NanoWatch: A Real-Time IoT-Integrated Nanoparticle Pollution Monitoring System

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Research Question
What are the limitations of current nanoparticle pollution monitoring methods, and how can an IoT-integrated static light scattering device overcome these challenges to enable real-time, affordable, and accurate environmental monitoring?

Methodology

Developed a portable, cost-efficient static light scattering (SLS) device using a 532 nm laser, photomultiplier tube (PMT), collimating optics, and an IoT-based ESP8266 module for real-time data transmission. The device completely enables in-situ analysis of pollution levels in any environment via the analysis of nanoparticles.

- Implemented two sampling systems:
    - **Air:** Compact bubbling chamber (ethanol-water, 70:30 v/v) enabling rapid (2–5 min) nanoparticle capture from ambient air.
    - **Water:** Batch-based direct sampling method simulating industrial wastewater scenarios.
- Conducted calibration and validation using AgNPs, TiO_2, and ZnO nanoparticles (10–100 ppm).
- Automated angular data collection using Arduino-controlled stepper motor for comprehensive multi-angle analysis.
- Developed a cloud-based dashboard displaying pollution trends and automated threshold-based alerts.

Data Analysis & Results

- Successfully detected nanoparticle pollution levels, correlating scattering intensity to nanoparticle concentration and environmental contamination.
- Validated results through comparative Transmission Electron Microscopy (TEM), confirming accurate nanoparticle sizing (30–60 nm).
- IoT integration enabled real-time monitoring of pollution trends, providing graphical visualization of concentration spikes over multiple sampling periods.
- Demonstrated device reliability and reproducibility across air and water samples.

Interpretation, Environmental Impact & Future Directions

- NanoWatch provides an accessible, cost-effective alternative to expensive, lab-based nanoparticle monitoring methods, significantly improving pollution tracking capabilities.
- The IoT-enabled real-time monitoring allows proactive intervention, protecting ecosystems and public health through early-warning alerts and regulatory compliance.
- Future enhancements will automate sampling for continuous monitoring, improve sensitivity for ultrafine nanoparticles (<10 nm), integrate AI-driven predictive analytics, and deploy multi-sensor networks for comprehensive environmental assessments.