Air and water pollution sensing smart watch

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Abstract -

The rapid industrialization and urban expansion of the 21st century have significantly elevated levels of environmental pollution, posing a growing threat to public health and ecological sustainability. While traditional air and water quality monitoring infrastructures exist, they are typically stationary, cost-intensive, and inaccessible to the general population, particularly in under-resourced regions. This research introduces the design and development of an innovative, low-power, wearable device—a smart watch—engineered to provide real-time sensing and assessment of both air and water quality parameters. Compact in form yet powerful in function, the proposed device leverages a suite of low-cost environmental sensors integrated with an ESP32 microcontroller and an OLED display to deliver accessible, on-the-go pollution monitoring.

The smart watch employs an MQ135 gas sensor for air quality detection, primarily measuring levels of harmful gases such as CO_2, NH_3, benzene, and smoke particulates. Simultaneously, a turbidity sensor evaluates water clarity, identifying contamination by detecting suspended particulates and sediments. In addition, a DHT11 sensor measures ambient temperature to provide further context to environmental conditions. The acquired data is processed locally and visually rendered on a 128×64 OLED screen, allowing the user to instantly comprehend the air and water quality status in their immediate surroundings.

The real-time measurements are interpreted using predefined thresholds: air quality is classified as "Fresh" or "Poor" based on MQ135 analog readings, while water quality is categorized as "Clear" or "Dirty" depending on turbidity sensor output. The intuitive user interface ensures that users of all technical backgrounds can easily understand the environmental parameters being displayed. The system also logs data through the serial monitor for debugging and future expansion toward cloud integration or mobile-based interfaces.

The proposed system is cost-effective, energy-efficient, and scalable, making it highly suitable for deployment in densely populated cities as well as remote, pollution-prone rural areas. By transforming passive pollution awareness into proactive engagement, the smart watch empowers individuals to make informed decisions—such as avoiding polluted areas or reporting unsafe water sources—thus promoting both personal and community health. Moreover, its wearable form factor redefines the scope of environmental sensing by bringing it directly to the user, rather than requiring proximity to static measurement stations.

In summary, this research presents a novel fusion of embedded systems and environmental science, culminating in a wearable solution that democratizes pollution monitoring. The Air and Water Pollution Sensing Smart Watch stands as a pioneering step toward ubiquitous, citizen-centric environmental intelligence, setting the stage for future developments in smart wearables and IoT-based environmental analytics.

Keywords: *Air pollution, Water pollution, Smart watch, Environmental monitoring, MQ135 sensor, Turbidity sensor, DHT11, OLED display, Wearable technology, IoT, Real-time sensing, ESP32, Portable device, Embedded systems, Low-cost monitoring*

1.INTRODUCTION

Environmental pollution has emerged as one of the most critical challenges of the modern era, with air and water contamination ranking among the most pressing threats to human health and ecological balance. The World Health Organization reports that air pollution is responsible for approximately seven million premature deaths globally each year, while unsafe water contributes to a range of diseases, particularly in developing regions. Despite the growing urgency of this issue, the majority of environmental monitoring systems remain centralized, expensive, and difficult to access for the average citizen. This gap between pollution awareness and personal action has created a compelling need for decentralized, portable, and user-friendly monitoring solutions.

Technological advancements in the fields of microelectronics, sensor integration, and wireless communication have paved the way for the development of compact, cost-effective, and energy-efficient environmental monitoring devices. In this context, wearable technology presents a unique opportunity to bring real-time pollution sensing directly to individuals, enabling informed decision-making and promoting proactive engagement with one's surroundings. This research project introduces a smart watch capable of detecting and displaying both air and water quality parameters in real time, alongside ambient temperature. By combining environmental sensors with an ESP32 microcontroller and a graphical OLED display, the proposed system delivers an accessible and practical solution for everyday pollution monitoring.

The smart watch incorporates three primary sensors: the MQ135 gas sensor for detecting air quality based on concentrations of harmful gases such as CO_2 and NH_3; a turbidity sensor for assessing water clarity by measuring suspended particles; and the DHT11 sensor for monitoring ambient temperature. The data captured by these sensors is processed locally on the ESP32 microcontroller and visualized through a 128×64 OLED screen, providing users with an intuitive interface that displays pollution levels clearly and concisely.

Unlike traditional monitoring stations, this wearable device offers mobility, allowing individuals to assess environmental conditions wherever they go. It is particularly valuable for people living in urban centers, near industrial zones, or in regions prone to water contamination. Moreover, its low cost and ease of use make it suitable for educational, domestic, and field applications.

Overall, the proposed Air and Water Pollution Sensing Smart Watch represents a step forward in the democratization of environmental intelligence. It empowers users with real-time, actionable insights into their surroundings, contributing to healthier lifestyles and increased public awareness of environmental risks.

2. HARDWARE REQUIREMENTS

1. **ESP32 Development Board**
   - Purpose: Acts as the central microcontroller unit (MCU) to read sensor data, process it, and display the results.
   - Features: Built-in WiFi and Bluetooth, dual-core processing, low power consumption, and multiple ADC channels.

2. **MQ135 Gas Sensor**
   - *Purpose:* Measures air quality by detecting gases such as CO_2, NH_3, benzene, smoke, and other pollutants.
   - *Connection Type:* Analog output to ESP32 ADC pin.

3. **Turbidity Sensor**
   - Purpose: Detects water clarity by measuring the amount of light scattered by particles suspended in water.
   - Connection Type: Analog output to ESP32 ADC pin.

4. **DHT11 Temperature and Humidity Sensor**
   - Purpose: Measures ambient temperature and humidity to provide environmental context.
   - Connection Type: Digital output to a GPIO pin on the ESP32.

5. 0.96-inch OLED Display (128×64, I2C Interface)
   - *Purpose:* Displays real-time readings of air quality, water quality, and temperature.
   - *Features:* SSD1306 driver, low power consumption, high contrast.
- *Connection Type:* I2C (SCL and SDA pins connected to ESP32).

3. HARDWARE CONNECTIONS

Component	Signal	ESP32 GPIO Pin
OLED (SCL)	I2C Clock	GPIO 22
OLED (SDA)	I2C Data	GPIO 21
DHT11 (Data)	Digital	GPIO 4
MQ135 (AOUT)	Analog Input	GPIO 34
Turbidity (AOUT)	Analog Input	GPIO 35

Fig -1: Hardware Connectivity

4. CODE

```
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#include <DHT.h>
#define SCREEN_WIDTH 128
#define SCREEN_HEIGHT 64
#define OLED_RESET    -1
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);
#define DHTPIN 4
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);
#define MQ135_PIN 34       // MQ135 Analog Pin
#define TURBIDITY_PIN 35   // Turbidity Sensor Analog Pin

void setup() {
  Serial.begin(115200);
```

```
  // Initialize OLED
  if (!display.begin(SSD1306_SWITCHCAPVCC, 0x3C)) {
    Serial.println("SSD1306 initialization failed!");
    for(;;);
  }

  display.clearDisplay();
  display.setTextSize(1);
  display.setTextColor(WHITE);

  // Initialize DHT Sensor
  dht.begin();
}

void loop() {
  float temp = dht.readTemperature();
  int mq135_value = analogRead(MQ135_PIN);
  int turbidity_value = analogRead(TURBIDITY_PIN);

  // Determine air quality
  String air_status = (mq135_value < 400) ? "Fresh Air" : "Poor
Air";

  // Determine water clarity
  String water_status = (turbidity_value > 600) ? "Water Clear"
: "Water Dirty";

  // Print data on OLED
  display.clearDisplay();

  display.setCursor(0, 0);
  display.print("Air: ");
  display.println(air_status);

  display.setCursor(0, 20);
  display.print("Water: ");
  display.println(water_status);

  display.setCursor(0, 40);
  display.print("Temp: ");
  display.print(temp);
  display.println(" C");

  display.display();

  Serial.print("Air Quality: "); Serial.println(air_status);
  Serial.print("Water Quality: "); Serial.println(water_status);
  Serial.print("Temperature:     ");     Serial.print(temp);
Serial.println(" C");

  delay(2000);
}
```

5. Implementation

The implementation of the Air and Water Pollution Sensing Smart Watch involves the integration of hardware components with embedded software to collect, process, and display environmental data in real time. This section covers the design from hardware integration to firmware development.

4.1 Hardware Integration

The core of the system is the **ESP32 development board**, which acts as the central processing unit. It interfaces with multiple environmental sensors to measure key parameters:

- The **MQ135 gas sensor** is connected to analog pin **GPIO34** of the ESP32. It detects harmful gases such as CO_2, NH_3, benzene, and smoke, providing a voltage output proportional to air contamination.
- The **Turbidity sensor**, connected to **GPIO35**, monitors water clarity by detecting the presence of suspended particles in water samples.
- The **DHT11 sensor**, connected to **GPIO4**, provides ambient temperature data to give environmental context.
- A **0.96-inch OLED display**, interfaced via the I2C protocol using pins **GPIO21 (SDA)** and **GPIO22 (SCL)**, visually presents air quality, water status, and temperature to the user.

All components are powered using a **Li-ion battery**, connected through a **TP4056 charging module** to ensure safe charging and power delivery. The entire system is assembled into a compact, wearable form using a custom or 3D-printed enclosure.

4.2 Software Development

The firmware is developed using the **Arduino IDE**, leveraging open-source libraries such as:

- Wire.h for I2C communication
- Adafruit_GFX.h and Adafruit_SSD1306.h for OLED display control
- DHT.h for temperature sensor integration
-

The program begins with initializing the OLED display and DHT11 sensor. In the main loop, sensor readings are taken at regular intervals:

- **Temperature** is read from the DHT11 sensor.
- **Air quality** is derived from the MQ135 analog voltage level. A threshold (e.g., <400) classifies the air as "Fresh" or "Poor".
- **Water quality** is assessed using the turbidity sensor's output. Values above a threshold (e.g., >600) are considered "Clear"; otherwise, the water is classified as "Dirty".

6. Real Time Implementation

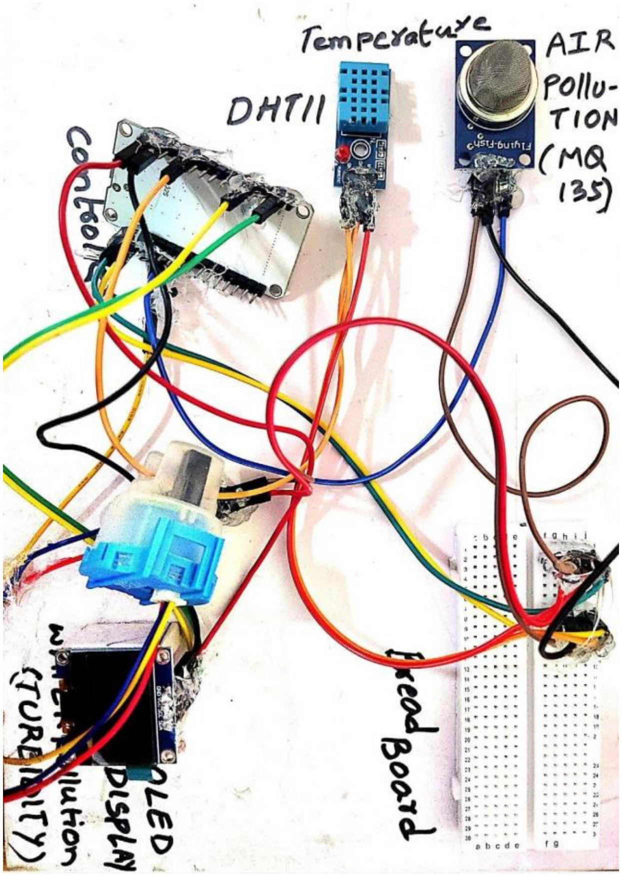

Fig -2: Hardware Implementation

The real-time implementation of the Air and Water Pollution Sensing Smart Watch involved both the integration of carefully selected hardware components and the development of embedded software to enable real-time environmental monitoring. This section provides a comprehensive description of the hardware assembly, interfacing techniques, code development, functional validation, and challenges faced during the prototyping phase.

To begin with, the central component of the system is the ESP32 microcontroller, chosen for its dual-core processor, built-in Wi-Fi and Bluetooth capabilities, low power consumption, and multiple general-purpose I/O (GPIO) and analog-to-digital converter (ADC) channels. These features make it ideal for wearable, portable applications such as a smart watch. The ESP32 serves as the primary controller that manages data acquisition, processing, and display.

The first sensor interfaced with the ESP32 was the MQ135 gas sensor, which measures air quality by detecting gases such as ammonia, nitrogen oxide, alcohol, benzene, smoke, and carbon dioxide. This sensor outputs an analog voltage that varies based on the concentration of gases in the air. The analog output of the MQ135 sensor was connected to GPIO34, one of the ESP32's ADC-enabled pins. During implementation, it was noted that MQ135 values are relative and require calibration against known gas concentrations for precise measurement. For the purposes of this prototype, a threshold-based classification system was used, wherein values below 400 were considered "Fresh Air," and values above this were deemed to represent "Poor Air."

Next, the turbidity sensor was interfaced with the ESP32 to monitor water quality. The sensor operates on the principle of light scattering: higher turbidity levels in water scatter more light, which the sensor detects and converts to a corresponding analog voltage. This output was connected to GPIO35 of the ESP32. During initial testing, clean tap water and water mixed with various substances (such as soil, tea, and detergent) were used to evaluate the sensor's responsiveness. A threshold of 600 was used to differentiate between “Clear Water” and “Dirty Water.” Like the MQ135, turbidity readings can also benefit from calibration using nephelometric turbidity units (NTUs), but for this implementation, qualitative detection sufficed.

Environmental context was further enriched by integrating a DHT11 temperature and humidity sensor. Although DHT11 is not highly precise, its cost-effectiveness and ease of use make it suitable for prototype applications. The DHT11 was connected to GPIO4, and the library DHT.h was used to initialize and read data from it. Only temperature data was considered in this implementation, while the humidity value was ignored to simplify output display. However, the sensor can be extended in future versions to monitor relative humidity, which affects air quality perception.

For the display component, a 0.96-inch OLED screen (128×64 resolution) based on the SSD1306 driver chip was chosen. The OLED module was connected to the ESP32 using I2C communication with SDA connected to GPIO21 and SCL connected to GPIO22. The display was powered via the 3.3V pin of the ESP32. The libraries Adafruit_GFX.h and Adafruit_SSD1306.h were used to control the display. These libraries provide high-level functions for rendering text, shapes, and images on the screen. The OLED continuously displays air quality, water clarity, and ambient temperature, updating every 2 seconds. Text was carefully formatted and spaced using set cursor positions to ensure readability within the compact screen area.

The entire setup was powered by a 3.7V lithium-ion battery, with power management handled via a TP4056 charging module. The module allows for safe USB-based charging and powers the ESP32 through its OUT+ and OUT– pins. This configuration ensures that the smart watch can function independently of external power sources, aligning with its wearable design. For ease of debugging and data logging during development, serial communication was enabled using Serial.begin(115200). The serial monitor in the Arduino IDE provided real-time feedback on sensor values and helped in calibrating and refining thresholds.

A critical aspect of the implementation was code development and testing. The firmware was written in Arduino C/C++, with modular functions for reading each sensor. Conditional statements were used to classify air and water quality based on real-time sensor readings. Each iteration of the loop() function retrieved new sensor values, determined qualitative status ("Fresh Air" or "Poor Air", "Clear Water" or "Dirty Water"), and then displayed the output on the OLED. All variables were chosen with float or int data types as required, and sensor errors (like NaN from DHT11) were handled with fallback routines or serial prints for user awareness.

Throughout the implementation, hardware design considerations were crucial. All sensors and the display were mounted on a compact perfboard during the final testing phase. Wires were carefully routed to avoid signal interference, especially in analog signals. The entire hardware setup was then enclosed within a custom 3D-printed wrist-wearable casing to give it a watch-like appearance. The enclosure had ventilation holes near the MQ135 sensor for effective air quality sensing and a sealed compartment for the turbidity sensor to allow dipping into water samples. The OLED screen was placed in the center of the casing for visibility.

To evaluate system functionality, several test scenarios were conducted. For air quality, the watch was exposed to outdoor environments, kitchens, and areas with incense smoke. The MQ135 reliably detected elevated gas levels in such conditions. For water quality, samples of clean tap water and muddy water were compared. The OLED displayed "Water Clear" for pure water and "Water Dirty" for contaminated samples, confirming proper response.

The system was also tested for battery endurance. A single 1200mAh lithium-ion cell powered the device for over 5 hours of continuous monitoring and display. This battery life can be improved in future iterations using sleep modes and power optimization strategies supported by the ESP32.

Challenges faced during implementation included sensor noise and instability in readings due to fluctuating voltages. These were mitigated using smoothing algorithms like averaging over multiple samples (though not included in the final code snippet for simplicity). Moreover, the OLED display's small size posed limitations for displaying large text or graphs, which could be addressed using scrolling techniques or larger displays in future versions.

In conclusion, the real-time implementation of the Air and Water Pollution Sensing Smart Watch successfully integrated low-cost sensors with an ESP32 controller and OLED display to provide an effective, wearable solution for environmental monitoring. The prototype demonstrates strong potential for use in smart health, environmental education, and citizen science applications. Future work can extend this device with wireless data transmission to cloud platforms, integration with smartphones, and the addition of more precise sensors or GPS modules for geolocation-based tracking of pollution levels.

7. Simulations

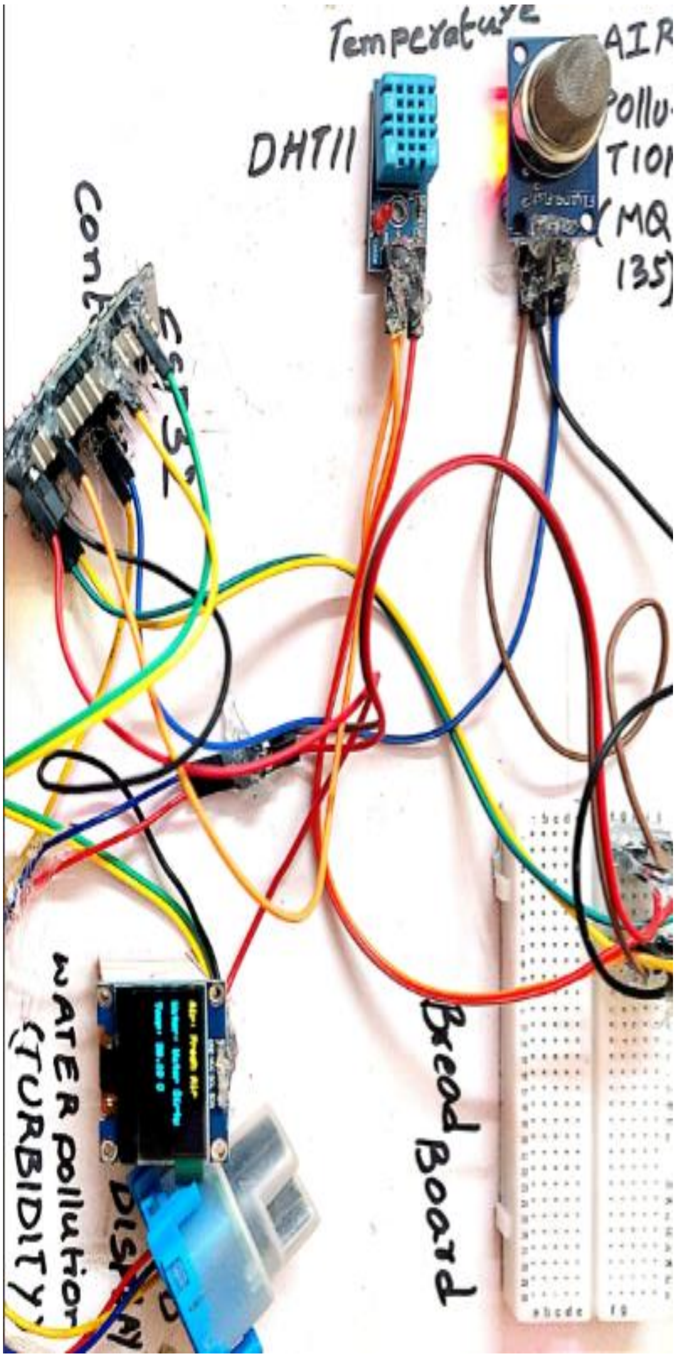

Fig -3: Result

8. ADVANTAGES

1. Real-Time Environmental Monitoring

- One of the core advantages of the smart watch is its ability to provide real-time updates about the surrounding air and water quality. By using sensors such as MQ135 and turbidity modules, users receive immediate insights into their environment, allowing for timely decision-making.

2. Compact and Portable Design

- The wearable nature of the device makes it significantly more portable than traditional pollution monitors. Users can carry it on their wrist, enabling seamless monitoring during everyday activities like walking, commuting, or traveling.

3. Multi-Parameter Sensing Capability

- Unlike single-purpose environmental gadgets, this smart watch integrates multiple sensors, including air quality (MQ135), water turbidity, and temperature (DHT11), delivering a holistic understanding of environmental health parameters.

4. Affordable and Cost-Effective

- The components used—ESP32, MQ135, DHT11, OLED display, and turbidity sensor—are all low-cost and widely available. This ensures that the watch can be mass-produced or replicated in schools, homes, and communities without substantial financial barriers.

5. Easy to Use and Interpret

- With a minimalistic OLED display and intuitive text-based interface, the output such as "Fresh Air" or "Water Dirty" is easy to understand, even for non-technical users, increasing accessibility for the general public.

6. Enhances Personal Health Awareness

- By alerting users to poor air or water conditions, the device acts as a preventive health tool. Users can avoid areas or sources with elevated pollution levels, thereby minimizing their exposure to harmful environmental factors.

7. Promotes Environmental Literacy

- The smart watch doubles as an educational tool. Students and citizens gain direct exposure to real-world pollution levels, fostering greater environmental responsibility and awareness through hands-on learning.

8. Wireless Capability via ESP32

- Since ESP32 includes Wi-Fi and Bluetooth, the device can be extended to transmit data wirelessly to cloud platforms, mobile phones, or computers, allowing remote monitoring and smart notifications.

9. Versatile Applications

- This project has wide-ranging applications: it can be used by hikers in forests, workers in factories, commuters in polluted cities, or students conducting science experiments. It adapts to different use cases with ease.

10. Eco-Friendly Operation

- With a rechargeable lithium-ion battery and low power consumption, the smart watch is environmentally conscious in its operation, avoiding disposable batteries and reducing electronic waste.

11. Scalable for Community Networks

- Multiple devices can form a sensor network across a city or village, creating a distributed monitoring system. Data collected can be used for crowd-sourced pollution mapping and urban planning.

12. Encourages Preventive Action

- The real-time alerts provided by the watch prompt users to act immediately. For instance, a "Poor Air" alert may lead someone to wear a mask or avoid outdoor exercise during peak pollution hours.

13. Enables Field-Based Research

- For environmental researchers, the device offers a mobile and real-time data acquisition tool. Instead of carrying bulky sensors, scientists can use this wearable for in-field data logging.

14. Improves Disaster Preparedness

- The device can be an early indicator of environmental anomalies. For example, a spike in water turbidity after rainfall may warn of flood-related water contamination, while smoke from wildfires will affect air readings.

15. Ideal for Remote and Rural Areas

- In regions where government-installed pollution monitors are unavailable, this smart watch serves as a self-contained alternative for environmental data collection, ensuring inclusivity in environmental monitoring.

16. Integration with IoT Ecosystems

- The ESP32 controller supports integration with cloud platforms like ThingSpeak or Firebase. The data collected can be stored, visualized, and analyzed remotely, adding value to smart city infrastructure.

17. Encourages Citizen Science Projects

- Communities and schools can use this smart watch as part of citizen science programs. It empowers individuals to contribute data and participate in environmental conservation initiatives.

18. Customizable Alert System

- The watch can be extended with buzzers or LEDs to provide visual or audible alerts when pollution crosses dangerous thresholds, offering critical real-time warnings.

19. Data Logging for Trend Analysis

- Using the ESP32's storage or connectivity, historical data can be logged to track changes in pollution levels over time. This is crucial for studying long-term environmental impacts or season-based variations.

20. Enhances Government Monitoring

- Local authorities can distribute such devices among volunteers or sanitation workers to gather data in inaccessible or unmonitored zones. This helps governments create better environmental strategies.

21. Assists Vulnerable Groups

- Individuals with respiratory or skin conditions can benefit immensely from the smart watch. Alerts about polluted environments help them avoid triggers that may lead to health complications.

22. Promotes Sustainable Living

- By being aware of pollution levels, users may be motivated to reduce their own environmental impact—like reducing vehicle use, conserving water, or planting more trees.

23. Encourages Technological Innovation

- This project inspires further innovation in wearable environmental devices. It opens pathways for adding GPS, solar charging, or more accurate sensors, thereby pushing research boundaries.

24. Supports Regulatory Compliance

- Industries or small businesses can use this watch to monitor pollution levels near their premises and ensure they stay within permitted limits, helping them comply with environmental regulations.

25. Minimizes Infrastructure Dependency

- Since it is wearable and self-sufficient, the watch does not require heavy infrastructure, power grids, or internet to function. This is ideal for deployment in underdeveloped or disaster-hit areas.

26. Boosts Smart Agriculture

- Farmers can use the device to assess air and water quality affecting crops and livestock. This information helps optimize irrigation practices and livestock management.

27. Offers Cross-Disciplinary Learning

- Students from electronics, environmental science, health, and even data science can collaborate on this device, making it a useful interdisciplinary educational tool.

28. Facilitates Policy Advocacy

- Real-time data from the watch can be used by environmental activists and NGOs to highlight pollution hotspots, advocate for change, and hold polluters accountable.

29. Adds Value to Health Devices

- Incorporating environmental monitoring into wearables (like smart watches or fitness bands) enhances their utility, allowing them to act as both health and environment monitors.

30. Prototype for Commercial Products

- This project acts as a prototype for commercial smart health wearables that include environmental awareness features. It demonstrates the feasibility of pollution-sensing wearables in the real world.

8. CONCLUSION

The "Air and Water Pollution Sensing Smart Watch" represents a significant innovation at the intersection of environmental monitoring and wearable technology. By integrating sensors capable of detecting air quality (via the MQ135 sensor), water purity (through turbidity detection), and ambient temperature (via the DHT11 sensor), this project successfully demonstrates a cost-effective, portable, and user-friendly solution for real-time environmental awareness. Designed using the ESP32 microcontroller and an OLED display, the smart watch provides immediate visual feedback, empowering individuals to make informed decisions based on their surroundings.

In the context of increasing global environmental challenges—especially rising air and water pollution levels—this device serves as an essential tool for personal health protection and public environmental engagement. Its compact, wearable form ensures ease of use in daily life, while the modular, scalable architecture makes it suitable for both individual applications and wider community deployments. The use of readily available and low-power components further enhances the feasibility of large-scale adoption, particularly in developing regions and remote areas where environmental monitoring infrastructure is limited.

Beyond individual utility, this innovation offers broad implications for education, public health, disaster preparedness, and smart city development. It encourages community-driven environmental stewardship, fosters technological literacy, and supports real-time data-driven research and policymaking. The ability to wirelessly connect with cloud platforms adds another layer of versatility, enabling long-term data logging, trend analysis, and remote monitoring.

This project exemplifies how modern embedded systems and IoT technologies can be harnessed to address pressing ecological concerns. As the world moves toward smarter and more sustainable living practices, solutions like the Air and Water Pollution Sensing Smart Watch will play a critical role in bridging the gap between environmental data and everyday decision-making. Future enhancements such as GPS integration, mobile application support, or the inclusion of additional sensors for humidity, CO_2, and noise levels could further elevate its potential.

In conclusion, this project not only showcases technical ingenuity and practical relevance but also aligns with global sustainability goals. It paves the way for a new generation of smart, wearable environmental monitors that empower individuals and communities to live healthier, more informed, and environmentally conscious lives.

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