



A Review on Indoor and Outdoor Air Environmental Monitoring Techniques

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Annotation

Now a days the most important noteworthy issue is environmental monitoring in all over the world, because of global warming and pollution there cause great effects on environment as well as human life and aquatic life. Thus, for the better understanding a review is conducted of how the various indoor monitoring techniques operate. In order to review the strategies and methods that are based on these factors that were chosen, a few parameters were chosen for this review. In recent times, there has been a noticeable trend toward the development of increasingly sophisticated and online-focused procedures. These advancements eventually highlight the growing demand for a greater number of ecology monitoring strategies.

Keywords: Environment Monitoring; Review; Indoor; Outdoor; Monitoring Techniques.



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1. Introduction

1.1 Background

Environmental monitoring has become the most crucial issue that needs to be resolved in light of the rising pollution levels and the effects of climate change. In a similar vein, other factors like workplace and home safety, or maybe more accurately, the safety of construction sites, have also contributed to the idea that environmental element monitoring is an essential part of preventing and minimizing the likelihood of problems or accidents occurring. Therefore, in order to prevent the problems from getting worse, there is also international pressure on climate change material, which alters the climate. As a result, governments have imposed stronger regulations and are working to improve the number of monitoring solutions they offer. If to talk about the main point which is environmental monitoring, it is divided into two mainly categories of location. They are considered either indoor or outdoor. For measuring inside confined areas, the indoor environmental monitoring is used, whether it can say they are for living or for work. When to discuss an outdoor space, which is typically defined as one that is open to the elements and not covered by a roof, it should note that it is influenced by the weather and surrounding surroundings. Given the quantity of time typically spend inside, it follows that the indoor

environment is crucial to both our well-being and the well-being of the environment. According to the European Commission, the majority of people in Europe spend 90% of their time indoors, or in closed spaces, mostly at home or at work. Therefore, it should come as no surprise to us that the environments in which live on a daily basis have the capacity to have a significant effect our health in either a favorable or negative way. These effects may not be immediately apparent, but they nonetheless have a significant impact on human health. Indoor spaces can occasionally be more hazardous and two to five times more poisonous than outdoor ones. Observing many Europeans which is suffering from asthma, and also know the reason that why they get asthma As a result, is brought on by substances or elements that are inhaled repeatedly over a period of time indoors. Numerous of these substances have detrimental effects on the body effect our health, and some can even cause death and know that it is all because of inhaling the toxic gasses in environment in which live for a long time that is why fresh air is needed. Speaking of the construction industry, to aware that certain materials—radon and asbestos, for instance—are utilized as components of building materials and have the potential to seep inside the structure, making their accumulation exceedingly hazardous and catastrophic. The most notable and widespread issue is the widespread use of tobacco products, which can negatively impact both the skin and the lungs and ultimately lead to the development of lung cancer. Numerous studies have connected indoor air quality, or IAQ, to conditions that are challenging to diagnose right away and have even been related to some issues related to mental illness. Because of this, monitoring indoor quality is crucial. [1]. In the end, these monitoring strategies help environment management systems to provide a cozy living space for the occupants. It may also result in the development of energy management systems, which effectively lower energy usage while maintaining comfort levels. The objective is to be able to offer a friendly environment that satisfies the user's requirements in terms of appearance and functionality. This indicates that the person is able to live or work under such circumstances and is unaware of the changes.[2].The data from these sensors is fed into machine learning algorithms that control the air quality in the greenhouse through the use of SMART approaches. One illustration of a greenhouse environment control system is shown in Figure 1. These monitoring methods have to be used in some places, such server rooms and libraries, to keep the temperature at a reasonable level in order to prevent heat or humidity from damaging the equipment, among them books and servers.

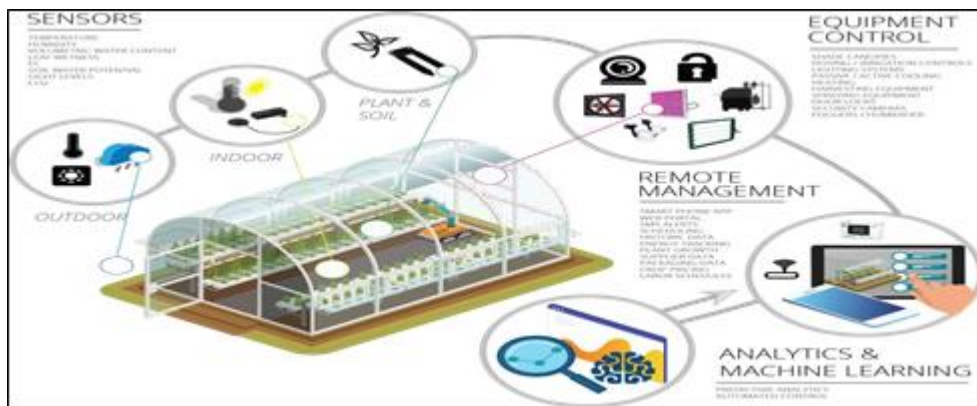


Figure 1: Greenhouse Indoor Environment Management

In addition, other systems use fuzzy strategies to lower the building's overall energy usage. These systems and techniques are called BEMS, or building energy management systems [3], and they work incredibly well in comparison to standard traditional techniques. To preserve energy, there are also passive methods that make the most of solar and ambient energy. They haven't, however, shown to be as successful in maintaining the occupants' comfort level thus far. Because it is less expensive than smart systems, building developers employ this strategy more frequently than occupants do [4].

1.2 Environmental Monitoring Techniques

Environmental monitoring has various applications. The two primary categories into which they fall are outside monitoring and indoor monitoring. Everybody has different standards. A few of these subcategories are shown in Figure 2 [5].

As is evident, monitoring strategies can be classified as either indoor or outdoor; yet, each of these primary categories has other subcategories. For instance, habitat monitoring pertains to the confined animal area, which needs to be continuously observed due to the presence of a critically ill living organism. Because these animals frequently need to live in quite particular settings, it's important to keep a close eye on the humidity levels in their surroundings. Precise assessments of the temperature and air quality are necessary for this to occur in order to maintain the ideal circumstances for the critter to live.

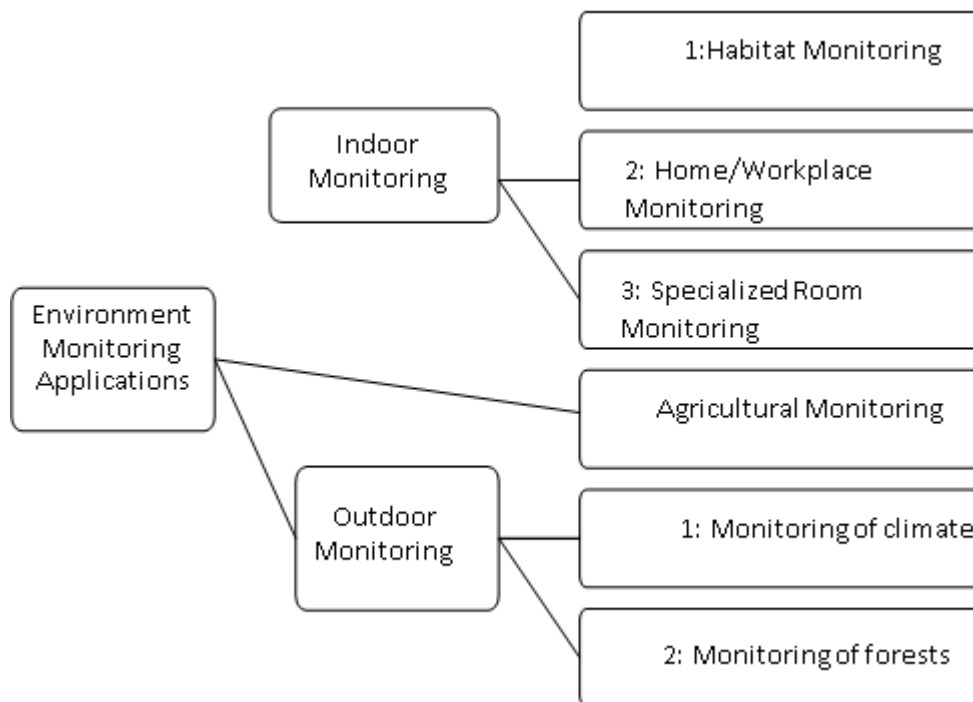


Figure 2: Shows the (Categories, and also subcategories of environment monitoring applications).

The monitoring of homes and workplaces is intended for indoor spaces where people live, such as homes and offices. Many things, including air quality, need to be measured in situations like this. In order to guarantee both comfort and safety for air contaminants like asbestos and radon as well as smoke emitted from fires, measurements are taken ranging from temperature to humidity. These components are required to keep an eye on indoor spaces at home and at business.

The third type of indoor monitoring is called "specialized room monitoring," which includes keeping an eye on particular spaces like server rooms and greenhouses that require particular operating conditions. For example, plants need specific humidity levels and temperatures, which need to be maintained at either a warm or cold temperature in server rooms or greenhouses. It is necessary to keep an eye on these temperatures to maintain the equipment and plants in suitable conditions. Many systems that monitor the greenhouse environment rely on machine learning methods in addition to wireless technologies to function as best they can. [6, 7].

Techniques for monitoring agriculture, the climate, and forests are included in outside monitoring. all of which take place outside and require the use of tools to keep an eye on the ambient air quality and temperature. This is significant because each of these sites needs to be observed for a number of reasons, including maintaining the current state of the area or averting potential disasters like acid rain in forests, which can destroy both agricultural products and living

creatures. The increased effects of climate change have led to a rise in the prevalence of climate monitoring, which is encouraging academics to pinpoint the causes of global warming and, in some manner, offer ways to stop it. [8-10].

The objective of this review is to compile and examine the most contemporary indoor monitoring methods that are applied to home or working environments. This would enable a more thorough evaluation as opposed to one that is dispersed with an excessive number of watered-down concepts. This category was selected because of the significance of air quality in certain settings, which, if neglected, can have serious consequences. Thus, the review of air-based monitoring in indoor work contexts and residential settings is the vital topic of this analysis.

The framework of this document is as follows: An outline of the historical background of the subject and its related problems was provided in the first section. The focus of the second section is on the research background and the criteria that need to be measured for indoor measurement. In order to find the most recent publications, the third section analyzes keywords related to air and indoor environment monitoring to list the relevant research papers. These papers are then analyzed using the properties mentioned in section 2 to provide a comprehensive overview of the review. The information listed is then summarized in section 4, which includes a table summarizing all of the review papers as well as a quick synopsis.

2. Two parameters for monitoring indoor environments

To comprehend how to examine the studies, one must have an overview of the existing parameters for the topic. Such parameters and specifications are listed in Table 1 and have been observed in other studies; however, they have been simplified because the objectives of other studies differ from the concepts put out in this study. Table 1 will be used as a guide to help identify the pertinent criteria for air quality monitoring systems related to homes and workplaces.

Table no 1: Showing environmental measurement also its parameters and Specifications.

No.	Parameters	Examples
1.	Types of Sample s	[Air/, Water/, Soil]
2.	Devices Locations	[Offline/, Online/, Remot]
3.	Samplings	[Invasive/, Non-invasive]
4.	Environment	[Indoor/, Outdoor]
5.	Operations	[Manual/, Automatic]

The factors help to provide a more comprehensive knowledge of the study article. However, as measuring the environment, a variety of other factors are theoretically possible to consider. However, for the sake of this study, only the most noteworthy ones are included. These measurements show how well the method and sensor are able to assess the surroundings.

One of the most fundamental sorts of factors is the sample type, which emphasizes the technique's main goal—that is, analyzing the components of the environment, whether they be solid, liquid, or gas. These variables could be anything, including the pollutants in the surroundings, the water utilized in the pipes, and the air itself, the humidity levels, which have a range of affects, the soil and its quality, and so on.

The device location is the next parameter, and it's crucial since it indicates the device's location. This technique would fall under the category of offline techniques if it is limited to measuring the air's temperature or humidity without being connected to anything other than a thermostat. On the other hand, modern smart houses are equipped with the potential to capable of measuring a range of components while remaining linked to the primary hub and maybe sending such data to the user's mobile device. It would refer to this method as an online methodology. Then, using thermal cameras or satellite imaging, remote measurements can be carried out from locations outside the

environmental jurisdiction. These function as distant cameras.

Another characteristic that describes the workings of the device and how samples are collected is sampling. Non-invasive refers to a device, like a thermal camera, that gathers environmental data and information without being immediately obtrusive. An aggressive device is one that collects these samples either directly or by using intrusive strategies, like soil sampling and ecological swabs. Whether the device operates inside or outside of a building is referred to as the environment factor. Indoor describes the space inside the house or place of business as well as the variable being measured. The term "outdoor" describes an area that is open and unrestricted by walls and roofing. Given that the measuring parameters and values vary depending on the location, this distinction is crucial. A temperature sensor that monitors an interior site with access to air conditioning, for example, has a different environmental need and threshold than a sensor that detects the outdoor natural temperature. Consequently, the differentiation is vital and required to quantify the methodology and its diverse capabilities concerning environmental surveillance.

The device's operation is covered by the final parameter. This describes the method of operation of the device, such as automated or manually triggered. Recently, there have been numerous examples of completely automated, online SMART approaches that set off specific actions when the environment or temperature changes. is evolving in a particular manner. Manual procedures cannot function without outside interference. As a result, they function differently from automated and intelligent methods. But the specifications can be a little more precise because the assessment is focused on a certain set of indoor home and workplace environments, as indicated in Table 2.

Table 2: Showing Indoor Monitoring System Parameters

No.	Acronym	Parameter	Example
1.	(AQ)	Quality of Air	[CO2./Radon/,Humidity/,Temperature]
2.	(DL)	Devices and Locations	[Offline/,Online/,Remote]
3.	(EL)	Experiments and Locations	[Office/,Workplace/,Home]
4.	(TE)	Technology Employed	[Wi-Fi/,Bluetooth/,Wired]
5.	(OT)	Operations and its Types	[Manual/,Automatic]

It is evident that several elements have been modified. Since all of the samples are located on the air, Air Quality (AQ) is used in place of sample type in this instance. But now there will be more information about the specific kind of air quality that is being discussed. CO2 concentration, humidity, temperature, and other factors assessed in an interior setting are a few of these.

The offline, online, and remote components are still present in the Device Location (DL), which is unaltered. To help with comprehension of the location of the experiment and the main topic of the review, the experiment location (EL) has been provided. The sort of solution utilized to install or deploy the sensor is the main emphasis of the technology being used (TE). For example, whether it is connected via wired, wireless, Bluetooth, or another method like the internet or network approaches. Additionally, Operation Type (OT) is unaltered. Therefore, the parameters from Table 2 are employed to do this measurement in order to review the procedures.

2. Review Results

The most noteworthy or recent environmental techniques are chosen to be studied and examined using the criteria that were expounded upon in the preceding section. All of the research publications and papers that have been chosen for review are listed in Table 2. Seven papers in all have been chosen for review. of which the remainder are from 2018 and one is from 2019. This suggests that in order to give a thorough overview of the various approaches and methodologies

available for measuring the quality of the environment, it would be wise to only use the most research and studies.

The numbering method used to identify the approaches will act as a unique identification for Table 4, which contains the techniques derived from observed parameters. This is necessary because Table 3's main goal is to simply list and display the variety of methodologies, which Table 4 then goes into further detail about. Additionally, it demonstrates the general outline of the methods and their recentness. Table 4 presents an illustration of each technique depending on the different factors offered, while Table 3 provides an overview of each of these procedures.

No.	Author	Year	Title
R.1	Mr. M Jin et, al.	(2018)	[Automated mobile sensing: Towards high- granularity agile indoor environmental quality monitoring][11]
R.2	Mr. A Schoeneck et, al	(2018)	[Smart homes, and the control of indoor air quality] [12]
R.3	Mr. J Liu et, al.	(2018)	[Indoor air quality, and occupants,' ventilation habits in China, Seasonal measurement and long-term monitoring] [13]
R.4	Mr. Y Geng et, al.	(2019)	[Indoor environmental quality of green office buildings in China: Large-scale and long-term measurement] [14]
R.5	Mr. A Tiele et, al	(2018)	[Designing and Development of a Low-Cost, Portable Monitoring Device for Indoor Environment Quality] [15]
R.6	Mr. O Blanco et. al	(2018)	[A Cost-Effective IoT System for Monitoring, Indoor Radon Gas Concentration] [16]

3. Summary

An automated mobile sensing sensor system for monitoring interior environmental quality is proposed in the first study (R1). This method makes use of a movable base that can measure a wide range of ambient and changeable characteristics. The information is gathered in both time and spatial dimensions, and an algorithm is used to map the interior space. The study showed that an effective mobile platform for measuring air change is available. This method is automated.

The second study (R2) includes an analysis and summary of SMART homes that employ indoor environment monitoring devices to control the standard of the home's air. The goal is to analyze methods that concentrate on using artificial intelligence in home applications to enhance air quality and provide thermal comfort through ongoing assessment and adjustment. Central Europe was the location of this experiment.

Though the experiment is divided into two phases—seasonal monitoring and long-term monitoring—the third study (R3) is carried out in China. Sensors for indoor air quality monitoring were placed to assess temperature, humidity, and pressure. This research has the advantage of being done over an extended period of time. As a result, it offers an excellent summary of how the air's quality has evolved over time and during particular seasons.

The fourth study (R4) has a similar large-scale scope and long-term observations, and it is also

carried out in China. The three buildings that were chosen as case studies in this experiment, each of which was located in a different climate zone, made a difference. The measurements took place from June 2017 to August 2018, a period of more than a year. This study also investigates the outdoor environment, which led to the finding of some cross-correlation, by contrasting the impacts of external temperature with the indoor thermal data. The study's conclusions included a collection of suggestions and ideas for improving the conditions of each of these structures.

The goal of the fifth research project (R5) was to develop a low-cost, portable, battery-operated sensor for assessing indoor environmental quality. This approach focuses on using generally accessible, commercially available sensors to build a prototype that can accurately evaluate air quality according to multiple factors with minor modifications. The list is somewhat long, as the method is primarily focused on CO₂ concentration monitoring. As well as temperature, humidity, and air quality, among other elements, to assess the general standard of the interior environment. This approach has the advantage of being inexpensive and, when weighed against its cost, being deemed effective. It is applicable to different applications. The sixth research (R6) monitors radon gas, a criterion for indoor air quality, using technology on the internet. Overexposure to radon, a gas that is incredibly hazardous, can be fatal. But the achievement of this study is to see various instruments and determine whether one is more effective in measuring radon gas. To take the risk of radon poisoning, alarms may also be delivered using the suggested method. This investigation, which assessed three distinct scenarios using various technologies and wireless connections, was carried out in Spain. In the end, the findings were encouraging and showed that the internet may be a useful resource for locating radon and preserving the indoor environment measuring systems' high caliber.

Table 4 provides a summary of every research study that is mentioned. This gives a summary of the papers on the list and how they work. Every reviewed work has a distinct objective. Some methods concentrate only on watching and assessing the effects of a particular environmental effect, whereas others carry out the monitoring in order to prevent or reduce such effect. However, in order to lessen the likelihood that any problem may arise, the majority of mitigation approaches use SMART and wireless techniques.

Table/chart 4: Summary of the Reviewed Papers and its Overview

S. No	Air Quality	Device Location	Experiment Location	Technology Employed	Operation Type
R.1	Quality of Air	(Mobile)	[California, USA.]	Spatiotemporal Algorithms.	It is Automated
R.2	(Thermal)	(Online)	[Central Europe]	Wireless devices.	It is Automated
R.3	(Thermal, CO ₂)	(Offline)	[China]	IAQ Sensors.	It is Manual
R.4	(Thermal, and Pressure)	(Offline)	[China]	Thermal Sensors.	It is Manual
R.5	(Thermal, Humidity, and CO ₂)	(Mobile)	[UK]	Low-cost sensors.	It is Manual
R.6	[Air (Radon Gas)]	(Online)	[Spain]	Radon Sensors.	It is Automated

Similarly, in order to give more specificity to the review results, there is also another aspect that can be investigated. This is the extra layer of detail that can be listed about the summarized research articles. Table 5 measures two parameters. These are quality of management, which refers to parameters like humidity, CO₂ concentration, air quality and so on while the fourth

parameter is the recorded values and range for these parameters.

Table 5. Detailed parameters used for the summarized research studies

No.	Acronym	Parameter	Example
1	QM	Quality of Measurement	Humidity, Oxygen, Air Quality ...
2	RV	Range of Values	The values recorded by the sensors

Following the information presented in Table 5, these are incorporated into the researches and presented again in Table 6. Some of the measured values are VOC which is an acronym for volatile organic compound, PM_{2.5} for particulate matter, RH which is relative humidity, CO₂ concentrations, Ozone concentrations, NO₃ concentrations, and AER or air exchange rates. As can be seen, the parameters are listed in Table 6 and it illustrates how strong each of the values is measured. In some research articles, the goal is to reduce and manage some of these values while in others the goal is to simply monitor them.

Table 6. Research summary parameter ranges

No.	Author	Year	Title	Quality of Measurement	Range of Values
1	Mr. M Jin et, al.	(2018)	Wireless recognizing automation: (Towards quick, high-granularity indoor quality of the atmosphere monitoring) [11]	Air Change	45-minute rate
				CO ₂	65 to 3000 pm
2	Mr. A Schoeneck et, al	(2018)	(Smart houses and the management of indoor air quality) [12]	Temperature	22 to 30 degrees celcius
				RH	30 to 50%
				CO ₂	1000 to 2000 pm
3	Mr. J Liu et, al.	(2018)	The relationship between China's indoor air quality and its residents' ventilation practices: seasonal assessments and ongoing observation. [13]	CO ₂	65 to 1000 ppm
				Temperature	24 to 45 degrees Celsius
4	Mr. Y Geng et, al.	(2019)	Indoor environmental quality of green office buildings in China: (Large-scale and long-term measurement). [14]	CO ₂	450 to 1200 ppm
				Temperature	22 to 30 degrees celcius
5	Mr. A Tiele et, al	(2018)	Creating and designing a portable, low-cost monitoring tool for the quality of indoor environments [15]	RH	40 to 70%
				Temperature	16 to 24 degrees celcius
				CO ₂	350 to 1000 ppm

				VOC	50 to 1000 ppm
				PM2.5	Under 35 $\mu\text{g}/\text{m}^3$
6	Mr. O Blanco et. al	(2018)	An Affordable Internet of Things System to Track the Concentration of Indoor Radon Gas [16]	RADON	151 to 203 Bq/m ³

4. Conclusion

Six research publications on the topic of indoor environmental monitoring that use air quality measurement were reviewed for this study. Based on the observations, it appears that the goal is to create a smarter, more affordable, and mobile gadget that can continuously check the air quality at all times. Modern methods have made an effort to get there. Others, however, decide to approach similar problems in a different manner.

The second group, which tries to only watch the changes and base its observations on environmental changes, is another observation. These studies only seek to pinpoint the causes of certain environmental impacts and offer recommendations and solutions for mitigating such effects. For example, insufficient window insulation that could cause the interior temperature to fluctuate, or needless CO₂ emissions as a result of outside pollutants entering the house and how it could be reduced.

The above presentation appears to be focused on measuring air, which is related to indoor monitoring techniques and methods. This review of environmental monitoring provides and presents an idea for a stepping stone for future youth researchers in order to understand the current trend in environmental monitoring tools.

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