Air Cloud: A Mobile Atmospheric Purification System

Abstract

Air pollution remains a significant global and national challenge, with adverse impacts on human health, the environment, and economies. In India, rapid industrialization, vehicular emissions, agricultural practices, and seasonal factors like festival celebrations contribute to worsening air quality. Power generation and industrial emissions further exacerbate pollution levels, with particulate matter and greenhouse gases being major pollutants. During festivals like Diwali, increased firecracker usage significantly worsens air quality, leading to acute pollution spikes. To address this issue, governments have implemented various measures, including emission regulations, vehicle emission standards, and temporary bans on firecracker sales. However, despite these efforts, air pollution continues to pose a grave threat, highlighting the need for sustained action, public awareness, and international cooperation to mitigate its impacts on health and the environment globally.

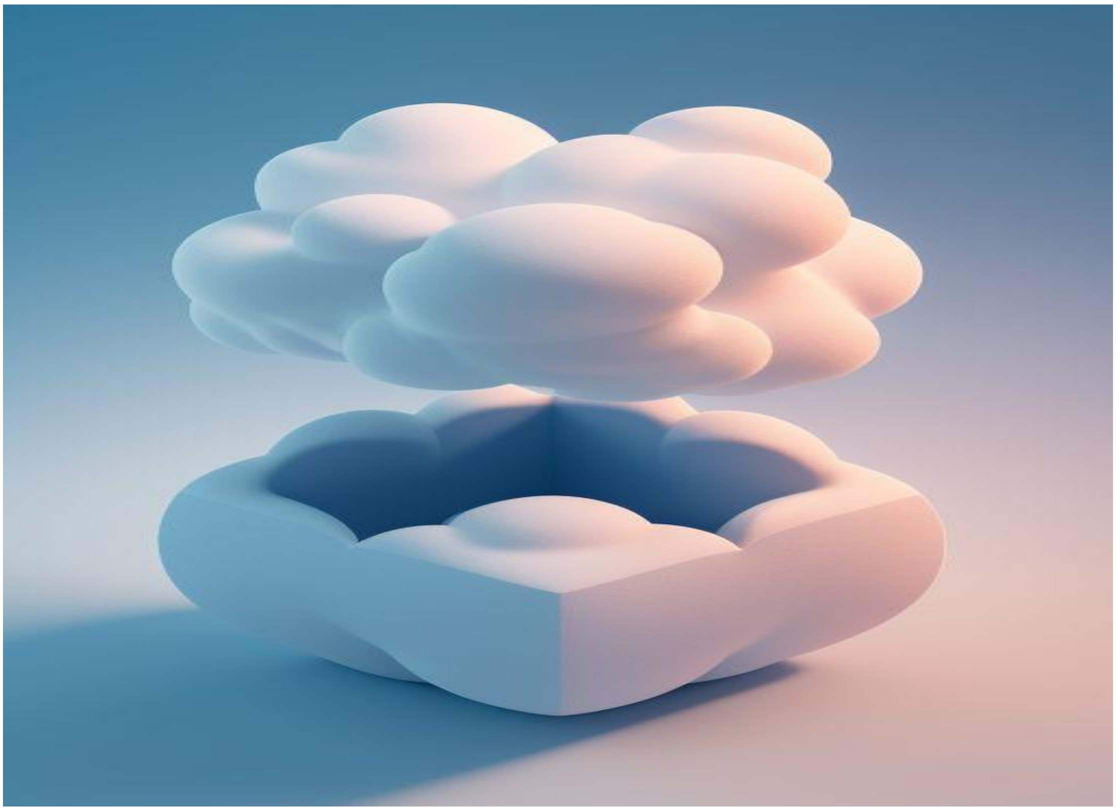
World's most polluted countries

Most polluted country ranking based on annual average PM2.5 concentration (μg/m³)

Rank	Country	2023	2022	2021	2020	2019
1	Bangladesh	79.9	65.8	76.9	77.1	83.3
2	Pakistan	73.7	70.9	66.8	59	65.8
3	India	54.4	53.3	58.1	51.9	58.1
4	Tajikistan	49	46	59.4	30.9	--
5	Burkina Faso	46.6	63	--	--	--
6	Iraq	43.8	80.1	49.7	--	39.6
7	United Arab Emirates	43	45.9	36	29.2	38.9
8	Nepal	42.4	40.1	46	39.2	44.5
9	Egypt	42.4	46.5	29.1	--	18
10	Democratic Republic of the Congo	40.8	15.5	--	--	32.1

Solution

Hydroxyl radicals (OH) are highly reactive species known for their ability to rapidly oxidize and degrade organic pollutants present in the atmosphere. OH radicals play a crucial role in air purification processes by breaking down pollutants into harmless byproducts such as carbon dioxide and water. PEC process integrates the benefits of photocatalysis and electrochemistry to generate OH radicals for pollutant degradation. Photocatalysis involves the activation of a semiconductor material (e.g., titanium dioxide) by light to create electron-hole pairs, leading to the generation of reactive species such as OH radicals. Electrochemical enhancement of the process involves the application of an external bias or potential to accelerate the generation of reactive species, thereby improving the efficiency of pollutant removal.



Working:

the development and integration of a filtration module with an OH generator using the Photoelectrochemical (PEC) process into an AirCloud system. The AirCloud, a man-made cloud developed by our team, operates through a three-stage working model comprising propulsion, detection, and filtration. The upper and lower parts of the cloud are filled with helium to facilitate propulsion. Initially, a detection cloud equipped with gas sensors monitors the Air Quality

Index (AQI). Based on the AQI data, a filtration cloud, integrated with the OH generator, is deployed to convert toxic gases into less harmful ones. Upon completion of the filtration process, the cloud returns to the ground after further AQI monitoring

Detection

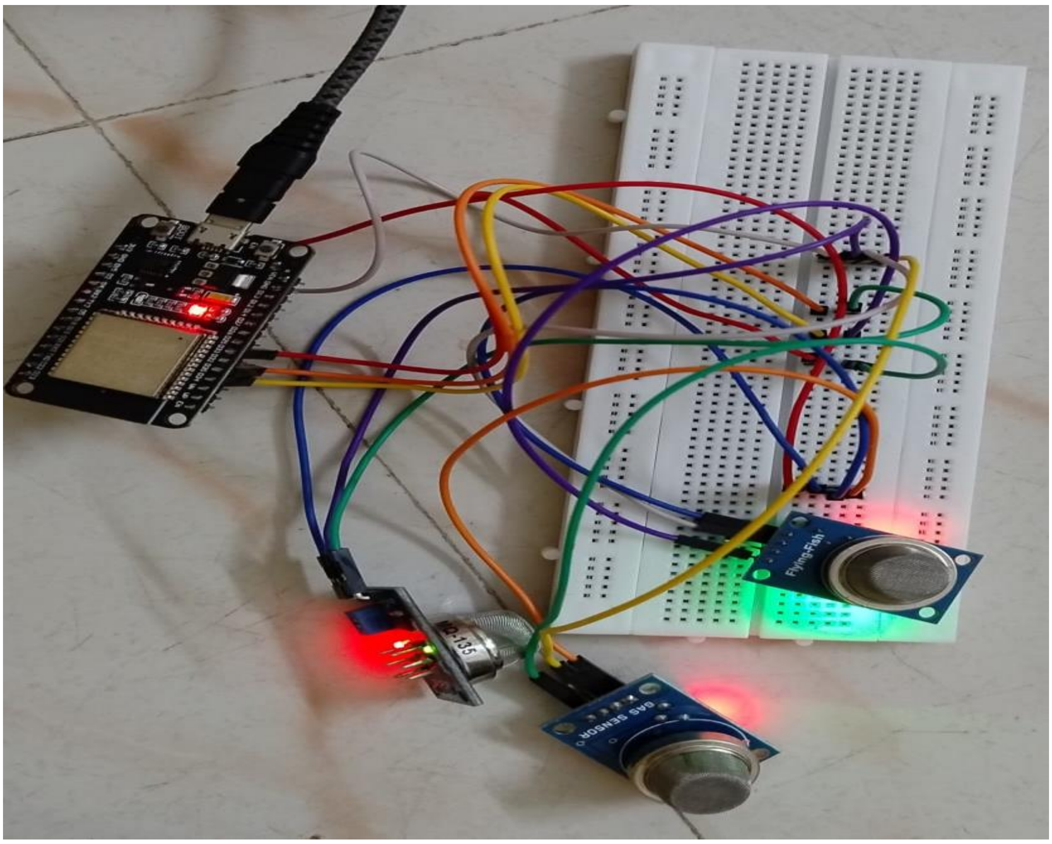
The detection module mainly consists of 3 components.

1.Sensors

2.A CSV file to store all the values.

3.GPS Tracking

The sensor's main functionality depends on the chemiresistors used in it. Chemiresistor is a component which sends electrical impulses according to the changes in the surrounding environment. The most commonly used chemiresistor is Tin dioxide(SnO_2) which is an n-type semiconductor that has flow of free electrons.



Working:

1. Gas sensors rely on chemiresistors, such as Tin Dioxide (SnO_2), to detect gases by measuring their conductivity.

2. SnO_2 is commonly used and is an n-type semiconductor, meaning it has excess free electrons, also known as donors.

3. Normally, the atmosphere contains more oxygen than combustible gases. Oxygen particles in the atmosphere attract the free electrons in SnO_2, preventing them from conducting current, resulting in an output current of zero.

4. In environments with toxic or combustible gases, these gases react with the adsorbed oxygen particles on the surface of SnO_2.

5. This reaction breaks the chemical bond between oxygen and free electrons, releasing the free electrons back into the semiconductor material.

6. With free electrons available again, the SnO_2 can conduct current, and the amount of current conducted is proportional to the concentration of the toxic or combustible gas present.

7. Higher concentrations of toxic gases result in more free electrons being released, leading to a greater conductivity and a stronger signal from the gas sensor.

The Sensors used are,

1.MQ-2: Detects the presence of Methane and flammable gases like lpg.

Weight: 5 grams

2.MQ-7: Detects the presence of Carbon monoxide in the air.

Weight: 5 grams

3.MQ-131: Detects the presence of Ozone in the air

Weight: 5 grams

4.MQ-135: Gives the percentage od the Air quality

Weight: 5 grams

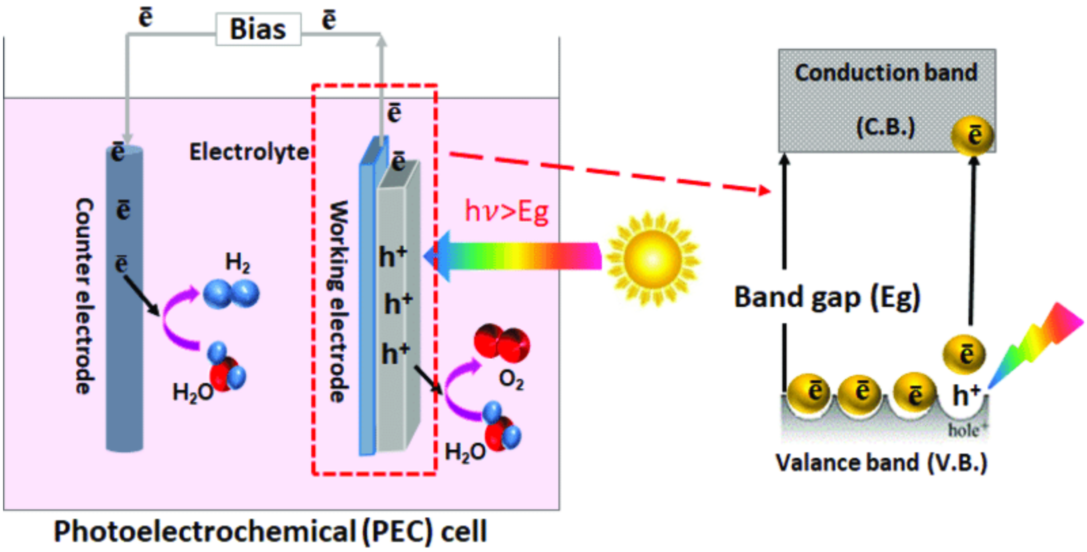
5.MQ-136: Detects the presence of Hydrogen sulphide in the air.

Weight: 5 grams

After the detection of air by the sensors the data is stored as CSV files via IOT.

Filtration

Photoelectrochemical processes involve the interaction of light with semiconductor materials, typically in the form of photoelectrodes. When these photoelectrodes are exposed to light, they absorb photons, which excite electrons from the valence band to the conduction band, creating electron-hole pairs.



In the presence of water molecules (H2O), these electron-hole pairs can participate in redox reactions. Specifically, the photogenerated electrons can reduce water molecules, leading to the formation of hydroxyl radicals (OH•) and hydrogen ions (H+). This process is often referred to as the photocatalytic water splitting reaction.

The overall reaction can be represented as:

2H2O + 2h+ (at the photoanode) + 2e- (at the cathode) -> O2 + 2H+ + 2OH•

Components Needed:

Photoactive Electrode: This is typically a semiconductor material capable of absorbing photons and generating electron-hole pairs upon illumination.

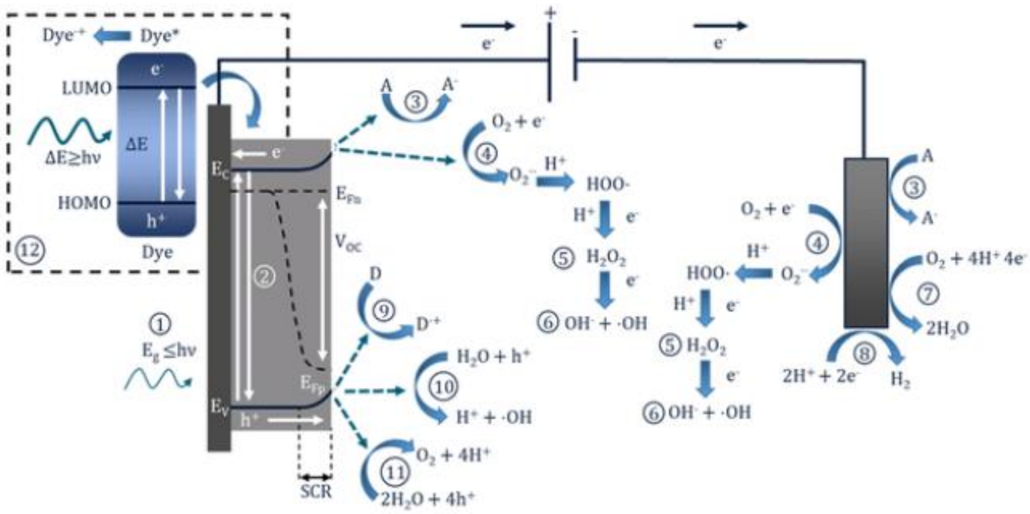
Common examples include titanium dioxide (TiO2), zinc oxide (ZnO), and bismuth vanadate (BiVO4).

Electrolyte: An electrolyte solution containing suitable ions to facilitate charge transfer between the electrode and the solution. Commonly used electrolytes include aqueous solutions containing ions like Na+, Cl-, or other metal ions.

Counter Electrode: Another electrode, usually made of a conductive material like platinum or graphite, used to complete the electrical circuit.

Light Source: A light source providing photons with sufficient energy to excite electrons in the photoactive electrode, typically sunlight or artificial light sources like UV lamps.

External Bias: Optionally, an external bias voltage can be applied to enhance the PEC process.



Here, the hydroxyl radicals (OH•) are generated at the surface of the photoelectrode and can subsequently participate in various chemical reactions, including the oxidation of pollutants and greenhouse gases, thereby contributing to the cleansing of the atmosphere.

Calculation:

Photoactive Electrode: 10 grams

Electrolyte Solution: 1000 grams

Counter Electrode: 100 grams

Supporting Structure and Housing: 100 grams

Total Weight = 10 grams (ZnO electrode) + 1000 grams (Electrolyte solution) + 100 grams (Graphite electrode) + 100 grams (Supporting structure) = 1210 grams

So, the estimated total weight of the PEC system is 1210 grams

Weight of PVC:

Density of PVC = 1.4g/cm^3

Weight of PVC = Surface area * Thickness* Density

= 2826*0.2*1.4

= 795.85g

Total weight of air-cloud = weight of PVC layer + weight of filtration

Weight of filtration module = 1210g

Total weight of air-cloud = 795.84g + 1210g = 2005.84g

Total weight of air-cloud = 2.00584kg = 2kg(approx.)

Cost Estimation:

Cost of Zinc Oxide (ZnO) electrode: $10

Cost of Electrolyte Solution: Negligible (assuming it's water)

Cost of Graphite Electrode: $5

Cost of Supporting Structure and Housing: $20

Miscellaneous Costs (wiring, connectors, etc.): $10

Total Cost = $10 (ZnO electrode) + $5 (Graphite electrode) + $20 (Supporting structure) + $10 (Miscellaneous) = $45

1 USD = 75 INR, we can calculate the cost in Indian Rupees (INR):

Total Cost (in INR) = $45 * 75 INR/USD ≈ 3375 INR

Beneficiaries

The team's decision to develop a smart air purifying drone stems from the escalating threats of air pollution and global warming. By targeting pollutants in the air, including particulate matter (PPM), these drones aim to mitigate air pollution and reduce its overall percentage. This initiative not only benefits human health but also contributes to the global effort to combat climate change by curbing emissions. Implementing these drones in urban cities, where air pollution is rampant, can significantly improve air quality. Ultimately, by reducing global warming, the initiative also aids in preserving marine and animal life, particularly in the Atlantic region. These drones are compact in size and can be deployed at places where the air pollution exceeds the saturation point.

Propulsion

A helium-filled PVC balloon envelope forms the core of this system. Helium, being the second lightest element, provides exceptional lift capacity in relation to Aircloud's weight. This allows the system to remain airborne for extended periods, strategically positioned over areas with the most significant air pollution concerns. This strategic deployment ensures Aircloud can directly target and combat pollution hotspots.

The choice of material for the balloon envelope is crucial for both performance and cost-effectiveness. Aircloud utilizes lightweight and durable PVC material. This combination maximizes Aircloud's lifting capacity while remaining cost-effective due to the readily available nature of PVC. The lightweight design keeps the airframe buoyant, allowing it to stay aloft for extended periods. Furthermore, the durability of the PVC ensures the system can withstand the rigors of long-term operation.

For added control and stability, particularly during deployment, retrieval, and adjustments in wind conditions, Aircloud incorporates a tethering system. This additional layer of security acts like a safety net, ensuring Aircloud remains on course while delivering clean air. The tethering system provides precise control during critical moments, allowing for safe and efficient operation. By combining readily available materials with well-established scientific principles, Aircloud's propulsion system achieves a sustainable, controllable, and cost-effective solution for airborne air filtration

Calculation:

Material - PVC with 0.2cm thickness and 60cm

Surface area of the cloud:

Surface area = 4*pi*r^2

= 4*3.14*30^2

= 2826cm sq

Weight of PVC:

Density of PVC = 1.4g/cm^3

Weight of PVC = Surface area * Thickness* Density

= 2826*0.2*1.4

= 795.85g

Total weight of air-cloud = weight of PVC layer + weight of detection

Weight of detection module = 44g

Total weight of air-cloud = 795.84g + 44g

Total weight of air-cloud = 0.844kg (approx.)

Consider safety factor of 1.2 for change in condition due to weather, manufacturing defects and weight variations

Safety factor = 1.2

Air density = 1.2kg/m^3

Helium density = 0.16kg/m^3

Required Buoyancy force = Total weight*safety factor = 1.013kgf

Volume of helium = Req buoyancy force/(Density difference*Gravity)

Density difference = 1.2kg/m^3 - 0.16kg/m^3 = 1.04kg/m^3

Volume of helium = 1.013kgf/(1.04kg/m^3 * 9.81m/s^2) = 0.101m^3

cost estimate of PVC balloon = Rs.2250

Price of 1 cubic meter of helium = Rs.2500 (industry grade)

Price of 0.101 cubic meter of helium = Rs.252.5

Business Model

Air Filtration as a Service (AFaaS):

Air-cloud operates as an Air Filtration as a Service (AFaaS) model. Municipalities, businesses, or event organizers can rent the system for a designated period. This eliminates the upfront cost of purchasing and maintaining their own air filtration units. Air-cloud handles deployment, maintenance, and data monitoring, delivering clean air as a service. Clients pay a rental fee based on the desired coverage area and duration of deployment, making it a turnkey solution for air quality improvement without a significant capital investment.

Advertising Revenue through "Cloudvertising":

The large, visible PVC balloon surface of Air-cloud is not just for aesthetics. This space can be leveraged as prime advertising space through "Cloudvertising." Sections of the cloud-shaped balloon can be rented to businesses for targeted promotions. Air-cloud offers location-based advertising packages. For instance, deploying Air-cloud near sporting events and renting ad space to relevant brands creates a win-win situation. Companies gain high-impact advertising in high-traffic areas, while Air-cloud generates additional revenue to offset operational costs.

Conclusion

Our innovative airborne cloud filtration system represents a groundbreaking approach to outdoor air purification. By integrating propulsion, detection, and filtration modules into a man-made cloud, we can efficiently monitor air quality, identify pollution hotspots, and deploy targeted filtration solutions to mitigate the impact of air pollution on public health and the environment.