iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IX **Month of publication:** September 2025

DOI: https://doi.org/10.22214/ijraset.2025.74165

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IX Sep 2025- Available at www.ijraset.com

IOT Based: Air Quality Monitoring System

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Abstract: Airpollutionhasemergedasacriticalglobalconcern,posing seriousthreatsto humanhealth, climate stability and ecological balance. Conventional air quality monitoring stations are often expensive, stationary, andlimitedincoverage, restricting theirabilitytoprovidereal-timelocalizeddata.Toaddressthis challenge, this study presents the design and development of an Internet of Things (IoT)-based Air Quality Monitoring System utilizing low-cost sensors and wireless communication. The proposed system employs the MQ135 sensor to detect harmful gases, such as carbon dioxide, ammonia, and nitrogen oxides, whereas the DHT11 sensor is used to monitor ambient temperature and humidity levels. The collected data were processed usingan ESP8266microcontroller,whichenabledreal-timewirelesstransmissionandvisualizationonanLCD display through an I2C interface. The modular design ensures portability, scalability, and energy efficiency, making it suitable for smart-city applications. The experimental results demonstrate the feasibility of the proposedsystemindeliveringaccurate andtimely airquality dataatasignificantly reducedcostcomparedwith traditional monitoring infrastructure. This study contributes to the advancement of low-cost environmentalmonitoringsolutions,enablingimprovedpublicawarenessanddata-drivendecision-makingforpollution control.

Keywords: IoT,AirQualityMonitoring,ESP8266,MQ135,DHT11,Real-timeMonitoring,SmartCities

I. INTRODUCTION

Airqualityhasbecomeamatter ofincreasingconcern duetorapidurbanization,industrialization,andvehicular emissions, which have collectively contributed to elevated levels of atmospheric pollutants. According to the World Health Organization (WHO), more than 90% of the world's population is exposed to air qualitylevels that exceed safe thresholds, leading to respiratory illnesses, cardiovascular problems, and reduced life expectancy.Conventionalairmonitoringsystems,whileaccurate,areoftenlarge-scale,high-costinstallations maintained by government agencies, and therefore cannot provide fine-grained, real-time data for specific localities.

The emergence of the Internet of Things (IoT) offers promising opportunities to overcome these limitations by enabling distributed, low-cost, andreal-timemonitoringsolutions. IoTfacilitates theinterconnection ofsensors, microcontrollers, and cloud platforms, therebyenhancing the accessibilityand accuracy of environmental data. Thisresearch focuses on developingan **IoT-**basedAirQualityMonitoring Systemthat integrates MQ135 gas sensorsfor pollutantdetection,DHT11sensorsfor atmosphericparameters, andanESP8266microcontrollerfor processing and communication.An LCD module with I2C converter provides local visualization of readings, while theWi-Fi capabilityoftheESP8266ensures wireless data transmission for potential integration with web dashboards or mobile applications.

Theproposedsystem aimstoprovidea cost-effective, portable,andscalablesolutiontomonitorairpollutionat both microandmacrolevels. Byimplementingthis system, communities can benefit from real-timeawareness of environmental conditions, enabling proactive measures for pollution control and improved quality of life.

Furthermore,theresearch contributestothebroader visionofsmartcities, whereIoT-enabledtechnologies enhance sustainability, efficiency, and citizen well-being.

II. PROPOSED SYSTEM

Air pollution monitoringhas been an area of extensive research owing to its direct impact on human health, environmentalsustainability,andeconomicdevelopment.Traditionalairqualitymonitoringstationsdeployed by government agencies are highly reliable but suffer from limitations such ashigh installation costs, maintenance expenses, and limited coverage. These shortcomings have driven researchers toward the developmentoflow-cost,IoT-enabledmonitoringsystemscapableofdeliveringreal-timeandlocation-specific data.

Several studies have focused on leveraging low-cost sensors for monitoring gaseous pollutants. For instance, Pawar et al. (2019) proposed a low-cost air monitoring unit using the MQ series of gas sensors andArduino- based platforms.

Their system successfullydemonstrated real-time gasdetection but was limited bythe absence ofwirelesscommunication,whichrestricteddataaccessibility. Similarly, Kumar and Singh (2020)implemented anArduino-andGSM-basedmonitoringsystem for carbonmonoxideandparticulatematter,achievingreal-time alerts through SMS. However, GSM-based communication incurs higher operational costs than Wi-Fi-enabled alternatives.

The integration of the Internet of Things (IoT) into air quality monitoring has significantly enhanced system efficiency. Guptaetal.(2021)developedanIoTsystem usingESP8266andcloudintegrationforreal-timeair quality monitoring. Their work highlighted the advantages of wireless data transmission and remote accessibility but lacked additional environmental parameters, such as temperature and humidity, which are crucial for the contextualanalysis of pollution levels. In another study, Ali and Hussain (2022) utilized an ESP32andmultiplegas sensorstomonitor a widerangeofpollutants, demonstratinghigh scalability. However, theirimplementationrequiressignificanthardwarecomplexityandincreasessystem costs, whichmaylimittheir widespread adoption.

Recent advancementshaveincorporatedvisualizationandalertmechanisms.Sharma etal.(2022)demonstrated aweb-basedair qualitydashboardforreal-timemonitoring,enablingbetteruserinteraction.Althougheffective, the system requires continuous Internet connectivity, which maynot always be feasible in semi-urban or rural settings.

Fromthereviewedliterature,itisevidentthatalthoughsignificantprogresshasbeenmadeinIoT-basedair qualitymonitoring, existing systems oftenfacetrade-offsbetweencost,scalability,anddatacomprehensiveness.

Some models focus only on gas detection, whereas others emphasize connectivity without considering contextualparameters,suchastemperatureandhumidity. Moreover, portabilityandlowpower consumption remain underexplored.

This study addresses these gaps by designing a cost-effective, IoT-enabled air quality monitoring system that integratestheMQ135sensor forpollutantdetectionandtheDHT11sensor for environmentalparameters,along with an ESP8266 module for wireless data communication. The addition of an LCD with an I2C converter provides localized real-timevisualization, whereas thesystem's modular design ensures portabilityand energy efficiency.Thiscombination providesabalancedapproachthatbridgesthegapbetween cost,functionality,and scalability, therebycontributing to theadvancement of practical IoT solutions for environmental monitoring in the future.

III. KEY FEATURES OF AIR MONITORING SYSTEM

The proposed IoT-basedAir QualityMonitoringSystem offers several distinctive features thatmakeit a practical,low-cost, andscalablesolution for real-timeenvironmentalmonitoring.Thekeyfeaturesareas follows:

1) *Low-CostDesign*
- Thesystemutilizescost-effectivecomponentssuchastheMQ135gassensor,DHT11sensor,and ESP8266 microcontroller, ensuring affordability without compromising on functionality.
- Comparedtoconventionalmonitoringstations,thisdesign providesa budget-friendlyalternative suitable for community-level deployment.

2) *Real-TimeMonitoring*
- Thesystem continuouslymonitorsenvironmentalparameters,includingairquality(CO_2,NH_3, NOx, etc.), temperature, and humidity.
- Real-timevisualizationisachievedthroughtheLCDmodulewith I2Cinterface, whilewireless connectivity enables potential cloud-based extensions.

3) *WirelessCommunication*
- WiththeintegratedESP8266Wi-Fimodule,datacanbetransmittedseamlesslytoexternal platforms for storage, analysis, and remote access.
- ThisfeaturefacilitatesintegrationintoIoTecosystems andenablesscalabilityfor smartcity applications.

4) *CompactandPortable*
- Thehardwareis designedwith portabilityin mind,makingiteasytodeployacross multiple locations, both indoors and outdoors.
- Itscompactsizeallowsuseinhouseholds,offices,industrialsites,andpublicspaces.

5) *EnergyEfficiency*
- Themodulararchitectureofthesystemensuresminimalpower consumption,allowingoperation on limited energy resources.
- Thismakesthesolutionviableinregionswith energyconstraintsor wherecontinuouspower supply is unreliable.

6) ScalabilityandModularity

- Thesystem can beeasilyexpandedbyintegratingadditionalsensors(e.g.,particulatematter sensors, CO sensors) or connecting to cloud-based platforms.
- Themodulardesign ensuresadaptabilityfor futureupgradesandbroaderenvironmental monitoring.

7) User-FriendlyInterface

- TheLCDdisplaywithI2Cconverter providesclearanddirect visualization ofreadings,making the system easy to use for non-technical users.
- Datacanbefurther extendedtodashboardsormobileapplicationsfor enhancedaccessibility.

IV. METHODOLOGY

Thedevelopmentprocessconsistsoffour major stages:dataacquisition,dataprocessing,datatransmission, and data visualization.

1) DataAcquisition

- TheMQ135sensorisemployedtodetect variousgasessuchascarbon dioxide(CO_2),ammonia (NH_3), nitrogen oxides (NOx), benzene, and other volatile organic compounds.
- TheDHT11sensorisintegratedtomeasuretemperatureandhumidity, astheseenvironmental factors influence air quality measurements.
- Bothsensorsprovideanalog/digitaldatathatisfedintotheESP8266microcontrollerforprocessing.

2) DataProcessing

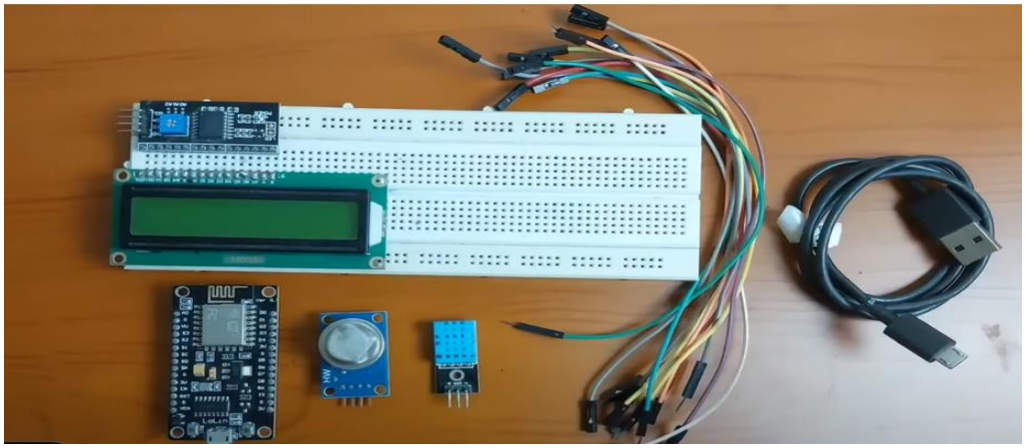
- TheESP8266microcontrolleractsasthecentralprocessingunit.
- Itreadstherawsensor valuesand convertsthemintomeaningful air qualityand environmental parameters using calibration equations and threshold levels.
- Conditionallogicisimplemented intheArduinoIDE environmentto classifytheair qualityindex (e.g., Good, Moderate, Poor, Hazardous).

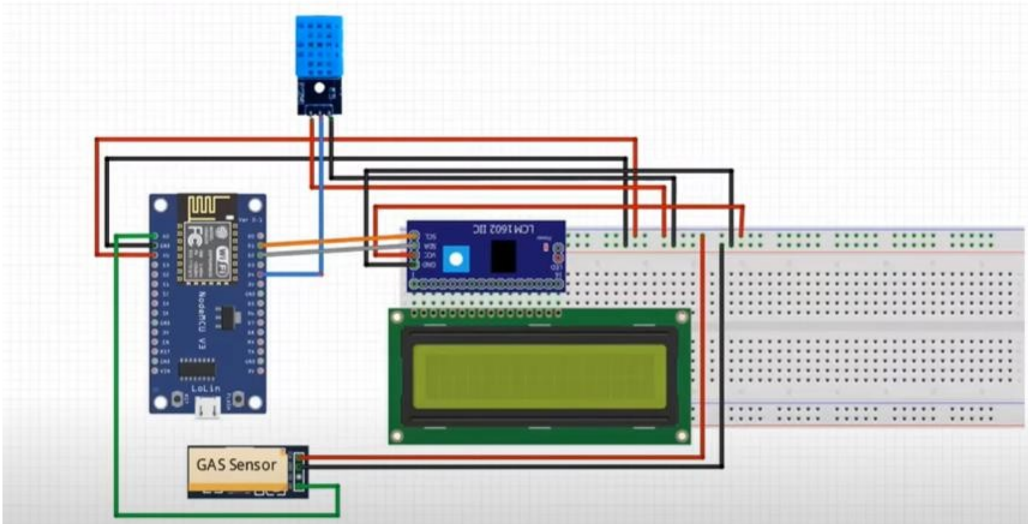
3) DataTransmission

- TheESP8266,withitsbuilt-inWi-Ficapability,enableswirelesscommunication.
- ProcessedsensordatacanbetransmittedtoanIoTcloudplatformforremotemonitoringandstorage.
- Thisallowsscalabilityandintegration with mobileor web-based dashboardsfor real-time visualization.

4) DataVisualization

- Locally, sensorreadingsaredisplayedon a16x2LCDwithanI2Cinterface, whichreducesthenumber of required pins and simplifies wiring.
- For remoteaccess, thesystem can beconfiguredtosenddataperiodicallytoa clouddatabaseor IoT platform, where the data is visualized in graphical form for analysis.





V. CONCLUSION

This paper presented an IoT-basedAir Quality Monitoring System using the ESP8266**,** MQ135, and DHT11 sensors with an LCD interface. The system effectively monitors airpollutants,temperature,andhumidityinrealtimewhileproviding bothlocalandwireless dataaccess. Its **lowcost,**portability, and scalability make it a practical alternative to traditional monitoring stations.
Theprojecthighlightsthepotentialof IoTinenvironmentalmonitoringandsmartcityapplications.
Futureenhancements mayincludeaddingparticulatematter sensors, mobiledashboards, and renewable energy integration to improve reliability and coverage.

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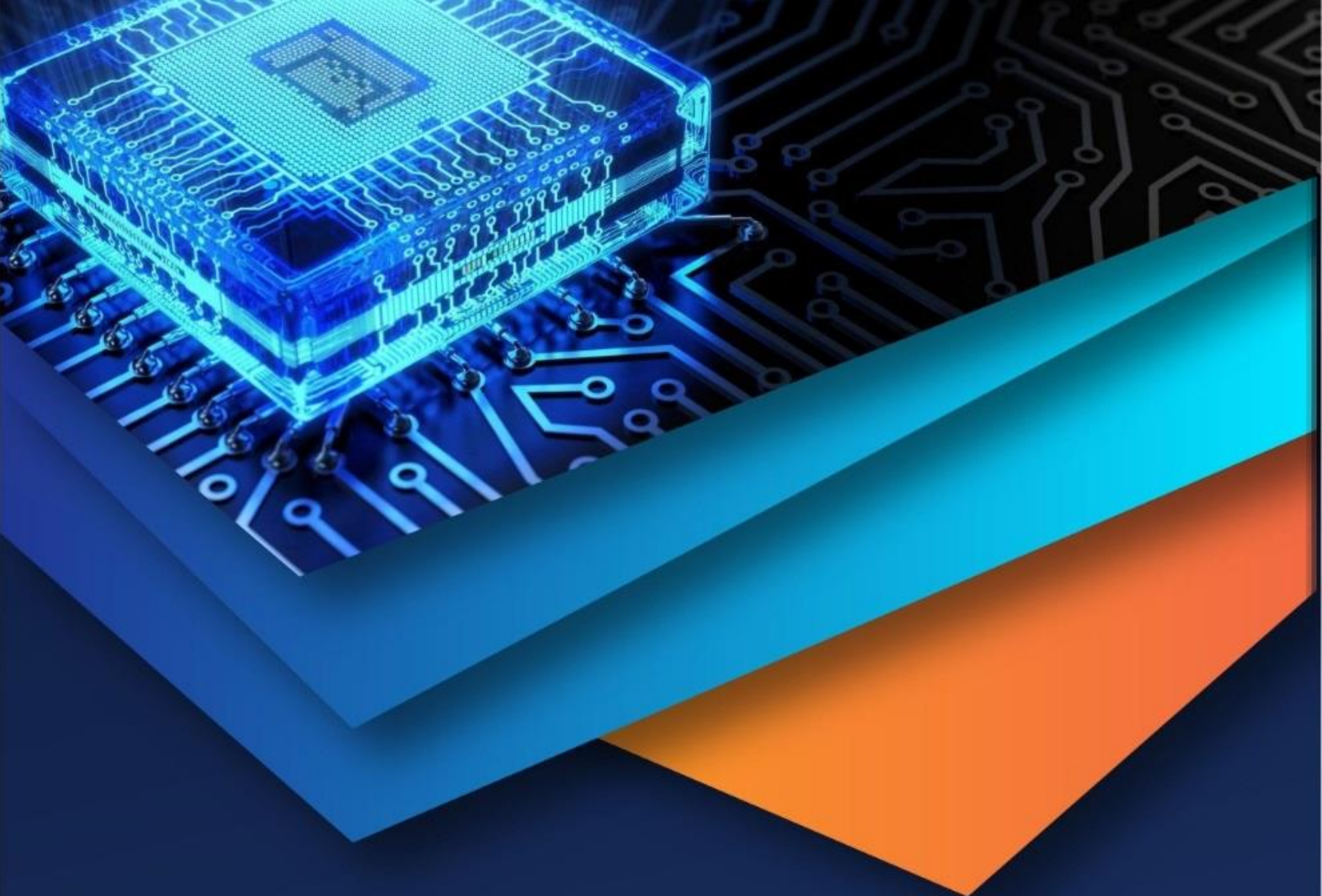

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