. ^ **a b c** Penney, David; Benignus, Vernon; Kephelopoulos, Stylianos; Kotzias, Dimitrios; Kleinman, Michael; Verrier, Agnes (2010), "Carbon monoxide", *WHO Guidelines for Indoor Air Quality: Selected Pollutants*, World Health Organization, ISBN 978-92-890-0213-4, OCLC 696099951, archived from the original on March 8, 2021, retrieved March 18, 2024
28. ^ "Carbon monoxide: toxicological overview". UK Health Security Agency. May 24, 2022. Retrieved April 17, 2024.
29. ^ **a b c** WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide (PDF). World Health Organization. 2021. hdl:10665/345329. ISBN 978-92-4-003422-8.[page needed]
30. ^ **a b** Soleimani, Farshid; Dobaradaran, Sina; De-la-Torre, Gabriel E.; Schmidt, Torsten C.; Saeedi, Reza (March 2022). "Content of toxic components of cigarette, cigarette smoke vs cigarette butts: A comprehensive systematic review". *Science of the Total Environment*. **813**: 152667. Bibcode:2022ScTEn.81352667S. doi:10.1016/j.scitotenv.2021.152667. PMID 34963586.
31. ^ "Considering smoking as an air pollution problem for environmental health | Environmental Performance Index". Archived from the original on September 25, 2018. Retrieved March 21, 2018.

32. ^ Arfaeinia, Hossein; Ghaemi, Maryam; Jahantigh, Anis; Soleimani, Farshid; Hashemi, Hassan (June 12, 2023). "Secondhand and thirdhand smoke: a review on chemical contents, exposure routes, and protective strategies". *Environmental Science and Pollution Research*. **30** (32): 78017–78029. Bibcode:2023ESPR...3078017A. doi:10.1007/s11356-023-28128-1. PMC 10258487 . PMID 37306877.
33. ^ Arfaeinia, Hossein; Ghaemi, Maryam; Jahantigh, Anis; Soleimani, Farshid; Hashemi, Hassan (June 12, 2023). "Secondhand and thirdhand smoke: a review on chemical contents, exposure routes, and protective strategies". *Environmental Science and Pollution Research*. **30** (32): 78017–78029. Bibcode:2023ESPR...3078017A. doi:10.1007/s11356-023-28128-1. ISSN 1614-7499. PMC 10258487. PMID 37306877.
34. ^ Health, CDC's Office on Smoking and (May 9, 2018). "Smoking and Tobacco Use; Fact Sheet; Secondhand Smoke". *Smoking and Tobacco Use*. Archived from the original on December 15, 2021. Retrieved January 14, 2019.
35. ^ Fernández, E; Ballbè, M; Sureda, X; Fu, M; Saltó, E; Martínez-Sánchez, JM (December 2015). "Particulate Matter from Electronic Cigarettes and Conventional Cigarettes: a Systematic Review and Observational Study". *Current Environmental Health Reports*. **2** (4): 423–9. Bibcode:2015CEHR...2..423F. doi:10.1007/s40572-015-0072-x. PMID 26452675.
36. ^ Vu, Tuan V.; Harrison, Roy M. (May 8, 2019). "Chemical and Physical Properties of Indoor Aerosols". In Harrison, R. M.; Hester, R. E. (eds.). *Indoor Air Pollution*. The Royal Society of Chemistry (published 2019). ISBN 978-1-78801-803-6.
37. ^ Abdullahi, Karimatu L.; Delgado-Saborit, Juana Maria; Harrison, Roy M. (February 13, 2013). "Emissions and indoor concentrations of particulate matter and its specific chemical components from cooking: A review". *Atmospheric Environment*. **71**: 260–294. Bibcode:2013AtmEn..71..260A. doi:10.1016/j.atmosenv.2013.01.061. Archived from the original on May 21, 2023. Retrieved April 11, 2024.
38. ^ Patel, Sameer; Sankhyan, Sumit; Boedicker, Erin K.; DeCarlo, Peter F.; Farmer, Delphine K.; Goldstein, Allen H.; Katz, Erin F.; Nazaroff, William W; Tian, Yilin; Vanhanen, Joonas; Vance, Marina E. (June 16, 2020). "Indoor Particulate Matter during HOMEChem: Concentrations, Size Distributions, and Exposures". *Environmental Science & Technology*. **54** (12): 7107–7116. Bibcode:2020EnST...54.7107P. doi:10.1021/acs.est.0c00740. ISSN 0013-936X. PMID 32391692. Archived from the original on April 28, 2023. Retrieved April 11, 2024.
39. ^ Thangavel, Prakash; Park, Duckshin; Lee, Young-Chul (June 19, 2022). "Recent Insights into Particulate Matter (PM_{2.5})-Mediated Toxicity in Humans: An Overview". *International Journal of Environmental Research and Public Health*. **19** (12): 7511. doi:10.3390/ijerph19127511. ISSN 1660-4601. PMC 9223652. PMID 35742761.
40. ^ You, Bo; Zhou, Wei; Li, Junyao; Li, Zhijie; Sun, Yele (November 4, 2022). "A review of indoor Gaseous organic compounds and human chemical Exposure: Insights from Real-time measurements". *Environment International*. **170**: 107611.

Bibcode:2022EnInt.17007611Y. doi:10.1016/j.envint.2022.107611.

PMID 36335895.

41. ^ Weschler, Charles J.; Carslaw, Nicola (March 6, 2018). "Indoor Chemistry". *Environmental Science & Technology*. **52** (5): 2419–2428. Bibcode:2018EnST...52.2419W. doi:10.1021/acs.est.7b06387. ISSN 0013-936X. PMID 29402076. Archived from the original on November 15, 2023. Retrieved April 11, 2024.
42. ^ **a b** Carter, Toby J.; Poppendieck, Dustin G.; Shaw, David; Carslaw, Nicola (January 16, 2023). "A Modelling Study of Indoor Air Chemistry: The Surface Interactions of Ozone and Hydrogen Peroxide". *Atmospheric Environment*. **297**: 119598. Bibcode:2023AtmEn.29719598C. doi:10.1016/j.atmosenv.2023.119598.
43. ^ Tsai, Wen-Tien (March 26, 2019). "An overview of health hazards of volatile organic compounds regulated as indoor air pollutants". *Reviews on Environmental Health*. **34** (1): 81–89. doi:10.1515/reveh-2018-0046. PMID 30854833.
44. ^ "U.S. EPA IAQ – Organic chemicals". *Epa.gov*. August 5, 2010. Archived from the original on September 9, 2015. Retrieved March 2, 2012.
45. ^ **a b** Davies, Helen L.; O'Leary, Catherine; Dillon, Terry; Shaw, David R.; Shaw, Marvin; Mehra, Archit; Phillips, Gavin; Carslaw, Nicola (August 14, 2023). "A measurement and modelling investigation of the indoor air chemistry following cooking activities". *Environmental Science: Processes & Impacts*. **25** (9): 1532–1548. doi:10.1039/D3EM00167A. ISSN 2050-7887. PMID 37609942.
46. ^ **a b c** Harding-Smith, Ellen; Shaw, David R.; Shaw, Marvin; Dillon, Terry J.; Carslaw, Nicola (January 23, 2024). "Does green mean clean? Volatile organic emissions from regular versus green cleaning products". *Environmental Science: Processes & Impacts*. **26** (2): 436–450. doi:10.1039/D3EM00439B. ISSN 2050-7887. PMID 38258874.
47. ^ Lebel, Eric D.; Michanowicz, Drew R.; Bilsback, Kelsey R.; Hill, Lee Ann L.; Goldman, Jackson S. W.; Domen, Jeremy K.; Jaeger, Jessie M.; Ruiz, Angélica; Shonkoff, Seth B. C. (November 15, 2022). "Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California". *Environmental Science & Technology*. **56** (22): 15828–15838. Bibcode:2022EnST...5615828L. doi:10.1021/acs.est.2c02581. ISSN 0013-936X. PMC 9671046. PMID 36263944.
48. ^ "Volatile Organic Compounds' Impact on Indoor Air Quality". *United States Environmental Protection Agency*. August 18, 2014. Retrieved May 23, 2024.
49. ^ "About VOCs". January 21, 2013. Archived from the original on January 21, 2013. Retrieved September 16, 2019.
50. ^ Oanh, Nguyen Thi Kim; Hung, Yung-Tse (2005). "Indoor Air Pollution Control". *Advanced Air and Noise Pollution Control. Handbook of Environmental Engineering*. Vol. 2. pp. 237–272. doi:10.1007/978-1-59259-779-6_7. ISBN 978-1-58829-359-6.
51. ^ "Ecode". *Eurofins.com*. Archived from the original on September 24, 2015. Retrieved March 2, 2012.
52. ^ "M1". *Eurofins.com*. Archived from the original on September 24, 2015. Retrieved March 2, 2012.

53. ^ "Blue Angel". Eurofins.com. Archived from the original on September 24, 2015. Retrieved March 2, 2012.
54. ^ "Indoor Air Comfort". Indoor Air Comfort. Archived from the original on February 1, 2011. Retrieved March 2, 2012.
55. ^ "CDPH Section 01350". Eurofins.com. Archived from the original on September 24, 2015. Retrieved March 2, 2012.
56. ^ **a b** "Smelly Moldy Houses". Archived from the original on December 15, 2021. Retrieved August 2, 2014.
57. ^ Meruva, N. K.; Penn, J. M.; Farthing, D. E. (November 2004). "Rapid identification of microbial VOCs from tobacco molds using closed-loop stripping and gas chromatography/time-of-flight mass spectrometry". *J Ind Microbiol Biotechnol*. **31** (10): 482–8. doi:10.1007/s10295-004-0175-0. PMID 15517467. S2CID 32543591.
58. ^ "Atmospheric carbon dioxide passes 400 ppm everywhere". *Physics Today* (6): 8170. 2016. Bibcode:2016PhT..2016f8170.. doi:10.1063/pt.5.029904.
59. ^ Xie Y, Li Y, Feng Y, Cheng W, Wang Y (April 2022). "Inhalable microplastics prevails in air: Exploring the size detection limit". *Environ Int*. **162**: 107151. Bibcode:2022EnInt.16207151X. doi:10.1016/j.envint.2022.107151. PMID 35228011.
60. ^ Liu C, Li J, Zhang Y, Wang L, Deng J, Gao Y, Yu L, Zhang J, Sun H (July 2019). "Widespread distribution of PET and PC microplastics in dust in urban China and their estimated human exposure". *Environ Int*. **128**: 116–124. Bibcode:2019EnInt.128..116L. doi:10.1016/j.envint.2019.04.024. PMID 31039519.
61. ^ Yuk, Hyeonseong; Jo, Ho Hyeon; Nam, Jihee; Kim, Young Uk; Kim, Sumin (2022). "Microplastic: A particulate matter(PM) generated by deterioration of building materials". *Journal of Hazardous Materials*. **437**. Elsevier BV: 129290. Bibcode:2022JHzM..43729290Y. doi:10.1016/j.jhazmat.2022.129290. ISSN 0304-3894. PMID 35753297.
62. ^ Eberhard, Tiffany; Casillas, Gaston; Zarus, Gregory M.; Barr, Dana Boyd (January 6, 2024). "Systematic review of microplastics and nanoplastics in indoor and outdoor air: identifying a framework and data needs for quantifying human inhalation exposures" (PDF). *Journal of Exposure Science & Environmental Epidemiology*. **34** (2). Springer Science and Business Media LLC: 185–196. doi:10.1038/s41370-023-00634-x. ISSN 1559-0631. Retrieved December 19, 2024. "MPs have been found in water and soil, and recent research is exposing the vast amount of them in ambient and indoor air."
63. ^ Gasperi, Johnny; Wright, Stephanie L.; Dris, Rachid; Collard, France; Mandin, Corinne; Guerrouache, Mohamed; Langlois, Valérie; Kelly, Frank J.; Tassin, Bruno (2018). "Microplastics in air: Are we breathing it in?" (PDF). *Current Opinion in Environmental Science & Health*. **1**: 1–5. Bibcode:2018COESH...1....1G. doi:10.1016/j.coesh.2017.10.002. S2CID 133750509. Archived (PDF) from the original on March 6, 2020. Retrieved July 11, 2019.
64. ^ Prasittisopin, Lapyote; Ferdous, Wahid; Kamchoom, Viroon (2023). "Microplastics in construction and built environment". *Developments in the Built Environment*. **15**. Elsevier BV. doi:10.1016/j.dibe.2023.100188. ISSN 2666-1659.

65. ^ Galloway, Nanette LoBiondo (September 13, 2024). "Ventnor introduces ordinance to control microplastics contamination". *DownBeach*. Retrieved October 2, 2024.
66. ^ Weschler, Charles J. (December 2000). "Ozone in Indoor Environments: Concentration and Chemistry: Ozone in Indoor Environments". *Indoor Air*. **10** (4): 269–288. doi:10.1034/j.1600-0668.2000.010004269.x. PMID 11089331. Archived from the original on April 15, 2024. Retrieved April 11, 2024.
67. ^ Weschler, Charles J.; Nazaroff, William W (February 22, 2023). "Human skin oil: a major ozone reactant indoors". *Environmental Science: Atmospheres*. **3** (4): 640–661. doi:10.1039/D3EA00008G. ISSN 2634-3606. Archived from the original on April 15, 2024. Retrieved April 11, 2024.
68. ^ Kumar, Prashant; Kalaiarasan, Gopinath; Porter, Alexandra E.; Pinna, Alessandra; KÃfÆ'Ã†â€™Ãfâ€ Açâ,-â,,çÃfÆ'Ãçâ,-Ã ÃfÃçÃçâ€šÃ-Ãçâ€žÃçÃfÆ'Ã†â€™ÃfÃçÃçâ€™ÃfÃçÃçâ€™Ãfâ€ Açâ,-â,,çÃfÆ'Ãçâ,-Ã ÃfÃçÃçâ€šÃ-Ãçâ€žÃçÃfÆ'Ã†â€™ÃfÃçÃçâ€™ÃfÃçÃçâ€™Ãfâ€ M.; Demokritou, Philip; Chung, Kian Fan; Pain, Christopher; Arvind, D. K.; Arcucci, Rossella; Adcock, Ian M.; Dillway, Claire (February 20, 2021). "An overview of methods of fine and ultrafine particle collection for physicochemical characterisation and toxicity assessments". *Science of the Total Environment*. **756**: 143553. Bibcode:2021ScTEn.75643553K. doi:10.1016/j.scitotenv.2020.143553. hdl:10044/1/84518. PMID 33239200. S2CID 227176222.
69. ^ Apte, M. G.; Buchanan, I. S. H.; Mendell, M. J. (April 2008). "Outdoor ozone and building-related symptoms in the BASE study". *Indoor Air*. **18** (2): 156–170. Bibcode:2008InAir..18..156A. doi:10.1111/j.1600-0668.2008.00521.x. PMID 18333994.
70. ^ "Eight-hour Average Ozone Concentrations | Ground-level Ozone | New England | US EPA". United States Environmental Protection Agency. Archived from the original on December 15, 2021. Retrieved September 16, 2019.
71. ^ **a b c** Park, J. H.; Cox-Ganser, J. M. (2011). "Meta-Mold exposure and respiratory health in damp indoor environments". *Frontiers in Bioscience*. **3** (2): 757–771. doi:10.2741/e284. PMID 21196349.
72. ^ "CDC – Mold – General Information – Facts About Mold and Dampness". December 4, 2018. Archived from the original on December 16, 2019. Retrieved June 23, 2017.
73. ^ Singh, Dr Jagjit; Singh, Jagjit, eds. (1994). *Building Mycology* (1 ed.). Taylor & Francis. doi:10.4324/9780203974735. ISBN 978-1-135-82462-4.
74. ^ **a b** Clarke, J.A; Johnstone, C.M; Kelly, N.J; McLean, R.C; anderson, J.A; Rowan, N.J; Smith, J.E (January 20, 1999). "A technique for the prediction of the conditions leading to mould growth in buildings". *Building and Environment*. **34** (4): 515–521. Bibcode:1999BuEnv..34..515C. doi:10.1016/S0360-1323(98)00023-7. Archived from the original on October 26, 2022. Retrieved April 10, 2024.
75. ^ Vereecken, Evy; Roels, Staf (November 15, 2011). "Review of mould prediction models and their influence on mould risk evaluation". *Building and Environment*. **51**: 296–310. doi:10.1016/j.buildenv.2011.11.003. Archived from the original on March

- 2, 2024. Retrieved April 11, 2024.
76. ^ BS 5250:2021 - Management of moisture in buildings. Code of practice. British Standards Institution (BSI). October 31, 2021. ISBN 978-0-539-18975-9.
 77. ^ Madgwick, Della; Wood, Hannah (August 8, 2016). "The problem of clothes drying in new homes in the UK". *Structural Survey*. **34** (4/5): 320–330. doi:10.1108/SS-10-2015-0048. ISSN 0263-080X. Archived from the original on May 7, 2021. Retrieved April 11, 2024.
 78. ^ May, Neil; McGilligan, Charles; Ucci, Marcella (2017). "Health and Moisture in Buildings" (PDF). UK Centre for Moisture in Buildings. Archived (PDF) from the original on April 11, 2024. Retrieved April 11, 2024.
 79. ^ "Understanding and addressing the health risks of damp and mould in the home". GOV.UK. September 7, 2023. Archived from the original on April 10, 2024. Retrieved April 11, 2024.
 80. ^ Clark, Sierra N.; Lam, Holly C. Y.; Goode, Emma-Jane; Marczylo, Emma L.; Exley, Karen S.; Dimitroulopoulou, Sani (August 2, 2023). "The Burden of Respiratory Disease from Formaldehyde, Damp and Mould in English Housing". *Environments*. **10** (8): 136. doi:10.3390/environments10080136. ISSN 2076-3298.
 81. ^ Microbiology of the Indoor Environment Archived July 23, 2011, at the Wayback Machine, microbe.net
 82. ^ http://www.info.gov.hk/info/sars/pdf/amoy_e.pdf
 83. ^ <https://www.info.gov.hk/info/sars/graphics/amoyannex.jpg>
 84. ^ "Progress in Global Surveillance and Response Capacity 10 Years after Severe Acute Respiratory Syndrome". "environmental contamination with SARS CoV RNA was identified on the carpet in front of the index case-patient's room and 3 nearby rooms (and on their door frames but not inside the rooms) and in the air intake vents near the centrally located elevators ... secondary infections occurred not in guest rooms but in the common areas of the ninth floor, such as the corridor or elevator hall. These areas could have been contaminated through body fluids (e.g., vomitus, expectorated sputum), respiratory droplets, or suspended small-particle aerosols generated by the index case-patient; other guests were then infected by fomites or aerosols while passing through these same areas. Efficient spread of SARS CoV through small-particle aerosols was observed in several superspreading events in health care settings, during an airplane flight, and in an apartment complex (12–14, 16–19). This process of environmental contamination that generated infectious aerosols likely best explains the pattern of disease transmission at the Hotel Metropole."
 85. ^ Azuma, Kenichi; Kagi, Naoki; Yanagi, U.; Osawa, Haruki (December 2018). "Effects of low-level inhalation exposure to carbon dioxide in indoor environments: A short review on human health and psychomotor performance". *Environment International*. **121** (Pt 1): 51–56. Bibcode:2018EnInt.121...51A. doi:10.1016/j.envint.2018.08.059. PMID 30172928.
 86. ^ Du, Bowen; Tandoc, Michael (June 19, 2020). "Indoor CO2 concentrations and cognitive function: A critical review". *International Journal of Indoor Environment and Health*. **30** (6): 1067–1082. Bibcode:2020InAir..30.1067D. doi:

10.1111/ina.12706. PMID 32557862. S2CID 219915861.

87. ^ Fan, Yuejie; Cao, Xiaodong; Zhang, Jie; Lai, Dayi; Pang, Liping (June 1, 2023). "Short-term exposure to indoor carbon dioxide and cognitive task performance: A systematic review and meta-analysis". *Building and Environment*. **237**: 110331. Bibcode:2023BuEnv.23710331F. doi:10.1016/j.buildenv.2023.110331.
88. ^ **a b** Lowther, Scott D.; Dimitroulopoulou, Sani; Foxall, Kerry; Shrubsole, Clive; Cheek, Emily; Gadeberg, Britta; Sepai, Ovnair (November 16, 2021). "Low Level Carbon Dioxide Indoors—A Pollution Indicator or a Pollutant? A Health-Based Perspective". *Environments*. **8** (11): 125. doi:10.3390/environments8110125. ISSN 2076-3298.
89. ^ Persily, Andrew (July 2022). "Development and application of an indoor carbon dioxide metric". *Indoor Air*. **32** (7): e13059. doi:10.1111/ina.13059. PMID 35904382.
90. ^ "Indoor Environmental Quality: HVAC Management | NIOSH | CDC". www.cdc.gov. February 25, 2022. Archived from the original on April 1, 2022. Retrieved April 1, 2022.
91. ^ Indoor Environmental Quality: Building Ventilation Archived January 20, 2022, at the Wayback Machine. National Institute for Occupational Safety and Health. Accessed October 8, 2008.
92. ^ "SAMHE - Schools' Air quality Monitoring for Health and Education". samhe.org.uk. Archived from the original on March 18, 2024. Retrieved March 18, 2024.
93. ^ "Document Display | NEPIS | US EPA". nepis.epa.gov. Archived from the original on November 16, 2023. Retrieved October 19, 2023.
94. ^ Zeeb & Shannoun 2009, p. 3.
95. ^ C.Michael Hogan and Sjaak Slanina. 2010, *Air pollution*. Encyclopedia of Earth Archived October 12, 2006, at the Wayback Machine. eds. Sidney Draggan and Cutler Cleveland. National Council for Science and the Environment. Washington DC
96. ^ "Radon Mitigation Methods". *Radon Solution—Raising Radon Awareness*. Archived from the original on December 15, 2008. Retrieved December 2, 2008.
97. ^ Zeeb & Shannoun 2009, p. ^[page needed].
98. ^ "Basic radon facts" (PDF). US Environmental Protection Agency. Archived (PDF) from the original on January 13, 2022. Retrieved September 18, 2018. This article incorporates text from this source, which is in the public domain.
99. ^ "Radon Action Level and Target Level". UKradon. Archived from the original on March 18, 2024. Retrieved March 18, 2024.
100. ^ "Radon Zone Map (with State Information)". U.S. Environmental Protection Agency. Archived from the original on April 1, 2023. Retrieved April 10, 2024.
101. ^ "UK maps of radon". UKradon. Archived from the original on March 7, 2024. Retrieved April 10, 2024.
102. ^ "Radon map of Australia". Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Archived from the original on March 20, 2024. Retrieved April 10, 2024.

103. ^ "Climate Change 2021: The Physical Science Basis". Intergovernmental Panel on Climate Change. Archived (PDF) from the original on May 26, 2023. Retrieved April 15, 2024.
104. ^ Chen, Guochao; Qiu, Minghao; Wang, Peng; Zhang, Yuqiang; Shindell, Drew; Zhang, Hongliang (July 19, 2024). "Continuous wildfires threaten public and ecosystem health under climate change across continents". *Frontiers of Environmental Science & Engineering*. **18** (10). doi:10.1007/s11783-024-1890-6. ISSN 2095-2201.
105. ^ Gherasim, Alina; Lee, Alison G.; Bernstein, Jonathan A. (November 14, 2023). "Impact of Climate Change on Indoor Air Quality". *Immunology and Allergy Clinics of North America*. **44** (1): 55–73. doi:10.1016/j.iac.2023.09.001. PMID 37973260. Archived from the original on November 15, 2023. Retrieved April 15, 2024.
106. ^ Lacressonnière, Gwendoline; Watson, Laura; Gauss, Michael; Engardt, Magnuz; Andersson, Camilla; Beekmann, Matthias; Colette, Augustin; Foret, Gilles; Josse, Béatrice; Marécal, Virginie; Nyiri, Agnes; Siour, Guillaume; Sobolowski, Stefan; Vautard, Robert (February 1, 2017). "Particulate matter air pollution in Europe in a +2 °C warming world". *Atmospheric Environment*. **154**: 129–140. Bibcode:2017AtmEn.154..129L. doi:10.1016/j.atmosenv.2017.01.037. Archived from the original on November 17, 2023. Retrieved April 15, 2024.
107. ^ Lee, J; Lewis, A; Monks, P; Jacob, M; Hamilton, J; Hopkins, J; Watson, N; Saxton, J; Ennis, C; Carpenter, L (September 26, 2006). "Ozone photochemistry and elevated isoprene during the UK heatwave of august 2003". *Atmospheric Environment*. **40** (39): 7598–7613. Bibcode:2006AtmEn..40.7598L. doi:10.1016/j.atmosenv.2006.06.057. Archived from the original on October 26, 2022. Retrieved April 15, 2024.
108. ^ Salthammer, Tunga; Schieweck, Alexandra; Gu, Jianwei; Ameri, Shaghayegh; Uhde, Erik (August 7, 2018). "Future trends in ambient air pollution and climate in Germany – Implications for the indoor environment". *Building and Environment*. **143** : 661–670. Bibcode:2018BuEnv.143..661S. doi:10.1016/j.buildenv.2018.07.050.
109. ^ Zhong, L.; Lee, C.-S.; Haghghat, F. (December 1, 2016). "Indoor ozone and climate change". *Sustainable Cities and Society*. **28**: 466–472. doi:10.1016/j.scs.2016.08.020. Archived from the original on November 28, 2022. Retrieved April 15, 2024.
110. ^ Zhao, Jiangyue; Uhde, Erik; Salthammer, Tunga; Antretter, Florian; Shaw, David; Carslaw, Nicola; Schieweck, Alexandra (December 9, 2023). "Long-term prediction of the effects of climate change on indoor climate and air quality". *Environmental Research*. **243**: 117804. doi:10.1016/j.envres.2023.117804. PMID 38042519.
111. ^ Niculita-Hirzel, Hélène (March 16, 2022). "Latest Trends in Pollutant Accumulations at Threatening Levels in Energy-Efficient Residential Buildings with and without Mechanical Ventilation: A Review". *International Journal of Environmental Research and Public Health*. **19** (6): 3538. doi:10.3390/ijerph19063538. ISSN 1660-4601. PMC 8951331. PMID 35329223.
112. ^ UK Health Security Agency (2024) [1 September 2012]. "Chapter 5: Impact of climate change policies on indoor environmental quality and health in UK housing".

- Health Effects of Climate Change (HECC) in the UK: 2023 report (published January 15, 2024).*
113. ^ World Health Organization, ed. (2010). *Who guidelines for indoor air quality: selected pollutants*. Copenhagen: WHO. ISBN 978-92-890-0213-4. OCLC 696099951.
 114. ^ "Air quality: UK guidelines for volatile organic compounds in indoor spaces". Public Health England. September 13, 2019. Retrieved April 17, 2024.
 115. ^ "Home - IEQ Guidelines". ieqguidelines.org. Retrieved April 17, 2024.
 116. ^ Toyinbo, Oluyemi; Hägerhed, Linda; Dimitroulopoulou, Sani; Dudzinska, Marzenna; Emmerich, Steven; Hemming, David; Park, Ju-Hyeong; Haverinen-Shaughnessy, Ulla; the Scientific Technical Committee 34 of the International Society of Indoor Air Quality, Climate (April 19, 2022). "Open database for international and national indoor environmental quality guidelines". *Indoor Air*. **32** (4): e13028. doi:10.1111/ina.13028. ISSN 0905-6947. PMC 11099937. PMID 35481936.cite journal: CS1 maint: numeric names: authors list (link)
 117. ^ Dimitroulopoulou, Sani; Dudzińska, Marzenna R.; Gunnarsen, Lars; Hägerhed, Linda; Maula, Henna; Singh, Raja; Toyinbo, Oluyemi; Haverinen-Shaughnessy, Ulla (August 4, 2023). "Indoor air quality guidelines from across the world: An appraisal considering energy saving, health, productivity, and comfort". *Environment International*. **178**: 108127. Bibcode:2023EnInt.17808127D. doi:10.1016/j.envint.2023.108127. PMID 37544267.
 118. ^ Pitarma, Rui; Marques, Gonçalo; Ferreira, Bárbara Roque (February 2017). "Monitoring Indoor Air Quality for Enhanced Occupational Health". *Journal of Medical Systems*. **41** (2): 23. doi:10.1007/s10916-016-0667-2. PMID 28000117. S2CID 7372403.
 119. ^ Wyon, D. P. (August 2004). "The effects of indoor air quality on performance and productivity: The effects of IAQ on performance and productivity". *Indoor Air*. **14**: 92–101. doi:10.1111/j.1600-0668.2004.00278.x. PMID 15330777.
 120. ^ Son, Young Joo; Pope, Zachary C.; Pantelic, Jovan (September 2023). "Perceived air quality and satisfaction during implementation of an automated indoor air quality monitoring and control system". *Building and Environment*. **243**: 110713. Bibcode:2023BuEnv.24310713S. doi:10.1016/j.buildenv.2023.110713.
 121. ^ IAQM (2021). *Indoor Air Quality Guidance: Assessment, Monitoring, Modelling and Mitigation (PDF) (Version 0.1 ed.)*. London: Institute of Air Quality Management.
 122. ^ a b Institute for Occupational Safety and Health of the German Social Accident Insurance. "Indoor workplaces – Recommended procedure for the investigation of working environment". Archived from the original on November 3, 2021. Retrieved June 10, 2020.
 123. ^ "Climate Change: Atmospheric Carbon Dioxide | NOAA Climate.gov". www.climate.gov. April 9, 2024. Retrieved May 6, 2024.
 124. ^ "Ventilation to reduce the spread of respiratory infections, including COVID-19". GOV.UK. August 2, 2022. Archived from the original on January 18, 2024.

Retrieved April 15, 2024.

125. ^ Dela Cruz, Majbrit; Christensen, Jan H.; Thomsen, Jane Dyrhauge; Müller, Renate (December 2014). "Can ornamental potted plants remove volatile organic compounds from indoor air? — a review". *Environmental Science and Pollution Research*. **21** (24): 13909–13928. Bibcode:2014ESPR...2113909D. doi:10.1007/s11356-014-3240-x. PMID 25056742. S2CID 207272189.
126. ^ Cummings, Bryan E.; Waring, Michael S. (March 2020). "Potted plants do not improve indoor air quality: a review and analysis of reported VOC removal efficiencies". *Journal of Exposure Science & Environmental Epidemiology*. **30** (2): 253–261. Bibcode:2020JESEE..30..253C. doi:10.1038/s41370-019-0175-9. PMID 31695112. S2CID 207911697.
127. ^ Wolverton, B. C.; Wolverton, J. D. (1996). "Interior plants: their influence on airborne microbes inside energy-efficient buildings". *Journal of the Mississippi Academy of Sciences*. **41** (2): 100–105.
128. ^ US EPA, OAR (July 16, 2013). "Mold". US EPA. Archived from the original on May 18, 2020. Retrieved September 16, 2019.
129. ^ Institute of Medicine (US) Committee on Damp Indoor Spaces and Health (2004). *Damp Indoor Spaces and Health*. National Academies Press. ISBN 978-0-309-09193-0. PMID 25009878. Archived from the original on January 19, 2023. Retrieved March 30, 2024.^[page needed]
130. ^ "Indoor Environmental Quality". Washington, DC: US National Institute for Occupational Safety and Health. Archived from the original on December 3, 2013. Retrieved May 17, 2013.
131. ^ Lewis, Alastair C; Allan, James; Carslaw, David; Carruthers, David; Fuller, Gary; Harrison, Roy; Heal, Mathew; Nemitz, Eiko; Reeves, Claire (2022). *Indoor Air Quality (PDF) (Report)*. Air Quality Expert Group. doi:10.5281/zenodo.6523605. Archived (PDF) from the original on June 5, 2023. Retrieved April 15, 2024.
132. ^ "Isiaq.Org". International Society of Indoor Air Quality and Climate. Archived from the original on January 21, 2022. Retrieved March 2, 2012.

Sources

[edit]

Monographs

- May, Jeffrey C.; Connie L. May; Ouellette, John J.; Reed, Charles E. (2004). *The mold survival guide for your home and for your health*. Baltimore: Johns Hopkins University Press. ISBN 978-0-8018-7938-8.
- May, Jeffrey C. (2001). *My house is killing me! : the home guide for families with allergies and asthma*. Baltimore: The Johns Hopkins University Press. ISBN 978-0-8018-6730-9.
- May, Jeffrey C. (2006). *My office is killing me! : the sick building survival guide*. Baltimore: The Johns Hopkins University Press. ISBN 978-0-8018-8342-2.
- Salthammer, T., ed. (1999). *Organic Indoor Air Pollutants — Occurrence, Measurement, Evaluation*. Wiley-VCH. ISBN 978-3-527-29622-4.

- Spengler, J.D.; Samet, J.M. (1991). *Indoor air pollution: A health perspective*. Baltimore: Johns Hopkins University Press. ISBN 978-0-8018-4125-5.
- Samet, J.M.; McCarthy, J.F. (2001). *Indoor Air Quality Handbook*. NY: McGraw–Hill. ISBN 978-0-07-445549-4.
- Tichenor, B. (1996). *Characterizing Sources of Indoor Air Pollution and Related Sink Effects*. ASTM STP 1287. West Conshohocken, PA: ASTM. ISBN 978-0-8031-2030-3.
- Zeeb, Hajo; Shannoun, Ferid, eds. (2009). *WHO Handbook on Indoor Radon: A Public Health Perspective*. World Health Organization. ISBN 978-92-4-154767-3. PMID 23762967. NBK143216. Archived from the original on March 30, 2024. Retrieved March 30, 2024.

Articles, radio segments, web pages

- Apte, M. G.; Buchanan, I. S. H.; Mendell, M. J. (April 2008). "Outdoor ozone and building-related symptoms in the BASE study". *Indoor Air*. **18** (2): 156–170. Bibcode:2008InAir..18..156A. doi:10.1111/j.1600-0668.2008.00521.x. PMID 18333994.
- Bad In-Flight Air Exacerbated by Passengers Archived December 15, 2021, at the Wayback Machine, Talk of the Nation, National Public Radio, September 21, 2007.
- Indoor Air Pollution index page, United States Environmental Protection Agency.
- Steinemann, Anne (2017). "Ten questions concerning air fresheners and indoor built environments". *Building and Environment*. **111**: 279–284. Bibcode:2017BuEnv.111..279S. doi:10.1016/j.buildenv.2016.11.009. hdl:11343/121890.

Further reading

[edit]

- Lin, Y.; Zou, J.; Yang, W.; Li, C. Q. (2018). "A Review of Recent Advances in Research on PM2.5 in China". *International Journal of Environmental Research and Public Health*. **15** (3): 438. doi:10.3390/ijerph15030438. PMC 5876983. PMID 29498704.
- Abdel Hameed, A. A.; Yasser, I. H.; Khoder, I. M. (2004). "Indoor air quality during renovation actions: a case study". *Journal of Environmental Monitoring*. **6** (9): 740–744. doi:10.1039/b402995j. PMID 15346177.

External links

[edit]

- US Environmental Protection Agency info on IAQ
- Best Practices for Indoor Air Quality when Remodeling Your Home, US EPA
- Addressing Indoor Environmental Concerns During Remodeling, US EPA
- Renovation and Repair, Part of Indoor Air Quality Design Tools for Schools, US EPA
- The 9 Foundations of a Healthy Building, Harvard T.H. Chan School of Public Health

- v
- t
- e

Pollution

History

Air

- Acid rain
- Air quality index
- Atmospheric dispersion modeling
- Chlorofluorocarbon
- Combustion
 - Biofuel
 - Biomass
 - Joss paper
 - Open burning of waste
- Construction
 - Renovation
- Demolition
- Exhaust gas
 - Diesel exhaust
- Haze
 - Smoke
- Indoor air quality
- Internal combustion engine
- Global dimming
- Global distillation
- Mining
- Ozone depletion
- Particulates
 - Asbestos
 - Metal working
 - Oil refining
 - Wood dust
 - Welding
- Persistent organic pollutant
- Smelting
- Smog
- Soot
 - Black carbon
- Volatile organic compound
- Waste

Biological

Digital

Electromagnetic

Natural

Noise

Radiation

- Biological hazard
- Genetic pollution
- Introduced species
 - Invasive species
- Information pollution
- Light
 - Ecological light pollution
 - Overillumination
- Radio spectrum pollution
- Ozone
- Radium and radon in the environment
- Volcanic ash
- Wildfire
- Transportation
 - Land
 - Water
 - Air
 - Rail
 - Sustainable transport
- Urban
- Sonar
 - Marine mammals and sonar
- Industrial
- Military
- Abstract
- Noise control
- Actinides
- Bioremediation
- Nuclear fission
- Nuclear fallout
- Plutonium
- Poisoning
- Radioactivity
- Uranium
- Electromagnetic radiation and health
- Radioactive waste



Soil

- Agricultural pollution
 - Herbicides
 - Manure waste
 - Pesticides
- Land degradation
- Bioremediation
- Open defecation
- Electrical resistance heating
- Soil guideline values
- Phytoremediation



Solid waste

- Advertising mail
- Biodegradable waste
- Brown waste
- Electronic waste
 - Battery recycling
- Foam food container
- Food waste
- Green waste
- Hazardous waste
 - Biomedical waste
 - Chemical waste
 - Construction waste
 - Lead poisoning
 - Mercury poisoning
 - Toxic waste
- Industrial waste
 - Lead smelting
- Litter
- Mining
 - Coal mining
 - Gold mining
 - Surface mining
 - Deep sea mining
 - Mining waste
 - Uranium mining
- Municipal solid waste
 - Garbage
- Nanomaterials
- Plastic pollution
 - Microplastics
- Packaging waste
- Post-consumer waste
- Waste management
 - Landfill
 - Thermal treatment
- Satellite
- Air travel
- Clutter (advertising)
- Traffic signs
- Overhead power lines
- Vandalism

Space

Visual

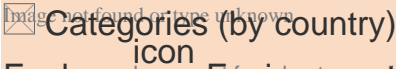
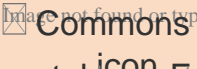


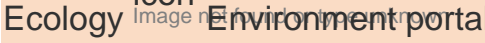

War

- Chemical warfare
- Herbicidal warfare (Agent Orange)
- Nuclear holocaust (Nuclear fallout - nuclear famine - nuclear winter)
- Scorched earth
- Unexploded ordnance
- War and environmental law
- Agricultural wastewater
- Biological pollution
- Diseases
- Eutrophication
- Firewater
- Freshwater
- Groundwater
- Hypoxia
- Industrial wastewater
- Marine
 - debris
- Monitoring
- Nonpoint source pollution

Water

- Nutrient pollution
- Ocean acidification
- Oil exploitation
- Oil exploration
- Oil spill
- Pharmaceuticals
- Sewage
 - Septic tanks
 - Pit latrine
- Shipping
- Stagnation
- Sulfur water
- Surface runoff
- Thermal
- Turbidity
- Urban runoff
- Water quality
- Pollutants
 - Heavy metals
 - Paint
- Brain health and pollution

Topics

Misc	<ul style="list-style-type: none"> Area source Debris Dust Garbology Legacy pollution Midden Point source Waste 	
	Responses	<ul style="list-style-type: none"> Cleaner production Industrial ecology Pollution haven hypothesis Pollutant release and transfer register Polluter pays principle Pollution control Waste minimisation Zero waste
	Lists	<ul style="list-style-type: none"> Diseases Law by country Most polluted cities Least polluted cities by PM_{2.5} Most polluted countries Most polluted rivers Treaties
   		
 		

- o v
- o t
- o e

Natural resources

Air	Pollution / quality	<ul style="list-style-type: none"> Ambient standards (US) Index Indoor Law <ul style="list-style-type: none"> Clean Air Act (US) Ozone depletion
	Emissions	<ul style="list-style-type: none"> Airshed Trading Deforestation (REDD)

Energy

- Bio
- Law
- Resources
- Fossil fuels (gas, peak coal, peak gas, peak oil)
- Geothermal
- Hydro
- Nuclear
- Solar
 - sunlight
 - shade
- Wind

Land

- Agricultural
 - arable
 - peak farmland
- Degradation
- Field
- Landscape
 - cityscape
 - seascape
 - soundscape
 - viewshed
- Law
 - property
- Management
 - habitat conservation
- Minerals
 - gemstone
 - industrial
 - ore
 - metal
 - mining
 - law
 - sand
 - peak
 - copper
 - phosphorus
 - rights
- Soil
 - conservation
 - fertility
 - health
 - resilience
- Use
 - planning
 - reserve

Life

- Biodiversity
- Bioprospecting
 - biopiracy
- Biosphere
- Bushfood
- Bushmeat
- Fisheries
 - climate change
 - law
 - management
- Forests
 - genetic resources
 - law
 - management
 - non-timber products
- Game
 - law
- Marine conservation
- Meadow
- Pasture
- Plants
 - FAO Plant Treaty
 - food
 - genetic resources
 - gene banks
 - herbal medicines
 - UPOV Convention
 - wood
- Rangeland
- Seed bank
- Wildlife
 - conservation
 - management

Water

Types /
location

- Aquifer
 - storage and recovery
- Drinking
- Fresh
- Groundwater
 - pollution
 - recharge
 - remediation
- Hydrosphere
- Ice
 - bergs
 - glacial
 - polar
- Irrigation
 - *huerta*
- Marine
- Rain
 - harvesting
- Stormwater
- Surface water
- Sewage
 - reclaimed water

Aspects

- Watershed
- Desalination
- Floods
- Law
- Leaching
- Sanitation
 - improved
- Scarcity
- Security
- Supply
- Efficiency
- Conflict
- Conservation
- Peak water
- Pollution
- Privatization
- Quality
- Right
- Resources
 - improved
 - policy

- Commons
 - enclosure
 - global
 - land
 - tragedy of
 - Economics
 - ecological
 - land
 - Ecosystem services
 - Exploitation
 - overexploitation
 - Earth Overshoot Day
 - Management
 - adaptive
 - Natural capital
 - accounting
 - good
 - Natural heritage
 - Nature reserve
 - remnant natural area
 - Systems ecology
 - Urban ecology
 - Wilderness
-
- Common-pool
 - Conflict (perpetuation)
 - Curse
- Resource
- Depletion
 - Extraction
 - Nationalism
 - Renewable / Non-renewable
 - Oil war
- Politics
- Petrostate
 - Resource war

Related

○  **Category** Image not found or type unknown

- v
- t
- e

Occupational safety and health

**Occupational
diseases
and injuries**

- Acrodynia
- Asbestosis
- Asthma
- Barotrauma
- Berylliosis
- Brucellosis
- Burnout
- Byssinosis ("brown lung")
- Cardiovascular
- Chalicosis
- Chronic solvent-induced encephalopathy
- Chronic stress
- Chimney sweeps' carcinoma
- Coalworker's pneumoconiosis ("black lung")
- Concussions in sport
- Decompression sickness
- De Quervain syndrome
- Erethism
- Exposure to human nail dust
- Farmer's lung
- Fiddler's neck
- Flock worker's lung
- Glassblower's cataract
- Golfer's elbow
- Hearing loss
- Hospital-acquired infection
- Indium lung
- Laboratory animal allergy
- Lead poisoning
- Low back pain
- Mesothelioma
- Metal fume fever
- Mule spinners' cancer
- Noise-induced hearing loss
- Phossy jaw
- Pneumoconiosis
- Radium jaw
- Repetitive strain injury
- Silicosis
- Silo-filler's disease
- Sports injury
- Surfer's ear
- Tennis elbow
- Tinnitus
- Writer's cramp

- Occupational hazard
 - Biological hazard
 - Chemical hazard
 - Physical hazard
 - Psychosocial hazard
- Occupational hygiene**
 - Occupational stress
 - Hierarchy of hazard controls
 - Prevention through design
 - Exposure assessment
 - Occupational exposure limit
 - Occupational epidemiology
 - Workplace health surveillance
 - Environmental health
 - Industrial engineering
- Professions**
 - Occupational health nursing
 - Occupational health psychology
 - Occupational medicine
 - Occupational therapist
 - Safety engineering
- Agencies and organizations**
 - International**
 - European Agency for Safety and Health at Work
 - International Labour Organization
 - World Health Organization
 - Canadian Centre for Occupational Health and Safety (Canada)
 - Istituto nazionale per l'assicurazione contro gli infortuni sul lavoro (Italy)
 - National**
 - National Institute for Safety and Health at Work (Spain)
 - Health and Safety Executive (UK)
 - Occupational Safety and Health Administration
 - National Institute for Occupational Safety and Health (US)
- Standards**
 - Bangladesh Accord
 - OHSAS 18001
 - ISO 45001
 - Occupational Safety and Health Convention, 1981
 - Worker Protection Standard (US)
 - Working Environment Convention, 1977

Safety


- Checklist
- Code of practice
- Contingency plan
- Diving safety
- Emergency procedure
- Emergency evacuation
- Hazard
- Hierarchy of hazard controls
 - Hazard elimination
 - Administrative controls
 - Engineering controls
 - Hazard substitution
 - Personal protective equipment
- Job safety analysis
- Lockout-tagout
- Permit To Work
- Operations manual
- Redundancy (engineering)
- Risk assessment
- Safety culture
- Standard operating procedure
- Immediately dangerous to life or health
- Diving regulations
- Occupational Safety and Health Act (United States)

Legislation

- Potty parity (United States)
- Right to sit (United States)
- Workers' right to access the toilet

- Aerosol
- Break
- Break room
- Drug policy
- Effects of overtime
- Environment, health and safety
- Environmental toxicology
- Ergonomics
- Fire Fighter Fatality Investigation and Prevention Program
- Hawks Nest Tunnel disaster
- Health physics
- Hostile work environment
- Indoor air quality
- International Chemical Safety Card
- Job strain
- National Day of Mourning (Canada)
- NIOSH air filtration rating
- Overwork
- Process safety
- Public health
- Quality of working life
- Risk management
- Safety data sheet
- Source control
- Toxic tort
- Toxic workplace
- Workers' compensation
- Workplace hazard controls for COVID-19
- Workplace health promotion

See also

-  **Category** image not found or type unknown
 - Occupational diseases
 - Journals
 - Organizations

-  **Commons** image not found or type unknown

- v
- t
- e

Heating, ventilation, and air conditioning

**Fundamental
concepts**

- Air changes per hour
- Bake-out
- Building envelope
- Convection
- Dilution
- Domestic energy consumption
- Enthalpy
- Fluid dynamics
- Gas compressor
- Heat pump and refrigeration cycle
- Heat transfer
- Humidity
- Infiltration
- Latent heat
- Noise control
- Outgassing
- Particulates
- Psychrometrics
- Sensible heat
- Stack effect
- Thermal comfort
- Thermal destratification
- Thermal mass
- Thermodynamics
- Vapour pressure of water

Technology

- Absorption-compression heat pump
- Absorption refrigerator
- Air barrier
- Air conditioning
- Antifreeze
- Automobile air conditioning
- Autonomous building
- Building insulation materials
- Central heating
- Central solar heating
- Chilled beam
- Chilled water
- Constant air volume (CAV)
- Coolant
- Cross ventilation
- Dedicated outdoor air system (DOAS)
- Deep water source cooling
- Demand controlled ventilation (DCV)
- Displacement ventilation
- District cooling
- District heating
- Electric heating
- Energy recovery ventilation (ERV)
- Firestop
- Forced-air
- Forced-air gas
- Free cooling
- Heat recovery ventilation (HRV)
- Hybrid heat
- Hydronics
- Ice storage air conditioning
- Kitchen ventilation
- Mixed-mode ventilation
- Microgeneration
- Passive cooling
- Passive daytime radiative cooling
- Passive house
- Passive ventilation
- Radiant heating and cooling
- Radiant cooling
- Radiant heating
- Radon mitigation
- Refrigeration
- Renewable heat
- Room air distribution
- Solar air heat
- Solar combisystem
- Solar cooling
- Solar heating

- Air conditioner inverter
- Air door
- Air filter
- Air handler
- Air ionizer
- Air-mixing plenum
- Air purifier
- Air source heat pump
- Attic fan
- Automatic balancing valve
- Back boiler
- Barrier pipe
- Blast damper
- Boiler
- Centrifugal fan
- Ceramic heater
- Chiller
- Condensate pump
- Condenser
- Condensing boiler
- Convection heater
- Compressor
- Cooling tower
- Damper
- Dehumidifier
- Duct
- Economizer
- Electrostatic precipitator
- Evaporative cooler
- Evaporator
- Exhaust hood
- Expansion tank
- Fan
- Fan coil unit
- Fan filter unit
- Fan heater
- Fire damper
- Fireplace
- Fireplace insert
- Freeze stat
- Flue
- Freon
- Fume hood
- Furnace
- Gas compressor
- Gas heater
- Gasoline heater
- Grease duct
- Grille

Components

**Measurement
and control**

- Air flow meter
- Aquastat
- BACnet
- Blower door
- Building automation
- Carbon dioxide sensor
- Clean air delivery rate (CADR)
- Control valve
- Gas detector
- Home energy monitor
- Humidistat
- HVAC control system
- Infrared thermometer
- Intelligent buildings
- LonWorks
- Minimum efficiency reporting value (MERV)
- Normal temperature and pressure (NTP)
- OpenTherm
- Programmable communicating thermostat
- Programmable thermostat
- Psychrometrics
- Room temperature
- Smart thermostat
- Standard temperature and pressure (STP)
- Thermographic camera
- Thermostat
- Thermostatic radiator valve
- Architectural acoustics
- Architectural engineering
- Architectural technologist
- Building services engineering
- Building information modeling (BIM)
- Deep energy retrofit
- Duct cleaning
- Duct leakage testing
- Environmental engineering
- Hydronic balancing
- Kitchen exhaust cleaning
- Mechanical engineering
- Mechanical, electrical, and plumbing
- Mold growth, assessment, and remediation
- Refrigerant reclamation
- Testing, adjusting, balancing

**Professions,
trades,
and services**

Industry organizations

- AHRI
- AMCA
- ASHRAE
- ASTM International
- BRE
- BSRIA
- CIBSE
- Institute of Refrigeration
- IIR
- LEED
- SMACNA
- UMC

Health and safety

- Indoor air quality (IAQ)
- Passive smoking
- Sick building syndrome (SBS)
- Volatile organic compound (VOC)
- ASHRAE Handbook
- Building science
- Fireproofing

See also

- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Home automation
- Template:Solar energy

Authority control databases image not found or type-unknown **Edit this at Wikidata**

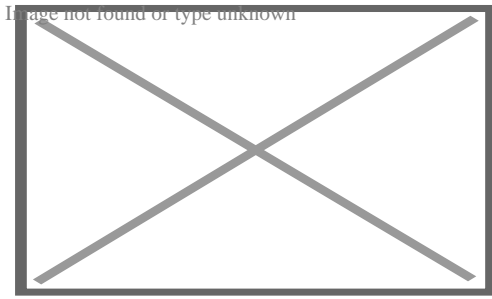
International

- FAST
- United States

National

- Latvia
- Israel

About Ventilation (architecture)



An ab anbar (water reservoir) with double domes and windcatchers (openings near the top of the towers) in the central desert city of Naeen, Iran. Windcatchers are a form of natural ventilation.[¹]

Ventilation is the intentional introduction of outdoor air into a space. Ventilation is mainly used to control indoor air quality by diluting and displacing indoor pollutants; it can also be used to control indoor temperature, humidity, and air motion to benefit thermal comfort, satisfaction with other aspects of the indoor environment, or other objectives.

The intentional introduction of outdoor air is usually categorized as either mechanical ventilation, natural ventilation, or mixed-mode ventilation.[²]

- Mechanical ventilation is the intentional fan-driven flow of outdoor air into and/or out from a building. Mechanical ventilation systems may include supply fans (which push outdoor air into a building), exhaust[³] fans (which draw air out of a building and thereby cause equal ventilation flow into a building), or a combination of both (called balanced ventilation if it neither pressurizes nor depressurizes the inside air,[³] or only slightly depressurizes it). Mechanical ventilation is often provided by equipment that is also used to heat and cool a space.
- Natural ventilation is the intentional passive flow of outdoor air into a building through planned openings (such as louvers, doors, and windows). Natural ventilation does not require mechanical systems to move outdoor air. Instead, it relies entirely on passive physical phenomena, such as wind pressure, or the stack effect. Natural ventilation openings may be fixed, or adjustable. Adjustable openings may be controlled automatically (automated), owned by occupants (operable), or a combination of both. Cross ventilation is a phenomenon of natural ventilation.
- Mixed-mode ventilation systems use both mechanical and natural processes. The mechanical and natural components may be used at the same time, at different times of day, or in different seasons of the year.[⁴] Since natural ventilation flow depends on environmental conditions, it may not always provide an appropriate amount of ventilation. In this case, mechanical systems may be used to supplement or regulate the naturally driven flow.

Ventilation is typically described as separate from infiltration.

- Infiltration is the circumstantial flow of air from outdoors to indoors through leaks (unplanned openings) in a building envelope. When a building design relies on

infiltration to maintain indoor air quality, this flow has been referred to as adventitious ventilation.^[5]

The design of buildings that promote occupant health and well-being requires a clear understanding of the ways that ventilation airflow interacts with, dilutes, displaces, or introduces pollutants within the occupied space. Although ventilation is an integral component of maintaining good indoor air quality, it may not be satisfactory alone.^[6] A clear understanding of both indoor and outdoor air quality parameters is needed to improve the performance of ventilation in terms of occupant health and energy.^[7] In scenarios where outdoor pollution would deteriorate indoor air quality, other treatment devices such as filtration may also be necessary.^[8] In kitchen ventilation systems, or for laboratory fume hoods, the design of effective effluent capture can be more important than the bulk amount of ventilation in a space. More generally, the way that an air distribution system causes ventilation to flow into and out of a space impacts the ability of a particular ventilation rate to remove internally generated pollutants. The ability of a system to reduce pollution in space is described as its "ventilation effectiveness". However, the overall impacts of ventilation on indoor air quality can depend on more complex factors such as the sources of pollution, and the ways that activities and airflow interact to affect occupant exposure.

An array of factors related to the design and operation of ventilation systems are regulated by various codes and standards. Standards dealing with the design and operation of ventilation systems to achieve acceptable indoor air quality include the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standards 62.1 and 62.2, the International Residential Code, the International Mechanical Code, and the United Kingdom Building Regulations Part F. Other standards that focus on energy conservation also impact the design and operation of ventilation systems, including ASHRAE Standard 90.1, and the International Energy Conservation Code.

When indoor and outdoor conditions are favorable, increasing ventilation beyond the minimum required for indoor air quality can significantly improve both indoor air quality and thermal comfort through ventilative cooling, which also helps reduce the energy demand of buildings.^[9]^[10] During these times, higher ventilation rates, achieved through passive or mechanical means (air-side economizer, ventilative pre-cooling), can be particularly beneficial for enhancing people's physical health.^[11] Conversely, when conditions are less favorable, maintaining or improving indoor air quality through ventilation may require increased use of mechanical heating or cooling, leading to higher energy consumption.

Ventilation should be considered for its relationship to "venting" for appliances and combustion equipment such as water heaters, furnaces, boilers, and wood stoves. Most importantly, building ventilation design must be careful to avoid the backdraft of combustion products from "naturally vented" appliances into the occupied space. This

issue is of greater importance for buildings with more air-tight envelopes. To avoid the hazard, many modern combustion appliances utilize "direct venting" which draws combustion air directly from outdoors, instead of from the indoor environment.

Design of air flow in rooms

[edit]

The air in a room can be supplied and removed in several ways, for example via ceiling ventilation, cross ventilation, floor ventilation or displacement ventilation.^[*citation needed*]

Ceiling ventilation

○

Image not found or type unknown

Ceiling ventilation Cross ventilation

○

Image not found or type unknown

Cross ventilation Floor ventilation

○

Image not found or type unknown

Floor ventilation Displacement ventilation

○

Image not found or type unknown

Displacement ventilation

Furthermore, the air can be circulated in the room using vortexes which can be initiated in various ways:

Tangential flow vortexes, initiated horizontally

○

Image not found or type unknown

Tangential flow
vortexes, initiated
horizontally

Tangential flow vortexes, initiated vertically

○

Image not found or type unknown

Tangential flow
vortexes, initiated
vertically

Diffused flow vortexes from air nozzles

○

Image not found or type unknown

Diffused flow
vortexes from air
nozzles

Diffused flow vortexes due to roof vortexes

○

Image not found or type unknown

Diffused flow
vortices due to roof
vortices

Ventilation rates for indoor air quality

[edit]

The examples and perspective in this article **deal primarily with the United States and do not represent a worldwide view of the subject**. You may improve this article, discuss the issue on the talk page, or create a new article, as appropriate. *(April 2024) (Learn how and when to remove this message)*

The ventilation rate, for commercial, industrial, and institutional (CII) buildings, is normally expressed by the volumetric flow rate of outdoor air, introduced to the building. The typical units used are cubic feet per minute (CFM) in the imperial system, or liters per second (L/s) in the metric system (even though cubic meter per second is the preferred unit for volumetric flow rate in the SI system of units). The ventilation rate can also be expressed on a per person or per unit floor area basis, such as CFM/p or CFM/ft², or as air changes per hour (ACH).

Standards for residential buildings

[edit]

For residential buildings, which mostly rely on infiltration for meeting their ventilation needs, a common ventilation rate measure is the air change rate (or air changes per hour): the hourly ventilation rate divided by the volume of the space (*I* or *ACH*; units of 1/h). During the winter, ACH may range from 0.50 to 0.41 in a tightly air-sealed house to 1.11 to 1.47 in a loosely air-sealed house.^[12]

ASHRAE now recommends ventilation rates dependent upon floor area, as a revision to the 62-2001 standard, in which the minimum ACH was 0.35, but no less than 15 CFM/person (7.1 L/s/person). As of 2003, the standard has been changed to 3 CFM/100 sq. ft. (15 L/s/100 sq. m.) plus 7.5 CFM/person (3.5 L/s/person).^[13]

Standards for commercial buildings

[edit]

Ventilation rate procedure

[edit]

Ventilation Rate Procedure is rate based on standard and prescribes the rate at which ventilation air must be delivered to space and various means to the condition that air.^[14] Air quality is assessed (through CO₂ measurement) and ventilation rates are mathematically derived using constants. Indoor Air Quality Procedure uses one or more guidelines for the specification of acceptable concentrations of certain contaminants in indoor air but does not prescribe ventilation rates or air treatment methods.^[14] This addresses both quantitative and subjective evaluations and is based on the Ventilation Rate Procedure. It also accounts for potential contaminants that may have no measured limits, or for which no limits are not set (such as formaldehyde off-gassing from carpet and furniture).

Natural ventilation

[edit]

Main article: Natural ventilation

Natural ventilation harnesses naturally available forces to supply and remove air in an enclosed space. Poor ventilation in rooms is identified to significantly increase the localized moldy smell in specific places of the room including room corners.^[11] There are three types of natural ventilation occurring in buildings: wind-driven ventilation, pressure-driven flows, and stack ventilation.^[15] The pressures generated by 'the stack effect' rely upon the buoyancy of heated or rising air. Wind-driven ventilation relies upon the force of the prevailing wind to pull and push air through the enclosed space as well as through breaches in the building's envelope.

Almost all historic buildings were ventilated naturally.^[16] The technique was generally abandoned in larger US buildings during the late 20th century as the use of air conditioning became more widespread. However, with the advent of advanced Building Performance Simulation (BPS) software, improved Building Automation Systems (BAS), Leadership in Energy and Environmental Design (LEED) design requirements, and improved window manufacturing techniques; natural ventilation has made a resurgence in commercial buildings both globally and throughout the US.^[17]

The benefits of natural ventilation include:

- Improved indoor air quality (IAQ)
- Energy savings
- Reduction of greenhouse gas emissions
- Occupant control
- Reduction in occupant illness associated with sick building syndrome
- Increased worker productivity

Techniques and architectural features used to ventilate buildings and structures naturally include, but are not limited to:

- Operable windows
- Clerestory windows and vented skylights
- Lev/convection doors
- Night purge ventilation
- Building orientation
- Wind capture façades

Airborne diseases

[edit]

Natural ventilation is a key factor in reducing the spread of airborne illnesses such as tuberculosis, the common cold, influenza, meningitis or COVID-19.^[18] Opening doors and windows are good ways to maximize natural ventilation, which would make the risk of airborne contagion much lower than with costly and maintenance-requiring mechanical systems. Old-fashioned clinical areas with high ceilings and large windows provide the greatest protection. Natural ventilation costs little and is maintenance-free, and is particularly suited to limited-resource settings and tropical climates, where the burden of TB and institutional TB transmission is highest. In settings where respiratory isolation is difficult and climate permits, windows and doors should be opened to reduce the risk of airborne contagion. Natural ventilation requires little maintenance and is inexpensive.^[19]

Natural ventilation is not practical in much of the infrastructure because of climate. This means that the facilities need to have effective mechanical ventilation systems and or use Ceiling Level UV or FAR UV ventilation systems.

Ventilation is measured in terms of air changes per hour (ACH). As of 2023, the CDC recommends that all spaces have a minimum of 5 ACH.^[20] For hospital rooms with airborne contagions the CDC recommends a minimum of 12 ACH.^[21] Challenges in facility ventilation are public unawareness,^[22]^[23] ineffective government oversight, poor building codes that are based on comfort levels, poor system operations, poor maintenance, and lack of transparency.^[24]

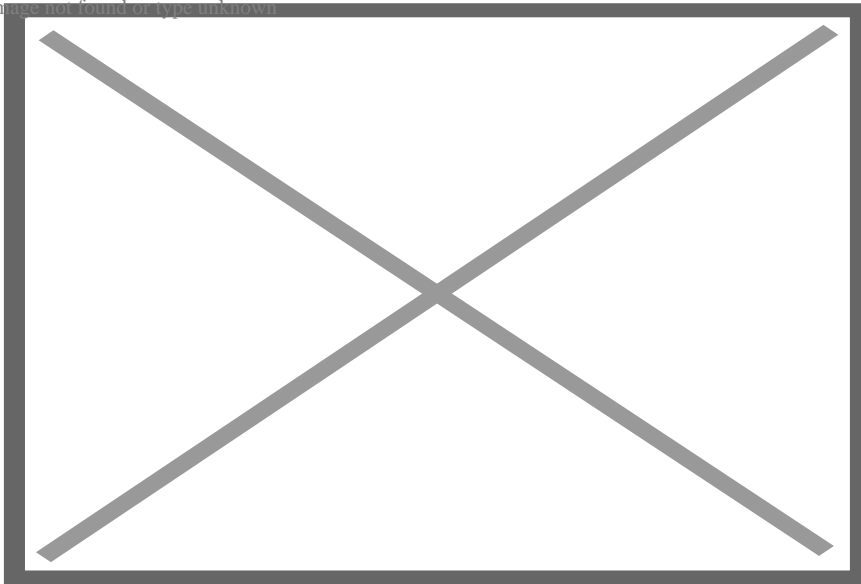
Pressure, both political and economic, to improve energy conservation has led to decreased ventilation rates. Heating, ventilation, and air conditioning rates have dropped since the energy crisis in the 1970s and the banning of cigarette smoke in the 1980s and 1990s.^[25]^[26]^[better source needed]

Mechanical ventilation

[edit]

Main article: HVAC

Image not found or type unknown



An axial belt-drive exhaust fan serving an underground car park. This exhaust fan's operation is interlocked with the concentration of contaminants emitted by internal combustion engines.

Mechanical ventilation of buildings and structures can be achieved by the use of the following techniques:

- Whole-house ventilation
- Mixing ventilation
- Displacement ventilation
- Dedicated subaerial air supply

Demand-controlled ventilation (DCV)

[edit]

Demand-controlled ventilation (**DCV**, also known as Demand Control Ventilation) makes it possible to maintain air quality while conserving energy.^{[27][28]} ASHRAE has determined that "It is consistent with the ventilation rate procedure that demand control be permitted for use to reduce the total outdoor air supply during periods of less occupancy."^[29] In a DCV system, CO₂ sensors control the amount of ventilation.^{[30][31]} During peak occupancy, CO₂ levels rise, and the system adjusts to deliver the same amount of outdoor air as would be used by the ventilation-rate procedure.^[32] However, when spaces are less occupied, CO₂ levels reduce, and the system reduces ventilation to conserve energy. DCV is a well-established practice,^[33] and is required in high occupancy spaces by building energy standards such as ASHRAE 90.1.^[34]

Personalized ventilation

[edit]



This section needs to be **updated**. Please help update this article to reflect recent events or newly available information. *(September 2024)*

Personalized ventilation is an air distribution strategy that allows individuals to control the amount of ventilation received. The approach delivers fresh air more directly to the breathing zone and aims to improve the air quality of inhaled air. Personalized ventilation provides much higher ventilation effectiveness than conventional mixing ventilation systems by displacing pollution from the breathing zone with far less air volume. Beyond improved air quality benefits, the strategy can also improve occupants' thermal comfort, perceived air quality, and overall satisfaction with the indoor environment. Individuals' preferences for temperature and air movement are not equal, and so traditional approaches to homogeneous environmental control have failed to achieve high occupant satisfaction. Techniques such as personalized ventilation facilitate control of a more diverse thermal environment that can improve thermal satisfaction for most occupants.

Local exhaust ventilation

[edit]

See also: Power tool

Local exhaust ventilation addresses the issue of avoiding the contamination of indoor air by specific high-emission sources by capturing airborne contaminants before they are spread into the environment. This can include water vapor control, lavatory effluent control, solvent vapors from industrial processes, and dust from wood- and metal-working machinery. Air can be exhausted through pressurized hoods or the use of fans and pressurizing a specific area.^[35]

A local exhaust system is composed of five basic parts:

1. A hood that captures the contaminant at its source
2. Ducts for transporting the air
3. An air-cleaning device that removes/minimizes the contaminant
4. A fan that moves the air through the system
5. An exhaust stack through which the contaminated air is discharged^[35]

In the UK, the use of LEV systems has regulations set out by the Health and Safety Executive (HSE) which are referred to as the Control of Substances Hazardous to Health (CoSHH). Under CoSHH, legislation is set to protect users of LEV systems by ensuring that all equipment is tested at least every fourteen months to ensure the LEV systems are performing adequately. All parts of the system must be visually inspected and thoroughly tested and where any parts are found to be defective, the inspector must issue a red label to identify the defective part and the issue.

The owner of the LEV system must then have the defective parts repaired or replaced before the system can be used.

Smart ventilation

[edit]

Smart ventilation is a process of continually adjusting the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills, and other non-IAQ costs (such as thermal discomfort or noise). A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following: occupancy, outdoor thermal and air quality conditions, electricity grid needs, direct sensing of contaminants, operation of other air moving and air cleaning systems. In addition, smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as a signal when systems need maintenance or repair. Being responsive to occupancy means that a smart ventilation system can adjust ventilation depending on demand such as reducing ventilation if the building is unoccupied. Smart ventilation can time-shift ventilation to periods when a) indoor-outdoor temperature differences are smaller (and away from peak outdoor temperatures and humidity), b) when indoor-outdoor temperatures are appropriate for ventilative cooling, or c) when outdoor air quality is acceptable. Being responsive to electricity grid needs means providing flexibility to electricity demand (including direct signals from utilities) and integration with electric grid control strategies. Smart ventilation systems can have sensors to detect airflow, systems pressures, or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement.^[36]

Ventilation and combustion

[edit]

Combustion (in a fireplace, gas heater, candle, oil lamp, etc.) consumes oxygen while producing carbon dioxide and other unhealthy gases and smoke, requiring ventilation air. An open chimney promotes infiltration (i.e. natural ventilation) because of the negative pressure change induced by the buoyant, warmer air leaving through the chimney. The warm air is typically replaced by heavier, cold air.

Ventilation in a structure is also needed for removing water vapor produced by respiration, burning, and cooking, and for removing odors. If water vapor is permitted to accumulate, it may damage the structure, insulation, or finishes. ^[citation needed] When operating, an air conditioner usually removes excess moisture from the air. A dehumidifier may also be appropriate for removing airborne moisture.

Calculation for acceptable ventilation rate

[edit]

Ventilation guidelines are based on the minimum ventilation rate required to maintain acceptable levels of effluents. Carbon dioxide is used as a reference point, as it is the gas of highest emission at a relatively constant value of 0.005 L/s. The mass balance equation is:

$$Q = G / (C_i - C_a)$$

- Q = ventilation rate (L/s)
- G = CO₂ generation rate
- C_i = acceptable indoor CO₂ concentration
- C_a = ambient CO₂ concentration^[37]

Smoking and ventilation

[edit]

ASHRAE standard 62 states that air removed from an area with environmental tobacco smoke shall not be recirculated into ETS-free air. A space with ETS requires more ventilation to achieve similar perceived air quality to that of a non-smoking environment.

The amount of ventilation in an ETS area is equal to the amount of an ETS-free area plus the amount V, where:

$$V = DSD \times VA \times A / 60E$$

- V = recommended extra flow rate in CFM (L/s)
- DSD = design smoking density (estimated number of cigarettes smoked per hour per unit area)
- VA = volume of ventilation air per cigarette for the room being designed (ft³/cig)
- E = contaminant removal effectiveness^[38]

History

[edit]


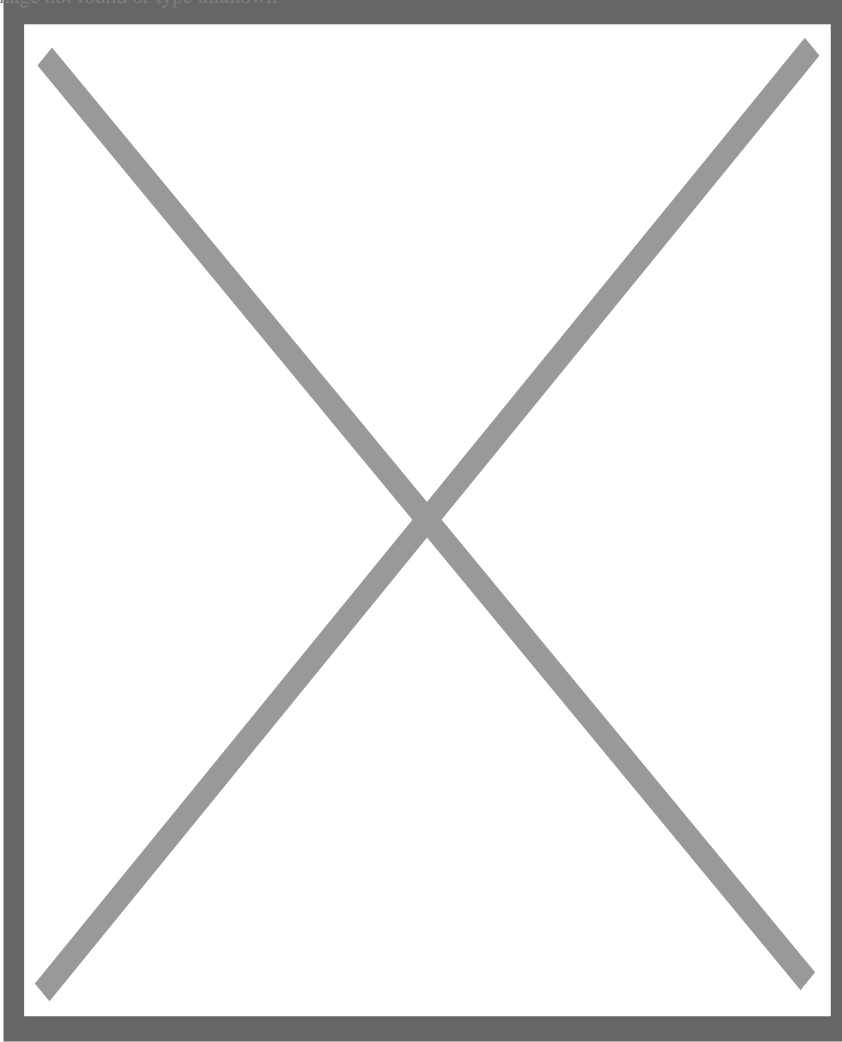
 This section **needs expansion**. You can help by adding to it. *(August 2020)*

Image not found or type unknown



This ancient Roman house uses a variety of passive cooling and passive ventilation techniques. Heavy masonry walls, small exterior windows, and a narrow walled garden oriented N-S shade the house, preventing heat gain. The house opens onto a central atrium with an impluvium (open to the sky); the evaporative cooling of the water causes a cross-draft from atrium to garden.

Primitive ventilation systems were found at the Pločnik archaeological site (belonging to the Vinča culture) in Serbia and were built into early copper smelting furnaces. The furnace, built on the outside of the workshop, featured earthen pipe-like air vents with hundreds of tiny holes in them and a prototype chimney to ensure air goes into the furnace to feed the fire and smoke comes out safely.^[39]

Passive ventilation and passive cooling systems were widely written about around the Mediterranean by Classical times. Both sources of heat and sources of cooling (such as

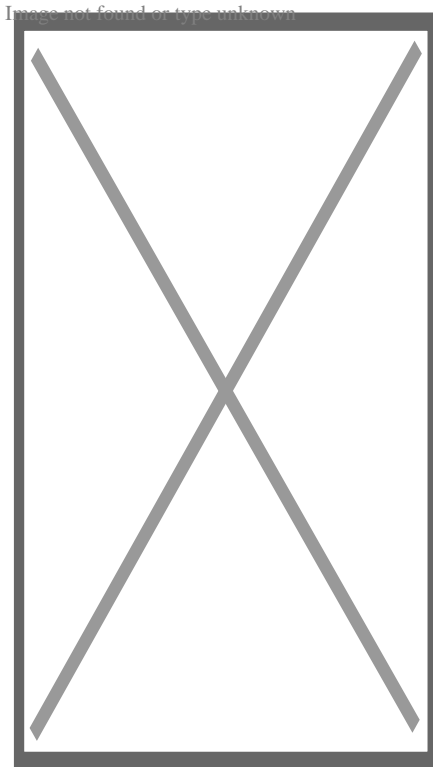
fountains and subterranean heat reservoirs) were used to drive air circulation, and buildings were designed to encourage or exclude drafts, according to climate and function. Public bathhouses were often particularly sophisticated in their heating and cooling. Icehouses are some millennia old, and were part of a well-developed ice industry by classical times.

The development of forced ventilation was spurred by the common belief in the late 18th and early 19th century in the miasma theory of disease, where stagnant 'airs' were thought to spread illness. An early method of ventilation was the use of a ventilating fire near an air vent which would forcibly cause the air in the building to circulate. English engineer John Theophilus Desaguliers provided an early example of this when he installed ventilating fires in the air tubes on the roof of the House of Commons. Starting with the Covent Garden Theatre, gas burning chandeliers on the ceiling were often specially designed to perform a ventilating role.

Mechanical systems

[edit]

Further information: Heating, ventilation, and air conditioning § Mechanical or forced ventilation



The Central Tower of the Palace of Westminster. This octagonal spire was for ventilation purposes, in the more complex system imposed by Reid on Barry, in which it was to draw air out of the Palace. The design was for the aesthetic disguise of its function.^{[40][41]}

A more sophisticated system involving the use of mechanical equipment to circulate the air was developed in the mid-19th century. A basic system of bellows was put in place to ventilate Newgate Prison and outlying buildings, by the engineer Stephen Hales in the mid-1700s. The problem with these early devices was that they required constant human labor to operate. David Boswell Reid was called to testify before a Parliamentary committee on proposed architectural designs for the new House of Commons, after the old one burned down in a fire in 1834.^[40] In January 1840 Reid was appointed by the committee for the House of Lords dealing with the construction of the replacement for the Houses of Parliament. The post was in the capacity of ventilation engineer, in effect; and with its creation there began a long series of quarrels between Reid and Charles Barry, the architect.^[42]

Reid advocated the installation of a very advanced ventilation system in the new House. His design had air being drawn into an underground chamber, where it would undergo either heating or cooling. It would then ascend into the chamber through thousands of small holes drilled into the floor, and would be extracted through the ceiling by a special ventilation fire within a great stack.^[43]

Reid's reputation was made by his work in Westminster. He was commissioned for an air quality survey in 1837 by the Leeds and Selby Railway in their tunnel.^[44] The steam vessels built for the Niger expedition of 1841 were fitted with ventilation systems based on Reid's Westminster model.^[45] Air was dried, filtered and passed over charcoal.^[46]^[47] Reid's ventilation method was also applied more fully to St. George's Hall, Liverpool, where the architect, Harvey Lonsdale Elmes, requested that Reid should be involved in ventilation design.^[48] Reid considered this the only building in which his system was completely carried out.^[49]

Fans

[edit]

With the advent of practical steam power, ceiling fans could finally be used for ventilation. Reid installed four steam-powered fans in the ceiling of St George's Hospital in Liverpool, so that the pressure produced by the fans would force the incoming air upward and through vents in the ceiling. Reid's pioneering work provides the basis for ventilation systems to this day.^[43] He was remembered as "Dr. Reid the ventilator" in the twenty-first century in discussions of energy efficiency, by Lord Wade of Chorlton.^[50]

History and development of ventilation rate standards

[edit]

Ventilating a space with fresh air aims to avoid "bad air". The study of what constitutes bad air dates back to the 1600s when the scientist Mayow studied asphyxia of animals in confined bottles.^[51] The poisonous component of air was later identified as carbon dioxide (CO₂), by Lavoisier in the very late 1700s, starting a debate as to the nature of "bad air" which humans perceive to be stuffy or unpleasant. Early hypotheses included excess concentrations of CO₂ and oxygen depletion. However, by the late 1800s, scientists thought biological contamination, not oxygen or CO₂, was the primary component of unacceptable indoor air. However, it was noted as early as 1872 that CO₂ concentration closely correlates to perceived air quality.

The first estimate of minimum ventilation rates was developed by Tredgold in 1836.^[52] This was followed by subsequent studies on the topic by Billings ^[53] in 1886 and Flugge in 1905. The recommendations of Billings and Flugge were incorporated into numerous building codes from 1900–the 1920s and published as an industry standard by ASHVE (the predecessor to ASHRAE) in 1914.^[51]

The study continued into the varied effects of thermal comfort, oxygen, carbon dioxide, and biological contaminants. The research was conducted with human subjects in controlled test chambers. Two studies, published between 1909 and 1911, showed that carbon dioxide was not the offending component. Subjects remained satisfied in chambers with high levels of CO₂, so long as the chamber remained cool.^[51] (Subsequently, it has been determined that CO₂ is, in fact, harmful at concentrations over 50,000ppm^[54])

ASHVE began a robust research effort in 1919. By 1935, ASHVE-funded research conducted by Lemberg, Brandt, and Morse – again using human subjects in test chambers – suggested the primary component of "bad air" was an odor, perceived by the human olfactory nerves.^[55] Human response to odor was found to be logarithmic to contaminant concentrations, and related to temperature. At lower, more comfortable temperatures, lower ventilation rates were satisfactory. A 1936 human test chamber study by Yaglou, Riley, and Coggins culminated much of this effort, considering odor, room volume, occupant age, cooling equipment effects, and recirculated air implications, which guided ventilation rates.^[56] The Yaglou research has been validated, and adopted into industry standards, beginning with the ASA code in 1946. From this research base, ASHRAE (having replaced ASHVE) developed space-by-space recommendations, and published them as ASHRAE Standard 62-1975: Ventilation for acceptable indoor air quality.

As more architecture incorporated mechanical ventilation, the cost of outdoor air ventilation came under some scrutiny. In 1973, in response to the 1973 oil crisis and conservation concerns, ASHRAE Standards 62-73 and 62-81) reduced required ventilation from 10 CFM (4.76 L/s) per person to 5 CFM (2.37 L/s) per person. In cold, warm, humid, or dusty climates, it is preferable to minimize ventilation with outdoor air to conserve energy, cost, or filtration. This critique (e.g. Tiller^[57]) led ASHRAE to reduce

outdoor ventilation rates in 1981, particularly in non-smoking areas. However subsequent research by Fanger,^[58] W. Cain, and Janssen validated the Yaglou model. The reduced ventilation rates were found to be a contributing factor to sick building syndrome.^[59]

The 1989 ASHRAE standard (Standard 62–89) states that appropriate ventilation guidelines are 20 CFM (9.2 L/s) per person in an office building, and 15 CFM (7.1 L/s) per person for schools, while 2004 Standard 62.1-2004 has lower recommendations again (see tables below). ANSI/ASHRAE (Standard 62–89) speculated that "comfort (odor) criteria are likely to be satisfied if the ventilation rate is set so that 1,000 ppm CO₂ is not exceeded"^[60] while OSHA has set a limit of 5000 ppm over 8 hours.^[61]

Historical ventilation rates

Author or source	Year	Ventilation rate (IP)	Ventilation rate (SI)	Basis or rationale
Tredgold	1836	4 CFM per person	2 L/s per person	Basic metabolic needs, breathing rate, and candle burning
Billings	1895	30 CFM per person	15 L/s per person	Indoor air hygiene, preventing spread of disease
Flugge	1905	30 CFM per person	15 L/s per person	Excessive temperature or unpleasant odor
ASHVE	1914	30 CFM per person	15 L/s per person	Based on Billings, Flugge and contemporaries
Early US Codes	1925	30 CFM per person	15 L/s per person	Same as above
Yaglou	1936	15 CFM per person	7.5 L/s per person	Odor control, outdoor air as a fraction of total air
ASA	1946	15 CFM per person	7.5 L/s per person	Based on Yaglou and contemporaries
ASHRAE	1975	15 CFM per person	7.5 L/s per person	Same as above
ASHRAE	1981	10 CFM per person	5 L/s per person	For non-smoking areas, reduced.
ASHRAE	1989	15 CFM per person	7.5 L/s per person	Based on Fanger, W. Cain, and Janssen

ASHRAE continues to publish space-by-space ventilation rate recommendations, which are decided by a consensus committee of industry experts. The modern descendants of ASHRAE standard 62-1975 are ASHRAE Standard 62.1, for non-residential spaces, and ASHRAE 62.2 for residences.

In 2004, the calculation method was revised to include both an occupant-based contamination component and an area-based contamination component.^[62] These two components are additive, to arrive at an overall ventilation rate. The change was made to recognize that densely populated areas were sometimes overventilated (leading to higher energy and cost) using a per-person methodology.

Occupant Based Ventilation Rates,^[62] ANSI/ASHRAE Standard 62.1-2004

IP Units	SI Units	Category	Examples
0 cfm/person	0 L/s/person	Spaces where ventilation requirements are primarily associated with building elements, not occupants.	Storage Rooms, Warehouses
5 cfm/person	2.5 L/s/person	Spaces occupied by adults, engaged in low levels of activity	Office space
7.5 cfm/person	3.5 L/s/person	Spaces where occupants are engaged in higher levels of activity, but not strenuous, or activities generating more contaminants	Retail spaces, lobbies
10 cfm/person	5 L/s/person	Spaces where occupants are engaged in more strenuous activity, but not exercise, or activities generating more contaminants	Classrooms, school settings
20 cfm/person	10 L/s/person	Spaces where occupants are engaged in exercise, or activities generating many contaminants	dance floors, exercise rooms

Area-based ventilation rates,^[62] ANSI/ASHRAE Standard 62.1-2004

IP Units	SI Units	Category	Examples
0.06 cfm/ft ²	0.30 L/s/m ²	Spaces where space contamination is normal, or similar to an office environment	Conference rooms, lobbies
0.12 cfm/ft ²	0.60 L/s/m ²	Spaces where space contamination is significantly higher than an office environment	Classrooms, museums
0.18 cfm/ft ²	0.90 L/s/m ²	Spaces where space contamination is even higher than the previous category	Laboratories, art classrooms
0.30 cfm/ft ²	1.5 L/s/m ²	Specific spaces in sports or entertainment where contaminants are released	Sports, entertainment
0.48 cfm/ft ²	2.4 L/s/m ²	Reserved for indoor swimming areas, where chemical concentrations are high	Indoor swimming areas

The addition of occupant- and area-based ventilation rates found in the tables above often results in significantly reduced rates compared to the former standard. This is compensated in other sections of the standard which require that this minimum amount of air is delivered to the breathing zone of the individual occupant at all times. The total

outdoor air intake of the ventilation system (in multiple-zone variable air volume (VAV) systems) might therefore be similar to the airflow required by the 1989 standard. From 1999 to 2010, there was considerable development of the application protocol for ventilation rates. These advancements address occupant- and process-based ventilation rates, room ventilation effectiveness, and system ventilation effectiveness^[63]

Problems

[edit]

- In hot, humid climates, unconditioned ventilation air can daily deliver approximately 260 milliliters of water for each cubic meters per hour (m^3/h) of outdoor air (or one pound of water each day for each cubic feet per minute of outdoor air per day), annual average.^[citation needed] This is a great deal of moisture and can create serious indoor moisture and mold problems. For example, given a 150 m^2 building with an airflow of $180 \text{ m}^3/\text{h}$ this could result in about 47 liters of water accumulated per day.
- Ventilation efficiency is determined by design and layout, and is dependent upon the placement and proximity of diffusers and return air outlets. If they are located closely together, supply air may mix with stale air, decreasing the efficiency of the HVAC system, and creating air quality problems.
- System imbalances occur when components of the HVAC system are improperly adjusted or installed and can create pressure differences (too much-circulating air creating a draft or too little circulating air creating stagnancy).
- Cross-contamination occurs when pressure differences arise, forcing potentially contaminated air from one zone to an uncontaminated zone. This often involves undesired odors or VOCs.
- Re-entry of exhaust air occurs when exhaust outlets and fresh air intakes are either too close, prevailing winds change exhaust patterns or infiltration between intake and exhaust air flows.
- Entrainment of contaminated outdoor air through intake flows will result in indoor air contamination. There are a variety of contaminated air sources, ranging from industrial effluent to VOCs put off by nearby construction work.^[64] A recent study revealed that in urban European buildings equipped with ventilation systems lacking outdoor air filtration, the exposure to outdoor-originating pollutants indoors resulted in more Disability-Adjusted Life Years (DALYs) than exposure to indoor-emitted pollutants.^[65]

See also

[edit]

- Architectural engineering
- Biological safety
- Cleanroom
- Environmental tobacco smoke
- Fume hood

- Head-end power
- Heating, ventilation, and air conditioning
- Heat recovery ventilation
- Mechanical engineering
- Room air distribution
- Sick building syndrome
- Siheyuan
- Solar chimney
- Tulou
- Windcatcher

References

[edit]

1. ^ *Malone, Alanna. "The Windcatcher House". Architectural Record: Building for Social Change. McGraw-Hill. Archived from the original on 22 April 2012.*
2. ^ *ASHRAE (2021). "Ventilation and Infiltration". ASHRAE Handbook—Fundamentals. Peachtree Corners, GA: ASHRAE. ISBN 978-1-947192-90-4.*
3. ^ **a b** Whole-House Ventilation | Department of Energy
4. ^ *de Gids W.F., Jicha M., 2010. "Ventilation Information Paper 32: Hybrid Ventilation Archived 2015-11-17 at the Wayback Machine", Air Infiltration and Ventilation Centre (AIVC), 2010*
5. ^ *Schiavon, Stefano (2014). "Adventitious ventilation: a new definition for an old mode?". *Indoor Air*. **24** (6): 557–558. Bibcode:2014InAir..24..557S. doi:10.1111/ina.12155. ISSN 1600-0668. PMID 25376521.*
6. ^ *ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, ASHRAE, Inc., Atlanta, GA, US*
7. ^ *Belias, Evangelos; Licina, Dusan (2024). "European residential ventilation: Investigating the impact on health and energy demand". *Energy and Buildings*. **304**. Bibcode:2024EneBu.30413839B. doi:10.1016/j.enbuild.2023.113839.*
8. ^ *Belias, Evangelos; Licina, Dusan (2022). "Outdoor PM2.5 air filtration: optimising indoor air quality and energy". *Building & Cities*. **3** (1): 186–203. doi:10.5334/bc.153.*
9. ^ *Belias, Evangelos; Licina, Dusan (2024). "European residential ventilation: Investigating the impact on health and energy demand". *Energy and Buildings*. **304**. Bibcode:2024EneBu.30413839B. doi:10.1016/j.enbuild.2023.113839.*
10. ^ *Belias, Evangelos; Licina, Dusan (2023). "Influence of outdoor air pollution on European residential ventilative cooling potential". *Energy and Buildings*. **289**. Bibcode:2023EneBu.28913044B. doi:10.1016/j.enbuild.2023.113044.*
11. ^ **a b** *Sun, Y., Zhang, Y., Bao, L., Fan, Z. and Sundell, J., 2011. Ventilation and dampness in dorms and their associations with allergy among college students in China: a case-control study. *Indoor Air*, 21(4), pp.277-283.*
12. ^ *Kavanaugh, Steve. Infiltration and Ventilation In Residential Structures. February 2004*

13. ^ M.H. Sherman. "ASHRAE's First Residential Ventilation Standard" (PDF). Lawrence Berkeley National Laboratory. Archived from the original (PDF) on 29 February 2012.
14. ^ **a b** ASHRAE Standard 62
15. ^ How Natural Ventilation Works by Steven J. Hoff and Jay D. Harmon. Ames, IA: Department of Agricultural and Biosystems Engineering, Iowa State University, November 1994.
16. ^ "Natural Ventilation – Whole Building Design Guide". Archived from the original on 21 July 2012.
17. ^ Shaq, Erlet. *Sustainable Architectural Design*.
18. ^ "Natural Ventilation for Infection Control in Health-Care Settings" (PDF). World Health Organization (WHO), 2009. Retrieved 5 July 2021.
19. ^ Escombe, A. R.; Oeser, C. C.; Gilman, R. H.; et al. (2007). "Natural ventilation for the prevention of airborne contagion". *PLOS Med.* **4** (68): e68. doi: 10.1371/journal.pmed.0040068. PMC 1808096. PMID 17326709.
20. ^ Centers For Disease Control and Prevention (CDC) "Improving Ventilation In Buildings". 11 February 2020.
21. ^ Centers For Disease Control and Prevention (CDC) "Guidelines for Environmental Infection Control in Health-Care Facilities". 22 July 2019.
22. ^ Dr. Edward A. Nardell Professor of Global Health and Social Medicine, Harvard Medical School "If We're Going to Live With COVID-19, It's Time to Clean Our Indoor Air Properly". *Time*. February 2022.
23. ^ "A Paradigm Shift to Combat Indoor Respiratory Infection - 21st century" (PDF). University of Leeds., Morawska, L, Allen, J, Bahnfleth, W et al. (36 more authors) (2021) A paradigm shift to combat indoor respiratory infection. *Science*, 372 (6543). pp. 689-691. ISSN 0036-8075
24. ^ Video "Building Ventilation What Everyone Should Know". YouTube. 17 June 2022.
25. ^ Mudarri, David (January 2010). *Public Health Consequences and Cost of Climate Change Impacts on Indoor Environments (PDF) (Report)*. The Indoor Environments Division, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency. pp. 38–39, 63.
26. ^ "Climate Change a Systems Perspective". Cassbeth.
27. ^ Raatschen W. (ed.), 1990: "Demand Controlled Ventilation Systems: State of the Art Review Archived 2014-05-08 at the Wayback Machine", Swedish Council for Building Research, 1990
28. ^ Mansson L.G., Svennberg S.A., Liddament M.W., 1997: "Technical Synthesis Report. A Summary of IEA Annex 18. Demand Controlled Ventilating Systems Archived 2016-03-04 at the Wayback Machine", UK, Air Infiltration and Ventilation Centre (AIVC), 1997
29. ^ ASHRAE (2006). "Interpretation IC 62.1-2004-06 Of ANSI/ASHRAE Standard 62.1-2004 Ventilation For Acceptable Indoor Air Quality" (PDF). American Society of Heating, Refrigerating, and Air-Conditioning Engineers. p. 2. Archived from the original (PDF) on 12 August 2013. Retrieved 10 April 2013.

30. ^ Fahlen P., Andersson H., Ruud S., 1992: "Demand Controlled Ventilation Systems: Sensor Tests Archived 2016-03-04 at the Wayback Machine", Swedish National Testing and Research Institute, Boras, 1992
31. ^ Raatschen W., 1992: "Demand Controlled Ventilation Systems: Sensor Market Survey Archived 2016-03-04 at the Wayback Machine", Swedish Council for Building Research, 1992
32. ^ Mansson L.G., Svennberg S.A., 1993: "Demand Controlled Ventilation Systems: Source Book Archived 2016-03-04 at the Wayback Machine", Swedish Council for Building Research, 1993
33. ^ Lin X, Lau J & Grenville KY. (2012). "Evaluation of the Validity of the Assumptions Underlying CO₂-Based Demand-Controlled Ventilation by a Literature review" (PDF). *ASHRAE Transactions NY-14-007 (RP-1547)*. Archived from the original (PDF) on 14 July 2014. Retrieved 10 July 2014.
34. ^ ASHRAE (2010). "ANSI/ASHRAE Standard 90.1-2010: Energy Standard for Buildings Except for Low-Rise Residential Buildings". American Society of Heating Ventilation and Air Conditioning Engineers, Atlanta, GA.
35. ^ **a b** "Ventilation. - 1926.57". *Osha.gov*. Archived from the original on 2 December 2012. Retrieved 10 November 2012.
36. ^ Air Infiltration and Ventilation Centre (AIVC). "What is smart ventilation?", AIVC, 2018
37. ^ "Home". *Wapa.gov*. Archived from the original on 26 July 2011. Retrieved 10 November 2012.
38. ^ ASHRAE, Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, Atlanta, 2002.
39. ^ "Stone Pages Archaeo News: Neolithic Vinca was a metallurgical culture". *www.stonepages.com*. Archived from the original on 30 December 2016. Retrieved 11 August 2016.
40. ^ **a b** Porter, Dale H. (1998). *The Life and Times of Sir Goldsworthy Gurney: Gentleman scientist and inventor, 1793–1875*. Associated University Presses, Inc. pp. 177–79. ISBN 0-934223-50-5.
41. ^ "The Towers of Parliament". *www.parliament.UK*. Archived from the original on 17 January 2012.
42. ^ Alfred Barry (1867). "The life and works of Sir Charles Barry, R.A., F.R.S., &c. &c" . Retrieved 29 December 2011.
43. ^ **a b** Robert Bruegmann. "Central Heating and Ventilation: Origins and Effects on Architectural Design" (PDF).
44. ^ Russell, Colin A; Hudson, John (2011). *Early Railway Chemistry and Its Legacy*. Royal Society of Chemistry. p. 67. ISBN 978-1-84973-326-7. Retrieved 29 December 2011.
45. ^ Milne, Lynn. "McWilliam, James Ormiston". *Oxford Dictionary of National Biography (online ed.)*. Oxford University Press. doi:10.1093/ref:odnb/17747. (Subscription or UK public library membership required.)
46. ^ Philip D. Curtin (1973). *The image of Africa: British ideas and action, 1780–1850*. Vol. 2. University of Wisconsin Press. p. 350. ISBN 978-0-299-83026-7. Retrieved

29 December 2011.








47. ^ "William Loney RN – Background". Peter Davis. Archived from the original on 6 January 2012. Retrieved 7 January 2012.
48. ^ Sturrock, Neil; Lawsdon-Smith, Peter (10 June 2009). "David Boswell Reid's Ventilation of St. George's Hall, Liverpool". *The Victorian Web*. Archived from the original on 3 December 2011. Retrieved 7 January 2012.
49. ^ Lee, Sidney, ed. (1896). "Reid, David Boswell". *Dictionary of National Biography*. Vol. 47. London: Smith, Elder & Co.
50. ^ Great Britain: Parliament: House of Lords: Science and Technology Committee (15 July 2005). *Energy Efficiency: 2nd Report of Session 2005–06*. The Stationery Office. p. 224. ISBN 978-0-10-400724-2. Retrieved 29 December 2011.
51. ^ **a b c** Janssen, John (September 1999). "The History of Ventilation and Temperature Control" (PDF). *ASHRAE Journal*. American Society of Heating Refrigeration and Air Conditioning Engineers, Atlanta, GA. Archived (PDF) from the original on 14 July 2014. Retrieved 11 June 2014.
52. ^ Tredgold, T. 1836. "The Principles of Warming and Ventilation – Public Buildings". London: M. Taylor
53. ^ Billings, J.S. 1886. "The principles of ventilation and heating and their practical application 2d ed., with corrections" Archived copy. OL 22096429M.
54. ^ "Immediately Dangerous to Life or Health Concentrations (IDLH): Carbon dioxide – NIOSH Publications and Products". CDC. May 1994. Archived from the original on 20 April 2018. Retrieved 30 April 2018.
55. ^ Lemberg WH, Brandt AD, and Morse, K. 1935. "A laboratory study of minimum ventilation requirements: ventilation box experiments". *ASHVE Transactions*, V. 41
56. ^ Yaglou CPE, Riley C, and Coggins DI. 1936. "Ventilation Requirements" *ASHVE Transactions*, v.32
57. ^ Tiller, T.R. 1973. *ASHRAE Transactions*, v. 79
58. ^ Berg-Munch B, Clausen P, Fanger PO. 1984. "Ventilation requirements for the control of body odor in spaces occupied by women". *Proceedings of the 3rd Int. Conference on Indoor Air Quality, Stockholm, Sweden*, V5
59. ^ Joshi, SM (2008). "The sick building syndrome". *Indian J Occup Environ Med*. **12** (2): 61–64. doi:10.4103/0019-5278.43262. PMC 2796751. PMID 20040980. in section 3 "Inadequate ventilation"
60. ^ "Standard 62.1-2004: Stricter or Not?" *ASHRAE IAQ Applications*, Spring 2006. "Archived copy" (PDF). Archived from the original (PDF) on 14 July 2014. Retrieved 12 June 2014.cite web: CS1 maint: archived copy as title (link) accessed 11 June 2014
61. ^ Apte, Michael G. Associations between indoor CO₂ concentrations and sick building syndrome symptoms in U.S. office buildings: an analysis of the 1994–1996 BASE study data." *Indoor Air*, Dec 2000: 246–58.
62. ^ **a b c** Stanke D. 2006. "Explaining Science Behind Standard 62.1-2004". *ASHRAE IAQ Applications*, V7, Summer 2006. "Archived copy" (PDF). Archived from the original (PDF) on 14 July 2014. Retrieved 12 June 2014.cite web: CS1 maint: archived copy as title (link) accessed 11 June 2014

63. ^ Stanke, DA. 2007. "Standard 62.1-2004: Stricter or Not?" ASHRAE IAQ Applications, Spring 2006. *"Archived copy" (PDF). Archived from the original (PDF) on 14 July 2014. Retrieved 12 June 2014.* cite web: CS1 maint: archived copy as title (link) accessed 11 June 2014
64. ^ US EPA. Section 2: Factors Affecting Indoor Air Quality. *"Archived copy" (PDF). Archived (PDF) from the original on 24 October 2008. Retrieved 30 April 2009.* cite web: CS1 maint: archived copy as title (link)
65. ^ Belias, Evangelos; Licina, Dusan (2024). "European residential ventilation: Investigating the impact on health and energy demand". *Energy and Buildings*. **304**. Bibcode:2024EneBu.30413839B. doi:10.1016/j.enbuild.2023.113839.

External links

[edit]

Ventilation (architecture) at Wikipedia's sister projects

-  Definitions from Wiktionary
-  Media from Commons
-  News from Wikinews
-  Quotations from Wikiquote
-  Texts from Wikisource
-  Textbooks from Wikibooks
-  Resources from Wikiversity

Air Infiltration & Ventilation Centre (AIVC)

[edit]

- Publications from the Air Infiltration & Ventilation Centre (AIVC)

International Energy Agency (IEA) Energy in Buildings and Communities Programme (EBC)

[edit]

- Publications from the International Energy Agency (IEA) Energy in Buildings and Communities Programme (EBC) ventilation-related research projects-annexes:
 - EBC Annex 9 Minimum Ventilation Rates
 - EBC Annex 18 Demand Controlled Ventilation Systems
 - EBC Annex 26 Energy Efficient Ventilation of Large Enclosures
 - EBC Annex 27 Evaluation and Demonstration of Domestic Ventilation Systems
 - EBC Annex 35 Control Strategies for Hybrid Ventilation in New and Retrofitted Office Buildings (HYBVENT)
 - EBC Annex 62 Ventilative Cooling

International Society of Indoor Air Quality and Climate

[edit]

- Indoor Air Journal
- Indoor Air Conference Proceedings

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

[edit]

- ASHRAE Standard 62.1 – Ventilation for Acceptable Indoor Air Quality
- ASHRAE Standard 62.2 – Ventilation for Acceptable Indoor Air Quality in Residential Buildings

- v
- t
- e

Heating, ventilation, and air conditioning

Fundamental concepts

- Air changes per hour
- Bake-out
- Building envelope
- Convection
- Dilution
- Domestic energy consumption
- Enthalpy
- Fluid dynamics
- Gas compressor
- Heat pump and refrigeration cycle
- Heat transfer
- Humidity
- Infiltration
- Latent heat
- Noise control
- Outgassing
- Particulates
- Psychrometrics
- Sensible heat
- Stack effect
- Thermal comfort
- Thermal destratification
- Thermal mass
- Thermodynamics
- Vapour pressure of water

Technology

- Absorption-compression heat pump
- Absorption refrigerator
- Air barrier
- Air conditioning
- Antifreeze
- Automobile air conditioning
- Autonomous building
- Building insulation materials
- Central heating
- Central solar heating
- Chilled beam
- Chilled water
- Constant air volume (CAV)
- Coolant
- Cross ventilation
- Dedicated outdoor air system (DOAS)
- Deep water source cooling
- Demand controlled ventilation (DCV)
- Displacement ventilation
- District cooling
- District heating
- Electric heating
- Energy recovery ventilation (ERV)
- Firestop
- Forced-air
- Forced-air gas
- Free cooling
- Heat recovery ventilation (HRV)
- Hybrid heat
- Hydronics
- Ice storage air conditioning
- Kitchen ventilation
- Mixed-mode ventilation
- Microgeneration
- Passive cooling
- Passive daytime radiative cooling
- Passive house
- Passive ventilation
- Radiant heating and cooling
- Radiant cooling
- Radiant heating
- Radon mitigation
- Refrigeration
- Renewable heat
- Room air distribution
- Solar air heat
- Solar combisystem
- Solar cooling
- Solar heating

- Air conditioner inverter
- Air door
- Air filter
- Air handler
- Air ionizer
- Air-mixing plenum
- Air purifier
- Air source heat pump
- Attic fan
- Automatic balancing valve
- Back boiler
- Barrier pipe
- Blast damper
- Boiler
- Centrifugal fan
- Ceramic heater
- Chiller
- Condensate pump
- Condenser
- Condensing boiler
- Convection heater
- Compressor
- Cooling tower
- Damper
- Dehumidifier
- Duct
- Economizer
- Electrostatic precipitator
- Evaporative cooler
- Evaporator
- Exhaust hood
- Expansion tank
- Fan
- Fan coil unit
- Fan filter unit
- Fan heater
- Fire damper
- Fireplace
- Fireplace insert
- Freeze stat
- Flue
- Freon
- Fume hood
- Furnace
- Gas compressor
- Gas heater
- Gasoline heater
- Grease duct
- Grille

Components

**Measurement
and control**

- Air flow meter
- Aquastat
- BACnet
- Blower door
- Building automation
- Carbon dioxide sensor
- Clean air delivery rate (CADR)
- Control valve
- Gas detector
- Home energy monitor
- Humidistat
- HVAC control system
- Infrared thermometer
- Intelligent buildings
- LonWorks
- Minimum efficiency reporting value (MERV)
- Normal temperature and pressure (NTP)
- OpenTherm
- Programmable communicating thermostat
- Programmable thermostat
- Psychrometrics
- Room temperature
- Smart thermostat
- Standard temperature and pressure (STP)
- Thermographic camera
- Thermostat
- Thermostatic radiator valve
- Architectural acoustics
- Architectural engineering
- Architectural technologist
- Building services engineering
- Building information modeling (BIM)
- Deep energy retrofit
- Duct cleaning
- Duct leakage testing
- Environmental engineering
- Hydronic balancing
- Kitchen exhaust cleaning
- Mechanical engineering
- Mechanical, electrical, and plumbing
- Mold growth, assessment, and remediation
- Refrigerant reclamation
- Testing, adjusting, balancing

**Professions,
trades,
and services**

Industry organizations

- AHRI
- AMCA
- ASHRAE
- ASTM International
- BRE
- BSRIA
- CIBSE
- Institute of Refrigeration
- IIR
- LEED
- SMACNA
- UMC

Health and safety

- Indoor air quality (IAQ)
- Passive smoking
- Sick building syndrome (SBS)
- Volatile organic compound (VOC)
- ASHRAE Handbook
- Building science
- Fireproofing

See also

- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Home automation
- Template:Solar energy

Authority control databases Image not found or type unknown **Edit this at Wikidata**

National

- Czech Republic

Other

- NARA

About Durham Supply Inc

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Things To Do in Tulsa County

Photo

Image not found or type unknown

Streetwalker Tours

0 (0)

Photo

Image not found or type unknown

OkieTundra

4.5 (84)

Photo

The Tulsa Arts District

4.7 (22)

Photo

Image not found or type unknown

The Cave House

4.6 (249)

Photo

Image not found or type unknown

The Blue Dome

4.5 (60)

Photo

Tulsa Air and Space Museum & Planetarium

4.3 (419)

Driving Directions in Tulsa County

Driving Directions From Waffle House to Durham Supply Inc

Driving Directions From Best Western Airport to Durham Supply Inc

Driving Directions From Country Inn & Suites by Radisson, Tulsa, OK to Durham Supply Inc

Driving Directions From Tulsa to Durham Supply Inc

Driving Directions From Brookhaven Hospitales to Durham Supply Inc

Driving Directions From Camp Bow Wow to Durham Supply Inc

[Heating contractor](#)

[HVAC contractor](#)

[Mobile Home Furnace Installation](#)

[Mobile Home Air Conditioning Installation Services](#)

[Mobile Home Hvac Repair](#)

[Mobile Home Hvac Service](#)

[Driving Directions From Golden Driller Statue to Durham Supply Inc](#)

[Driving Directions From Tulsa Zoo to Durham Supply Inc](#)

[Driving Directions From Gathering Place to Durham Supply Inc](#)

[Driving Directions From Bob Dylan Center to Durham Supply Inc](#)

[Driving Directions From The Tulsa Arts District to Durham Supply Inc](#)

[Driving Directions From Gathering Place to Durham Supply Inc](#)

[Mobile home supply store](#)

[Air conditioning repair service](#)

[Air conditioning store](#)

[Reviews for Durham Supply Inc](#)

Durham Supply Inc

Image not found or type unknown

Gerald Clifford Brewster

(5)

We will see, the storm door I bought says on the tag it's 36x80, but it's 34x80. If they return it.....they had no problems returning it. And it was no fault of there's, you measure a mobile home door different than a standard door!

Durham Supply Inc

Image not found or type unknown

Ethel Schiller

(5)

This place is really neat, if they don't have it they can order it from another of their stores and have it there overnight in most cases. Even hard to find items for a trailer! I definitely recommend this place to everyone! O and the prices is awesome too!

Durham Supply Inc

Image not found or type unknown

B Mann

(5)

I was in need of some items for a double wide that I am remodeling and this place is the only place in town that had what I needed (I didn't even try the other rude place)while I was there I learned the other place that was in Tulsa that also sold mobile home supplies went out of business (no wonder the last time I was in there they were VERY RUDE and high priced) I like the way Dunham does business they answered all my questions and got me the supplies I needed, very friendly, I will be back to purchase the rest of my items when the time comes.

Durham Supply Inc

Image not found or type unknown

Ty Spears

(5)

Bought a door/storm door combo. Turns out it was the wrong size. They swapped it out, quick and easy no problems. Very helpful in explaining the size differences from standard door sizes.

Durham Supply Inc

Image not found or type unknown

Dennis Champion

(5)

Durham supply and Royal supply seems to find the most helpful and friendly people to work in their stores, we are based out of Kansas City out here for a few remodels and these guys treated us like we've gone there for years.

Exploring Collaboration with Utility Incentive Programs for Mobile Homes [View GBP](#)

Frequently Asked Questions

What are utility incentive programs for mobile homes, and how do they benefit HVAC systems?

Utility incentive programs offer financial incentives or rebates to mobile home owners for upgrading to energy-efficient HVAC systems. These programs aim to reduce energy consumption, lower utility bills, and improve the overall efficiency of heating and cooling in mobile homes.

How can collaboration with utility companies enhance the adoption of efficient HVAC systems in mobile homes?

By partnering with utility companies, manufacturers and service providers can increase awareness about available incentives, streamline application processes, and offer bundled services that make it easier for homeowners to upgrade their HVAC systems while taking advantage of financial benefits.

What criteria must a mobile home meet to qualify for utility incentives on HVAC upgrades?

Eligibility typically depends on factors such as the type of HVAC system being installed (e.g., energy-efficient models), compliance with program-specific guidelines (such as SEER ratings), and sometimes income qualifications or participation in energy audits offered by the utility company.

What challenges might arise when implementing these collaborative efforts between utilities and mobile home residents?

Challenges may include limited awareness among residents about available programs, upfront costs despite rebates, complexities in navigating program requirements, and potential logistical issues related to retrofitting older mobile homes with new technology.

Royal Supply Inc

Phone : +16362969959

City : Oklahoma City

State : OK

Zip : 73149

Address : Unknown Address

Google Business Profile

Company Website : <https://royal-durhamsupply.com/locations/oklahoma-city-oklahoma/>

Sitemap

Privacy Policy

About Us

Follow us