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CO monitoring in Awka Metropolis: Issues, Challenges and Monitoring Solutions

Fidelis C. Obodoeze[1], Vincent C. Onuzulike[2], James I. Odegwo[3] and Victoria O. Odegwo[4]

[1]Department of Computer Engineering, Akanu Ibiam Federal Polytechnic, Unwana, Nigeria
[2]Department of Electronic and Computer Engineering, Nnamdi Azikiwe University, Awka, PMB 5025 Awka, Anambra State, Nigeria
[3]Department of Data Science and Analytics, Southern Delta University, Ozoro, Nigeria
[4]The University Library, Renaissance University, Ugbawka, Enugu State, Nigeria

[2]vc.onuzulike@unizik.edu.ng, [3]ifeanyijo@dsust.edu.ng, [4]vickybeauty_1@yahoo.com

Corresponding Author : [1]drfcobodoeze@gmail.com

Abstract

Carbon monoxide (CO) is a dangerous and poisonous gas and its pollution poses significant environmental and health risks in urban areas, including Awka Metropolis. This study explores CO monitoring techniques and control strategies to mitigate its impact. Various detection methods, including IoT-based air quality sensors, satellite imaging, and ground-level monitoring stations, are evaluated for their effectiveness in tracking CO concentration levels. Additionally, the study examines the role of government policies, industrial regulations, and public awareness campaigns in reducing CO emissions. Findings highlight the need for integrated monitoring systems, real-time data analytics, creation of public awareness and sustainable urban planning to improve air quality in Awka. The study also underscores the importance of renewable energy adoption and vehicular emission controls in minimizing CO pollution.

KEYWORDS: *Awka metropolis, CO pollution, Carbon Monoxide*

1. INTRODUCTION

Carbon monoxide (CO) monitoring in Awka Metropolis is crucial due to the city's rapid urbanization and industrial growth. Studies have highlighted the environmental challenges faced by Awka, including air pollution from increased human activities (Idhoko et al, 2024). Research has utilized machine learning techniques to predict air quality, including CO levels, using historical data and environmental parameters. Additionally, GIS techniques have been applied to map air quality indices in specific areas like Nnamdi Azikiwe University, providing insights into pollution levels (Idhoko et al, 2024).

The estimated population of Awka Metropolis as of June 2025 is 301,657 residents (City, 2025). However, population figures in Nigeria are often based on projections due to irregular census data collection (Igwenagu , 2025).
Awka has seen rapid population growth due to urbanization, economic activities, and its status as the capital of Anambra State. Here are some key trends:.

1. Urban Expansion – The city's population has steadily increased, leading to housing development,

commercial expansion, and infrastructure upgrades.

2. Migration Patterns – People move to Awka for education (e.g., Nnamdi Azikiwe University), business opportunities, and government jobs.
3. Transportation and Infrastructure – Growth has led to traffic congestion, increased demand for public services, and expansion of road networks.
4. Environmental Impact – Rising population contributes to air pollution, waste management challenges, and increased CO emissions.

Fig.1 shows the map of Awka, Anambra State, Nigeria.

Fig. 1: Map of Awka Metropolis (Source: Google Map, 2025)

Air pollution monitoring is equally gaining attention in different states and cities of Nigeria. This is as a result of the increasing environmental concerns posed by air pollution. Several air pollution monitoring systems are being deployed in several parts of Nigeria to monitor the levels of air pollution in the atmosphere by the various air pollutants such as CO. For instance, platforms like IQAir provide real-time air quality data, including PM2.5 and other pollutants, for various locations in Nigeria. Additionally, research initiatives, such as the IoT-based air quality detection system, are being developed to monitor and analyze air quality using advanced technologies like Arduino microcontrollers and wireless sensor networks. These systems aim to provide accessible and accurate air quality data to help address pollution challenges.

1.1 Why is Carbon Monoxide Dangerous?

Carbon monoxide (CO) is a toxic gas that can't be detected by human senses as it is
odourless, tasteless and colorless. This means that if left undetected by a CO monitor, CO can build up to levels that can cause harm to life.

When carbon monoxide is breathed, it displaces oxygen within the blood by combining with hemoglobin producing carboxyhemoglobin. This limits the body's ability to carry oxygen to body tissues including the brain and heart. How quickly this occurs is dependent upon the concentration levels of carbon monoxide being inhaled and how long for.

1.2 Symptoms of CO poisoning:

Symptoms of CO poisoning include the following:
headaches or dizziness, breathlessness, nausea,loss of consciousness, tiredness, pains in the chest or stomach, erratic behavior and visual problems (Brouhard, 2024).

1.3 How is Carbon Monoxide Produced?

Carbon monoxide is a toxic gas that is produced as a byproduct of combustion. It is found in the exhaust of internal combustion engines and in the emissions of industrial processes that involve burning fossil fuels. This is an issue for breathing air compressors that rely on the air in the atmosphere to be clean enough to fill breathing air tanks. One solution that companies use to keep that air clean is a compressed air monitor, such as the ACG+ which checks the air before it makes it to the cylinders and if it detects any CO, it shuts off the compressor.

1.4 Effects of Carbon Monoxide

Carbon monoxide (CO) pollution has several environmental effects:

1. Air Quality Degradation – CO contributes to poor air quality, especially in urban areas with high vehicle emissions.
2. Impact on Human Health – Exposure to CO reduces oxygen transport in the bloodstream, leading to dizziness, confusion, and even death in extreme cases.
3. Contribution to Climate Change – While CO itself is not a greenhouse gas, it reacts with other atmospheric compounds, influencing the levels of methane, a potent greenhouse gas
4. Ecosystem Disruption – CO pollution can affect plant growth and disrupt ecosystems by altering atmospheric chemistry.

Carbon monoxide (CO) pollution is a serious air quality issue, especially in urban areas and enclosed environments. Mitigation strategies to combat CO pollution involve both **prevention** and **control** at various levels (individual, industrial, and governmental). Here's a breakdown of the main strategies:

Efforts to reduce CO pollution include stricter emission regulations, improved vehicle technologies, and public awareness campaigns.

1.5 Carbon monoxide detection using sensors

Currently, carbon monoxide sensors for detection can be categorized into semiconductor, electrochemical, infrared, and catalytic combustion types, based on their detection principles. The working principles and advantages/disadvantages are as follows:

Semiconductor sensors

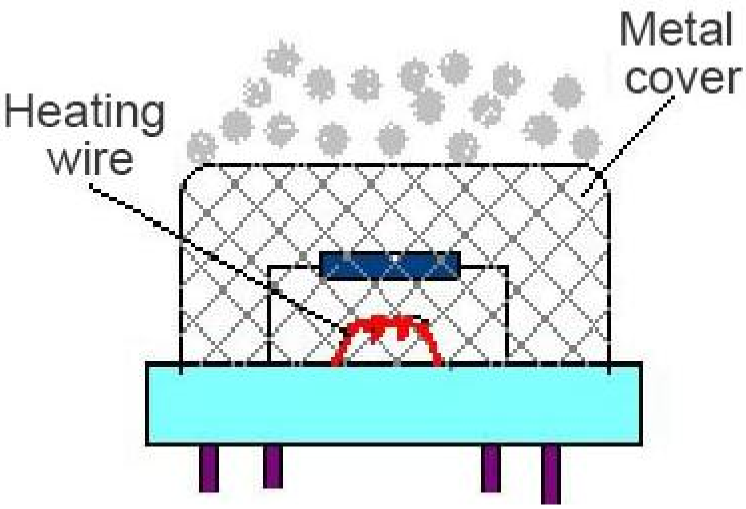

Fig. 2: Semi-conductor gas sensor's working principle (Renkeer, 2024)

Semiconductor gas sensors use changes in semiconductor resistance to detect gas composition or concentration. Fig.2 shows the semiconductor's chamber. According to different physical properties, semiconductor gas sensors can be divided into resistive and non-resistive types. The resistive semiconductor gas sensor uses the change in resistance caused by the semiconductor to contact the gas to detect the concentration of the gas. The non-resistive semiconductor gas sensor directly detects the gas based on the adsorption and reaction of the gas, causing certain characteristics of the semiconductor to change. or indirect detection.

The sensitivity of the semiconductor gas sensor is very high. It is like a vigilant "watchman", extremely sensitive to the presence of specific gases, and can even detect trace gas concentrations. Such keen sensitivity not only facilitates

industrial production, but also shines in fields such as environmental protection and medical diagnosis. However, the sensitivity of semiconductor gas sensors is affected by temperature. In high or low temperature environments, sensitivity will be affected, resulting in slower reaction speed or unstable detection results. This is like a person's reaction becoming slower in a cold or hot environment.
Pros: High sensitivity. Trace gas concentrations can be measured.
Small size and low cost.
Cons: Susceptible to interference from other gases, which may affect its detection accuracy.
Greatly affected by temperature.

Electrochemical sensors:

The principle of an electrochemical sensor is illustrated in Fig.3 below.

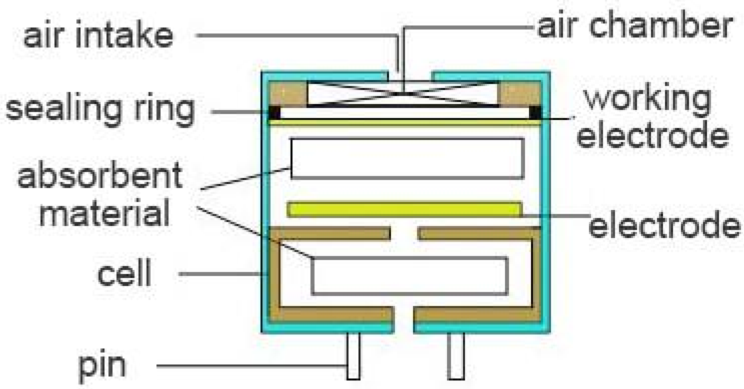

Fig. 3: Electrochemical sensor's working principle (Renkeer, 2024)

When a fixed voltage is applied to the positive and negative electrodes of the electrochemical cell, reactions occur at the working electrode (anode) and the counter electrode (cathode). Taking the example of a carbon monoxide sensor, the chemical reaction can be represented by the following equation:

$$\text{Active pole: } CO+H_2O \rightarrow CO_2+2H^{+}+2e^{-}$$

$$\text{Opposite pole: } \frac{1}{2}O_2+2H^{+}+2e^{-} \rightarrow H_2O$$

$$\text{Response: } 2CO+O_2 \rightarrow 2CO_2$$

The oxidation-reduction reaction continuously occurs between the working electrode and the counter electrode, creating a potential difference between the electrodes. However, due to the polarization of the electrodes caused by the reactions occurring at both electrodes, it becomes challenging to maintain a constant potential between the electrodes. This limitation also affects the detectable range of carbon monoxide concentration.

The overall reaction involves the oxidation of carbon monoxide to carbon dioxide, resulting in the flow of electrons and the generation of an external current. Charge balance is achieved through the movement of charge carriers in the electrolyte.

The main characteristic of electrochemical sensors is that the current is directly proportional to the carbon monoxide concentration, and the output signal exhibits a good linear relationship with the gas concentration. This makes signal processing and displays conveniently. Another advantage is that these sensors operate at room temperature, eliminating the need for heaters. As a result, the electrode potential can be powered by dry batteries, eliminating the need for mains power.

Pros: Small size, low power consumption, high sensitivity, good stability, good linearity, good repeatability, and longer lifespan.
Cons: There are significant differences in price, performance, and manufacturing processes among different brands of electrochemical sensors.

Infrared sensors:

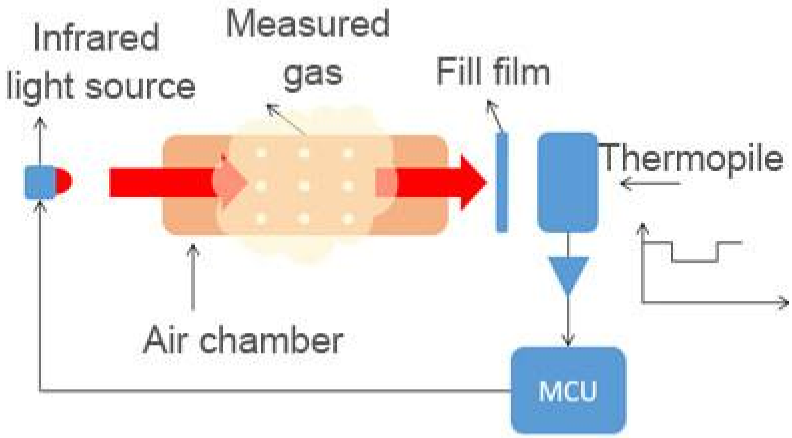

Fig. 4: Infrared sensor's hardware architecture (Renkeer, 2024)

The detection principle of infrared sensors is as follows: Molecules composed of two different atoms have a dipole moment (product of the dipole length and the charge of one end of the dipole). When infrared light is irradiated onto a gas, it will absorb light of specific wavelengths that are related to the molecular structure of that gas. Fig.4 depicts the hardware architecture of Infrared sensor.

The absorbed wavelengths can determine the type of gas, and the intensity of absorption can be used to measure the concentration of the gas. Infrared sensors have high sensitivity and accuracy, making them commonly used in instrumentation. However, they have a complex structure and higher cost, which limits their use in alarm systems.
Pros: Wide measurement range, high accuracy, less susceptible to environmental interference.
Cons: High cost, higher maintenance requirements, larger size, lower accuracy in detecting low concentrations, not suitable for long-term power supply usage.

Catalytic combustion sensors:

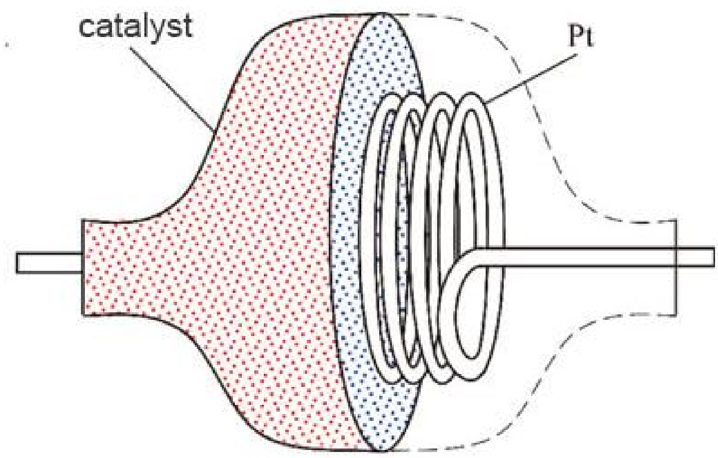

Fig. 5: Catalytic combustion sensor's hardware architecture (Renkeer, 2024)

Fig.5 shows the architecture of catalytic combustion sensor. Catalytic combustion sensors consist of a pair of sensing elements. One of the elements is highly sensitive to carbon monoxide gas and is coated with multiple layers of catalyst.

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The other element is insensitive and is used to compensate for changes in ambient temperature. This pair of sensing elements, along with another pair of high-precision resistors, forms a Wheatstone bridge.

Pros: Accurate measurement, fast response time, long lifespan.
Cons: Operates in a flame state, posing a combustion and explosion hazard. Most elements are susceptible to poisoning by organic vapors.

2. RELATED WORKS IN LITERATURE

Nwabueze (2022) presented the work "Air Pollution Modeling in Awka Metropolis". This research explores machine learning techniques for predicting air pollution levels, including CO. It highlights the role of data-driven models in environmental monitoring. This study explores machine learning techniques for predicting air pollution levels in Awka. It utilizes ensemble learning algorithms such as Random Forest, XGBoost, AdaBoost, and Extra Trees to forecast PM2.5 emissions. The research highlights the effectiveness of ensemble models in achieving high prediction accuracy and reducing residual errors.

Asogwa et al (2023) explored how to use data-driven approaches to predict PM2.5 pollution in Awka Metropolis in the study |SMART CITY PM2.5 Air Pollution Modeling Techniques". It compares Train-Test Data Split and K-Fold Cross Validation techniques to assess the performance of various machine learning models,

Monitoring of Concentration of Air Pollutants from Vehicular Emission (T.O Oluseyia and M.I Akinyemi (2017). This study from the University of Lagos examines CO, NOx, SO2, and particulate matter levels along major highways in Lagos. It highlights the impact of vehicular emissions on air quality, showing that pollution levels often exceed regulatory limits due to heavy traffic congestion and poor traffic management.

Ambient Air Quality Monitoring in Metropolitan Lagos (Njoku et al, 2016). This research assesses CO, CO2, NO, NO2, SO2, and suspended particulate matter across 21 sampling locations in Lagos. It finds that CO levels vary from good to very poor depending on location, with major traffic intersections showing the highest pollution levels. The study recommends stricter vehicle emission management and industrial air pollution control.

Investigation of Carbon Monoxide Concentration from Anthropogenic sources (Akinyemi M. L. and Usikalu M. R.(2013). This paper evaluates CO emissions from various sources, including trucks, generators, and cooking activities. It finds that trucks emit the highest CO concentration (289.64 ppm), followed by diesel-powered generators (116.23 ppm), while firewood cooking emits the lowest levels (5.75 ppm). The study emphasizes the need to reduce fossil fuel reliance to improve air quality.

3. METHODOLOGIES TO CONTROL AND MONITOR CO POLLUTION

This section presents the major strategies to combat or reduce CO pollution in the cities and metropolis.

3.1 CO Prevention and Control Measures

There are several measure that can be adopted by several managers and governments in Nigeria and Anambra State to prevent and control CO pollution levels in order ti reduce the negative impacts on the environment and humans.

They are as follows:

A. Source Reduction Strategies

1.Vehicle Emissions Control:

- Regular vehicle maintenance and emissions inspections.
- Use of catalytic converters in vehicles to convert CO to CO_2 .
- Promotion of electric and hybrid vehicles.
- Carpooling, public transportation, and biking to reduce traffic.

2.Industrial Controls

- Implementing cleaner combustion technologies in factories.
- Installing CO scrubbers and oxidation catalysts in smokestacks.
- Switching to cleaner fuels (natural gas instead of coal or heavy oil).

3.Indoor Environment Improvements

- Proper ventilation in homes, especially when using gas heaters, stoves, or fireplaces.
- Regular maintenance of fuel-burning appliances.
- Installation of CO detectors in homes and workplaces.

4.Policy and Regulatory Measures
- Stricter Emissions Standards
- Enforcing limits on CO emissions from vehicles and industries.
- Requiring low-emission zones in high-traffic urban areas.

5.Air Quality Monitoring and Public Alerts
- Monitoring CO levels in cities and issuing public health advisories.
- Encouraging temporary reductions in traffic or industrial activity during high CO episodes.

6.Promotion of Clean Energy
- Incentives for renewable energy (solar, wind) and reducing fossil fuel dependence.

7.Public Awareness and Education
- Campaigns to educate people about CO risks and safe appliance use.
- Training for proper maintenance and detection practices.
- Promoting awareness about the importance of CO detectors.

8.Technological Innovations:
- Development of more efficient combustion engines.
- Smart CO detectors and IoT-based air quality systems.
- Urban planning tools that model and manage air flow to reduce CO build-up.

3.2 CO Monitoring in Nigeria

Carbon monoxide (CO) levels are being monitored in Nigeria to assess air quality and potential health hazards. Studies and monitoring efforts are underway, particularly in urban areas, to understand the impact of vehicular emissions and other sources of CO. While the current CO level in Nigeria is considered safe based on available data, according to AQI.in, ongoing monitoring and research are crucial for identifying potential issues and implementing preventative measures.

Nigeria has several air pollution monitoring systems and initiatives aimed at addressing environmental challenges: These systems aim to improve air quality and public health.

1. National Environmental Standards and Regulations Enforcement Agency (NESREA): NESREA oversees air quality monitoring and enforces regulations to reduce pollution levels. It collaborates with state and local governments to implement policies targeting industrial emissions and vehicle standards (Disciplines.ng, 2025). The following are the detailed CO monitoring in Nigeria:

1.Monitoring Efforts: Several studies and monitoring programs are focused on assessing CO levels in urban areas, with a particular focus on high-traffic areas and areas with high commercial activity.

2. Reducing emissions of CO from vehicles: Studies have shown that CO levels can be higher in areas with more traffic, indicating a significant impact from vehicular emissions.

3. The primary reason for monitoring CO levels is to assess their potential impact on human health and well-being. High CO concentrations can lead to various health problems, including headaches, dizziness, and in severe cases, respiratory issues and even death.

4. According to the Guardian reports, there is a lack of awareness about the dangers of CO poisoning among many Nigerian households.
5.Recommendations: The studies and research suggest a need for continuous monitoring of CO levels, implementation of air pollution control policies, promotion of cleaner technologies, and public awareness campaigns to educate the public about the dangers of CO poisoning.

3.3 The latest CO monitoring systems for Awka Metropolis

The latest advancements in CO monitoring systems involve more sophisticated technologies and features, offering enhanced accuracy, real-time alerts, and various application types. These systems range from portable personal monitors to fixed, continuous monitors for specific environments.

The major features of CO monitoring systems include the following:

A. Types of CO monitoring Systems:

1. Portable/Personal Monitors:
These are designed for individual use and come in various forms, like clip-on monitors or wrist-worn devices, offering continuous monitoring and alerting the user in case of CO exposure.

2.Fixed/Standalone Monitors:
These are typically wall-mounted and designed for specific environments, such as plant rooms, parking garages, or homes, providing continuous, real-time CO detection and alerting.

3.Multi-Gas Monitors:
Some monitors are designed to detect multiple gases, including CO, along with other parameters like oxygen or carbon dioxide.

4.Wireless Monitors:
These monitors transmit data wirelessly to a central monitoring station, offering greater flexibility and ease of installation, particularly in industrial or commercial settings.

B. Key Features & Technologies:

1. Real-time Detection:
Modern CO monitors provide real-time data, allowing users to quickly react to potential hazards.
2. Advanced Sensors:
Some monitors utilize biomimetic sensors, which mimic the way hemoglobin reacts to CO, providing more accurate and sensitive detection.
3. Alerting Systems:
Monitors typically feature audible and visual alarms to alert users of CO levels.
4. Data Logging & Reporting:
Many monitors can log data, allowing users to track CO levels over time and identify potential sources of contamination.
5. Remote Monitoring & Control:
Some systems offer remote monitoring and control capabilities, enabling users to view data and adjust settings from a central location.

C. Applications:
1. Residential:
Carbon monoxide detectors are crucial for home safety, helping to prevent carbon monoxide poisoning.
2. Industrial:
CO monitoring systems are essential in industries with CO-producing processes or where CO can accumulate.
3. Commercial:
CO monitors are used in various commercial settings, including parking garages, plant rooms, and warehouses.
4. Emergency Response:
Portable CO monitors are used by emergency responders to assess CO levels at incident scenes.

D. Considerations:
1. Sensor Technology:
Different sensor technologies offer varying degrees of accuracy and sensitivity. Understanding the type of sensor in a monitor can help determine its suitability for a specific application.

2. CO Gas Monitors:
Carbon monoxide (CO) gas monitors are essential for detecting this odorless, colorless, and highly toxic gas. They help prevent poisoning by alerting users when CO levels become dangerous. Here are some options:

- Portable CO Detectors: Ideal for personal safety in workplaces like garages, tunnels, and loading docks.
- Fixed CO Monitors: Installed in homes, industrial sites, and confined spaces to provide continuous monitoring.
- Multi-Gas Monitors: Devices that detect CO along with other gases like oxygen (O_2) and carbon dioxide (CO_2)
- Industrial CO Monitors: Used in steel mills, fire departments, and chemical production facilities

RKI Instruments and Analox manufacturers offer very good options for different types of CO gas monitors or detectors for both domestic, scientific and industrial uses. Figs.6 and 7 depict different models of Gas monitors from the stable of RKI Instruments. The EC-600 CO monitor is used for remote monitoring with alarm indicator.

Fig. 6: EC-600 CO Gas monitor with wireless strobe lights and horns for remote alarm indication (RKIInstruments, 2025)

Fig. 7: RKI's Model EC-600 CO Gas monitor (RKIInstruments, 2025)

RKI's Model EC-600 is an indoor monitor that detects Carbon Monoxide (CO) with a range of 0-150 ppm. It's a sleek low profile design which lends itself to laboratory or commercial applications. The EC-600 comes ready to operate with a simple wall mount bracket and 10 foot power cord. If Carbon Monoxide is present, the user is notified by an audible alarm tone and multicolored LED display (RKIInstruments, 2025). .The EC-600 uses a fast responding low-cost plug-in style electrochemical sensor.

Fig.8 shows the Analox CO detectors for home and industrial uses.

Analox CO detectors for home and industrial uses: Analox offers a choice of wall mount or portable Carbon monoxide (CO) monitoring solutions.

Fig. 8: Analox CO Monitors and Detectors Analox (2025)

The Ax60+ CO protects users in plant rooms, parking garages and anywhere that carbon monoxide can collect. COSAMs is a fixed continuous real-time monitor of carbon monoxide (CO). ACG+ is a multi-gas analyzer to measure: oxygen (O2), carbon dioxide (CO2), carbon monoxide (CO), Volatile Organic Compounds (VOC's) and Dew Point in compressed air. The unit can be wall mounted or used as a portable system.

4. CONCLUSION

Effective carbon monoxide (CO) monitoring and control in Awka Metropolis is essential for safeguarding public health and improving air quality. This study highlights the need for advanced monitoring technologies, such as IoT-based sensors, real-time data analytics, and satellite imaging, to track CO pollution accurately. Implementing strict emission regulations, promoting clean energy alternatives, and enhancing public awareness are crucial steps toward mitigating CO pollution. Additionally, collaboration between government agencies, researchers, and local communities is vital for enforcing pollution control measures. By adopting sustainable urban planning and investing in environmentally friendly transportation, Awka can significantly reduce CO levels and enhance the well-being of its residents.

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