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Research article

Advancement of Environmental Monitoring System Using IoT and Sensor: A Comprehensive Analysis

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Abstract: The emergence of the Internet of Things (IoT) has brought a revolution in global communication network technology. It has acquired many day-to-day applications in healthcare, education, agriculture, etc. In addition, IoT has also had a significant impact in the field of environmental monitoring.The significant factors in a healthy environment are air quality, water pollution, and waste management, where the world's population can live securely. Monitoring is necessary for us to achieve global sustainability. As monitoring technology has advanced in recent years, environmental monitoring systems have evolved from essential remote monitoring to an advanced environment monitoring (AEM) system, incorporating Internet of Things (IoT) technology and sophisticated sensor modules.The present manuscript aims to accomplish a critical review of noteworthy contributions and research studies about environmental monitoring systems, which involve monitoring air quality, water quality, and waste management.The rapid growth of the world's population and the exhaustion of natural resources, coupled with the increasing unpredictability of environmental conditions, lead to significant concerns about worldwide food security, global warming, water pollution, and waste overflowing. Automating tasks in the building environment, based on the Internet of Things (IoT) application, is meant to eliminate problems with the traditional approach. This study aims to examine and evaluate numerous studies involving monitoring air, water, waste, and overall environmental pollution, as well as their effect on the environment. This article categorizes studies based on their research purposes, techniques, and findings. This paper examines advanced environmental monitoring systems through sensor technology, IoT, and machine learning.

Keywords: IoT; environmental monitoring; air pollution; water pollution; waste management; machine learning

1. Introduction

There are several factors contribute to the sustainable growth of the entire world, including education, agriculture, industry and more. However, one of the most crucial factors is the environment. Health and hygiene are key components of a healthy environment, which leads to sustainable societies. Therefore, it is imperative that health and hygiene is monitored to ensure that the citizens of any nation can lead a healthy life. The environment is a vital component of human health, and proper planning, management and response to all types of disasters can significantly contribute to the well-being of human society.Environment monitoring (EM) techniques have been refined by the use of advanced environmental monitoring (AEM) methods, which allow more precise monitoring of factors impacting the environment.Wireless sensor networks (WSNs), which use modern sensors and artificial intelligence (AI) to monitor and control the environment, are becoming increasingly popular.The Internet of Things (IoT) is the communications network of everyday objects containing sensors, actuators and connectivity to external devices. It enables remote monitoring and control of physical objects at a distance and in real time.As a result of the presence of Internet of Things, artificial intelligence and wireless sensors, modern methods of monitoring the environment are known as advanced environmental monitoring (AEM) systems. "Internet of Things" (IoT) refers to a concept in which machines and other physical objects are connected to the Internet [1]. IoT allows them to exchange data, communicate with each other, and gather information from external sources [2]. The International Data Corporation estimates that by 2026, there will be more than a $61 billion market for connected devices, including industrial machines, vehicles, and homes on the Internet. To transform our society and industry, Internet of Things (IoT) is a new paradigm that has recently becoming a key consideration in a variety of markets [3]. Various devices equipped with sensing, identification, processing, communication, and actuation capabilities can seamlessly be integrated [4]. The long-term health of the global economy depends on several factors, including economic development, quality education, agricultural production, and other areas. However, it is essential to remember that environmental conditions also play a role in determining sustainable growth [5].

1.1. Applications of IoT

The Internet of Things has the potential to improve many aspects of life, including security, transportation, and health care. Public sector organizations are using IoT to track things like lost pets, monitor home security systems, or keep tabs on appliance maintenance schedules [6].

The Internet of Things (IoT) can be used by consumers to reserve a table at a restaurant, monitor their progress during exercise or look up coupons. Organizations can use the Internet of Things (IoT) to monitor supply chains and track customers' spending habits, collect customer and employee feedback, monitor and maintain inventory levels, and engage in predictive maintenance of their machines and devices shown in Figure 1.

1.1.1 IoT in agriculture

In-depth sensor readings from an Internet of Things (IoT) device can be used to monitor and manage micro-climate conditions in indoor & outdoor plantings, increasing yields. This prevents wasting a precious resource by watering only when needed.

1.1.2. Smart healthcare

Hospitals can monitor their patients' health in their homes with IoT devices. Doing so can reduce the time patients spend in hospitals while providing real-time information that could save lives. In addition to monitoring beds and equipment, intelligent beds can be used for monitoring [7].

1.1.3. Smart home

Home monitoring systems for elderly care provide more comfort for elderly patients. In addition to real-time home monitoring and determining if a patient has fallen ill or suffered from a heart attack, these devices can also detect whether patient is experiencing an oxygen shortage.

1.1.4. Smart insurance applications

The Internet of Things will have a profound impact on the insurance industry. Insurance companies can offer discounts to customers who wear fitness trackers such as Fitbit. By encouraging healthier habits and customized policies, insurers can benefit everyone involved—insurers, customers, and even themselves.

1.1.5. Environmental monitoring

An environmental monitoring system monitors the environment's quality using several parameters, including relative humidity, temperature, dew point, and frost point. Rotronic offers solutions for these parameters and differential pressure, pressure, and flow. It also monitors CO_2 levels.

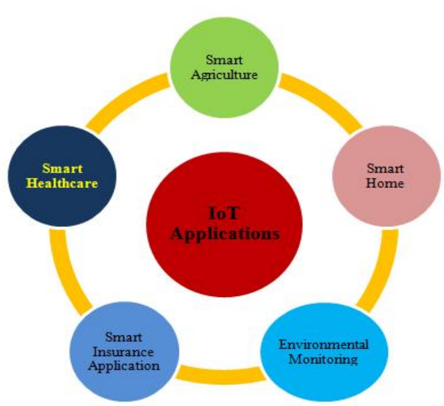

Figure 1. Applications of IoT.

1.2. IoT layered architecture

The four-layered IoT architecture of IoT in Figure 2 is as follows.

1.2.1. Perception layer

The perception layer is the physical layer of the Internet of Things (IoT), which uses sensors to gather information about the environment. The Sensing layer includes sensors and actuators that collect data from the environment and emit transmission over the network respectively. The network layer connects to other intelligent objects to exchange data [8].

1.2.2. Network layer

Internet/network gateways, data acquisition systems (DASs), and sensor networks are present in this layer. DAS performs essential gateway functions such as data aggregation and conversion (collecting data from sensors and then converting it to digital format). Advanced gateways can also open up connections between sensor networks and the Internet, allowing them to communicate with each other. The network layer connects to other smart things, devices, and servers. It also handles data transmission and processing.

1.2.3. Preprocessing layer

It is important to perform preprocessing on sensor data. This removes unnecessary data from the sensor data using filtering, processing, and analytics. Temporary storage provides functionalities such as replication, distribution, and storage. Finally, security performs encryption and ensures data integrity as well as privacy.

1.2.4. Application layer

The business layer manages the entire IoT system, including applications, business models, and privacy concerns.

The application layer is the interface between the IoT device and the network with which it needs to communicate. It manages data formatting and presentation and, is responsible for ensuring hand-offs that occur when moving data from one network to another.

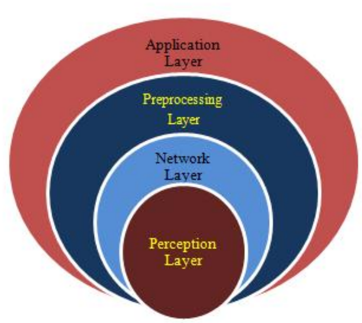

Figure 2. IoT 4-Layered Architecture.

1.3. Characteristics of IoT

1) It is scalable and efficient.

2) Devices that are turned off when not in use typically consumes less electricity. When not in use, they should be set to sleep automatically.

3) Communication between devices may be intermittent in that a device connected to another device at one instant may no longer be connected in another instant.

4) The lack of physical objects using IP to connect supports the IoT's development.

5) As the Internet evolves, existing IP addressing will become obsolete.

1.4. Challenges in IoT

1) In order to be effective, privacy context awareness must recognize an object’s context effectively.

2) A digital device must be integrated with the physical environment as a result of the processor.

3) Every application running in an IoT environment must have identification at every layer of the protocol stack.

4) In the IoT environment, as devices are continuously being added, communication patterns must be established among them and strict security measures must be integrated into the environment.

5) Sensors are used to collect and aggregate data in an IoT environment. A set of rules governs the authentication and authorization of these sensors for sharing information.

6) IoT security implementation should keep in mind that every entity on IoT has a limited and more specifically short lifespan.

7) Humans and IoT elements must be able to trust each other. Besides ensuring the trustworthiness of IoT machines, human privacy must also be protected.

IoT sensors help to generate renewable energy, such as solar power, increase energy efficiency, thereby reducing the greenhouse gases that cause global warming by measuring carbon consumption, as well as measuring waste [9].

The health and hygiene of a population are essential to its sustainability and progress, which is why monitoring the environment, is so crucial. Environmental monitoring is an effective way to ensure the safety of a community by controlling different kinds of pollution and addressing the challenges that become apparent due to detrimental situations [10–12]. Environmental monitoring studies environmental conditions and changes, including contamination of water, dangerous radiation, smogginess, and different cloud activities. Environmental management aims at the discourse provocations so the environment can be secure for a good community and planet. Pollution sources include artificial and natural causes [13,14]. The advancement of science and technology in recent years, especially robotics and intelligent retrieval, has enabled environmental monitoring systems to observe the constituent influence of the environment more keenly than ever before. Smart communities use noncable networks to monitor vehicular pollution levels [15–17]. Arya et al. explored the use of Unmanned Aerial Vehicles (UAVs) to implement a network for Industry 5.0 applications along with the advantages and the disadvantages of Smart City implementations [18]. JinyuanXu et al. detailed a summary of agricultural IoT. Existing problems and future trends were reported in relation to agrarian IoT [19]. J. Canning et al. have implemented a system that monitors environmental conditions using smartphones and plant sensors [20]. Air quality monitoring is essential to ensure that early precautionary measures can be taken, which may be done via the Smart Environmental Monitoring system with the Internet of Things (IoT). This is a cost-effective and efficient way to control air pollution and curb climate change [21,22].

A framework is implemented as an embedded system using sensors connected to an Arduino microcontroller. It can be used to monitor and control aquatic environmental parameters [23]. Vu KhanhQuy et al. present a survey of IoT solutions. They discuss how IoT can be integrated into the intelligent agriculture sector by evaluating its architecture, applications, and research timeline [24]. LPWAN-based battlefield applications require context-aware environmental monitoring [25]. Jarrod Trevathan et al. present an IoT light attenuation sensor design and explore the calibration process needed to determine the sensor's range and accuracy [26]. There are many challenges to using agricultural IoT technology, including limited network coverage, the need to fund new monitoring projects, the costs of transmitting data over long distances, and the concern that batteries to operate sensors will not last all day. In a simulation study by Mo Dong et al., the authors used ns-3 to model an IoT sensor network for long-range wide-area monitoring in a farm setting. They found that the long-range Lora WAN protocol can maintain a good transmission [27].

Wireless sensor networks (WSNs) are made up of detectors that performs on AI based monitoring & controlling methods. IoT devices are working in WSNs for constructive waste management, vehicle marking, temperature control, and pollution control [28,29]. Therefore, fresh approaches of environmental monitoring are known as SEM systems due to their use of intelligent system and sensory technology.

The main objective of the Smart Environment Monitoring (SEM) project is to discourse the provocation due to unacceptable effects on the environment through intelligent monitoring so that all primary indicators of growth, including a healthy society, are assorted. Various applications of this technology are proposed for multiple purposes, aiming to serve particular occasions, which may comprise weather reports, acid precipitation control, contaminated water control & monitoring, and crop damage assessment. A cloud-based system that connects IoT devices and various suitable sensors is one example of an intelligent environment system. This system can monitor water quality, air quality, waste management, and control. Such systems can be shown in Figure 3, which depicts contaminated water, Pollution of air, waste management (waste collection and disposal), and its control. The organization involved in such monitoring gets to the cloud through accumulation from various sensors connected to it via the internet. The existing literature on SEM methods does not contain many surveys or reviews. A poll published in a peer-reviewed journal on quick-witted agricultural systems [30,31], intelligent home technologies [32,33], innovative health monitoring systems [34,35], an Internet of Things (IoT)-based ecological system [36,37], an IoT-enabled marine environment monitoring system [38], and a survey on pollution monitoring system design and implementation details [39] are just a few of the articles highlighting different aspects of SEM sensor networks.

It is difficult to find surveys or reviews on this topic in the existing literature, so we conducted a critical study of AEM techniques. Many factors affect the environment, including water pollution, waste management, and industrial air pollution. Diffraction & noise pollution are also severe problems. This review will examine the most common methods used to mitigate these challenges. From this, we have been motivated to write an extensive study about Sensor and SEM systems, which includes beneficial components harming the environment, such as IoT and sensory technologies. The rest of the paper is structured as follows: Section 2 explains the different environmental monitoring systems, followed by a summary table. Discussion, analysis, and recommendation have been summarized in section 3. Finally, section 4 presents the conclusion & Future scope.

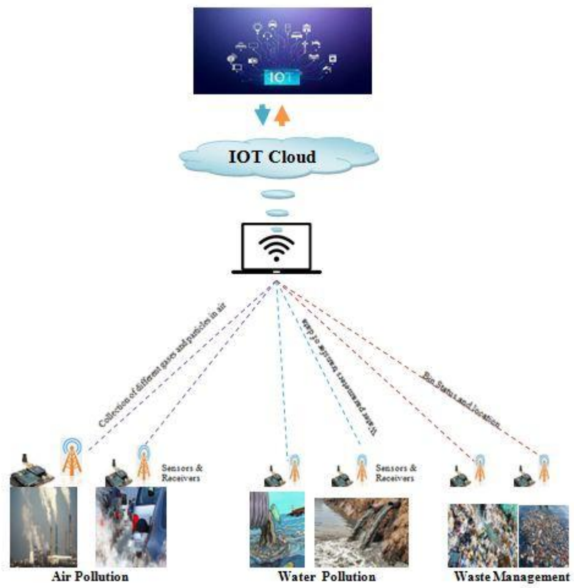

Figure 3. Advanced Environmental Monitoring System (AEMs).

2. Related Work

Many experts have researched innovative environment monitoring systems. Intelligent air monitoring systems are being used to study the effects of pollution on health. Water pollution monitoring systems are being utilized to determine whether a community's water supply is contaminated with too much or too little salt or other contaminants [40]. Waste management systems are being developed for use in cities where waste must be disposed of in a way that does not damage natural resources such as soil or water quality [41]. The authors have attempted to critically report significant findings and limitations of the current research on intelligent environmental monitoring.

Environmental monitoring is essential for sound management of natural resources, safeguarding human health, and enhancing the social, economic, and cultural well-being of communities in Figure 4.

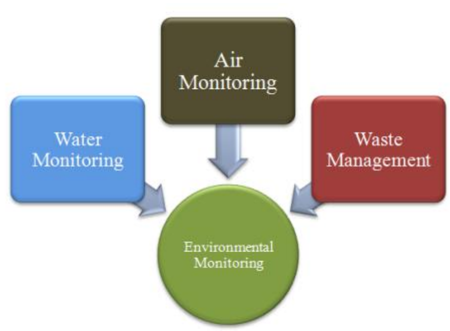

Figure 4. Smartly Environmental Monitoring.

Earlier, there has been no such review regarding the literature on the Internet of Things (IoT) and sensor technologies for AEM.

Few difficulties, including the quality of air within our surroundings, water, and waste management, have been found in our literature survey. Major advanced sensor technologies have been used to review the challenges in AEM.

This study gave scientists, policymakers, and researchers' insight into implementing and monitoring effective solutions for the environment that faces challenges mainly due to bad air quality, water pollution, and waste management. This section has also studied intelligent waste management because these factors affect water contamination, soil erosion, and air contamination, which is the backbone of any conceived and evolving economy [42,43]. Effective waste management is the reuse of waste products and resources to reduce the creation of new waste while reducing the effects on the environment [44].

In this Table 1, we can see the different techniques used for designing intelligent waste management using the Internet of things.

Table 1. Summary of different Smart Waste Management (SWM) systems.

Authors & Year	Title	Techniques used	Findings
Feri Teja Kusuma etal. (2019) [45]	IoT: intelligent garbage monitoring using android and real-time database	Ultrasonic sensor and GSM Module	➢Real time database is used for garbage collection. ➢Doesn't need servers. ➢Monitoring the garbage ➢All officers will receive the exact location notification.
Dominic Abuga, N.S Raghav(2021) [46]	Ingenious SW management	Net logo, Ultrasonic sensor, and GSM Module	➢Incorporates an innovative, real-time garbage bin mechanism to help keep cities clean. ➢Cannot find the precise location of the nodes of wms.
S.R. Jino Ramson, Vishnu S. etal. (2021) [47]	A Wireless Monitoring of trash bin level using IoT	TBLMU	➢ The real-time remote monitoring system alerts the garbage level in the trash bins. ➢ In the future system can analyze the geolocation coordinates of almost filled and partially filled bins to create an optimized truck route will be our future work.
A. Alfred Kirubaraj etal. (2022) [48]	IoT based Trash Bin Monitoring System using Lora WAN	IR sensor & RF module	➢ The developed method works efficiently to measure the filling levels of the solid waste garbage bins. ➢ In the future, deep learning methods can be used to find the geolocation coordinates of bins to create an optimized truck route.
NorfadzliaMohd. Yusof etal. (2018) [49]	Real-time monitoring system for waste bin smartly.	WSN	The proposed system is an efficient and cost-effective waste collection management system.

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Authors & Year	Title	Techniques used	Findings
Javier Caridad et al. (2018) [50]	Waste Collection System smartly with Lora WAN Nodes & Optimization of routes	Lora WAN	➢ Proposed system based on monitoring of waste and management platform used in rural environments. ➢ To evaluate the efficiency and the viability of the system's implementation, a case study was done in the region of Salamanca.
Michael Reiner Kamm etal. (2020)[51]	Intelligent Waste Collection Processes	IoT	➢ Implemented smart devices in glass containers, measuring filling levels over several months. ➢ The proposed framework is based on the re-engineered collection of waste processes.
Kai Dean Kang et al. (2020) [52]	E waste collection systems usingIoT: household E waste management in Malaysia	IoT & Sensors	➢ The proposed work shows the application of intelligent collection systems in the Malaysian e-waste management and recycling sector. ➢ To record the disposal data, e-waste level measurement sensors are fitted. ➢ Improving the household waste E- collection system in Malaysia is beneficial.
Shivani. B et al. (2022) [53]	Smart City Waste Management system using IoT	NodeMCU	➢ The proposed work eliminates the waste overflow. ➢ The use of a mobile application notifies the user of the proper time of disposal bin.
Djavan De et al. (2018) [54]	Implementation, design, and evaluation of an Internet of Things network system for restaurant food waste management	RFID	➢ An Internet of Things (IoT)-based system has been developed and applied in the city of Suzhou, China, to improve RFW collection management. ➢ One con is that RFID tags are expensive and cannot be reprogrammed quickly.
SaharIdwan et al. (2020) [55]	Solid Waste inSmart Cities using Internet ofThings	RFID	➢ They are using a system of Internet of Things technology to determine the schedule and routes of waste trucks. ➢ RFID tags are costly.
Eyhab Al-Masri et al. (2018) [56]	Recycle.io: An IoT-Enabled Framework for Urban Waste Management	Azure Cloud, Ultrasonic sensor	➢ The author uses artificial intelligence and image processing to design a system that can fully sort and separate trash, save travel time, and optimizes collection routes. ➢ The possibility of disconnecting the Internet has remained uncertain.
Yu huei et al. (2018) [57]	Smart IoT System for Waste Management	RFID, Wifi Module	➢ The new smart bin will include several new features, including detecting the amount and smell of garbage. ➢ An infrared sensor is highly recommended in place of an ultrasonic sensor to detect waste.

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Authors & Year	Title	Techniques used	Findings
Patric Marques et al. (2019) [58]	Smart cities infrastructure architecture applied to a WM scenariousing IoT	Cloud, Bluetooth, RFID	➢ The proposed approach is based on smart cities. ➢ Smart bin with separated waste. ➢ To send & receive information IoT Cloud is used. ➢ Raspberry Pi's cost is low. ➢ Consumption of power is low.
M. Thürer et al. (2019) [59]	Kanban system for collection of solid waste using IOT	Cloud, RFID, GPS, water spider	➢ Proposed system is based on the collection of solid waste smartly. ➢ GPS is used to locate the bin remotely. ➢ To send & receive information IoT Cloud is used. ➢ Collection of waste for solid waste only.
DebajyotiMisra et al. (2018) [60]	WM System monitored by cloud using IoT	GSM, Cloud	➢ ICT-Enabled Smart Waste Management Systems (SWMSs) can help illuminate the problems and challenges of integrating technologies into an existing waste-disposal system. ➢ This paper aims to show how ICT can be integrated with the SWM. It does not include a description of other ICT technologies such as the Internet of Things (IoT) and Blockchain.
K Pardini et al. (2019) [61]	A survey on SWM solutions using IoT	IoT	➢ This paper analyzes existing literature on the Internet of Things (IoT)-infrastructure-based waste and sanitation management in urban environments. ➢ An IoT-based reference model is presented, as well as described a comparison study of several IoT devices and their application.
Elsai et al. (2021) [62]	A GIS-based MCDM of Harar’s municipal solid waste landfill in Ethiopia.	GIS	➢ Urban areas typically select sites for landfills and recycling centers in areas lacking enough land& require high level of infrastructure.
Ajay Singh et al. (2019) [63]	Municipal waste management using GIS &Remote sensing.	GIS & RS	➢ The proposed approach uses GIS and Rs methods to describe the effective landfill site selection.
Hoang L Vu et al. (2020) [64]	Composition of residential Waste with collection truck with using GIS optimization of route	GIS	➢ An intelligent system for collecting household trash. Requiring high-skilled personnel to implement the system.
Anjali V. Tarone et al (2018) [65]	Smart Garbage Monitoring System Using IOT	ESP8266 & GPS	➢ This study estimates the time, distance, and travel time required to collect a particular amount of waste.
N Ferronato et al. (2020) [66]	The municipal solid waste management system of Bolivia uses GIS	GIS	➢ To select a disposal site, manual and computerized analyses must be integrated.

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Authors & Year	Title	Techniques used	Findings
Patrick Okot et al. (2019) [67]	Urban solid waste disposal using GIS of Gulu Municipality	GIS	➢ Implementing GIS for waste collection can help municipal decision-makers find the optimal waste collection route.
Do Hyun Kim et al. (2020) [68]	Descriptive & Predictive analysis of data using GIS for efficient management of waste	GPS & GIS	➢ Improving routes for waste collection requires the integration of GPS and GIS to create a real-time map of the route's optimum path.
Abinet et al. (2020) [69]	Disposal of Solid Waste Site Selection Using GIS of Markos Town, Ethiopia	GPS	➢ Study on disposal of solid waste. ➢ Limiting the analysis to one year of data may have concealed seasonal dissimilarities in the data.
Louati Amal et al. (2020) [70]	Study on a collection of municipal solid waste using GIS	GIS& GPS	➢ The system can communicate the specific activities of drivers. However, real-time communication is not addressed.
Ahmad Mussa et al. (2021) [71]	Disposal of solid waste in Logia town using GIS	RS & GIS	➢ Landfills should be located away from water bodies to avoid contamination. ➢ Using GIS & RS Infrastructure cost is high.
Sumayya et al. (2018) [72]	Management of Solid Waste of Karachi using GPS and GIS	GIS & GPS	➢ Evaluating the possible website for disposal of waste secluded from the watercourse bodies. Time is an overwhelming and high price for timeperiod implementation.
Sneha et al. (2020) [73]	Urban area disposal of solid waste using Remote sensing & GIS	Remote Sensing	➢ Identify, evaluate and quantify methane emissions. Operating costs increase.
Najaf et al. (2018) [74]	Smart Garbage collection system using Arduino and Ultrasonic sensor	Ultrasonic Sensor	➢ Using an ultrasonic sensor to know the bin status and overcome overflowing waste bins. ➢ Power Consumption is more while using GSM.
Minhaz et al. (2020) [75]	IoT-based intelligent garbage management system for Urban	Atmega 328P	➢ To ensure environmental hygiene and sustainability in urban areas, the proposed integrated system consists of an identification system, an automatic lid system, a display system, and a communication system.
Ramson et al. (2021)[76]	Bin level monitoring system forsolid waste management using IoT	Ultrasonic sensor	➢ This paper presents a self-powered, simple connect, and Internet of things (IoT) solution to monitor the unfilled level of trash bins from a central monitoring platform. The IoT-based monitoring platform.
Ayaz Hussain et al. (2020) [77]	Management of waste and Air Pollutants prediction Using Machine Learning &IoT	Moisture & Ultrasonic Sensor	➢ To manage the garbage disposal & forecast the pollutants of air present in the surrounding bin environment smart bin using machine learning & Deep learning is proposed.

2.1. Research based on Smart Monitoring of Water Pollution (SMWP) system

Due to the rapid increase in globalization and overutilization of land and sea assets, drinking water quality is worsening. Moreover, many waterworks serving increasing citizens suffer from shortages since many rivers, lakes, and aquifers are drying up because of global climate change. To confront these severe threats, intelligent water management systems are in great urge to ensure vigorous control of the quality and quantity of drinking water. Since a water monitoring system allows real-time water quality control and appropriate management resources in urban areas, it is essential in our daily lives. Table 2 presents significant contributions of the MWP system.

Table 2. Summary of different Smart Monitoring of Water Pollution (SMWP) systems.

Authors & Year	Title	Techniques Used	Findings
Sunghwa Han et al. (2020) [78]	Monitoring of Lagoon water quality using Image analysis & Machine learning	Machine Learning	Remote sensing is used to control the agricultural pollution of water. Image analysis & machine learning is used for the Prediction of water pollution level in Lagoon water.
Qi Chen et al. (2018) [85]	Water contamination monitoring system using IoT	Fast Fourier Transform (FFT), SVM	➢ Assessment of water contamination level using Machine learning.
Nikhil M Ragi et al. (2019) [80]	Water Quality prediction using ML techniques.	ANN	➢ Prediction for alkalinity, chloride, sulphate values using neural network. ➢ The accuracy is 87.23% using the Levenberg Marquardt algorithm.
MochamadHariadi et al (2019) [81]	Water Monitoring in Surabaya using Big Data	Big Data, SVM	➢ Analysis & classification of water contamination using machine learning. ➢ The accuracy is 91.38% using a support vector machine.
Razib Hayat Khan et al. (2020) [86]	Surface water observation system using IoT sensors for Bangladesh population	IoT Sensors	➢ Assessment of surface water quality using IoT sensors for Bangladesh population.
Ina Nasto et al. (2022) [87]	Monitoring water quality smartly in Vlora	WSN	➢ Monitoring of water quality smartly using the wireless sensor. ➢ The proposed system is a low-cost, lightweight system, and power consumption is very low.
Nasro Min Allah et al. (2019) [88]	Water quality monitoring smartly using IoT for domestic applications.	WSN	➢ Monitoring of water quality like pH, Turbidity, temperature & ORP values.

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Authors & Year	Title	Techniques Used	Findings
SanagalaSrinijia et al (2018) [89]	Monitoring system for water quality using IoT	WSN	➢ Proposed system based on the tank filling & cleans of the tank. ➢ The system has less effort than the Smartphone user interface.
Suhas Kulkarni et al. (2020) [90]	Monitoring of tank water system smartly using IoT	RFID	➢ The framework is real-time tank water level monitoring. ➢ Using IoT environments, the system cost is low, real-time, user-friendly, etc.
Sathish Pasika et al. (2020) [91]	water quality monitoring using IoT	WSN	➢ The proposed system is a cost-efficient system. ➢ The monitoring system is for Hyderabad city to determine the pH, Turbidity, and water level.
Satyam Srivastava et al (2018) [92]	Analysis of water quality using smartphone	Bayesian Algorithm	➢ An inexpensive, battery-operated, phone-controlled device with embedded sensors is suggested to monitor and record water conditions at remote sites.
Arif UI Alam et al. (2021) [93]	Multi-parameter low water monitoring system	WSN	➢ The findings demonstrate that the sensor was susceptible and variably capable of measuring temperatures between 0 and 50 °C.
Manish Ku. Jha et al. (2018)[94]	Water quality and usage monitoring smartly	WSN	➢ This project aims to develop a device that will enable consumers to measure their water consumption and, in turn, conserve water.
He Sui et al. (2020) [95]	Water monitoring application using NB-IoT Protocol	NB Protocol	➢ This paper proposes a new method for monitoring water quality using NB-IOT protocol communication. The prototype system shows that it can meet the needs of Bolong Lake.
Saravanan et al. [151]	IoT based water quality monitoring in SCADA	GSM Module	In real-time and with good accuracy, the device measured selected parameters in drinking water (including color).
George et al. [152]	Lake water quality monitoring using IoT	Forel–Ule color scale	An innovative low-cost method is presented in the study, utilizing satellite data to validate water quality products and assist decision-makers.
Wu et al. [153]	For water quality detection using MEMS	Sensor network	With an orthogonal three-wire structure, the Pt thermistor responds to the temperature at 5.95 °C.
Schima et al. [154]	Service-oriented turbidity and dissolved organic matter monitoring with optical sensors	Sensor system	In situ sensors showed very high agreement with laboratory photometers, but with less methodological effort.

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Authors & Year	Title	Techniques Used	Findings
Cui et al. [155]	Water Quality Monitoring System Using nRF24L01 Wireless Communication	Sensor system	A commercial residual chlorine sensor was used (free chlorine and monochloramine) and was able to communicate online.
Alam et al. [156]	Gold thin film electrodes are used in a reusable, reagent-free chlorine sensor	Sensor system	Like commercial sensors, the sensor sensitivity was very high.

Remotely sensed images have been used in literature to develop machine learning methods in conjunction with IoT and wireless sensors to predict pollution levels in lagoon waters. This allows for the pollutants to be monitored in real-time and that information to be used for agriculture [78]. Researchers used machine learning to predict the quality of water and determine whether it is clean or polluted, but achieving acceptable results proved challenging. The paper offered a real-time contamination monitoring approach based on sensors that estimated temperature, water discharge, and other parameters. However, the data collared were limited to a single area only. Dissolved Solids Analysis (DSA) is used to assess a variety of water pollutants in single and mixed water samples [79]. The paper is based on artificial intelligence and water quality parameters predictions using neural networks [80]. Results showed that alkalinity and chloride were predicted more accurately than the sulphate content in most cases. Extensive data examination and cases in the sort of water contamination have been examined using a Support Vector Machine (SVM) to classify water contamination [81]. C. Sunil et al. proposed a system monitoring framework using sensor interfacing devices such as the Raspberry Pi [82]. Industrial pollution can threaten the health of an entire population, and IoT technology can help address the problem by quickly detecting and quantifying the level of contamination [83]. The Philippines experiences flooding, and water level rise regularly. Modern flood monitoring and forecasting systems are essential to increase people's awareness in real-time [84] effectively. An inexpensive system called Supervisory Control and Data Acquisition (SCADA) was proposed for monitoring water quality parameters remotely (using a GSM module) [151]. Forel-Ule color scale stickers and a mobile app, TurbAqua, were developed to measure watercolor and clarity using Mini Secchi Disks [152]. Integrated a platinum (Pt) sensor for temperature measurement into a micro-electro-mechanical system (MEMS) [153]. Created an open-source optical system for real-time turbidity monitoring using infrared detectors [154]. A microcontroller system with wireless communication was developed to measure water quality parameters[155].As with commercial sensors, the sensor showed high sensitivity and accuracy [156].

2.2. Research-based on the Smart Monitoring of Air Pollutants (SMAP) System

SMAP techniques and systems have also been studied in this paper. An overview of different SMAP strategies used in other literature on monitoring air quality systems is mentioned in Table 3.

Various sensors and machine learning are used to distinguish air quality. Monitoring and characterization of water quality were achieved in this work. However, interoperability issues were reported due to the use of various sensors [96]. A system capable of evaluating air quality using fixed and mobile nodes of sensors was executed, with the capability to verify the standard in both stationary and portable ways. Compatible sensors were utilized as mobile nodes, operating in a moving environment [97]. Data captured by intelligent sensor nodes were operated and examined using machine learning methods. A new air quality control procedure was developed with the help of the Internet of Things (IoT) and machine learning techniques, allowing air pollution assessment by deploying gas sensors [98]. Sensory systems have been deployed in the vehicle to monitor air quality, using machine learning, mobile sensor nodes, and wireless sensor networks [99]. The air quality is assessed by considering the presence of several components, some of which are particulate matter (PM) 2.5 and ozone concentrations. Using an extreme machine learning technique, a model was created to predict PM2.5 concentrations from Spatio-temporal data arranged over a specific schedule over a range of distances covered by sensors [100]. A review of forecasting models suggested for urban air quality was conducted, including the use of ozone, sulphur dioxide, and nitrogen dioxide. There was a differentiation between the available models and the models used in this work. Air quality control mechanisms have been implemented using RFID and gas sensor mechanisms in [101], where it was demonstrated that RFID could be used to detect and communicate with nodes from a wireless sensor network (WSN); these devices were connected across WSN architecture. SMAP [102] has been designed to measure atmospheric gases, pollutants, and temperature. This system was tested by [103,104] using technology, and the results were beneficial for detecting humidity, carbon dioxide, and temperature.

In [105], an indigenous air quality system was presented to detect CO_2, NO, temperature and humidity. This system used artificial intelligence and machine learning techniques to develop expert systems for air quality assessment. Furthermore, PM10, PM2.5, SO_2, NO, & O_3 were detected. Using machine learning methods trained by Spatio-temporal data in [106], PM10 components were also detected—this was extended using deep learning for detection and detailed analysis of O_3 members only. Another work employed heterogeneous sensors [107]. SVM was used to analyze the data captured through heterogeneous sensors and estimated air quality. The main contribution of this study in [112, 113]is to present the connection between the COVID-19 pandemic, public health, and indoor air quality while addressing the importance of real-time monitoring systems for public health and wellness. Edge and cloud computing will make the Internet of Things (IoT) rapid, light, and more reliable [114,115]. Internet of Things (IoT) and cloud-edge computing are two distinct disciplines that have evolved separately [116,117]. However, they are increasingly becoming interdependent and will likely have a significant effect on the future [118,119]. The design of a compound of cloud and edge computing architectures and the implementation of IoT can be crucial [120,121]. The growing populations of the world are closely associated with rising levels of air pollution [122,123]. This can harm people's health, not only in outdoor areas but also inside buildings [124]. The Environmental Protection Agency (EPA) reports that the air inside a building is measurably more polluted than that outside. Most people spend 80 to 90 percent of their time indoors; therefore, indoor air has a more significant direct impact on human health than outdoor air [126–132]. Indoor air quality is the condition of the indoor environment, including buildings and other public facilities that may affect mental and respiratory health [133–139]. The COVID-19 outbreak has sparked public interest in indoor air quality monitoring, which was not a focus area for public facilities such as shopping complexes, hospitals, banks, restaurants, educational institutes, and so forth before the outbreak [140–144]. The atmospheric conditions of the Earth are becoming increasingly polluted each year due to the growth of civilization and increasing emissions from industries and automobiles [145–149]. However, the air is an indispensable resource for life. Many people are indifferent to the severity of air pollution or have not recognized its effects [150].

Table 3. Summary of different Smart Monitoring of Air Pollution (SMAP) Systems.

Authors & Year	Title	Techniques Used	Findings
Laurent Dupont et al. (2019)[97]	Air Quality Monitoring and data-driven modeling	WSN	➢ Research on sensor network-based air quality monitoring. ➢ Using decision tree & neural network, humidity and noise influence the prediction model.
Timothy M. Amado et al. (2018)[96]	Monitoring of Air Quality	ML	➢ Research on monitoring of air quality using heterogeneous sensors and Prediction using machine learning. ➢ Accuracy of 98.67%, 97.78%, 98.67%, 94.22%, and 99.56% by using five predictive models.
Chetan Shetty et al. (2020)[98]	Air pollution model using ML & IoT	ML	➢ To build real-time predictive models for carbon monoxide emission. ➢ The system checks the sensory value with the threshold value. If the value is higher than the threshold value, it automatically notifies the owner.
Man Sing Wong et al. (2018) [108]	Application & Development of an Improved Integrated EM System	Infrared Sensor & ML	➢ Research-based on the detection of an organic compound using Infrared sensor and machine learning techniques ➢ Detection of volatile organic compounds in the air.
Temeseganayele et al (2018) [101]	Prediction & Monitoring of air pollution using IoT	RFID, IoT	➢ The proposed system is based on monitoring and predicting the air pollutants in a particular area using IoT & Machine learning i.e., the LSTM model.
Min Ye Thu et al. (2018) [102]	Monitoring of air quality smartly.	ML	➢ Designed a low-cost and long-range air quality monitoring system. ➢ Real-time monitoring of air for Myanmar and a prediction model using machine learning.
Paul D. Rosero-Montalvo et al (2018) [105]	Intelligent monitoring of air quality using machine learning	ML	➢ To choose the contaminated sectors in a geographical location, K means classification is used. ➢ Intelligent monitoring quality of air using machine learning techniques.

Continued on next page

Authors & Year	Title	Techniques Used	Findings
Abu Buker Siddique et al (2022) [109]	A secure & Intelligent air monitoring using Blockchain and neural network	Blockchain & NN	➢ Design and implement a low-cost indoor air quality monitoring system. ➢ Neural networks and Blockchain are used to make predictions about whether the air is polluted or not. ➢ In the future, this system can extend to infant care, indoor pet health monitoring, and patient care.
Patricia Arroyo et al (2021)[110]	A LC based Air Quality System	Linear regression and NN	➢ This paper describes the construction of a portable device for measuring outdoor air quality. ➢ The data were calibrated using linear regression and neural network techniques. ➢ The results of both the gaseous pollutant and PM sensors have been quite good, with correlations above 0.95 being achieved.
Ivan Popovic et al. (2021) [111]	Identification of the effects of neighboring PV systems on urban environments	Cross Correlation	➢ This paper uses a novel method for identifying degrading effects on neighboring photovoltaic systems.
JunHo Jo et al. (2020) [125]	Monitoring of Indoor Air Quality using IoT	IoT & Cloud Computing	➢ This paper describes a system "Smart-Air" and a web server. ➢ Implemented at Hanyang University of Korea successfully to demonstrate its feasibility.

3. Discussion, analysis, and recommendation

Analysis and recommendations based on an extensive literature review are discussed in this section on the available automated environment monitoring systems, including the following: Air quality assessment, contaminated water monitoring, and waste management. The contributions focus on several Automated Environment Monitoring methods for air-quality assessment, contaminated water monitoring, and waste management. The systems were also evaluated based on the techniques used. The following are the significant discussion points to consider:

1) This research contain various grounds mainly on SMAP, SMWP, and SWM can lead to a good design of an intelligent environment system which in future might also help the economy's growth through a safe and clean environment.

2) A few types of sensors are used along with sensory data, machine learning approaches, and IoT appliances. The current study mainly focuses on the influence of existing studies on contaminated water monitoring, the application of SEM, air quality assessment, and intelligent waste management systems.

3) Many researchers in most SEM methods currently use SMAP, SMWP, and SWM CNN-based deep learning methods.

4) In most applications, the sensory data vary. The regions of interest and data type don't match for different research work.

5) Classification or Prediction can be made using these methods like water is distinguish as polluted or clean water, just like how air quality can be predicted.

There are no common challenges found in the above studies reported. Also, the purposes and techniques differ a lot from each other. Here, the few challenges observed are as follows:

1) Data from heterogeneous sensors must be transformed and analyzed to ensure the interoperability of that data.

2) Noisy data can be a problem for statistical analysis. One common type of noise, sensor noise, can occur when measurements are fed into a system by a sensor.

3) The machine learning methods predominantly work training the data and classification are SVM & Neural networks.

4) Fuzzy set theory-based and deep learning techniques solve a few analysis problems. However, there are limitations associated with the big data involved or the high computational complexity.

5) No robust machine-learning model exists to address the challenges of environmental monitoring and control.

Quantitative & qualitative research has been carried out in Environmental Monitoring using IoT & Machine learning and IoT & WSN. Table 4 shows a summary of this research using the above methods.

Trends in the scholarly literature have been assessed through a search of the Scopus database during a thirteen-year examination period (2010–2022). Extrapolations using these publication statistics were conducted to predict trends in SEM technology that may be useful for engineers and manufacturers of SEM systems.

An interesting finding is that analysis using advanced machine-learning methods lags behind research that does not use machine learning.

Table 4. Measure of research contribution using IoT & ML and IoT & WSN.

Year	Study using IoT & Machine Learning	Study Using IoT & WSN
2010-2011	0	03
2012-2013	0	09
2014-2015	3	24
2016-2017	8	47
2018-2019	47	97
2020-2021	117	82
2022	47	27

Figure 5 shows the research trends in two main categories: SEM using IoT & ML techniques and IoT & WSN techniques. The trend line suggests that the SEM has yet to be implemented and studied widely on machine learning or other approaches for training and subsequent classification or Prediction. As reported, however, there has been an increase in research each year, but more impact of IoT and Machine Learning in recent years can be seen in Figure 5.

The discussion and analysis above allow us to identify strategies for improving environmental monitoring methods and tools. More powerful, robust, and innovative ways would benefit everyone. The above discussion and analysis lead us to recommend the following:

1) There should be a framework for machine learning that needs to develop.

2) Irrespective of the purposes of using the SEM, a robust set of classification, forecasting models & Predictions should be designed to operate any data.

3) Because most of the research has failed using de-noising data & their pre-processing, suitable de-noising methods must be implemented.

4) To deal with big data issues involved in a few significant studies, data deduplication approaches and methods are needed.

5) Government-level involvement from global and local perspectives is required for developing any nation and city. As Smart Environment plays a crucial role in achieving sustainable goals, the rural areas are kept behind most of the time, so it is challenging to set up the necessary infrastructure for IoT, WSN, and other sensors.

6) When it comes to implementing sensors, ensure the data from them is compatible with all acquisition and analysis systems to avoid interoperability issues.

A number of review articles were reviewed in an attempt to include major observations of some significant reviews on SEM. However, it was found to be very difficult to report any such extensive review on the SEM in particular. The need to study the most critical contributions to research addressing environmental challenges due to main factors motivated us to explore this topic. This literature review helped us reach some conclusions and make recommendations for designing a robust SEM system.

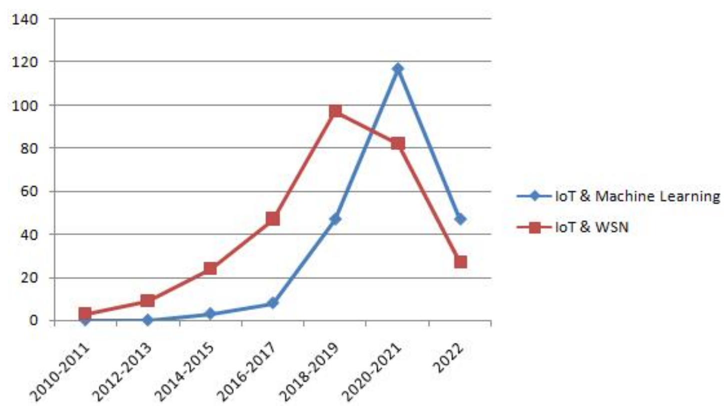

Figure 5. Trends of SEM Methods.

4. Conclusion and future scope

In this paper, the author extensively reviews research studies on various environmental monitoring systems used for different purposes. The analysis and discussion of the review suggest vital recommendations for improving these systems. Research on deep learning, handling big data, and using consistent classification approaches has led to a realization of the need for extensive research in these areas. We have focused on water, air quality monitoring and intelligent waste management systems that can deal with environmental challenges. The significant challenges in implementing smart sensors, artificial intelligence (AI), and wireless sensor networks (WSNs) need to be addressed for sustainable growth through Smart Environmental Monitoring (SEM). Participation by environmental organizations, regulatory bodies, and general awareness would strengthen SEM efforts. Pre-processing techniques can be used to improve the quality of sensory data. These techniques include filtering and signal processing, which makes the data more suitable for tasks associated with SEM. The future scope of the work aims to study other environmental factors such as flexible sensing, energy harvesting sensing, marine pollution, sound pollution, etc.

Conflict of interest

The authors declare no conflict of interest.

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