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IoT for Smart Environment Monitoring Based on Python: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author SHH wrote the detailed review of previous works related to IoT for smart environment monitoring, author ABS gave the idea and put the framework of the review. Both authors read and approved the final manuscript.

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ABSTRACT

Air pollution, water pollution, and radiation pollution are significant environmental factors that need to be addressed. Proper monitoring is crucial with the goal that by preserving a healthy society, the planet can achieve sustainable development. With advancements in the internet of things (IoT) and the improvement of modern sensors, environmental monitoring has evolved into a smart environment monitoring (SEM) system in recent years. This article aims to have a critical overview of significant contributions and SEM research, which include monitoring the quality of air , water pollution, radiation pollution, and agricultural systems. The review is divided based on the objectives of applying SEM methods, analyzing each objective about the sensors used, machine learning, and classification methods. Moreover, the authors have thoroughly examined how advancements in sensor technology, the Internet of Things, and machine learning methods have made environmental monitoring into a truly smart monitoring system.

Keywords: Environmental monitoring; smart environmental monitoring; Internet of Things (IoT); sensors.

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1. INTRODUCTION

Many factors contribute to long-term global growth, including the economy, quality education, agriculture, and industries, but one of the most important is the environment [1]. Health and hygiene are vital elements of the survival of humanity and the well-being of every nation because they come from an environment free of pollution and hazards. It is thus essential to check that people can live a healthy life in every country. Environment monitoring (Em) entails adequate emergency preparation and management, managing various pollutants, and effectively resolving the problems resulting from unhealthy external conditions. Em is concerned with water contamination, air pollution, toxic radiation, weather changes, earthquakes, and so on. Different factors, some human and others natural, are responsible for pollution [2,3]. The rule of Em is to solve problems to create a stable community and a safe environment on the planet [4].

With recent advances in the science and technology sector, in particular, Artificial Intelligence (AI), machine learning, and the internet of things (IoT), Em has become a Smart Environmental Monitoring system (SEM) [5]. Technology has enabled Em procedures to track environmental impacts more precisely and optimize environmental pollution control with other undesirable effects [6]. The concept of smart cities replaces old and outdated ways in which urban environments are created and designed. Smart cities are being planned via wireless networks to monitor vehicle levels of city pollution.

Modern sensors that run on AI-based surveillance and control methods include wireless networks or wireless sensor networks (WSNs). IoT is used for the efficient management, labeling of vehicles, temperature management, and emission control of WSNs. IoT, AI, and wireless sensors mean current environmental monitoring approaches are known as SEM systems. Using modern technology features such as IoT, Artificial intelligence, and WSN, the environment will be more controlled and monitored [7,8].

We analyzed IoT-based applications in smart environment-related fields in this paper. We provided a thorough and critical analysis of research studies on various environmental monitoring systems used for various purposes. We have primarily concentrated on water monitoring quality, air monitoring quality, and smart agriculture monitoring systems to address environmental issues.

This paper is organized as follows. Section II explains background theory that is related to the study. Section III discusses the related work that are linked to environment monitoring. Section IV focuses on discussion and analysis and finally, Section V ended with conclusion.

2. INTERNET OF THINGS (IOT)

The Internet of Things or IoT means the trillions of physical devices connected to the Internet and the worldwide storage and exchange of data. With the emergence of cost-effective computer chips and a broad-based wireless network, anything from a pill to an aircraft can now be transformed into a part of the IoT. Through connecting and attaching sensors to all these different things, artificial intelligence can be applied to otherwise dumb devices so they can share real-time data without needing a human. The Internet of things makes our society more intelligent and adaptive and fuses the digital and physical worlds [8,9,10,11].

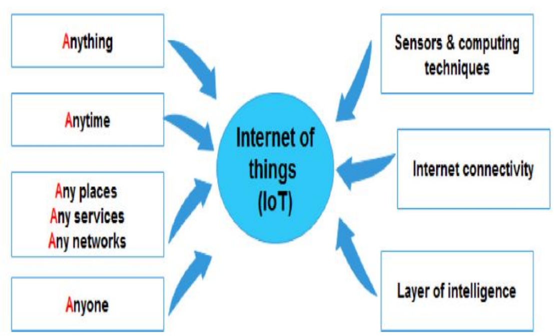

Fig. 1. Concepts of Internet of Things (IoT) [12]

3. ENVIRONMENTAL MONITORING

Currently, society overlooks specific challenges in environmental monitoring since the aim is to collect and investigate environmental data to avoid undefined potential hazards. Concurrently, the primary causes of environmental infection are rising communities, urban populations, electricity, transportation, and rural improvements. Natural disasters, such as landslides, earthquakes, hurricanes, water surges, and tsunamis, are also causes of environmental aspects that amplify attacks [13]. Furthermore, global warming, seawater acidification, and biodiversity loss may have a far-reaching effect on the atmosphere. Moreover, air, water, and noise pollution are thought to be the most extreme environmental complexities. Surprisingly, the more association between air, water, and noise infection and human well-being is acknowledged, the more risk is mitigated [14].

Soil, atmosphere, and water are the three major forms of environmental monitoring.

Air Monitoring: Environmental data collected from various environmental networks and institutes using advanced observation methods such as sensor networks and Geographic Information System (GIS) models are incorporated into air dispersion models, incorporating pollution, meteorological, and topographic data to detect and forecast concentrations of air pollutants [15,16].

Soil Monitoring: Grab sampling (individual samples) and composite sampling (multiple pieces) are used to track soil, establish baselines, and detect threats such as acidification, biodiversity loss, compaction, pollution, erosion, organic material loss, salinization, and slope instability [17,18].

Water Monitoring: A collection of water samples may evaluate the water quality for laboratory analysis or using samples capable of recording data over a long period or periodically at a single stage. The Water Department uses water quality data for water management decisions [19,20].

Essentially, since a human usually breathes once every 3 to 4 seconds, Air pollution is considered an example of a directly damaging environmental factor in personal health. Furthermore, water is the primary source of life for all living beings, not only humans and plants. Untreated waste, toxic product release, oil leaks, and spills, draining from old mines, and agricultural chemicals that are blown off or poured into public water sources are the leading causes of water contamination. Currently, it is predicted that by 2030, developing countries will be harmed by a water shortage caused by the world's population rising to 4 billion. Furthermore, noise is a significant complication in this case because it can be produced from various sources, including transportation, factories, concerts, and a variety of other causes. As a result, IoT sensors and networking could provide a solution to the acquisition issue [13,14].

4. SMART IOT FOR ENVIRONMENTAL MONITORING

Current approaches in low-power wireless network technology have created scientific constraints for developing various types of multifunctional miniature IoT sensors, such as chemical, visual, thermic, and vital, that can be attached to specific wireless sensor arrangements [13,14,21].

Environmental monitoring systems have developed over time into Smart Environmental Monitoring (SEM) systems, which now include modern sensors, Machine Learning (ML) techniques, and the Internet of Things (IoT). For example, IoT devices and wireless sensor networks have made advanced environmental monitoring through IoT a more streamlined and AI-controlled operation [13,14].

Data collected by IoT environmental monitoring sensors from a broad range of environmental conditions can be incorporated into a single cloud-based environmental system through the Wireless Sensor Network (WSN). IoT devices embedded with ML can register, characterize, track, and analyze elements in a specific environment [13,14].

IoT for environmental monitoring enables the development of wireless, remote environmental monitoring systems, allowing the activities to remove much of the interaction between humans in system function, reducing human labor, improving sampling and frequency and frequency, facilitating sophisticated on-site testing, providing lower latency, and connecting response detection systems [22,23].

5. CHALLENGES AND FUTURE DIRECTIONS OF IOT BASED ON ENVIRONMENT MONITORING

In today's technological world, the Internet of Things (IoT) has emerged as a common research subject. The combination of sensors and actuators creates a robust framework for Em that can be used as networks of self-governing objects in real-time systems. IoT is becoming more prevalent in smart cities, everyday life, and various sectors. IoT contributes to smart environments, such as home automation, smart wearables, surveillance systems, and smart health care, among other things. Making smart transportation mechanisms for smart cities, low cost solutions interoperability and smart power grids are the most future directions IoT research areas [6,11,16]. Most IoT sensors used by Em use batteries. Once the sensor is in the field, it is almost difficult to swap the battery, resulting in high power demand and, eventually, a global energy crisis. As a result, another challenge is to design sensors that do not need a battery replacement during their lifespan, which can be accomplished by making more devices that operate on renewable energy sources. One of the most current is the combination of IoT and solar energy [16,21]. Since the internet is the heart of IoT, issues with internet access would result in unreliable connectivity and insufficient performance of an IoT system. Almost all base stations/gateways are equipped with a cap on the number of users who can connect simultaneously; if the count approaches the limit, certain users will not obtain service. So, for IoT to be efficient, a country's internet should be easy and inexpensive [11,16,21].

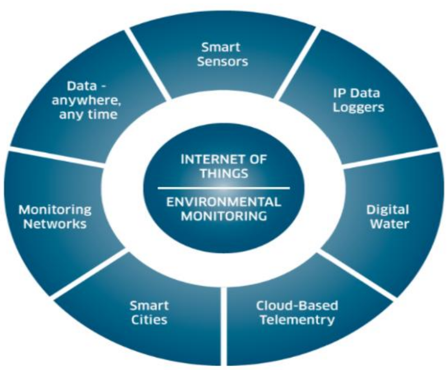

Fig. 2. Environment Monitoring with IoT [24]

6. USED TECHNOLOGIES BASED ON IOT FOR ENVIRONMENT MONITORING

In this section, we explained the most used technologies in the literature review based on IoT for Environment Monitoring.

- Python Programming Language
  Python is a high-level scripting language, interpreted, dynamic, and object-oriented. Python is intended to be highly readable. It often uses English keywords rather than punctuation, and it has fewer syntactical constructions than other languages. for environment monitoring, python has a significant rule because of its libraries that is specially related to Smart Em[14].
- Thing Speak
  Thing Speak is a cloud-based IoT analytics application that allows you to compile, visualize, and analyze live data streams. You can send data from your devices to Thing Speak, generate instant visualizations of live data, and send notifications. Moreover, Thing Speak has an essential rule in environment monitoring systems. Thing Speak is an IoT Cloud interface for sending sensor data to the cloud [25].
- Python in IoT
  Python is the language of choice for many developers in the market. It is simple to learn, has clear syntax, and is supported by a large online community. Python is an excellent choice for IoT backend development as well as device software development. Furthermore, Python can be run on Linux devices, and MicroPython can be used with microcontrollers [26].
- Open CV
  Open CV-Python is a Python linking library for solving computer vision problems. Open CV is used for a wide range of image and video processing tasks, including facial recognition and identification, license plate interpretation, photo editing, advanced robotic vision, optical character recognition, and much more [27].
- PuTTy
  PuTTY is a free and open-source terminal emulator, serial console, and network file transfer program. It supports various network protocols, including Secure Copy Protocol (SCP), Secure Shell Protocol (SSH), Telnet, rlogin, and raw socket access. It can also connect to a serial port [28].
- Tensor Flow
  Tensor Flow is a Python library for fast numerical computing developed and published by Google. It is a base library that can build Deep Learning models directly or through wrapper libraries built on top of Tensor Flow [29].
- Keras
  Keras is an open-source software library that offers a Python framework for artificial neural networks. Keras serves as an interface for the Tensor Flow library [30].

- Arduino
  Arduino is a free and open-source electronics platform with simple hardware and software. Arduino boards can read inputs such as a light on a sensor, a finger on a button, or a Twitter message and convert them into outputs such as triggering a motor, turning on an LED, or publishing something online [31].
- Raspberry Pi
  The Raspberry Pi is a low-cost, credit-card-sized device that plugs into a computer monitor or TV and operates with a standard keyboard and mouse. It is a capable tiny computer that allows people of all ages to explore programming and learn how to program in languages such as Scratch and Python [32].

7. LITERATURE REVIEW

In this section, several studies have been carried out on monitoring the smart environment based on IoT, and it's segregated into three subsections: Agriculture Monitoring, Water pollution, and Air Pollutions monitoring systems.

7.1 Agriculture Monitoring Based IoT

This section includes studies and analysis of systems of smart agricultural monitoring (SAM), including crop surveillance, pest control, fertilizer control, and so on. Table 1 shows the overview of the research study for some major papers.

Anusha et al. [33] developed a smart system for plant surveillance and watering using IoT, a Raspberry Pi processor, and sensors to detect environmental conditions. The machine will accurately understand and then relay to user's environmental information in agriculture. The instrument monitors different parameters, such as temperature, moisture, soil humidity, and light strength.

Vaishali et al. [34] developed A framework to help in an automated system of irrigation. The smart irrigation system is helpful because it automates and regulates irrigation without manual intervention. For farmers and gardeners who do not have time to water crops/plants, the main use of this project is. The farmers have considerable problems in watering their farm fields. And they don't know when the current will be enough to pump water. The humidity and temperature sensors track plants' humidity (water content) and temperature. The moisture sensor sends a signal to the raspberry pi, which sends a message to the Water Pump, which activates it and supplies the water to the respective plant if the moisture level is lower than the limit. The motor status and temperature are seen on a mobile device even without visitation.

Nawandar and Satpute [35] Proposed an automated irrigation system and greenhouse/garden/farm monitoring system that can track crop water needs, alert irrigation and consumer, provide data on agricultural land in real-time and history. It also ensures efficient water use by using an automated irrigation method for plants, taking plant and soil needs into account.

Aneesa James et al. [36] Suggested a way to monitor agricultural area irrigation and crop protection using the Internet of Things (IoT). Raspberry Pi analyzes the collected field information, and an onboard computer is provided with the warning to monitor the device. The photo of the intruder is taken and sent to the farmer's phone by the Pi Camera. The device is switched ON/OFF as required with an application on the smartphone of the farmer. This only guarantees prompt irrigation when the field is dry and advises the farmer against a potential assault on wildlife. Crop Sense thus provides farmers with a viable alternative and helps to improve crop quality and productivity in the long term.

Thorat et al. [37] proposed a system for detecting leaf disease, a remote server monitoring system, the sensing of temperature and humidity, the sensing of soil moisture, etc. The sensor networks are used to measure moisture, temperature, and humidity instead of manual surveillance. Different sensors are installed in several farms; a single controller is known as Raspberry PI (RPI) for monitoring all of these sensors. A camera interfaced with an RPI can identify leaf disease. Plants are sent to farmers by Wi-Fi Server via RPI, such as a leaf disease as an immediate status and other crop environmental factors, including humidity, temperature, or moisture.

Prathibha et al. [38] Discussed that monitoring environmental conditions is a critical factor in increasing the production of productive crops. The most important feature of this paper is the temperature and humidity monitoring in agriculture with sensors based on the single-chip CC3200. The CC3200 captures pictures and sends pictures with an MMS via wireless LAN to farmers mobile phones.

Vineela et al. [39] Explained that IoT has wide application in the field of agriculture, minimizing water and fertilizer use, thus rising yields. They proposed a device to use sensors to measure soil moisture, humidity, and temperature. In the event of an inadequate supply of moisture, these criteria can be automated. Test results demonstrate that this to be a complete solution to irrigation solution. Applying a method like this in the field is almost certainly to boost crop yields and reduce wastage.

Pathak et al. [40] proposed a system that would allow water to be allocated for farming under any conditions. Heat, turbidity, pH, and moisture were collected using IoT platform outfitted with associated sensors and wireless communication systems. Thing Speak was used to view sensor data in the cloud environment in this IoT platform. To pick appropriate crops for particular soil conditions, the data obtained at Thing Speak is used in the proposed Cuckoo Search Algorithm.

Using IoT, machine learning, and WSN, plant growth monitoring Kumar et al. 2019 [17] was introduced and named "gCrop." The work employs a third-degree regression model and achieves a prediction accuracy of 98 percent, the computational complexity, on the other hand, was high.

Rao and Sridhar [41] proposed a method for making agriculture smarter by using automation and IoT technologies. The IoT enables a wide range of applications, including monitoring and selecting crop development, supporting irrigation decisions, etc. An automatic IoT irrigation system based on Raspberry Pi is proposed to modernize and increase crop productivity.

The health of crops and thus farm growth are affected by the environment. Via IoT, sensors, and IO technology, we aimed to examine the state of research in SEM. In the assessment of SEM methods, attention was given to factors in farming, such as soil, humidity, water pollution, air quality, temperature, etc. The study will also concentrate in sub-sections on monitoring water pollution and air quality monitoring methods.

Table 1. Smart Agriculture Monitoring based on IoT study

Purpose of study	Method/Device Used	Software and Programming Used
Plant Monitoring and Watering [33]	IoT, Raspberry Pi, Sensors for sensing environmental conditions	Python programming languages
Control the water and Monitor the plants [34]	IoT, Raspberry Pi, Water pump, Moisture, and sensors of temperature	Android Application (Blue Term), Python
Greenhouse, garden, farm monitoring and watering [35]	Raspberry Pi, Temperature and humidity sensors and soil moisture sensor	HTTP Server , Python
Monitor agricultural area and crop protection [36]	Raspberry Pi, Soil Moisture Sensor,	Python, XAMPP, Mosquitto, Android Studio,
Detecting Leaf Disease and Remote Monitoring [37]	Raspberry Pi, Temperature & Humidity Sensors, Soil Moisture	Raspbian as OS, Apache Server, Python, Open CV,
Crop yield Monitoring [38]	Network Processor, Temperature & Humidity sensors, and cameras.	Python
Crop Field Monitoring [39]	Raspberry Pi, Temperature & Humidity Sensors, Soil Moisture Sensor	Python, Thing Speak
Green area Monitoring [40]	Arduino, Temperature Sensor, Soil Moisture Sensor,	Python and Thing Speak
Growth of Plant Monitoring [17]	IoT, Machine Learning based green crop, WSN	Open CV Python
Crop Field Monitoring [41]	IoT, Raspberry Pi, Soil Moisture Sensor, Temperature Sensor,	Python, C++, Java, Thing Speak

7.2 Monitoring of Smart Water Pollution (MSWP)

Several studies have been carried out on monitoring smart water pollution (MSWP) methods using machine learning, IoT, and wireless sensor systems. Table 2 shows a couple of significant MSWP contributions

Liu et al. [42] proposed approach to water quality prediction by using Long Short Term Memory (LSTM) neural networks and IoT environment establishes analysis, pre-processing data, parameter setting, and the LSTM deep neural network learning method. The research findings demonstrate the consistency and accuracy of the model's expected values and actual values, demonstrating that LSTM deep neural networks are realistic and effective in predicting drinking water quality.

Preetham, K. et al. [43] Proposed a system that uses sensors to monitor water quality parameters and information detected continuously is transferred to the mobile aqua-farmer through the cloud. Steps to reduce losses and improve productivity will therefore be taken promptly. The authors used Raspberry Pi and python programming languages for this study. The proposed device controls the aquarium and grows plants using aquarium wastewater; in addition, pH and nitrogen neutralized water from the grow bed's hydrogen clay pellets is fed back into the aquarium.

Jha, [44] Proposed a system to monitor the groundwater quality. The CC3200 microcontroller is used to build a cloud-based setup. Numerous sensors are installed in the overhead tank to measure the consistency of the groundwater contained in it. Data from sensors are transferred to the cloud using a microcontroller. A decision Tree classifier has been used in the proposed scheme to identify drinkable (positive) instances or not drinkable (negative). The microcontroller is also linked to the display system and mobile devices through GSM and Bluetooth. The author also compared the different algorithms used for dataset classification. The research can be expanded for a distributed environment using big data stream processing in the spark system.

Budiarti et al. [45] developed an interactive IoT-based system to assess water quality by creating a sensor-based environmental water control system. The Raspberry Pi's use as an embedded device helps sensors to be detected. The use of remote communications technologies can facilitate data transmission between objects. Thus, the IoT water quality system can be used as an integrated superficial water monitoring system and is available online in real-time.

Konde and Deosarkar [46] created a reconfigurable sensor unit for the smart water quality environment (SWQM). FPGA architecture, sensors, Zigbee, the FPGA is the heart of the developing device. It is programmed in Quartus II using VHDL. Six parameters, including pH, water level, humidity, and CO2 (or CO2), are also measured simultaneously in real-time using several sensors at different locations.

Similarly , Myint et al. [47] Presented an IoT water quality monitoring system's reconfigurable smart sensor interface unit. An FPGA design board, sensors, a Zigbee wireless communication module, and a personal computer are included in the smart WQM device. The critical component of the proposed device is the FPGA board, programmed with the software Quartus II software and the Qsys Tool in a very high integrated circuit definition (VHDL). The proposed WQM system gathers five parameters of water data from several different sensor nodes in both parallel and in real-time, including water pH, water level, turbidity, carbon dioxide, and water temperature on the water surface.

Remote sensing images was analyzed, and machine learning algorithms was used to predict the pollution level in lagoon water, which is helpful for the agriculture field [18]. The prediction results from this work were not entirely satisfactory because they used neural network-based machine learning.

In [48] presented a smart drinking water measurement method. The machine includes a Raspberry Pi board with several sensors. The developed user interface will help end-users use the system efficiently and take decisions based on displayed screen performance. The fuzzy decision used in this paper is an efficient way to detect the consistency of drinking water in real-time, unlike manual methodologies.

Pokhrel et al. [49] proposed a system for water quality monitoring that integrates with IoT technology. The device will automatically track water quality, and it is low-cost and does not need an additional workforce. This real-time framework creates, gathers, transfers, and saves sensor data to a web server. Data were analyzed, and instant reports were created to be viewed in the web browser from anywhere and anytime. This system was designed to minimize labor, lower costs, and improve water delivery and monitoring quality.

Moparthi, 2018 [20] discussed that water contamination has been an increasing issue in recent years. Hence, the authors built a system to track water quality and identify the pH from claiming water using IoT by using an Arduino board for finding the pH and a GSM module for message techniques.

Rabiya Basri and santhi priya, 2017 [19] designed a low-cost system for real-time monitoring of water quality using IoT. The system is made up of multiple sensors which measure the physical and chemical water parameters. The water may be measured with temperature, pH, turbidity, and conductivity. The central controller processes the values of the sensor. As a central controller, the Raspberry PI platform can be used. The sensor data can finally be accessed through IoT via the internet.

7.3 Smart Air Quality Monitoring (SAQM) Systems

In this section, SAQM methods and frameworks have been studied, and Table 3 summarizes the different approaches to air quality control systems used in recent literature.

Sriyanka and Patil [50] discussed a monitoring system that informs the environment and briefly touches on technology progress in environmental monitoring and identifies a new scope in monitoring existing environmental issues. The system is designed with the economic and productive use of Arduino, Raspberry Pi 3, Zigbee, and Adafruit IO. The sensors will collect and transmit to Raspberry Pi via Zigbee from the Arduino data on different environmental parameters. Raspberry Pi 3 transfers processed data via python programming to the internet and use Adafruit IO as an IoT platform. Experimental results indicate that the instrument can precisely measure carbon monoxide, carbon dioxide, fuel gasses, smoke, and air quality.

Table 2. Monitoring of smart water pollution (MSWP)

Purpose of the study	Method/Device Used	Software and Programming Used
Monitoring the quality of drinking water [42]	LSTM	Keras and Sensor Flow Python
aquaculture water quality Monitoring [43]	IoT, Raspberry Pi, pH, turbidity, temperature sensors.	Python, Cloud Operations, Thing Speak, Android Studio
Groundwater quality monitoring [44]	Decision Tree classifier of Machine Learning, Microcontroller, Ph and Temperature Sensors.	Python, Cloud operations
Monitoring of Drinking Water Quality [45]	IoT, Raspberry Pi, Modem WIFI, Environment Sensors.	Python, Maria DB, SQL Lite,
Water Quality Monitoring [46]	IoT, FPGA board, (Humidity, CO2, pH, turbidity , temperature) sensors.	Python with Linux OS
Lagoon Water - Controlling agricultural water pollution with remote sensing [18]	Prediction using machine learning and image processing,	Python Programming Language
Monitoring the Drinking Water Quality [48]	Raspberry Pi, Multi sensor Array,	Python Programming Language
Water Pollutions Quality Monitoring [47]	Sensors (PH, pH, Digital Thermometer, Turbidity, CO2), Radio Frequency (RF) Module and FPGA Board	Python Programming Language
water quality monitoring in real time [49]	Arduino, pH Sensor, conductive sensor,	Mongo DB, Arduino IDE, Python
Drinking Water Quality Monitoring [20]	Arduino, Ph Sensor, GSM	Python, Arduino IDE Software
Checking the Quality of Drinking Water [19]	Raspberry Pi, Sensors of temperature, pH, turbidity, conductivity	Python, Cloud Computing features.

Malche et al. [51] Proposed a system that tracks real air quality and sound noise environments in the area and facilitated safe network data transmission, resolving the IoT system's security issues. The method proposed would also research the temperature and humidity levels to find ways to minimize them. The researchers used many tools for this study including sensors of Sound, Temperature & Humidity sensor, cloud server, gas sensor, microcontroller board, Raspberry pi 3. Moreover, the approach proposed is very versatile and expandable. Many more sensor nodes to enhance its functionality can be easily added.

Tiwari et al. [7] Developed a framework and implemented for IoT monitoring of environmental parameters. The IoT with The Raspberry Pi Embedded System has been developed, compressed, and cost-efficient to track environmental parameters such as intensity, light intensity, humidity, methane gas concentration, and temperature. The results achieved help follow environmental conditions in real-time. By interfacing with Raspberry Pi based embedded device, environmental parameters such as humidity, light intensity, methane gas, and temperature were monitored via commercial sensors. The sensor information is digitalized and stored in RPi memory board via an analog to digital Converter, then sent to the Thing Speak platform. Furthermore, with the Python Flask library's aid, local Web servers are built on the RPi platform.

Jaladi et al. [32] A wireless network sensor system for the environmental monitoring of the base station with Raspberry Pi, XBee for networking protocol, sensor node for combination sensor, controller, or Zigbee has been developed. The sensor sensors sensor data from the sensor on the network of WLAN sensors collect final tags, send data to the coordinator and router, and provide multi-client services, including displaying and storing data at base stations and sending stored information to the cloud. The customer can access it from a distance. Sensors of this type are all temperature, vibration, stress, humidity, light, and pollution.

Wu et al. [52] Presented an environmental Internet of Things (IoT) low-power wearable sensor node, creating an XBee-based wireless sensor network (WSN). The wearable sensor node monitors environmental data and then transmits them via WSN to a remote cloud server. A Web-based application displays the data on a cloud server to registered users. The experimental results demonstrate that the presented wearable sensor network interface can accurately control the conditions of the environment.

Nikhila [53] They have developed A web-based monitoring system for different environmental parameters, such as light intensity, carbon monoxide (CO) emission, temperature, moisture, and terrain. Arduino Uno and Raspberry Pi server are used to implementing the framework. Different sensors such as LDR, MQ7, DHT11, and Accelerometer Sensors are used. The calculated ambient parameters are loaded along with the date and time marks on a website. These can be seen anywhere from a computer such as a laptop or a smartphone powered by the internet. IDE and python are used to write the software code.

Ayele and Mehta [15] Proposed a prediction and monitoring system of air pollution based on IoT. This device may measure air pollution in a given region, analyze air quality, and predict air quality. The proposed framework would concentrate on air pollutant control with the IoT combination with a machine learning algorithm, namely the LSTM.

Gupta et al. [54] Suggested and developed an IoT-based Smart Cities air quality monitoring system. Effective air quality data are accessed and analyzed via smart appliances to determine the impact on urban residents. The intelligent equipment measures atmospheric temperature, humidity, carbon monoxide, LPG, smoke, and other toxic particulate matter, such as PM2,5 and PM10. The collected data can be accessed globally through an Android app.

Thu et al. [55] presented an intelligent air quality monitoring device with a compact, low-cost sensor, and long-range communication protocol. The sensors accumulate four parameters, temperature, moisture, dust, and carbon dioxide. The proposed end-to-end scheme in Yangon, Myanmar's commercial capital, was built and implemented in a case study in June 2018. The device allows users to connect to a dashboard in real-time to track status.

Farhan Mohd Pu'ad et al. [56] The Raspberry Pi was used to create a system for measuring air quality. The proposed method was built with a Raspberry Pi3, two Arduino Nanos, three gas sensors, and a GPS module. An LCD screen and a web server were used to display system information such as API, air condition based on API, current position's latitude and longitude, temperature, and humidity. The experimental validation showed a 3.23 percent error between the proposed system and nearby CAQMs (Continuous air quality monitoring stations).

Sai et al. [16] deals with air quality measurement with the MQ135 sensor and the Carbon Monoxide CO with the MQ7 sensor. In this study the authors implemented a framework using IoT channels such as Thing Speak or Cayenne to raise consciousness among all individuals about the environmental damage we are causing.

Kiruthika and mamakeswari, 2017 [57] An IoT-based system is proposed to tackle air pollution, which is particularly problematic in densely populated countries. An embedded system links several sensors that gather information about their surroundings. A prediction algorithm is proposed based on the collected data to apply a solution to any problem that may occur proactively. Thing Speak open data IoT platform with data analytics is used to test the obtained findings. The low cost of the proposed system is a significant advantage. This model can be easily set up and applied in any area to monitor and control the quality of its environment due to its scalability, dynamicity, and versatility.

Table 3. Monitoring of Smart Water Pollution (MSWP)

The Purpose of the study	Method and Device Used	Software and Programming Used
Air Pollution Monitoring [50]	Raspberry Pi, Arduino, ZigBee, Sensing Unit (MQ7, MQ2, CH4, MQ135, MG811, MQ216	Python, PuTTy Software, Adafruit IO
Monitoring the air from harmful gases [51]	Raspberry Pi, CO2 Sensor, Smoke and Ozone Sensors, Temperature and Humidity Sensors	IoT Cloud Server, Python, MongoDB, Apache, NodeJS
Environment Monitoring [7]	Raspberry Pi, Methane Sensor, Humidity Sensor, Temperature Sensor, Light Intensity Sensor.	IoT platform ThingSpeak, Python
Air Pollution Monitoring [32]	Raspberry Pi, Arduino, ZigBee, sensors (Humidity, Pressure, Moisture, and pollution), WSN.	Python, Android Studio
Environment Condition Monitoring [52]	CO2 Sensor, Light Sensor, XBee Module, WSN,	Python, MySQL Database.
Various environment parameter monitoring [53]	Sensors Unit, Arduino, Raspberry Pi,	Python, PHP , HTML
Air Pollution Monitoring [15]	DHT11(Humidity and Temperature) Sensor, MQ135(Gas) Sensor, Microcontroller.	Python, ThingSpeak
Air pollution Monitoring [54]	Raspberry Pi, MQ-2 Sensor, DHT11 Sensor,	Android Studio, ThingSpeak, Python
Air Quality Monitoring [55]	Arduino, Telaire, CO2 Sensor, Dust Sensor, temperature & humidity sensors. LoRaWAN gateway	Python, ARIMA,
Air Quality Measurement [56]	Raspberry Pi, Gas sensors, Arduino Nano	Python, PHP, CSS, HTML
Air Monitoring System [16]	MQ7 and MQ135 sensors, Arduino, WIFI Module	IoT platform ThingSpeak, Anaconda
Air Pollution Monitoring [57]	WIFI Module, Raspberry PI, Sensor Nodes (Temperature & Humidity), MQ5 Gas Sensor	MYSQL database, ThingSpeak, Python

8. DISCUSSION AND ANALYSIS

SEM systems, including air quality evaluation, water pollution, and agricultural monitoring systems and subsidiary implementations of the three major studies, were investigated in this survey. The contributions included a broad range of SEM approaches, including air quality assessments, for various purposes [7,15,16,42-49]; water pollution control methods [18-20,34-

41]; and smart agriculture monitoring systems [17,25-33].

SEM research has many goals, the most important of which are SAM, MSWP, and SAQM. The research of water pollution, air quality, soil humidity, and humidity would help design safe environment systems for long-standing economic growth and smart agriculture.

The methods used for each purpose are categorized based on the sensory data used, machine learning methods used, IoT devices used, and sensor types involved. The current study focused on the impact of previous research on water quality management, air quality assessment, SEM applications, and intelligent agriculture systems.

Our review study noticed that the researchers use Raspberry, Arduino, machine learning algorithms, and sensors based on environmental monitoring such as humidity, temperature, Moisture, gas detection, etc. Python programming language in most SEM methods. Sensory data differ in most SEM applications, and there is no robust data that can be used in an infinite number of ways. The types of data and areas of focus for different research projects are not the same. The methods have been used for classification or prediction; for example, water can be classified as polluted or clean, and water and air quality can also be predicted (e.g., level of degradation).

9. CONCLUSION

Rapid industrialization, urbanization, and population growth are causing environmental concerns. In order to reduce these environmental issues and provide a better environment, it is necessary to constantly monitor the environment. In recent years, people have become more aware of the environment they live in. This awareness has prompted the development of a reliable system of environmental monitoring. In this paper, we reviewed IoT-based applications in smart environment-related fields and provided a comprehensive and critical review of research studies on various environmental monitoring systems used for different purposes. We have concentrated primarily on quality of water monitoring, air quality monitoring, and smart agricultural monitoring systems that can manage environmental issues. Finally, we observed and explained how advances in sensor technology, Internet of Things, and machine learning algorithms have transformed environmental monitoring into a truly smart environment monitoring system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Astill J, Dara RA, Fraser EDG, Roberts B, Sharif S. Smart poultry management: Smart sensors, big data, and the internet of things. Comput. Electron. Agric., vol. 2020;170:105291.
DOI: 10.1016/j.compag.2020.105291.
2. Vinod Kumar TM. Smart Environment for Smart Cities. In Smart Environment for Smart Cities. TM Vinod Kumar Ed. Singapore:Springer Singapore. 2020;1–53.
3. Islam M. Development of Smart Healthcare Monitoring System in IoT Environment. 2020;11.
4. Kishorebabu V, Sravanthi R. Real Time Monitoring of Environmental Parameters Using IOT. Wirel. Pers. Commun. 2020;112(2):785–808.
DOI: 10.1007/s11277-020-07074-y.
5. Singh AK, Raj M, Sharma V. Architecture, Issues and Challenges in Monitoring based on IoT for Smarter Environment," in 2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC), Erode, India. 2020;142–146.
DOI: 10.1109/ICCMC48092.2020.ICCMC-00029.
6. Choudhary V, The JH, Beltran V, Lim HB. AirQ: A Smart IoT Platform for Air Quality Monitoring," in 2020 IEEE 17th Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, NV, USA. 2020;1–2.
DOI: 10.1109/CCNC46108.2020.9045550.
7. Tiwari A, Sadistap S, Mahajan SK. Development of Environment Monitoring System Using Internet of Things. In Ambient Communications and Computer Systems. GM Perez, S Tiwari, MC Trivedi, and KK Mishra, Eds. Singapore: Springer Singapore, 2018;696:403–412.
8. Nižetić S, Šolić P, López-de-Ipiña D, González-de-Artaza, Patrono L. Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future. J. Clean. Prod. 2020; 274:122877.

DOI: 10.1016/j.jclepro.2020.122877.
9. Stoyanova M,Nikoloudakis Y, Panagiotakis S, Pallis E, Markakis EK. A Survey on the Internet of Things (IoT) Forensics: Challenges, Approaches and Open Issues; 38.
10. Khanna A. Internet of Things (IoT), applications and challenges: A comprehensive review. Internet Things; 76.
11. Ramson SRJ, Vishnu S, Shanmugam M. Applications of Internet of Things (IoT) – An overview. In 2020 5th International Conference on Devices, Circuits and Systems (ICDCS), Coimbatore, India.2020; 92–95.
DOI: 10.1109/ICDCS48716.2020.243556.
12. Hajjaji Y, Boulila W, Farah IR, Romdhani I, Hussain A. Big data and IoT-based applications in smart environments: A systematic review. Comput. Sci. Rev. 2021;17.
13. Singh AK, Raj M, Sharma V. Architecture, Issues and Challenges in Monitoring based on IoT for Smarter Environment. In 2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC), Erode, India. 2020;142–146.
DOI: 10.1109/ICCMC48092.2020.ICCMC-00029.
14. Otanasap N, Chalermsuk C, Bungkom-khun P. A Survey of IoT: Advances in Smart and Dynamic Environmental Monitoring. 2019;11.
15. Ayele TW, MehtaR. Air pollution monitoring and prediction using IoT," in 2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT), Coimbatore. 2018; 1741–1745.
DOI: 10.1109/ICICCT.2018.8473272.
16. Sai KBK, Ramasubbareddy S, Luhach AK. IOT Based Air Quality Monitoring System Using Mq135 and Mq7 with Machine Learning Analysis. 2019;8.
17. Kumar S, Chowdhary G, Udutalapally V, Das D, Mohanty SP. Gcrop: Internet-of-Leaf-Things (IoLT) for Monitoring of the Growth of Crops in Smart Agriculture. In 2019 IEEE International Symposium on Smart Electronic Systems (iSES) (Formerly iNiS), Rourkela, India. 2019;53–56.
DOI: 10.1109/iSES47678.2019.00024.
18. Li Y, Wang X, Zhao Z, Han S, Liu Z. Lagoon water quality monitoring based on digital image analysis and machine learning estimators. Water Res. 2020;172:115471.
DOI: 10.1016/j.watres.2020.115471.
19. Rabiya Basri Syed, santhi priya N. Water Quality Monitoring Using IOT. International Journal of Innovative Science and Research Technology (IJISRT). 2017;2(7): 189-193.
www.ijisrt.com
ISSN - 2456-2165,
20. Moparthi DNR. Water Quality Monitoring System Using IOT. 2018;5.
21. Khan WA, et al. Smart IoT Communication: Circuits and Systems. In 2020 International Conference on COMmunication Systems & NETworkS (COMSNETS), Bengaluru, India. 2020;699–701.
DOI:10.1109/COMSNETS48256.2020.9027430.
22. Yanes AR, Martinez P, Ahmad R. Towards automated aquaponics: A review on monitoring, IoT, and smart systems. J. Clean. Prod. 2020;263:121571.
DOI: 10.1016/j.jclepro.2020.121571.
23. Akhter F, Khadivizand S, Lodyga J, Siddiquei HR, Alahi EE. Design and Development of an IoT enabled Pedestrian Counting and Environmental Monitoring System for a Smart City. 2021;6.
24. What is Environmental Monitoring?. Definition and FAQs | OmniSci. https://www.omnisci.com/technical-glossary/environmental-monitoring
25. Razali MAA, Kassim M, Sulaiman NA, Saaidin S. A ThingSpeak IoT on Real Time Room Condition Monitoring System. In 2020 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS), Shah Alam, Selangor, Malaysia. 2020;206–211.
DOI:10.1109/I2CACIS49202.2020.9140127.
26. Iswanto, Megantoro P, Pramudita BA. IoT-based weather station with python user interface for measurement technique of educational purpose. Surakarta, Indonesia. 2020;020027.
DOI: 10.1063/5.0030365.
27. Vaidya B, Patel A, Panchal A, Mehta R, Mehta K, Vaghasiya P. Smart home automation with a unique door monitoring system for old age people using Python, Open CV, Android and Raspberry pi. In 2017 International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai. 2017;82–86.\
DOI: 10.1109/ICCONS.2017.8250582.

28. Design and Development of Gunung Lang Temperature and Humidity Monitoring System using LoRa Technology. Adv. J. Tech. Vocat. Educ. 2018;2(3).
29. Rane M, Patil A, Barse B. Real Object Detection Using Tensor Flow. In ICCCE. A. Kumar and S. Mozar, Eds. Singapore: Springer Singapore; 2020.2019;570:39–45.
30. Mamandipoor B, Majd M, Sheikhalishahi S, Modena C, Osmani V. Monitoring and detecting faults in wastewater treatment plants using deep learning. Environ. Monit. Assess. 2020;192(2):148. DOI: 10.1007/s10661-020-8064-1.
31. Zhang H, Li G, Li Y. A Home Environment Monitoring Design on Arduino. In 2018 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS), Xiamen, China. 2018;53–56. DOI: 10.1109/ICITBS.2018.00021.
32. Jaladi AR, Khithani K, Pawar P, Malvi K, Sahoo G. Environmental Monitoring Using Wireless Sensor Networks(WSN) based on IOT. 2017;04(01):8.
33. Anusha k Ak, UB Dr. U B Mahadeva-swamy. Automatic IoT Based Plant Monitoring and Watering System using Raspberry Pi," Int. J. Eng. Manuf. 2018;8(6):55–67. DOI: 10.5815/ijem.2018.06.05.
34. Vaishali S, Suraj S, Vignesh G, Dhivya S, Udhayakumar S. Mobile integrated smart irrigation management and monitoring system using IOT. In 2017 International Conference on Communication and Signal Processing (ICCSP), Chennai. 2017;2164–2167. DOI: 10.1109/ICCSP.2017.8286792.
35. Nawandar NK, Satpute VR. IoT based low cost and intelligent module for smart irrigation system. Comput. Electron. Agric. 2019;162:979–990. DOI: 10.1016/j.compag.2019.05.027.
36. Aneesa James, Saji A, Athira Nair, Joseph D. Crop Sense– A Smart Agricultural System using IoT; 2019. DOI: 10.5281/ZENODO.3566563.
37. Thorat A, Kumari S, Valakunde ND. An IoT based smart solution for leaf disease detection. In 2017 International Conference on Big Data, IoT and Data Science (BID), Pune, India. 2017;193–198. DOI: 10.1109/BID.2017.8336597.
38. Prathibha SR, Hongal A, Jyothi MP. IOT Based Monitoring System in Smart Agriculture. In 2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT), Bangalore, India. 2017;81–84. DOI: 10.1109/ICRAECT.2017.52.
39. Vineela MT, NagaHarini J, Kiranmai C, Harshitha G, AdiLakshmi B. IoT Based Agriculture Monitoring and Smart Irrigation System Using Raspberry Pi. 2018;05(01):4.
40. Pathak A, AmazUddin M, Abedin Md J, Andersson K, Mustafa R, Hossain MS. IoT based Smart System to Support Agricultural Parameters: A Case Study," Procedia Comput. Sci. 2019;155:648–653. DOI: 10.1016/j.procs.2019.08.092.
41. Rao RN, Sridhar B. NIoT based smart crop-field monitoring and automation irrigation system. In 2018 2nd International Conference on Inventive Systems and Control (ICISC), Coimbatore. 2018;478–483. DOI: 10.1109/ICISC.2018.8399118.
42. Liu P, Wang J, Sangaiah A, Xie Y, Yin X. Analysis and Prediction of Water Quality Using LSTM Deep Neural Networks in IoT Environment. Sustainability. 2019;11(7): 2058. DOI: 10.3390/su11072058.
43. Preetham K, Mallikarjun BC, Umesha K, Mahesh FM, Neethan S. Aquaculture monitoring and control system: An IoT based approach. International Journal of Advance Research, Ideas and Innovations in Technology. 2019;5(2).
44. Jha BK. Cloud-Based Smart Water Quality Monitoring System using IoT Sensors and Machine Learning. Int. J. Adv. Trends Comput. Sci. Eng. 2020;9(3)3403–3409. DOI: 10.30534/ijatcse/2020/141932020.
45. Budiarti RPN, Tjahjono A, Hariadi M, Purnomo MH. Development of IoT for Automated Water Quality Monitoring System. In 2019 International Conference on Computer Science, Information Technology, and Electrical Engineering (ICOMITEE), Jember, Indonesia. 2019;211–216. DOI: 10.1109/ICOMITEE.2019.8920900.
46. Konde S,DeosarkarDSB. IOT Based Water Quality Monitoring System. 2020;11.
47. Myint CZ, Gopal L, Aung YL. Reconfigur-able smart water quality monitoring system in IoT environment. In 2017 IEEE/ACIS 16th International Conference on Computer and Information Science (ICIS), Wuhan. 2017;435–440. DOI: 10.1109/ICIS.2017.7960032.

48. Khatri P, Gupta KK, Gupta RK. Raspberry Pi-based smart sensing platform for drinking-water quality monitoring system: A Python framework approach. Drink. Water Eng. Sci. 2019;12(1):31–37. DOI: 10.5194/dwes-12-31-2019.
49. Pokhrel S, Pant A, Gautam R, Kshatri DB. Water Quality Monitoring System Using IOT. 2020;3(1):10.
50. Sriyanka, Patil SR. Smart Environmental Monitoring through Internet of Things (IoT) using Raspberry Pi 3. In 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), Mysore, India. 2017;595–600. DOI: 10.1109/CTCEEC.2017.8455056.
51. Malche T, Maheshwary P, Kumar R. Environmental Monitoring System for Smart City Based on Secure Internet of Things (IoT) Architecture. Wirel. Pers. Commun. 2019;107(4):2143–2172. DOI: 10.1007/s11277-019-06376-0.
52. Wu F, Rüdiger C, Redouté J-M, Rasit Yuce M. A Wearable Multi-sensor IoT Network System for Environmental Monitoring. In Advances in Body Area Networks I, G. Fortino and Z. Wang, Eds. Cham: Springer International Publishing. 2019;29–38.
53. Nikhila J. Web based Environmental Monitoring System using Raspberry Pi. In 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), Mysore. 2017;1074–1080. DOI: 10.1109/CTCEEC.2017.8454964.
54. Gupta H, Bhardwaj D, Agrawal H, Tikkiwal VA, Kumar A. An IoT Based Air Pollution Monitoring System for Smart Cities. In 2019 IEEE International Conference on Sustainable Energy Technologies (ICSET), Bhubaneswar, India. 2019;173–177. DOI: 10.1109/ICSETS.2019.8744949.
55. Thu MY, Htun W, Aung YL, Shwe PEE, Tun NM. Smart Air Quality Monitoring System with LoRa WAN. In 2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS), Bali. 2018;10–15. DOI: 10.1109/IOTAIS.2018.8600904.
56. Pu'ad, Muhamad Farhan Mohd, Teddy Surya Gunawan, Mira Kartiwi, Zuriati Janin. Development of Air Quality Measurement System using Raspberry Pi. In 2018 IEEE 5th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA). 2018;1-4.
57. Kiruthika R, mamakeswari A. Low cost pollution control and air quality monitoring system using Raspberry Pi for Internet of Things. 2017;8.

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