

# GLOBAL CASE STUDIES OF IMPROPER PLUMBING AND VENTILATION: HEALTH RISKS AND REGULATORY GAPS IN ASIA, EUROPE, AND THE UNITED STATES

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## ABSTRACT

*This paper presents a comparative analysis of improper plumbing and ventilation installations across residential and commercial buildings in Asia, Europe, and the United States. Drawing on field observations and documented case studies, it identifies systemic failures in code enforcement, substandard construction practices, and cultural differences in building design that contribute to the spread of sewer gases and offensive odors. In countries such as China, Thailand, and Cambodia, the absence or poor implementation of plumbing codes has led to widespread sewer gas leakage due to missing water traps and exposed drain lines. In South Korea, the widespread use of wet-room bathroom designs, where sinks and showers drain directly onto the floor, reflects cultural preferences for space efficiency but raises concerns about hygiene and cross-contamination. In Russia, the installation of electric fans into natural ventilation systems during apartment renovations disrupts airflow and causes odor migration between units. European examples, such as condensation on toilet cisterns in Italy and missing trap inserts in Polish hostels, highlight additional regional challenges. In contrast, the United States benefits from strict code enforcement, licensed contractors, and centralized mechanical ventilation systems, which largely prevent such issues. However, isolated problems still occur, particularly when renovations alter fixture elevations without proper adjustments. The paper concludes that effective mitigation requires not only robust building codes but also consistent enforcement, professional training, and public awareness to ensure safe and healthy indoor environments globally.*

**Keywords:** Plumbing, Ventilation, Sewer gas, Building codes, Code enforcement, Wet-room design, Odor control, Indoor air quality, Construction practices, Asia, Europe, United States.

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## 1. Introduction

Mahatma Gandhi said: “Sanitation is more important than independence”. The integrity of plumbing and ventilation systems is crucial for maintaining healthy and safe indoor environments in multi-story residential and commercial buildings [1, 2]. However, issues arising from improper design, installation, and lack of adherence to building codes can lead to significant problems, including the widespread presence of offensive odors, particularly sewer gas [3, 4]. These odors are not merely a nuisance; sewer gas contains hazardous substances such as hydrogen sulfide, ammonia, carbon dioxide, methane, nitrogen oxides, and sulfur dioxide, some of which are flammable and can pose serious health risks ranging from fatigue and headaches to pneumonia, unconsciousness, or even fatalities at high concentrations [5]. Beyond chemical hazards, compromised ventilation systems can also facilitate the spread of viruses and pathogens, undermining public health measures like self-isolation and quarantine [6].

This paper examines various instances of improper plumbing and ventilation across different continents, with a focus on specific case studies. It discusses the underlying causes of these issues, their public health implications, and contrasts the regulatory and enforcement landscapes in affected regions with those in countries where such problems are less prevalent. The aim is to highlight the systemic nature of these challenges and emphasize the critical need for universal compliance with building codes and the adoption of best practices to ensure public health and safety.

## 2. Specific examples

### 2.1 Sewer gas leakage in China

The problem of sewer gas leakage in China has persisted for decades and is a pervasive issue in various types of buildings, including airports, hotels, industrial facilities, private residences, and educational institutions. Despite the development of national building codes and regulations by the Ministry of Housing and Urban-Rural Development (MOHURD), enforcement is often lacking, and substandard installation practices are common. New buildings in China continue to face these problems, indicating a systemic failure in compliance [3].

A primary cause is the non-compliance with building codes, particularly the failure to install water traps and the improper installation of vertical outlet toilets. Water traps are simple devices designed to hold a small amount of water, forming a liquid barrier that prevents sewer gases from escaping into indoor spaces. Chinese national standards, such as GB 50015-2019, specify installation of floor drains and require appropriate traps for each plumbing fixture to prevent odor spread. However, these requirements are often ignored or improperly substituted.

Figure 1(a) and (b) show examples of unsealed sink drainpipes, while Figure 1(c) shows a plastic bag filled with water to temporarily stop sewer gas leakage from a floor drain in a hotel room in Zhengzhou, China, installed without a water trap [3].



Figure 1. (a) Exposed sewer pipes due to the absence of a water trap and unsealed connections; (b) Exposed sewer line lacking a proper seal; (c) Plastic bag filled with water used as a temporary measure to block sewer gas escaping from a floor drain without a water trap in a hotel room in China.

Sewer gas leakage in China is a widespread problem, which is not being properly addressed, as newly constructed and renovated buildings have these problems. In many buildings throughout China sewer pipes and plumbing fixtures are installed in violation of Chinese national standards, allowing sewer gases to escape.

The presence of sewer gas, heavy with hydrogen sulfide, can dull the sense of smell, making detection difficult and insidious. Long-term exposure to low concentrations can lead to symptoms like fatigue, headaches, dizziness, and pneumonia. In higher concentrations, hydrogen sulfide can cause unconsciousness or be fatal. Furthermore, methane in sewer gas is flammable, creating an explosion

hazard, particularly in confined spaces like basements and underground garages where these gases tend to accumulate. General population of China is used to the smell, so these instances are rarely reported and have not been addressed.

Similar issues with sewer gas leakage have been observed in Thailand and Cambodia, which do not have specific plumbing codes. Instead, in Thailand, plumbing installation practices are generally governed by the Building Control Act B.E. 2522 from 1979, last amended in 2007. In Cambodia it is the Law on Construction last updated in 2019.

## 2.2 Sink and shower drain onto the floor in South Korea

In South Korea, and Seoul specifically, it is common for bathroom sinks to drain directly onto the bathroom floor, as illustrated in Figure 2. This design reflects a broader architectural approach in South Korea, where bathrooms are often constructed as wet rooms with a central floor drain in Figure 2(a). According to housing norms and practices, especially in older or more compact apartments, the entire bathroom is designed to be water-resistant, allowing for easy cleaning and multipurpose use of space. The sink's drainage pipe typically leads to the floor in Figure 2(b), where water flows into a shared drain used by the shower and sometimes the washing machine. While this setup may seem unconventional to those accustomed to enclosed plumbing systems, it aligns with the Korean emphasis on efficient space utilization and ease of maintenance [7]. According to the Seoul Metropolitan Government Ordinance on Building and National Plumbing practices, there is no explicit requirement for a dedicated drainpipe for each fixture such as a sink.

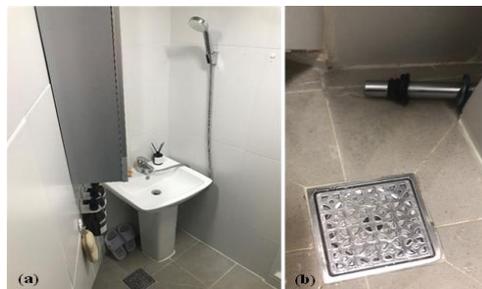


Figure 2. (a) Bathroom sink and shower in South Korea draining directly onto the bathroom floor without a dedicated sewer line, consistent with wet-room design; (b) Exposed sink drainpipe discharging onto the bathroom floor.

Wet-room bathroom designs are relatively uncommon in Western countries due to differences in building codes, cultural norms, and historical plumbing practices. In many Western contexts, plumbing regulations require fixture-specific drainage systems to prevent cross-contamination and ensure hygienic separation of wastewater sources. This has led to the widespread adoption of dry-zone bathroom layouts, where only the shower or bathtub area is exposed to water. In contrast, South Korean bathrooms are often fully waterproofed and sloped toward a central floor drain, allowing multiple fixtures to share a single drainage outlet. This design is well-suited to compact urban housing and aligns with local preferences for frequent cleaning and spatial efficiency. In Western contexts, shared drainage is more often associated with infrastructural deficiencies or plumbing poverty rather than intentional design, further reinforcing the divergence in bathroom architecture across regions.

## 2.3 Water condensation in Italy

Figure 3(a) illustrates a standard bathroom installation in Rome, Italy, where the sink is properly connected to a dedicated drain line and the floor drain is sealed. However, due to elevated humidity levels in parts of Italy, condensation frequently forms on bathroom fixtures. Figures 3(b-d) show visible moisture accumulation on the surface of a toilet cistern, a phenomenon exacerbated during colder months. In many Italian installations, the toilet cistern is mounted high above the bowl, resulting in condensate dripping onto the user during winter in Figure 3(c). Figure 3(d) presents a concealed cistern installation, where condensation has visibly dampened the wall surface. Although condensation on toilet cisterns is a well-documented issue in humid environments, the Italian plumbing code does not currently mandate thermal insulation for cisterns. Scientific literature confirms that condensation occurs when warm, humid air contacts cooler surfaces, such as water tanks or pipes, especially in poorly ventilated spaces. Studies have modeled this behavior using thermodynamic and computational fluid dynamics approaches, demonstrating that condensation is intensified by high humidity, low surface temperatures, and the presence of non-condensable gases like air [8-10].



Figure 3. (a) Properly installed sink with a sealed floor drain; (b) Visible water condensation forming on the surface of a toilet cistern; (c) Magnified view of condensation droplets on the cistern; (d) Concealed toilet cistern behind a wall causing condensation and mold growth on the wall surface.

## 2.4 Floor drain design in Poland

In Poland, the requirement to use a water trap (syfon) in plumbing systems is established under the Regulation of the Minister of Infrastructure on the technical conditions to be met by buildings and their location (Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie). Specifically, § 125 of this regulation states that: “Every sanitary fixture must be equipped with a trap to prevent the ingress of sewer gases into rooms”. This legal requirement ensures hygienic and safe indoor environments by mandating that all plumbing fixtures, such as sinks, bathtubs, and toilets, include a water-sealed trap to block odors and gases from the sewage system [11].



Figure 4. (a) Bathroom floor drain with a properly installed water trap to prevent sewer gas escape; (b) shower room at the New World hostel in Warsaw with missing trap inserts and exposed sewer lines; (c) magnified view of (b), clearly showing the absence of the trap insert.

Figure 4(a) shows the bathroom floor drain with a water trap, which prevents sewer gas escape. However, if the floor drain insert is removed, sewer pipes become exposed and release toxic sewer gas. Figure 4(b) shows the shower room at the New World hostel, located at Nowy Świat 27, 00-029 Warszawa, Poland, with removed inserts from the shower drains. Figure 4(c) is a magnified view clearly showing a missing insert. The hotel management refused to address this problem.

In Poland, such conditions may constitute a violation of the national Construction Law (Prawo budowlane), which mandates that buildings must be maintained in a manner that ensures safety, hygiene, and environmental protection [12]. The County Building Supervision Inspectorate (Powiatowy Inspektorat Nadzoru Budowlanego) is the primary authority responsible for enforcing compliance with these regulations. If a facility fails to maintain proper drainage systems, such as by removing trap inserts and allowing sewer gas to escape, this may be grounds for administrative intervention. Additionally, the State Sanitary Inspection (Państwowa Inspekcja Sanitarna) may become involved if the issue poses a public health risk, particularly in hospitality settings [13]. Under Article 62 of the Construction Law, building owners are required to conduct periodic inspections to assess the technical condition of installations, including plumbing and ventilation systems. Failure to comply may result in fines, mandatory repairs, or even temporary closure of the facility [14]. In cases where management refuses to act, guests or third parties may file formal complaints with the local building inspectorate or sanitary authority, triggering an official investigation and enforcement process.

## 2.5 Ventilation problems in Russia after renovations

In recent years, residents of multi-story apartment buildings in Russian cities such as Tomsk and Moscow have reported a growing problem of offensive odors in kitchens, bathrooms, and toilets. This issue, which was largely absent during the Soviet era, has been traced to modifications in the buildings' natural ventilation systems. The primary cause is the installation of wall-mounted electric fans into ventilation grills by individual apartment owners, typically during renovations [15]. These fans are often wired to operate in tandem with room lighting, resulting in periodic activation that disrupts the building's originally passive airflow system.

The natural ventilation systems in Soviet-era buildings were designed to rely on the stack effect, where warm indoor air rises and exits through vertical shafts, drawing in fresh air from outside. However, when an electric fan is activated in one apartment, it introduces forced airflow into the shared ventilation shaft. This artificial pressure can reverse the intended flow of air, pushing odors, such as tobacco smoke or sewage gases, into neighboring apartments. Documented cases in Tomsk include a persistent tobacco smell in a third-floor toilet of a nine-story building and a recurring sewer odor in a ninth-floor bathroom of a ten-story building, both of which had wall fans installed [15].

Temporary mitigation strategies, such as sealing the ventilation grill with plastic film and adhesive tape, have proven effective in eliminating odors but introduce secondary issues like increased humidity and mold growth. While fans equipped with backdraft dampers can prevent air from entering the apartment, they still interfere with the overall ventilation dynamics of the building. A more effective local solution involves installing an air check valve in the ventilation grill, which allows air to exit but blocks reverse airflow, thereby preserving the integrity of the natural ventilation system.

This problem underscores a significant gap in current Russian building regulations. While existing codes specify airflow requirements, they do not explicitly prohibit the installation of individual electric fans in shared ventilation systems. Addressing this issue requires both regulatory updates and enforcement mechanisms to ensure compliance. Globally, similar challenges in naturally ventilated buildings highlight the need for revised building codes that account for modern renovation practices and their unintended consequences on shared infrastructure.

## 2.6 Unsealed toilets in USA after renovation

In contrast to the odor issues observed in Russian multi-story residential buildings with natural ventilation systems, such problems are generally not prevalent in the United States. This difference is largely attributable to the widespread use of forced mechanical ventilation systems in U.S. buildings. These systems are designed to actively extract air from individual units through centralized exhaust fans located in basements or on rooftops, thereby maintaining consistent airflow and preventing the backflow of odors between apartments.

ASHRAE Standard 62.2 outlines the minimum ventilation requirements for residential buildings in the U.S., emphasizing mechanical systems that ensure acceptable indoor air quality (IAQ) [16]. These systems typically include dedicated exhaust fans in bathrooms and kitchens, as well as supply fans that introduce fresh air into living spaces. The design prevents cross-contamination between units and eliminates the need for residents to install individual fans in ventilation grills, which is a common practice in Russian buildings and a primary cause of odor propagation there.

Research conducted by Lawrence Berkeley National Laboratory further supports the effectiveness of these systems. Simulations of mid-rise multifamily buildings demonstrated that balanced ventilation systems, such as those with heat recovery ventilators or energy recovery ventilators, significantly reduce the transport of contaminants like formaldehyde and CO<sub>2</sub> between units [17]. These systems maintain pressure differentials that isolate each apartment, a concept known as compartmentalization, which is critical for preventing odor and pollutant migration. Moreover, U.S. building codes and energy standards enforce strict requirements for air tightness and ventilation system performance. For example, the International Energy Conservation Code mandates air leakage testing and sets maximum allowable leakage rates for residential units [18]. These regulations ensure that buildings are not only energy-efficient but also maintain high IAQ standards, further minimizing the risk of odor issues.

In summary, the integration of centralized mechanical ventilation systems, adherence to ASHRAE standards, and rigorous building code enforcement collectively contribute to the absence of widespread odor problems in U.S. multi-story residential buildings. These practices offer a model for improving ventilation infrastructure in other regions facing similar challenges.



Figure 5. (a) Recessed toilet flange resulting from tile installation during renovation; (b) oversized ring used to seal the toilet above the new floor level.

However, sewer gas leakage can still happen in the U.S. When tile is installed in a bathroom, it often raises the finished floor level above the original height of the toilet flange, as shown in Figure 5(a). According to plumbing best practices, the toilet flange should ideally sit on top of the finished floor, with its top surface approximately  $\frac{1}{4}$  inch above the tile. This positioning ensures a tight, leak-free seal between the toilet and the waste pipe. If the flange ends up below the tile surface, a standard wax ring may not provide adequate compression to form a proper seal, increasing the risk of leaks and sewer gas escape.

To address this, oversized or extra-thick sealing rings are commonly used to compensate for the height difference, as shown in Figure 5(b). These rings are designed to bridge the gap between the toilet base and the recessed flange, ensuring a secure connection. In some cases, flange extenders or spacer kits may also be installed to raise the flange height to the correct level, especially when the gap exceeds what a wax ring can safely accommodate.

Importantly, the seal between the toilet and the flange cannot be visually inspected or pressure-tested once the toilet is installed, due to the concealed nature of the connection. This makes proper installation critical. A poor seal can lead to hidden leaks that damage subflooring or allow sewer gases to enter the living space.

While the International Plumbing Code (IPC) and Uniform Plumbing Code (UPC) do not specify exact flange height tolerances, they do require that all plumbing fixtures be installed to prevent leakage and ensure proper function [19]. This implicitly supports the use of appropriate flange height and sealing methods, such as oversized wax rings or flange extenders, when tile or other flooring raises the finished floor level.

Modern residential construction and renovation projects must adhere to a variety of codes and standards to ensure safety, efficiency, and occupant comfort. One of the foundational documents in this regard is the International Residential Code (IRC), which outlines requirements for plumbing fixtures, including minimum numbers, locations, and performance standards [20].

In the realm of building performance, HVAC systems play a critical role in maintaining indoor air quality and thermal comfort. Research presented at the ASHRAE Buildings XV Conference explores advanced HVAC design strategies that improve energy efficiency while maintaining occupant comfort [21]. These findings are particularly relevant as the industry continues to adopt more sustainable practices.

Further studies delve into the performance of building envelopes and the integration of renewable energy systems in residential and commercial buildings. These papers highlight the importance of material selection, insulation strategies, and passive design techniques in reducing energy consumption [22, 23]. Additionally, ASHRAE's Addendum H to Standard 62.2-2019 provides updated guidance on ventilation requirements for residential buildings, emphasizing the need for balanced airflow and pollutant control to ensure healthy indoor environments [24].

Together, these resources form a comprehensive foundation for professionals seeking to design and construct buildings that are both code-compliant and environmentally responsible.

## Discussion

Building, plumbing, and ventilation codes must be continuously updated to adapt to emerging challenges and prevent nuisances. However, the existence of such codes alone is not sufficient. Effective enforcement is essential to ensure their intended impact.

The situations in China and Russia illustrate a significant gap between the presence of building codes and their practical enforcement. In China, although national standards for plumbing and drainage are well established (such as GB 50015-2019 and CJ/T 186-2018), issues like sewer gas leakage remain common, even in newly constructed or renovated buildings. These problems are often the result of inadequate implementation and oversight. Contributing factors include the sale of unfinished apartments, where subsequent contractor work is not subject to government quality control, and a general public tolerance for sewer odors. Technical deficiencies, such as the use of air admittance valves instead of water traps and the omission of critical components like toilet flanges, further compound the issue.

In contrast, the United States provides an example of effective enforcement. The use of licensed professionals, mandatory inspections, and penalties for non-compliance has created a system that largely prevents widespread odor problems. This comparison highlights that the core issue is not a lack of

technical standards or knowledge, but rather the absence of institutional mechanisms that ensure consistent oversight and quality assurance.

The consequences of these enforcement failures extend beyond inconvenience. Exposure to sewer gases presents serious public health risks, including toxicity, flammability, and the potential transmission of airborne pathogens. In Russia, for example, the intermittent nature of sewer odors caused by individual fan usage demonstrates how small-scale actions can disrupt the ventilation system of an entire building.

To address these challenges on a global scale, a comprehensive strategy is required. This strategy should include the following components:

1. **Enforcing Existing Codes:** Government agencies must conduct regular inspections and impose penalties for violations to ensure compliance with established standards.
2. **Mandating Key Components:** Building codes should explicitly require essential plumbing elements, such as toilet flanges for vertical outlet toilets.
3. **Enhancing Professional Training:** Certification programs and ongoing education for plumbers, contractors, and construction workers are necessary to improve installation quality and adherence to standards.
4. **Adopting International Best Practices:** Countries should study and adapt successful regulatory and construction practices from regions with strong plumbing and ventilation infrastructures.
5. **Raising Public Awareness:** Public education campaigns can inform citizens about the health risks associated with sewer gases and the importance of proper plumbing and ventilation. This awareness can increase demand for compliance and reduce tolerance for substandard conditions [24].

In conclusion, while codes and standards are foundational to building safety and hygiene, their effectiveness depends on the strength and consistency of the systems that enforce them.

While the health risks associated with improper plumbing and ventilation are well-documented, the economic and environmental consequences are equally significant and often underappreciated. Poor plumbing practices can lead to chronic water damage, mold growth, and structural deterioration, all of which carry substantial financial burdens for property owners, tenants, and municipalities.

**Water Damage and Structural Repairs:** Leaks from unsealed toilets, improperly installed fixtures, or missing water traps can cause persistent moisture accumulation in subfloors, walls, and ceilings. Over time, this leads to rot, corrosion of building materials, and even foundational instability. Repairing such damage often requires extensive demolition and reconstruction, with costs ranging from hundreds to tens of thousands of dollars depending on the severity and location of the issue.

**Mold Remediation:** Moist environments created by plumbing leaks or poor ventilation are ideal for mold growth. Mold not only poses health risks but also necessitates specialized remediation services. According to industry estimates, mold removal can cost between \$500 and \$6,000 per incident, with severe infestations in large buildings exceeding \$30,000. In addition to direct costs, mold can reduce property values and lead to legal liabilities for landlords and building managers.

**Increased Energy Consumption:** Inefficient ventilation systems, such as those disrupted by unauthorized fan installations, can compromise HVAC performance. This leads to increased energy usage as systems work harder to maintain indoor air quality and temperature. In humid climates, condensation on uninsulated plumbing fixtures can also increase the load on dehumidifiers and air conditioning systems, further raising energy bills and carbon emissions.

**Environmental Degradation:** Improperly sealed plumbing systems may allow untreated wastewater or sewer gases to escape into the environment. This can contaminate soil and groundwater, especially in areas lacking centralized sewage treatment. Additionally, methane, a common component of sewer gas, is a potent greenhouse gas, contributing to climate change when released into the atmosphere.

**Insurance and Legal Costs:** Persistent plumbing and ventilation issues can lead to increased insurance premiums or denial of coverage. In commercial or hospitality settings, such as hotels or hostels, unresolved problems may result in regulatory fines, lawsuits, or forced closures, compounding financial losses.

In summary, the consequences of substandard plumbing and ventilation extend far beyond immediate discomfort or odor. They represent a significant drain on economic resources and pose long-term environmental risks. Addressing these issues proactively through proper design, installation, and enforcement is not only a public health imperative but also a sound economic and environmental strategy.

## Conclusions

This study highlights the widespread and often overlooked consequences of improper plumbing and ventilation practices in residential and commercial buildings across multiple regions. The examples from China, Thailand, Cambodia, South Korea, Russia, Italy, and Poland reveal that the root causes of these issues are not limited to technical deficiencies but are deeply tied to systemic failures in code enforcement, professional training, and public awareness.

In countries where building codes exist but are poorly enforced, such as China and Russia, sewer gas leakage and ventilation failures are common, even in newly constructed or renovated buildings. These failures pose serious health risks, including exposure to toxic and flammable gases, and contribute to the degradation of indoor air quality. In contrast, the United States demonstrates how rigorous code enforcement, mandatory inspections, and the use of licensed professionals can largely prevent such problems, although isolated issues still occur, particularly during renovations.

The findings underscore that effective solutions must go beyond technical fixes. A comprehensive approach is required, involving the enforcement of existing codes, mandatory inclusion of critical plumbing components, improved training for construction professionals, and increased public education on the health risks associated with poor plumbing and ventilation. International collaboration and the adoption of best practices from regions with successful regulatory frameworks can further support global improvements.

Ultimately, ensuring safe and healthy indoor environments demands not only the presence of robust standards but also the institutional capacity and political will to enforce them consistently. Addressing these challenges is essential for protecting public health and improving the quality of life in urban environments worldwide.

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