IoT and artificial intelligence-based monitoring and risk-based control of harmful gases in Smart House areas

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Abstract. This study investigates the problem of insufficient safety-oriented control of Indoor Air Quality (IAQ) within Smart House environments and proposes an IoT- and Artificial Intelligence-based system for monitoring harmful gases. In smart homes, comfort-oriented functions (heating, lighting, energy management) typically dominate, while real-time monitoring of gases such as CO, CO_2, NO_2, SO_2, as well as risk factors in basements and technical zones including radon (Rn), hydrogen sulfide (H_2S), and methane (CH_4), often remains limited.

The proposed AIoT approach employs a multi-point sensor network to collect measurements across different zones, performs filtering and validation at the gateway level, and determines operational modes ("Normal – Warning – Hazard") through anomaly/peak detection and risk index calculation. For CO and H_2S, instantaneous variation and peak criteria are applied, whereas for radon, a 24-hour average and trend-based assessment are utilized.

In hazard mode, Smart House actuators activate ventilation systems, control valves, trigger alarms, and, when necessary, switch equipment to a safe operating state. As a result, the system extends the Smart House concept from a comfort-centered approach to a risk-based intelligent control model that ensures health protection and life safety.

Keywords: Smart House, Internet of Things (IoT), Artificial Intelligence (AI), Indoor Air Quality (IAQ), harmful gases, carbon monoxide (CO), carbon dioxide (CO_2), sensor network, risk index, adaptive ventilation control.

1.1 The Relevance of the Air Quality Problem in Intelligent Buildings

Although the "smart house" concept and, more broadly, the intelligent building approach have rapidly expanded in residential buildings in recent years, the primary focus of these systems is often directed toward increasing comfort and optimizing energy consumption [1]. In practice, solutions typically prioritize functions such as automation of heating and cooling modes, scenario-based lighting control, security cameras and access control, and remote control of household appliances [2]. Against this background, the comprehensive normalization of indoor air environments that directly affect human health, as well as their real-time intelligent monitoring, is generally either relegated to secondary importance or limited to monitoring only a restricted set of parameters (for example, temperature, relative humidity, sometimes CO_2 or particulate matter) [2]. However, indoor air quality in residential environments is determined not only by "comfort microclimate" indicators but also by the dynamics of toxic and hazardous gases, which, due to their often invisible nature, tend to be detected only at later stages [3].

It is known that indoor air primarily consists of nitrogen and oxygen; however, prolonged human presence in enclosed spaces, insufficient ventilation, and combustion processes disrupt the O_2/CO_2 balance: a gradual decrease in oxygen and an increase in carbon dioxide are observed. At early stages, elevated CO_2 levels manifest subjectively as fatigue, drowsiness, reduced concentration, and a sensation of "stale air"; at higher concentrations, symptoms such as headaches, dizziness, and decreased functional activity may intensify [4]. On the other hand, toxic gases such as carbon monoxide (CO) represent one of the most dangerous risk factors in enclosed environments: malfunctioning gas appliances, incomplete combustion, and chimney or ventilation failures can generate CO, which binds to hemoglobin with high affinity, sharply reducing the blood's oxygen-carrying capacity and potentially leading to severe hypoxia and fatal outcomes within a short period [1]. In addition, gases such as nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) are considered significant pollutants due to their irritant and toxic effects on the respiratory system when present at elevated concentrations [3]. These risks are therefore not merely issues of "air comfort," but directly concern health and life safety [1,3].

The scope of the problem is not limited to indoor spaces alone. In residential buildings, sources of air pollution and risk formation often originate in lower sections of the building—basements and technical zones—and can subsequently spread to living areas through vertical shafts, ducts, service penetrations, cracks, and leakage paths. In this context, radon (Rn) requires particular attention: as a colorless and odorless radioactive gas formed by natural decay processes in soil, radon can enter buildings through foundation cracks and structural openings; long-term radon exposure has been associated with an increased risk of lung cancer [5]. At the same time, hydrogen sulfide (H_2S) may form near basements and sewer-utility systems as a result of anaerobic decomposition processes; at low concentrations, it has an irritant effect, while at higher concentrations it can produce acute toxic effects and severe clinical conditions [6]. Sewer leaks, dried traps, and improperly functioning ventilation pipes accelerate the spread of H_2S and other sewer-related gases. Furthermore, gases such as methane (CH_4) are hazardous primarily due to their flammability and explosion risk rather than toxicity; additionally, in enclosed spaces they can displace oxygen and increase the risk of asphyxiation as a "simple asphyxiant" [7]. Thus, "air safety" in residential buildings is a complex issue that requires consideration not only of indoor measurements but also of hidden risks originating from basements and technical areas [5–7].

Currently, in many residential and office buildings, these risks are not systematically normalized: ventilation effectiveness is often assessed based on general design practices rather than actual demand; monitoring of gas appliance operation is typically limited to periodic inspections; and gas accumulation in basements and technical areas is usually addressed only after problems become evident—through odors, complaints, or incidents (Figure 1.1).

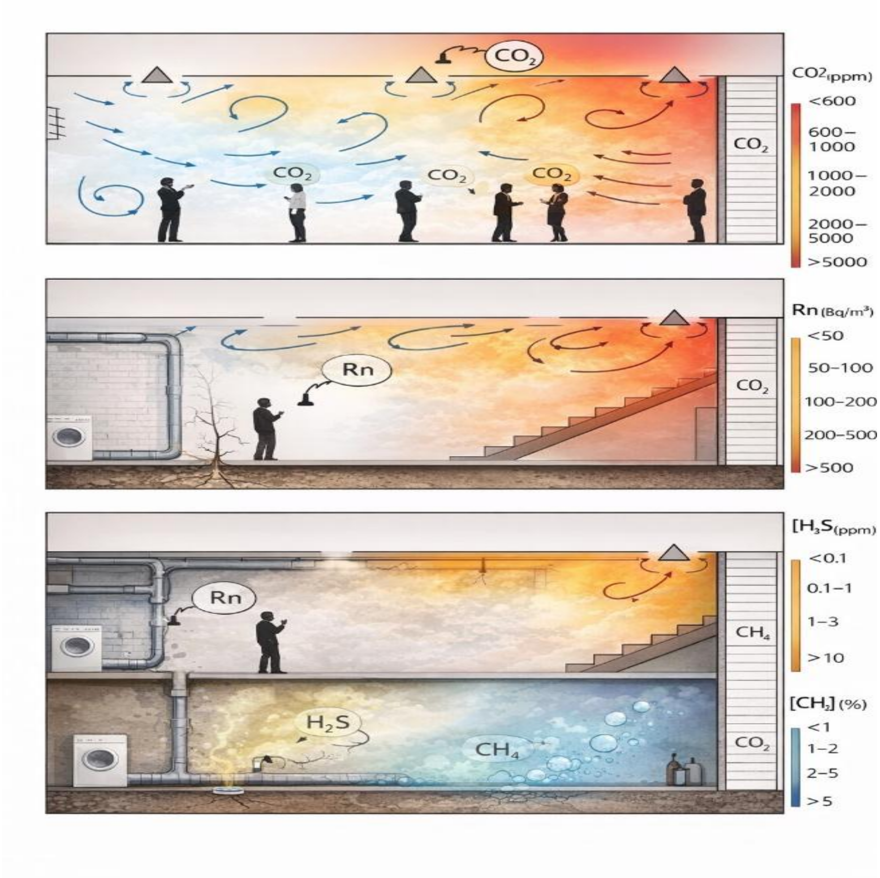

Fig. 1.1. Risks of harmful gases in building basements and technical areas.

Reviews of IoT-based IAQ monitoring platforms indicate that although real-time measurement has become technologically accessible, only a small fraction of platforms fully integrate the "measurement → analysis → control decision" chain; most remain at the monitoring stage [2]. This technological base demonstrates that the issue is no longer the impossibility of measurement; rather, the main gap lies in properly organizing these measurements within intelligent building environments, distributing them across zones, comparing them with regulatory thresholds, and transforming them into automated control decisions [2,3].

Therefore, intelligent buildings require a new approach to air environment control—one that extends beyond comfort parameters to include toxic and hazardous gases critical for human health and safety [2,3]. The essence of the proposed system is to elevate air quality control in residential buildings, enterprises, and offices from the "monitoring" stage to the level of "intelligent management." In this approach, the CO_2/O_2 balance, combustion-related CO risks, levels of harmful gases such as NO_2 and SO_2, as well as potential contamination from radon, H_2S, CH_4, and VOC sources in basements and technical zones are integrated within a unified system; measurements are collected from properly selected zonal points, concentration dynamics are assessed, and in cases of threshold exceedance, automated scenarios are triggered—such as alerts, enhanced ventilation, isolation of risk zones, and switching gas appliances to safe operating modes [2,3]. In this way, the frequently overlooked and fragmented issue of "air safety" within the smart house concept is structured as a unified risk-based model, and the application domain of intelligent building technologies expands beyond comfort toward ensuring health and life safety [2,3].

Currently, in residential buildings, enterprises, as well as other institutions and offices, the above-mentioned issues are not systematically regulated and are not properly organized from a scientific and technical perspective. At the same time, in recent years reliable sensors have been developed to measure oxygen concentration in indoor spaces, as well as the concentration of harmful gases (CO, SO_2, NO_2) in outdoor air.

We propose a new system to monitor the cleanliness of air in residential buildings, enterprises, and other institutions and offices from the standpoint of its impact on human health.

2. Distribution of Gases and Selection of Measurement Points in IoT-Based IAQ Monitoring Platforms

IoT-based IAQ (Indoor Air Quality) monitoring platforms enable real-time tracking of air parameters in enclosed spaces, and their most important advantage is replacing "single-point" measurement with a multi-point sensor network [2]. However, since gas concentrations in indoor environments are not spatially uniform, the reliability of platform results directly depends on proper sensor placement and the correct selection of measurement points [2,3]. Therefore, when designing an IAQ system, it is necessary to consider indoor airflow patterns, thermal stratification, occupancy (number of people), risk sources (combustion appliances), and vertical transport channels (basement–shaft–floors) [2].

2.1 Indoor Airflows and Uneven Distribution of Concentrations

Indoor air mixing is formed not only by diffusion but mainly by convection and ventilation flows: radiator and air-conditioner streams, heat from household appliances, cooking activities, and even human movement generate microflows. While these microflows may enhance mixing in some areas, they can also create "dead zones" in others due to weak circulation [2]. As a result, CO_2 and other pollutant levels may vary at different points within the same room.

In an IoT platform, the primary way to compensate for this is to select measurement points not only based on the geometric center of the room, but also in areas of intensive use where airflow is more representative of actual conditions [2].

2.2 Monitoring CO_2 (and O_2 Balance) in the Breathing Zone

CO_2 is one of the most widely used indicators in IAQ assessment, since human respiration is its primary indoor source, and levels tend to accumulate over time when ventilation is insufficient [4]. Increased CO_2 levels may be associated with fatigue, drowsiness, decreased attention, and a feeling of "stale air." Therefore, CO_2 sensors should represent the breathing zone [4].

In practice, placing sensors at a height of 1–1.8 meters in areas where people spend the most time (work desk, bedroom area, children's play zone, etc.) increases measurement representativeness [4]. At the same time, sensors placed too close to ventilation inlets/outlets or strong window drafts may distort readings; the goal of an IoT system is to monitor the true average room condition rather than localized airflow effects [2,4].

Since CO_2 accumulation dynamics may also relate to O_2 balance disturbances, the IAQ platform should be complemented with adaptive ventilation control mechanisms based on occupancy and measurement trends [2,4].

2.3. Combustion-Related Risks: Source-Oriented Monitoring of CO, NO_2, SO_2

In residential buildings, combustion-related risks mainly arise in kitchens (gas stoves), individual heating systems (boilers), and in cases of chimney or ventilation malfunction. In these scenarios, carbon monoxide (CO) is particularly dangerous: CO binds to hemoglobin and significantly reduces the blood's oxygen-carrying capacity, potentially causing severe hypoxia or even fatal outcomes within a short period [1].

Therefore, in IoT-based IAQ platforms, CO sensors should be placed near risk sources but away from direct heat or steam exposure; the objective is to detect accumulation caused by incomplete combustion or ventilation failure in a timely manner [1].

NO_2 and SO_2 are also considered indoor air pollutants and may pose respiratory risks at elevated concentrations [3]. Accordingly, monitoring is more justified in kitchen areas, near combustion equipment, and at points where polluted air infiltration is possible [3]. Since combustion-related gases can reach peak levels rapidly, the IAQ platform should include alert mechanisms and safety scenarios (e.g., enhanced ventilation, risk notifications) [1,3].

2.4. Basements and Technical Zones: Integration of Radon, H_2S, CH_4 Risks into the IAQ System

One of the key advantages of IoT platforms is their ability to include not only living areas but also basements and technical zones within separate monitoring loops. Many gases originate in these zones and may be transported to upper floors through shafts, stairwells, service penetrations, and ventilation ducts [2].

Radon (Rn) is particularly important in this regard: it is a colorless, odorless radioactive gas, and long-term exposure has been linked to an increased risk of lung cancer. Therefore, radon monitoring should be planned especially in basements and risk zones near ground-level floors [5].

Hydrogen sulfide (H_2S) may form near sewer and utility lines; at low levels it causes irritation, while at higher concentrations it may produce acute toxic effects [6]. Methane (CH_4), besides its flammability and explosion risk, can displace oxygen at high concentrations and act as a "simple asphyxiant," increasing suffocation risk; thus, CH_4 monitoring in technical zones is also justified from a safety perspective [7].

Consequently, for an IAQ platform to be truly risk-based, it must go beyond an "indoor comfort" approach and integrate hidden hazards originating from basements and technical areas into a unified monitoring system [5–7].

In IoT-based IAQ monitoring platforms, proper distribution of sensors across rooms and building zones (e.g., living room, kitchen, basement) increases measurement representativeness and enables timely risk detection [2,3]. In this approach, indicators such as CO_2, CO, VOC, PM2.5, and radon are measured at zone-specific sensor nodes and transmitted via Wi-Fi/Bluetooth over the home network to a cloud server, and from there to a mobile application and monitoring dashboard (Figure 2.1) [2].

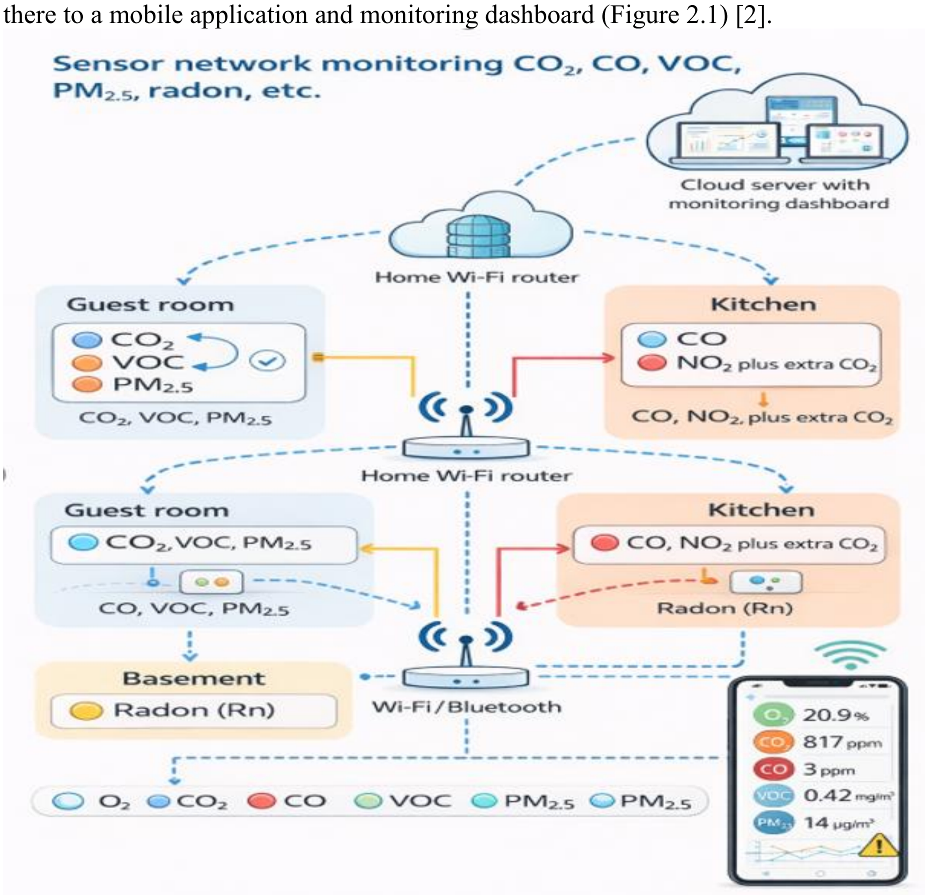

Fig. 2.1. IoT-based sensor network environment for measuring CO_2, CO, VOC, PM2.5, and radon (Rn) indicators.

3. Application of IoT and AI for Monitoring and Control of Harmful Gases in Buildings

Timely detection of harmful gases in residential and office buildings — including CO, CO_2, NO_2, SO_2 — as well as risk factors such as radon (Rn), hydrogen sulfide (H_2S), and methane (CH_4), which may accumulate in basements and technical zones, is critically important for human health and safety [3,5–7]. Some of these gases (e.g., CO and radon) are odorless and colorless, allowing the risk to remain unnoticed, while others (e.g., H_2S), although detectable by smell, often fail to attract sufficient attention before reaching dangerous levels [5,6]. Therefore, hazardous concentrations must be identified not only after complaints or incidents occur, but through real-time sensor network monitoring with rapid response mechanisms activated when risk levels increase.

The Internet of Things (IoT) technology addresses this challenge by enabling continuous data collection from sensors installed across various building zones, transmitting data via communication protocols, and monitoring it through centralized platforms. The advantage of IoT-based Indoor Air Quality (IAQ) monitoring platforms lies in replacing single-point measurements with multi-point observations, thereby reducing inaccuracies caused by spatial concentration variability within rooms and across building zones [8]. Particularly for accumulating indicators such as CO_2, tracking concentration dynamics as occupancy, ventilation, and usage patterns change provides a reliable basis for decision-making. Elevated CO_2 levels may be associated with fatigue, drowsiness, and decreased attention; therefore, monitoring this parameter is functionally important for adaptive ventilation control [4].

However, from a safety perspective, the most critical issue in buildings is the real-time detection of combustion-related toxic gases, especially carbon monoxide (CO). Malfunctioning gas equipment and incomplete combustion processes generate CO, which binds to hemoglobin and significantly reduces the blood's oxygen-carrying capacity, potentially causing severe hypoxia in a short time. Therefore, CO control must rely on continuous monitoring rather than periodic inspections alone [1]. Gases such as NO_2 and SO_2 are also classified as indoor air pollutants and pose respiratory risks when concentrations exceed permissible levels. Monitoring is particularly necessary in kitchen areas, near combustion devices, and in zones exposed to outdoor pollutant infiltration [3]. Since some of these gases may reach peak levels rapidly, IoT platforms should incorporate predefined alert mechanisms and safety scenarios (e.g., enhanced ventilation, user notifications) [1,3].

A significant portion of building-related risks originates outside living areas — in basements and technical zones. Radon (Rn) is an odorless and colorless radioactive gas; long-term exposure has been associated with an increased risk of lung cancer, making radon monitoring especially important in basements and ground-floor areas [5]. Hydrogen sulfide (H_2S) may form near sewage and utility systems due to anaerobic decomposition processes. While irritating at low concentrations, H_2S becomes acutely toxic at higher levels, necessitating additional monitoring loops in technical zones [6]. Methane (CH_4), besides being flammable and posing explosion risks, may displace oxygen at high concentrations and act as a simple asphyxiant; therefore, CH_4 monitoring in technical zones is also justified from a safety standpoint [7]. The potential vertical transport of these risks through shafts and communication ducts (basement–shaft–

rooms) requires zone-interconnected sensor placement strategies within IoT systems [2,5–7].

Although IoT systems provide the technological foundation for harmful gas monitoring, ensuring full safety requires more than measurement alone. The main advantage emerges when IoT is integrated with Artificial Intelligence (AI) methods. AI enables trend analysis, anomaly detection, and risk prediction based on collected data, allowing the system not only to display current levels but also to identify dangerous scenarios early and accelerate decision-making processes [2]. For example, adaptive ventilation control based on CO_2 dynamics, immediate alerts and intensified ventilation during CO exceedances, activation of basement air exchange when radon levels rise, and preventive measures triggered by H_2S or CH_4 risks represent practical outcomes of this approach [1,2,4–7].

Thus, the integration of IoT and AI elevates harmful gas monitoring in buildings from simple parameter tracking to an intelligent, risk-based safety management model [2,3].

4. Proposed System Structure, Block Diagram, Algorithm, and Results

The objective of the proposed system is to establish a unified IoT- and Artificial Intelligence (AI)-based platform for real-time measurement of harmful gases in residential and office buildings, risk assessment, and automatic execution of control measures when hazards are detected.

Functionally, the system operates within three primary environments:

1. Residential rooms and common areas (CO_2 and general IAQ indicators)
2. Combustion risk zones (kitchen, boiler/heating areas – CO, NO_2, SO_2)
3. Basements and technical zones (radon, H_2S, CH_4) [1,3,5–7].

Multi-point sensor nodes transmit measurement data to a local gateway. The gateway functions as an edge computing module, performing preliminary data filtering and processing. It then either transmits the data to the cloud or, in critical situations, makes on-site decisions and activates predefined safety scenarios.

On the user side, a mobile application or web-based dashboard provides real-time indicators, risk levels, historical data, and alert notifications.

4.1. Functional Structure of the System

1. The system architecture is formed by the following main layers and modules:

Sensor Layer: Sensors used to measure harmful gases are deployed throughout the residential building in the form of multi-point sensor nodes.

Communication Layer: Communication protocols such as Wi-Fi, Bluetooth, and ZigBee are utilized, along with gateways for data aggregation and transmission.

Edge Computing and Control Layer: This layer is responsible for measurement filtering, detection of peak-condition anomalies, calculation of the risk index, and selection of appropriate hazard response scenarios.

Cloud and Application Layer: This layer includes data storage, analytics, historical records, reporting, web-based dashboards, and mobile notifications.

Actuator Layer: This layer manages ventilation fans, valves, audible/visual alarm systems, and relay-based switching of equipment into a safe operating mode.

Through this architecture, the system ensures continuous monitoring and reporting under "normal mode," while in "critical mode," it activates rapid alerting and automatic intervention mechanisms.

4.2. Block Diagram Development

Figure 4.1 illustrates the overall data flow and control relationships of the proposed IoT- and AI-based system in the form of a block diagram. The diagram presents the architecture starting from the sensor layer, extending through the edge computing module and cloud environment, and culminating in the on-site safety control mechanisms.

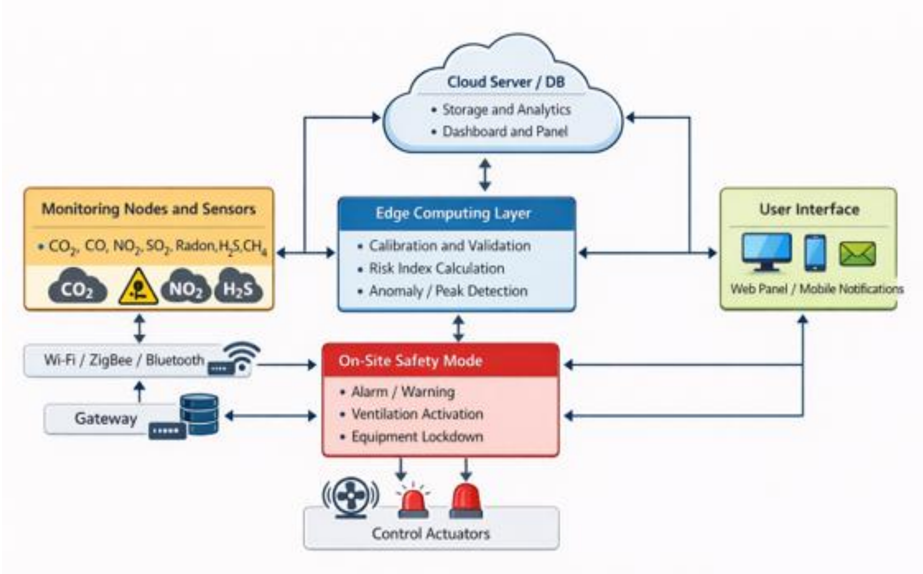

Fig. 4.1. Block diagram of the harmful gas monitoring and control system.

4.3. Operational Algorithm

The system operates sequentially according to the following stages:

Initialization and Self-Check: Sensor nodes are activated, network connectivity is verified, and calibration parameters are loaded.

Measurement: Each node reads gas concentration values at defined intervals (e.g., every 10–60 seconds).

Filtering and Validation: Noise reduction is performed using filtering techniques and logical validation procedures. Sensor faults and unrealistic spikes are identified and eliminated.

Zone-Level Aggregation: Measurements from sensors located within the same zone are aggregated into a zone-level indicator (e.g., average or weighted average). This approach reduces errors caused by uneven spatial distribution.

Time-Window-Based Evaluation: For gases such as CO, H_2S, and CH_4, instantaneous measurements and short time windows (1–5 minutes) are considered critical.

- For radon, a longer time window (e.g., 24 hours) and trend analysis are more informative.

Risk Index Calculation: A normalized risk coefficient is calculated for each gas, and an overall risk index is computed using weighted aggregation.

Peak/Anomaly Detection: Short-term sharp concentration increases (especially for CO and H_2S) are prioritized using the ΔC/Δt criterion.

Decision-Making and Scenario Selection: The system determines the operational mode ("Normal – Warning – Hazard") and selects the corresponding response measures.

Execution: Ventilation systems, valves, and alarm mechanisms are activated as required, and user notifications are sent.

Reporting: All measurements and events are recorded in the database, and periodic reports are generated.

4.4. Risk Index Calculation

Since the hazard levels of different gases are not identical, the measurements are normalized and combined into a weighted index to obtain a unified decision-making criterion.

For each gas, a dimensionless risk coefficient r_i is defined for the measured concentration C_i as follows:

$$r_i = clip(\frac{C_i - T_{i,norm}}{T_{i,danger} - T_{i,norm}}, 0,1) \qquad 4.1$$

Here, $T_{i,norm}$ represents the "normal" threshold level, $T_{i,danger}$ represents the "danger" threshold level, and clip(·,0,1) is a function that constrains the value to the interval [0, 1].

The overall risk index is calculated as follows:

$$R\dot{I} = \sum_{i=1}^{n} \omega_i * r_i \qquad 4.2$$

Here, ω_i denotes the weighting coefficient corresponding to the hazard level of the gas (e.g., higher weight for CO, moderate weight for CO_2, and a separate weight for radon reflecting its long-term risk). For gases such as CO and H_2S, a "peak indicator" is additionally incorporated in order to reduce response delay:

$$p_i = clip(\frac{\frac{\Delta C_i}{\Delta t}}{\left(\frac{\Delta C_i}{\Delta t}\right)_{i,krit}}, 0,1) \qquad 4.3$$

$$R\dot{I}^* = R\dot{I} + \alpha \max(p_i)$$

Here, $\frac{\Delta C_i}{\Delta t}$ represents the rate of change of concentration, $\left(\frac{\Delta C_i}{\Delta t}\right)_{i,krit}$ denotes the critical rate of change, and α is a coefficient regulating the influence of peak values. In the decision-making process, the modified risk indicator $R\dot{I}^*$ is used as the primary evaluation parameter.

To standardize decision-making within the system, the "Normal – Warning – Hazard" levels are defined based on both concentration thresholds and time conditions.

For gases that pose short-term acute risks, instantaneous values and short evaluation windows are taken as the primary criteria. In contrast, for long-term risk factors such as radon, the 24-hour average concentration and trend analysis are considered more significant.

Gas / Parameter	Normal (S0)	Warning (S1)	Danger (S2)	Automatic Response Example
CO_2	$C < T_{CO_2, norm}$	$T_{CO_2,norm} \leq C_{-C_{O,}, warn}$	$C > T_{CO_2,danger}$	Adapt ventilation, notify [4]
CO	$C < T_{CO,, norm}$	$T_{CO,norm} \leq C_{-C_{O}, warn}$	$C > T_{CO_2,danger}$	Alarm + max. ventilation + safe mode [1]
NO_2	$C < T_{NO_2, norm}$	$T_{CO,norm} \leq C < T_{CO, warn}$	instant $C(t)$ or peak $\Delta C / \Delta t$	Alarm + max. ventilation [3]
SO_2	$C < T_{SO_2, norm}$	$T_{NO_2,norm} \leq C_{-C_{O,}, warn}$	5-min average	Ventilation + notification [3]
Radon (Rn)	$C < T_{Rn, norm}$	$T_{Rn,norm} \leq C_{-Rn, danger}$	24-hour average ε_{24h+} + trend	Ventilation + source check [3]
H_2S	$C < T_{H_2S, norm}$	$T_{H_2S,norm} \leq C_{-CH_2, danger}$	instant $C(t)$ or peak	Basement ventilation up, trend wätched [3]
CH_4	$C < T_{CH_4, norm}$	$T_{CH_4,norm} \leq C_{-CH_4, danger}$	instant $C(t)$	Alarm + technical zone ventilation [6]
General decision rules:	1 If $RI^* < 0.3$ → Normal (only monitoring + log) 2 If $0.3 \leq RI^* < 0.6$ → Warning (notification + adaptive ventilation) 3 If $RI^* \geq 0.6$ or any gas in S2 → Danger (alarm + actuators + emergency [7]			

Fig.4.2. Table of alarm levels for gases

General Decision Rule (System Level)

$RI^* < 0.3$ → Normal (monitoring + logging)

$0.3 < RI^* < 0.6$ → Warning (notification + adaptive ventilation)

$RI^* \geq 0.6$or S2 level for any gas→ Hazard (alarm activation + actuators + emergency response)

Here, the weighting coefficients wiw_iwi and threshold values are calibrated according to the building type, zone-specific risk level, and selected regulatory standards. A higher priority weight is assigned to CO, a comfort–health balance approach is applied for CO_2, and for radon, the assessment is based on long-term exposure trends.

5. Conclusion

The proposed IoT- and AI-based system elevates harmful gas monitoring in buildings from a simple "measurement" level to a risk-based intelligent control model. Through multi-point sensor deployment, spatial variability is reduced and the representativeness of measurements is significantly improved.

For high-risk gases such as CO, H_2S, and CH_4, peak and anomaly detection mechanisms enhance early warning capabilities and enable automatic intervention in critical situations (activation of ventilation, alarm triggering, transition to safe mode). Adaptive ventilation control based on CO_2 dynamics not only mitigates the "stuffy air" effect but also provides a more balanced management strategy between energy consumption and health requirements.

Monitoring long-term risk factors such as radon through 24-hour averaging and trend analysis transforms “hidden threats” in basements and technical zones into visible and manageable risks.

As a result, the system enhances overall safety levels while also supporting well-grounded maintenance decisions through historical data recording and reporting capabilities.

6. References

1. Afendiyev I.N., Shiraliyeva R.K., Mammadbeyli A.K., Aliyev R.R., Seyidov N.Z., Fatullayeva L.K. Diagnosis and treatment of the toxic effects of carbon monoxide (methodical tool). National Journal of Neurology 2019 No. 1 (15), 86-103 p.
2. Dai X., Shang W., Liu J., Xue M., Wang C. Achieving better indoor air quality with IoT systems for future buildings: Opportunities and challenges. Science of The Total Environment 2023, Vol. 895, 164858 p.
3. World Health Organization (WHO), WHO Regional Office for Europe. WHO Guidelines for Indoor Air Quality: Selected Pollutants. Copenhagen: WHO Regional Office for Europe 2010, 454 p.
4. Health Canada. Residential Indoor Air Quality Guidelines: Carbon Dioxide. Ottawa: Health Canada 2021, 64 p.
5. World Health Organization (WHO). Radon and health (Fact sheet). World Health Organization 2023.
6. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Hydrogen Sulfide and Carbonyl Sulfide. Atlanta: U.S. Department of Health and Human Services, Public Health Service 2016, 298 p.
7. Canadian Centre for Occupational Health and Safety (CCOHS). Methane (Chemical Profile). CCOHS 2023 (Fact sheet last revised: 2023-02-07).
8. Vugar Abdullayev Hajimahmud, Alex Khang, Gardashova Latafat Abbas, Rashad İsmibeyli, Jale Agazade Firudin, Khurshudov Dursun: Application of Artificial Intelligence and Internet of Things in the Manufacturing Sector, Machine Vision and Industrial Robotics in Manufacturing: Approaches, Technologies, and Application***s***. 2024 . S.145-154