Shaping Tomorrow's
Built Environment Today

ASHRAE Position Document on

INDOOR AIR QUALITY

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ASHRAE is a global professional society of over 55,000 members, committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration and their allied fields (HVAC&R). ASHRAE position documents are approved by the Board of Directors and express the views of the Society on specific issues. These documents provide objective, authoritative background information to persons interested in issues within ASHRAE's expertise, particularly in areas where such information will be helpful in drafting sound public policy. The documents also clarify ASHRAE's position for its members and building professionals.

Indoor Air Quality is a Public Interest Issue

Indoor air is the dominant pathway for exposure to airborne contaminants given that people spend the majority of their time indoors, and indoor air commonly contains numerous contaminants originating from both indoor and outdoor sources. Many of the contaminants impact health, comfort, well-being, learning outcomes and work performance. It is important that IAQ is considered in the design, construction and operation of buildings and HVAC systems. ASHRAE and its partners have long pursued improved IAQ through a range of activities.

Why ASHRAE Takes Positions on Indoor Air Quality

Indoor air quality (IAQ) has long been a critical issue for ASHRAE and its members because of the connection to ventilation and other HVAC systems in buildings.

ASHRAE's Standards 62.1 (commercial and institutional buildings) and 62.2 (residential buildings) (ASHRAE 2022a, 2022b) intended to support acceptable IAQ have been the benchmarks for ASHRAE's members and others involved with IAQ (e.g., practitioners; contractors; industrial hygienists) since 1973. ASHRAE has been concerned with all aspects of IAQ through its Position Documents, other standards and guidelines, conferences, and other efforts.

Positions and Recommendations

ASHRAE Takes the Positions that:

- IAQ impacts people's health, comfort, well-being, learning outcomes and work performance. Improved IAQ brings substantial health and economic benefits from a broad public health perspective, as well as to individual building owners and occupants.

- The provision of acceptable IAQ is an essential building service and central to ASHRAE's purpose.
- Achieving and maintaining good IAQ should be included in all decisions that affect the design and operation of buildings and HVAC systems, including efforts to improve building energy efficiency, sustainability and resiliency.
- The importance of IAQ and the fundamentals of achieving good IAQ through building design and operation should be included in educational programs.
- ASHRAE's IAQ standards should be adopted by building codes and regulations.

Appendix A of this document provides evidence to support these positions, including the effects of IAQ on human health, comfort, well-being, learning outcomes and work performance, and the economic benefits of improved IAQ.

ASHRAE Recommends the following:

- Fundamental and applied IAQ research and standards development in the following areas:
    - The relationship of ventilation rates and contaminant concentrations to occupant health, comfort, well-being, learning outcomes and work performance.
    - Approaches to improving IAQ beyond dilution ventilation, e.g., air cleaning and source control.
    - Development of tools to allow economic valuation of IAQ benefits for individual buildings and groups of buildings.
    - Development of monitoring and HVAC equipment to control IAQ by measurement of contaminants.
    - Development of diagnostics for commissioning and maintenance of ventilation and related IAQ systems.
    - The role of IAQ in building sustainability and resilience.
    - Development of IAQ control systems and solutions that contribute to other building goals including reducing energy use and greenhouse gas emissions and supporting grid integration.
    - Research on new contaminants of concern and development of technologies and approaches to address them.

ASHRAE is committed to:

- Maintaining and updating IAQ standards, guidelines and handbooks.
- Integrating principles of IAQ within its professional education programs
- Advancement of IAQ research including tools and applications.
- Using its leadership position to develop partnerships with international organizations to promote research, education, and best practices in IAQ.

References

ASHRAE, 2022a. ANSI/ASHRAE Standard 62.1-2022: *Ventilation for Acceptable Indoor Air Quality*. Peachtree Corners: GA, ASHRAE.

ASHRAE, 2022b. ANSI/ASHRAE Standard 62.2-2022: *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*. Peachtree Corners: GA, ASHRAE.

Appendix A—Background

This document contains a high level discussion of indoor air quality given that ASHRAE has published many informative documents related to indoor air quality such as the *ASHRAE Handbook—Fundamentals* (ASHRAE 2021a) (particularly Chapters 9 through 12) and two IAQ guides: *Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning* and *Residential Indoor Air Quality Guide: Best Practices for Acquisition, Design, Construction, Maintenance and Operation* (ASHRAE 2009, 2018a).

Additionally, many other important IAQ issues are not covered here, as there are separate Position Documents that cover specific topics including: Infectious Aerosols, Environmental Tobacco Smoke, Unvented Combustion Devices and IAQ, Filtration and Air Cleaning, and Limiting Indoor Mold and Dampness in Buildings (ASHRAE 2022a, 2020a, 2020b, 2021b, 2021c). Instead, this document focuses on recommendations in several broad areas including policy, research, and education related to IAQ.

Overview

An established and still growing body of literature, summarized in this appendix, has demonstrated that: (1) IAQ impacts occupant health, comfort, well-being and the ability to work and learn, and therefore, (2) improving IAQ will bring benefits at the societal and individual levels.

Indoor air quality (IAQ) refers to the types and concentrations of airborne contaminants found in buildings. And while there is no universally accepted definition of "good" IAQ, there are three widely accepted approaches to improving IAQ in buildings:

- Source control
    - Use building materials, furnishings, appliances, and consumer products with low contaminant emissions.
    - Minimize indoor contaminant sources caused by occupant activities.
    - Remove outdoor contaminants via filtration and air cleaning before they enter a building; and
    - Design, operate, and maintain building enclosures, HVAC systems, and plumbing systems to reduce the likelihood of moisture problems and/or quickly mitigate them when they happen.
- Ventilation
    - Ensure that clean air is delivered to occupied spaces in order to effectively dilute and remove contaminants emitted by indoor sources and that air is exhausted in the vicinity of localized indoor sources.
- Air cleaning and contaminants removal
    - Use effective air cleaning technologies to remove contaminants from outdoor ventilation air and recirculated indoor air.

Cost-benefit analyses have estimated that the health and economic benefits of improved IAQ are far greater than the costs of implementing these improvements. Also, many strategies exist, and others continue to emerge, that can help achieve good IAQ with lower energy impacts. Ultimately, an integrated design approach that considers both IAQ and energy, in addition to other key aspects of building performance such as site impacts, water use and other environmental impacts, is required to achieve high performing buildings that are energy efficient and achieve good IAQ. For more information on integrated design in context of IAQ see the ASHRAE IAQ Design Guide.

ASHRAE Activities in Support of IAQ

ASHRAE provides technical resources, coordinates and funds research, organizes conferences, and educates practitioners about IAQ. ASHRAE has also developed and continues to support standards, guidelines, and other resources related to improving IAQ. For example, ASHRAE promulgates the following standards that specifically address IAQ:

- ANSI/ASHRAE Standard 62.1, *Ventilation and Acceptable Indoor Air Quality* (ASHRAE 2022b). This Standard, first published in 1973, establishes minimum ventilation and other IAQ related requirements for buildings other than residential and health care. Its outdoor air ventilation rate requirements have been adopted into the International Mechanical Code and Uniform Mechanical Code, the two most common model building codes in the US. The standard is also referenced by most green building programs including LEED.
- ANSI/ASHRAE Standard 62.2, *Ventilation and Acceptable Indoor Air Quality in Residential Buildings* (ASHRAE 2022c). This Standard, first published in 2003, covers residential buildings. Minimum ventilation requirements from this standard have been adopted into codes, including California’s Title 24, and into LEED for Homes and the U.S. Environmental Protection Agency’s (EPA) Indoor airPlus program.
- ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities* (ASHRAE 2021d). Standard 170 brought together several documents used throughout North America into a single standard. It is now widely used in building codes for ventilation requirements in hospitals and other health care facilities.
- ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings* (ASHRAE 2020c). Developed in conjunction with USBGC, the International Code Council and Illuminating Engineering Society (IES), this standard provides IAQ requirements beyond those in Standard 62.1. The standard was developed to be adopted as part of voluntary green/sustainable rating systems, green building incentive programs, and local building regulations. The most recent version of the standard (2020) serves as the technical content of the 2018 *International Green Construction Code* (ICC 2021).

In addition, ASHRAE has published a number of design guides help practitioners achieve good IAQ in buildings, including:

- *Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning*, resulting from a collaborative effort of six leading organizations in the building community, presents best practices for design, construction, and commissioning that have proven successful in other building projects. It provides information and tools that architects and design engineers can use to achieve an IAQ-sensitive building that integrates IAQ into the design and construction process along with other design goals, budget constraints, and functional requirements.
- *Residential Indoor Air Quality Guide: Best Practices for Acquisition, Design, Construction,*

Maintenance and Operation addresses IAQ issues in residential buildings.

A more complete list of standards, guidelines, and other relevant ASHRAE publications is included in Appendix B of this document.

Appendix A References

ASHRAE 2022a. Position Document on Infectious Aerosols. Peachtree Corners, GA: ASHRAE.

ASHRAE, 2022b. ANSI/ASHRAE Standard 62.1-2022, *Ventilation and Acceptable Indoor Air Quality*. Peachtree Corners, GA: ASHRAE.

ASHRAE, 2022c. ANSI/ASHRAE Standard 62.2-2022, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*. Peachtree Corners, GA: ASHRAE.

ASHRAE 2021a. *ASHRAE Handbook—Fundamentals*. Peachtree Corners, GA: ASHRAE.

ASHRAE, 2021b. *ASHRAE Position Document on Filtration and Air Cleaning*. Peachtree Corners, GA: ASHRAE.

ASHRAE 2021c. *ASHRAE Position Document on Limiting Indoor Mold and Dampness in Buildings*. Peachtree Corners, GA: ASHRAE.

ASHRAE, 2021d. ANSI/ASHRAE Standard 170-2021, *Ventilation of Health Care Facilities*. Peachtree Corners, GA: ASHRAE.

ASHRAE 2020a. *ASHRAE Position Document on Environmental Tobacco Smoke*. Peachtree Corners, GA: ASHRAE.

ASHRAE 2020b. *ASHRAE Position Document on Unvented Combustion Devices and Indoor Air Quality*. Peachtree Corners, GA: ASHRAE.

ASHRAE, 2020c. ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1-2020, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings*. Peachtree Corners, GA: ASHRAE.

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ICC 2021. *International Green Construction Code* (IgCC). Washington, DC: International Code Council.

Appendix B—Literature

This appendix summarizes the relevant literature supporting this position document and provides additional context for the positions and recommendations contained herein.

What is Indoor Air Quality?

For the purposes of this document, indoor air quality (IAQ) refers to the types and concentrations of contaminants in indoor air that are known or suspected to affect people's comfort, well-being, health, learning outcomes and work performance. Primary classes of these contaminants include particulate matter (both biological, including allergens, potential pathogens, and non-biological), organic gases (e.g., volatile and semi-volatile organic compounds), and inorganic gases (e.g., carbon monoxide, ozone, and nitrogen oxides). Other factors contributing to IAQ include water vapor and odors. Indoor concentrations of contaminants are influenced by outdoor concentrations, ventilation and infiltration, indoor emissions, and a number of other contaminant-specific source and sink mechanisms (e.g., deposition, chemical reactions, and air cleaning).

IAQ impacts humans by exposure to pollutants by inhalation, dermal and ingestion pathways. Personal and indoor exposures to many airborne contaminants are commonly higher than outdoor exposures (e.g., Meng et al., 2009; Morawska et al., 2013; Sexton et al., 2004; Wallace, 2000; Wallace et al., 1991, 1985), and the majority of human exposure to outdoor contaminants also typically occurs indoors (e.g., Asikainen et al., 2016; Azimi and Stephens, 2018; Chen et al., 2012, 2012; Logue et al., 2012; Weschler, 2006). These elevated exposures arise because of the large amount of time that people spend indoors (Klepeis et al., 2001) and because concentrations of many contaminants are higher indoors than outdoors (e.g., Abt et al., 2000; Adgate et al., 2004; Meng et al., 2005; Rodes et al., 2010; Wallace et al., 1991; Zhang et al., 1994).

While this appendix does not address hygrothermal conditions, the recommendations in the position document recognize the effects of temperature and moisture levels on IAQ through changes in contaminant emission rates, the growth of microorganisms on building surfaces, the survival of infectious pathogens in air and on surfaces, the survival of house dust mites (a source of allergens), people’s perception of the quality of indoor air, and ultimately, the effects of moisture and moisture associated problems (e.g. mold, fungi or house dust mite) on the prevalence of building related symptoms.

How Does IAQ Impact Health, Comfort, Well-Being, Learning Outcomes and Performance?

IAQ impacts occupant health, comfort, well-being, learning outcomes and performance (Jones, 1999; Spengler and Sexton, 1983; Sundell, 2004). There is a small but growing body of epidemiology literature that has specifically linked indoor contaminant exposures or sources to various adverse health outcomes, including but not limited to: combustion appliances (e.g., gas stoves) and respiratory illness in children (e.g., Garrett et al., 1998; Kile et al., 2014; Lanphear et al., 2001; Melia et al., 1977); VOCs and childhood asthma (e.g., Rumchev, 2004); chemical household products and respiratory symptoms in children (e.g., Sherriff, 2005) and asthma in adults (e.g., Zock et al., 2007); phthalates and asthma and allergy symptoms in children (e.g., Bornehag et al., 2004; Jaakkola and Knight, 2008; Kolarik et al., 2008); pet allergens and childhood asthma (e.g., Lanphear et al., 2001); radon exposure and lung cancer (Samet, 1989); airborne- transmitted infectious diseases such as pulmonary tuberculosis (TB) (Burrell, 1991), severe acute respiratory syndrome (SARS) (Li et al., 2007), COVID-19 (ASHRAE, 2020) and the common cold (Myatt et al., 2004); and carbon monoxide (CO) poisoning (Ernst and Zibrak, 1998); among others.

Some attempts have been made to quantify the burden of health effects associated with chronic (i.e., long-term) exposure to contaminants in indoor air. For example, Logue et al. (2011) and Logue et al. (2012) estimated the health impacts of long-term exposure to contaminants commonly found in U.S. homes using Disability Adjusted Life Years (DALYs) to establish a hierarchy of contaminants of concern. Similarly, Asikainen et al. (2016) estimated the annual disease burden caused by exposure to air pollutants in residential buildings in the European Union to be approximately 2.1 million DALYs per year, driven primarily by exposure to fine particulate matter (diameter ≤ 2.5 µm; PM2.5) originating from outdoor sources, followed by PM2.5 from indoor sources.

Additionally, excessive dampness or moisture in buildings is associated with a range of problems including mold, dust mites and bacteria; and exposure to damp environments is associated with respiratory problems including asthma (e.g., Heseltine et al., 2009; IOM, 2004; Kanchongkittiphon et al., 2014; Mendell et al., 2011). Indoor contaminants can act as respiratory irritants, toxicants, and adjuvants or carriers of allergens (Bernstein et al., 2008) and can adversely affect human productivity (Wargocki et al., 1999) and cause odor problems. Recent evidence has also suggested that pollutants in indoor air may reduce cognitive function (Allen et al., 2016; Satish et al., 2012).

One of the most common health complaints is the occurrence of building-related symptoms including eye, nose, and throat irritation, difficulty in concentrating and thinking clearly, headaches, fatigue and lethargy, upper respiratory symptoms, and skin irritation and rashes, as well as overall poor well-being (e.g., Bluyssen et al., 1996; Mendell, 1993; Mendell and Smith, 1990; World Health Organization, 1983). The term "sick building syndrome" ("SBS") has been used to describe the excess prevalence of these symptoms, without attribution to specific pathogens or illnesses or building characteristics and is viewed as more informative than building-related symptoms (Redlich et al., 1997). The term "building-related illness" refers to diseases including hypersensitivity pneumonitis and Legionnaires' disease, which are associated with specific exposures to pathogens and other contaminants in a building (Bardana et al., 1988).

What are Effective Ways to Improve IAQ?

The foremost approach to improving IAQ is source control both indoors and outdoors (Carrer et al., 2018; Nazaroff, 2013). Reducing or minimizing indoor contaminant sources can be achieved through selection of construction materials, furnishings, and maintenance products with low emission rates, restricting occupant use of fragranced or scented products (Steinemann et al., 2011), and minimizing the emissions from human activities for example by installing "walk-off" mats (Farfel et al., 2001; Layton and Beamer, 2009). Another form of source control is local exhaust ventilation, which removes contaminants before they have the opportunity to mix within occupied spaces, such as for residential cooker/range hoods (Delp and Singer, 2012; Lunden et al., 2015), and wet spaces, e.g., bathrooms and laundry rooms.

One element of source control is to keep buildings dry, for example by minimizing indoor sources of water vapor through source control and the control of moisture using humidifiers and dehumidifiers, as well as by designing and constructing building enclosures and HVAC systems to limit moisture problems (ASHRAE, 2018a, 2009; Heseltine et al., 2009). Episodic water events that invariably happen (e.g., floods, leaks, etc.) must be managed rapidly and effectively to prevent water damage and sustained dampness.

After effective source control, ventilation is used to dilute indoor contaminants with clean outdoor air. Literature reviews show that increasing ventilation rates led to improved health outcomes (e.g., Carrer et al., 2015; Sundell et al., 2011). Using ventilation to improve IAQ should also include minimizing the entry of contaminants from outdoors in polluted ambient environments (e.g., Liu and Nazaroff, 2001; Singer et al., 2016; Stephens et al., 2012; Stephens and Siegel, 2012; Walker and Sherman, 2013), (for example by reducing enclosure leakage or effectively filtering the outdoor air supply).

The third strategy, after source control and ventilation, is to clean indoor air via particle filtration and gaseous air cleaning. The *ASHRAE Position Document on Filtration and Air Cleaning* (ASHRAE, 2018b) and the U.S. Environmental Protection Agency's *Guide to Air Cleaners in the Home* (US EPA, 2018) both address many important issues related to filtration and air cleaning, as do recent literature reviews (e.g., Fisk, 2013; Zhang et al., 2011). For example, particle filters have been shown to reduce indoor concentrations of airborne particles and some empirical evidence shows that their use can have positive impacts on health. Some sorbent air cleaners have been shown to effectively reduce concentrations of gaseous contaminants, albeit with minimal empirical data on their impacts on health.

The complex relationship between IAQ and external environmental conditions, coupled with the effects of climate change, necessitates a shift towards designing and operating buildings that are not only comfortable and healthy for the occupants but are also sustainable. It is generally believed that achieving good IAQ can only result with increased energy consumption. However, many strategies exist that can both secure high IAQ and reduce energy use, including increased envelope airtightness, heat recovery ventilation, demand-controlled ventilation, and improved system maintenance (Persily and Emmerich, 2012). Additionally, more dynamic ventilation strategies are being developed that allow time shifting and other variable ventilation strategies such as smart ventilation (e.g., Rackes and Waring, 2014; Sherman et al., 2012; Sherman and Walker, 2011).

What Are the Economic Costs and Benefits of Improving IAQ?

Socio-economic costs of air pollution can be substantial (Asikainen et al., 2016; Boulanger et al., 2017; Jantunen et al., 2011). Providing improved IAQ is estimated to have substantial economic benefits (e.g., Aldred et al., 2016a, 2016b; Bekö et al., 2008; Brown et al., 2014; Chan et al., 2016; Fisk et al., 2012, 2011; Fisk and Chan, 2017; MacIntosh et al., 2010; Montgomery et al., 2015; Rackes et al., 2018; Zhao et al., 2015). The economic benefits accrue from having higher worker productivity (e.g., Allen et al., 2016; Wargocki and Wyon, 2017), improved learning (e.g., Haverinen-Shaughnessy et al., 2011; Wargocki and Wyon, 2013), lower absentee rates (e.g., Milton et al., 2000), and reduced healthcare costs. In workplaces, measures that result in only small improvements in performance or absence will often be cost effective because, in developed countries, employee costs (e.g., salaries, health benefits) far exceed the costs of maintaining good IAQ (Wargocki et al., 2006; Woods, 1989). Additional economic benefits are possible through reduced maintenance costs and avoidance of IAQ investigations and remediation measures by designing, constructing, and operating buildings in a manner that reduces the likelihood of serious IAQ problems, such as widespread dampness and mold.

Several studies that have estimated the costs and benefits of improved source control, ventilation, and air-cleaning technologies are summarized below:

Source control: Wargocki and Djukanovic (2005) estimated the costs associated with improving IAQ by reducing the load of pollution sources in a hypothetical building. The additional investments in energy, HVAC first costs and maintenance costs, and building construction costs were highly cost effective, with payback times below two years and an estimated return on investment that was four to seven times higher than the assumed interest rate of 3.2%. However, no specific analysis was conducted to estimate how much of these effects can be attributed to source control and how much to increased ventilation rates. Asikainen et al. (2016) estimated that a 25% reduction in indoor

PM2.5 sources, a 50% reduction in indoor VOCs and dampness, and a 90% reduction in radon, carbon monoxide, and second hand smoke in residential buildings in the European Union could reduce the burden of disease associated with residential indoor air exposures by approximately 44%.

Ventilation: Fisk et al. (2011) estimated that the combined potential annual economic benefit of implementing a combination of IEQ improvements in U.S. offices (including increasing ventilation rates, adding outdoor air economizers, eliminating high indoor temperatures during winter, and reducing dampness and mold problems) is approximately $20 billion per year. Similarly, Fisk et al. (2012) estimated that the economic benefits of increasing minimum ventilation rates in U.S. offices far exceed energy costs and that adding economizers would yield health, performance, and reduced absence benefits while saving energy. Dorgan et al. (1998) estimated the costs of improving ventilation in 40% of office buildings in the US considered unhealthy i.e., not meeting standard 62.1; the payback time of such activity was estimated to be below 1.4 years because of benefits for health and work performance resulting from it. Rackes et al. (2018) introduced an outcome-based ventilation framework for assessing performance, health, and energy impacts to inform ventilation rate decisions in U.S. office buildings and estimated that the economic benefits of increased ventilation rates in offices are routinely greater than additional energy costs or adverse health costs associated with introducing more outdoor contaminants through increased ventilation.

Filtration, air cleaning and contaminant removal: Bekö et al. (2008) estimated that the health and productivity benefits of higher-performance filters would exceed their costs by well over a factor of 10 in an example office building. Montgomery et al. (2015) estimated benefit- to-cost ratios of up to 10 for improved filtration in office buildings in a variety of cities.

Fisk and Chan (2017) similarly estimated benefit-to-cost ratios ranging from three to 133 for the use of filters and/or portable air cleaners in both residences and commercial buildings. In all of the above studies, the avoided health care costs were the largest benefit of air cleaning. These and other studies on the costs and benefits of filtration and air cleaning were reviewed in Alavy and Siegel (2019).

Limited interview-based studies of decision-makers in the building industry in the U.S. have shown that they tend to underestimate the positive impacts of ventilation and filtration upgrades while overestimating costs (Hamilton et al., 2016). These findings suggest the need for educational activities to inform the industry on the costs and benefits of achieving good IAQ.

Summary

It is clear from the work cited in this appendix that IAQ in buildings is an essential building service that is vitally important to building occupants, owners, and designers, and therefore to ASHRAE. The health and economic impacts of IAQ are significant, and it is therefore essential to consider IAQ in all phases of building planning, design, and operation. Current design approaches and technologies include meeting minimum requirements (e.g., for ventilation as provided by ASHRAE Standards 62.1 and 62.2 (ASHRAE 2022a, 2022b)) and following guidelines for beyond-minimum performance (e.g., ASHRAE's IAQ design guides [ASHRAE 2009, 2018a]).

Appendix B References

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DOCUMENT REVISION COMMITTEE ROSTER

The ASHRAE Position Document on Indoor Air Quality was developed by the Society's Indoor Air Quality Position Document Revision Committee, formed on January 26, 2018, with Donald Weekes Jr. as its chair.

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