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Exploring the Role of UAVs in Combating Air Pollution: Applications and Impact

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Abstract:- As environmental concerns are on the rise with the advent of pollution in metropolitan cities, Unmanned Aerial Vehicle (UAV) technology has the potential to mitigate air pollution through a variety of applications. This paper aims to shed light on the practical benefits of integrating UAVs into pollution management strategies.

Keywords:- *UAV, Drones, Air Pollution Control, Environmental Monitoring, Emission Reduction, Sustainable Logistics, Pollution Detection, Eco-Friendly Technology, Real-Time Air Quality Monitoring, Green Transportation, Clean Energy Solutions, Environmental Impact Of Uavs.*

I. INTRODUCTION

Pollution is a detrimental issue around the world and exists in various types. It is prevalent in various metropolitan areas such as London, New Delhi, Mumbai, and Kolkata. Around 4.2 million deaths take place each year due to heart disease, respiratory diseases, and cancer.

Air pollution can be divided into two forms, the first and most abundant being gaseous. These can include particulate matter, ozone, carbon monoxide, and carbon dioxide. The second being water-based pollution, which can be caused by various accidents such as oil spills and marine dumping.

Specifically, particulate matter is comprised of microscopic particles/liquid droplets that contain acids, metals, or soil particles. Exposure to ozone (O3) can cause respiratory issues, aggravating diseases such as asthma. Carbon monoxide (CO) combines with hemoglobin in our blood to form oxyhemoglobin, thereby diminishing the oxygen-carrying capacity of blood cells. Additionally, large concentrations of CO2 in the atmosphere can lead to global warming, as seen with the melting of ice caps in Antarctica. In humans, CO2 can cause cardiac arrhythmias, seizures, and apoxia.

Multiple countries around the world have standardized methods to gauge the amount of air pollution present in the surrounding area. For instance, Canada uses the Air Quality Health Index (AQHI) to report the degree of pollution in different regions. On the other hand, London, and Indian states like Mumbai, New Delhi, and Kolkata use the Air Quality Index (AQI). Land–use zoning has been used to isolate human activities that can cause air pollution from the rest of the population. While Pollution Control Devices (PCD) have been used to destroy contaminants, they have a major disadvantage: they can only remove chemicals and other dirt before it has been emitted into the environment; this is because the devices require pollutants to be gathered and contained before they can be removed.

Unmanned Aerial Vehicle (UAV) technology has gained popularity over the years and has been used for air quality monitoring. Concentrations of chemicals like CO2, CH4, and volatile organic compounds (VOCs) have been successfully measured (Alvear et al., 2017; Babaan et al. 2018, Berman et al. 2012; Fladeland et al. 2011; Gu et al. 2018, Illingworth et al. 2014, Ruiz-Jimenez et al. 2019). Over the years, several uses of UAV technology can be seen. For context, UAV vision-guided aerial-ground air quality sensing system, to monitor and forecast AQI distributions in spatial-temporal perspectives has been developed by Yang et al. (2019). Air quality monitoring and forecasting was performed using the fusion of haze images taken by the UAV and AQI data was collected by a 3D wireless sensor network (Babaan et al. 2018). Additionally, Malaver et al. explored the possibility of flying a UAV as part of a solarpowered wireless network system to monitor the behavior of greenhouse gases, using solar energy to solve power consumption issues that affect the UAV's payload and its flight time.

So far, the latest solutions include the deployment of massive sensors in the city. As these sensors are fixed they can only capture data with low spatial resolutions and cannot easily track the change of air pollution in the vicinity. Vehicle-based sampling systems have improved coverage but they are limited by factors such as site access, topography, and a proper connection to the source. Unmanned Aerial Vehicles (UAVs) are becoming more and more popular due to their ability to produce a high spatial resolution. Recent advancements in UAV research have proven them to be a low cost solution for examining lower-lying areas.

Environmental drones (E-drones) are autonomous drones used to detect and monitor air pollution, as well as their mitigation at higher altitudes in specific regions. It produces Air Quality Health Index (AQHI) maps of the regions it covers for longterm analysis.

In this paper written by Singh, Atul P. et al. the drone prototype consists of a fan and wings filled with abatement chemicals. It will be controlled by a remote control and will contain 20-25 liters of water. It will also contain a sensor that measures the Air Quality Index (AQI) of the surrounding

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area. The materials used include purified water, negative ionizers, a titanium oxide plate, and a UV lager cleaner. The chemicals used have a low half-life and are strong oxidizing agents, allowing them to rapidly neutralize the particulate matter in the air. The purified water can dissipate larger dust particles in the air. The oxygen atoms present in the water can react with pollutants such as SO2 and NO2 to form H2SO4 and HNO3 respectively. The remote control will allow it to lower lying areas such as industrial areas and chimneys. A thin film of activated carbon will surround the walls of the drone to ensure that any pollutant it absorbs will not cause it to fall to the ground.

➢ *Below is a Sketch of the Proposed Prototype:*

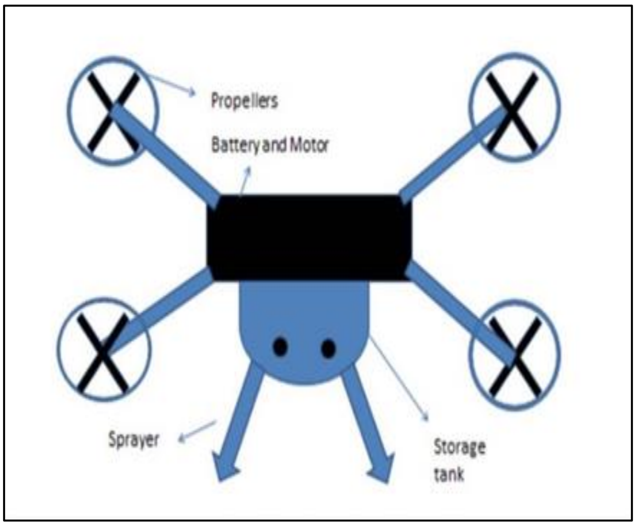

Fig 1: Prototype of the Drone Setup to Control the Air Pollutants

Using Gu, Qijun, et al. 2018 Modular design, the system consists of the UAV and a ground station. The UAV will integrate all the data from the onboard sensors and provide the geo-location of the data in real-time. It will also contain a data acquisition (DA) module, and a data fusion (DF) module. A flight plan will be provided to the UAV beforehand which will direct it.

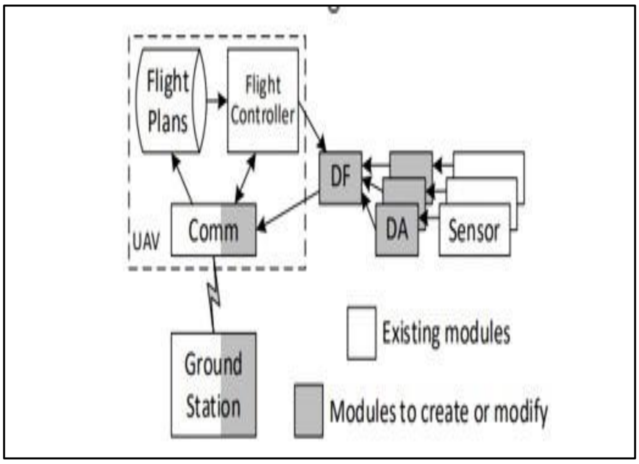

Fig 2: A simple Chart to Explain the Functioning of the UAV System

It will contain two core air pollution sensors, a particulate matter sensor, and a nitrogen dioxide (NO2) sensor. The PM sensor contains an integrated data acquisition module that will send the data to the ground station. The NO2 sensor is an electrode gas sensor that transforms the analog impulses into digital data that can be interpreted.

For the Data fusion, its job is to integrate the UAV's geolocation data, time data, and sensor data. The flight controller will provide the geolocation data to the module. Each data source contains a data servlet that will run inside the data fusion module. One servlet reads the GPS data from the flight controller, while the other servlet reads data from the air pollutant sensors. Three data source servlet programs run in the OCC to collect data from the PM sensor, NO2 sensor and flight controller.

II. MATERIALS

Using the research picked up by Rohi, Godall, et al. 2020, the E-drone has a base station where environmental data is acquired. The station contains a solar panel with power connections running down the side to provide a continuous power supply during data acquisition.

➢ *E-Drone Specifications:*

- Chassis: Carbon fiber chassis, offering a lightweight yet robust frame.
- Power Supply: 11.1V, 3200 mAh lithium polymer battery provides reliable, long-lasting electrical power.
- Motors: 4 brushless motors coupled with 10x5 inch propellers to provide efficient thrust and maneuverability.
- Electronic Speed Controllers (ESC): One for each motor, facilitating precise control over motor speed.
- Development Board: Utilized for programming autonomous surveillance tasks.
- Gyrometer: Ensures stability during takeoff, landing, and aerial patrols.
- Altitude Sensor: Measures the drone's altitude to aid in-flight navigation.
- GPS: Provides location tracking for accurate positioning.
- Xbee: Enables a wireless connection to a host computer up to a distance of 15.5 km using a 2.1dB antenna, facilitating remote control and data transmission.
- Ultrasound Sensor: Enhances safety by detecting obstacles and enabling avoidance maneuvers. Air Pollution Sensors: Equipped with individual gas sensors for each pollutant, allowing environmental monitoring with pre-set threshold values for alerts.

➢ *An in-Depth Description of the E-Drone Specifications:*

- Chassis: Constructed of lightweight carbon fiber, the drone's chassis is able to support a multitude of devices such as a
- Power Supply Unit (PSU), sensors, and modules. The chassis itself weighs 460 grams, and its dimensions are 550mm x

- 550mm. The finished prototype model, with all components attached, weighed approximately 1500 grams.
- Brushless motors: 4 motors convert the power supplied by the
- PSU (lithium-ion battery) to mechanical power, thereby spinning the propellors for flight.
- Propellors: 4 propellors mounted onto the brushless motors, with dimensions of 10 x 5 inches each.
- Electronic Speed Controllers (ESC): Specifically, the speed of the motors was varied using ESCs. Four of the ESCs are
- connected to the Lithium Polymer battery and each ESC was connected to a motor.
- Development board: The E-drone system was then programmed using the Arduino Uno Rev 3 to provide the system with the necessary autonomous navigation.
- Gyrometer: A GY-521 gyrometer is used to stabilize the drone during takeoff and landing, additionally providing acceleration, orientation, and gyrometric data native to the system
- Altitude Sensor: The BMP085 was used to find the barometric altitude of the drone. The drone was designed to go to a particular height to and gather pollution information.
- Xbee: An Xbee Pro 900HP wireless module is used to carry out communication between the E-drone and computer at the remote base station of the host PC. It has a 2.1 dB antenna, which enables it to create a wireless connection between the drone and the PC where its range is up to 15.5 km. With a high gain antenna, this range is increased to 45km.
- Ultrasound Sensor: The HC-SRO4 ultrasound sensor is installed on the anterior side of the E-drone system and is applied for tasks such as obstacle detection and avoidance. If the sensor detects an obstacle less than 35cm in front of it during flight, it takes a detour to avoid crashing into said obstacle.
- Air Pollution Sensors: The primary method through which the E-drone is able to quantify levels of air pollution is through the use of gas sensors depicted in Figure 2 It shows that the concentrations of each of the air pollutants are measured separately and with distinct sensors. Figure 3 below contains pictures of the gas sensors that were used to take measurements of CO2, CO, NH3, SO2, PM. O3 and NO2 in the E-drone system.

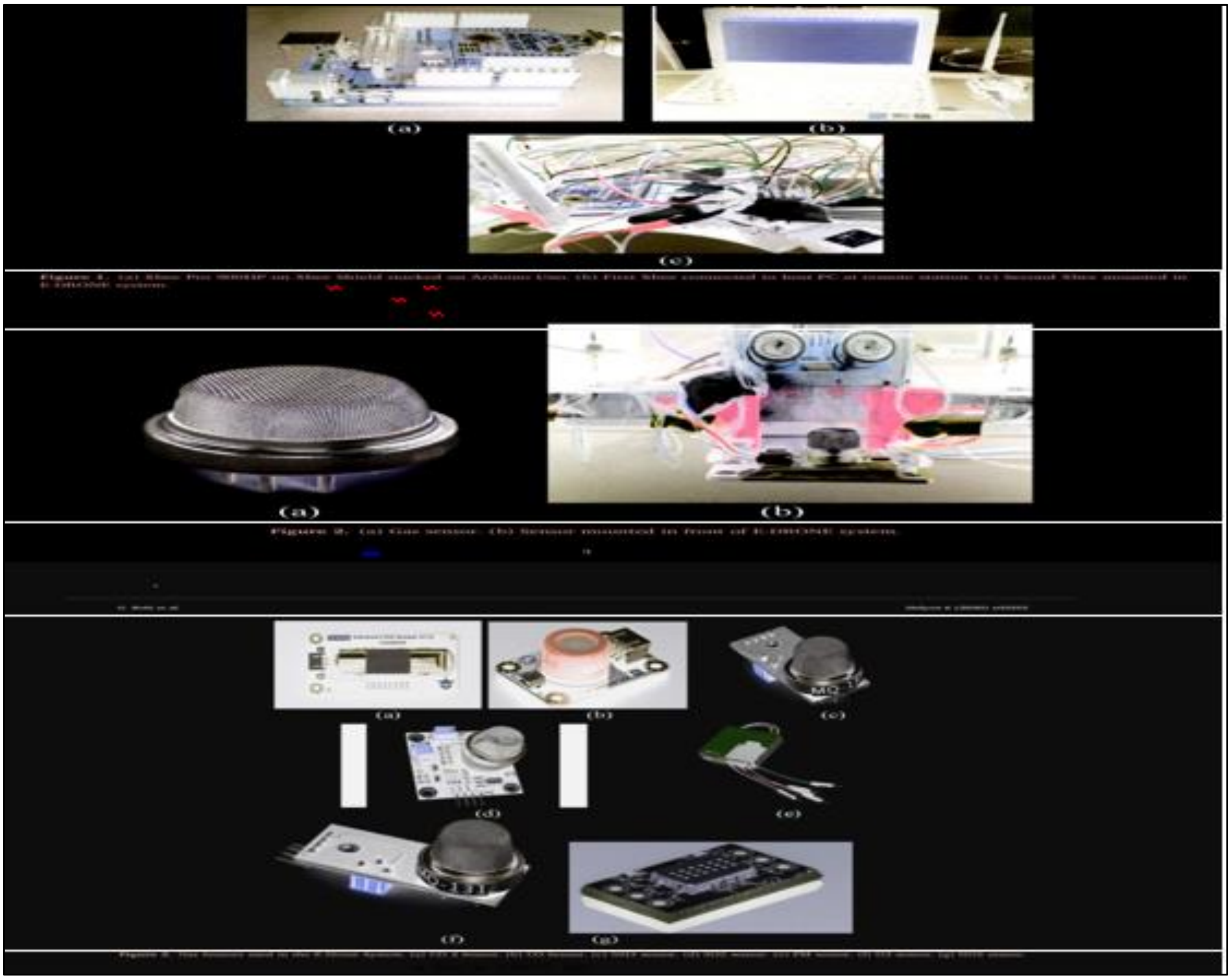

Fig 3: E-Drone System

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III. EXPERIMENT AND DATA ANALYSIS

The first test involved studying the air pollution gradient in a busy highway, the highway had a daily traffic count of about 55000 vehicles. The UAV departed 100 m away from the highway and flew an 800 m path perpendicular to the highway.

The second test was the increase in air pollution with distance from a highway intersection. This site was located at the junction of two principal roads (daily traffic volume = 157,000 and 137,000). The UAV took off from a position 10m away from one highway and flew a straight line of 500m parallel to another highway.

The third test was designed to check the air pollution gradient in proximity to a truck stop. It was the largest local truck stop in this region and located near an interstate highway (AADT = 36,000). The UAV departed 200 m away from the board of the stop and flew a 1000 m path.

The last test was to check the vertical air pollution gradient over a restaurant chimney. The UAV flew upward from the ground and hovered for 10 s at 10, 15, 20, and 25 m.

For the current consumption, an approximate 30 amp was consumed when the UAV was airborne irrespective of the orientation or speed, while it was about 1 amp on the ground.

Since the voltage of the battery was about 16V, the power consumption during the flight was then about 480 watts and 16 watts on ground. Battery shows many consumptions linear in tests. Consumption rate is around 3.73%/min, hence the total flight time would be 27 minutes with a full charge.

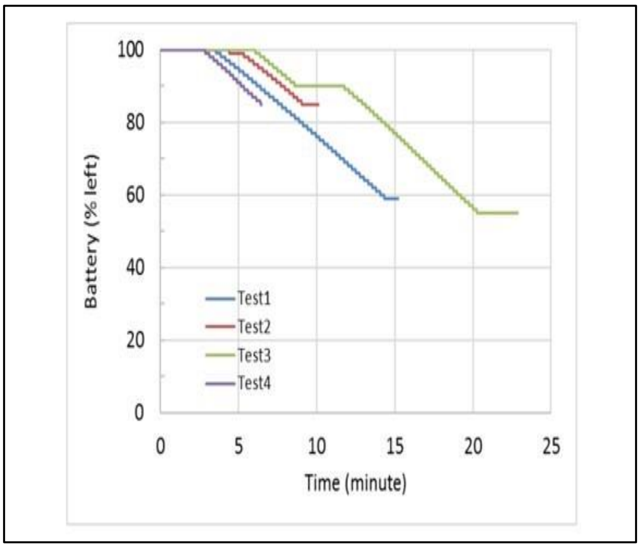

Fig 4: Graph of Battery Life Over Time for Each Test

IV. CONCLUSION

Unmanned Aerial Vehicles or drones can be used to a great extent in combating air pollution. In their various operational uses from environmental sensing to greener supply chains, UAVs present unique solutions to some of the biggest environmental issues of the current generation. Because of the ability to efficiently gather data in distant or inaccessible locations and the ability to lessen reliance on conventional transportation sources that contribute to air pollution, UAVs can help to cogently and non-cogently decrease emissions and enhance air quality. However, there are many issues associated with the use of UAVs in environmental sectors at large. The challenges include; technical barriers, legal frameworks, and infrastructure in order to enhance the use of UAVs in pollution control. However, it must be also noted that the potential of UAVs in terms of minimizing air pollution is still colossal. So as technology develops and legal requirements change UAVs will become an essential part of our fight for a cleaner planet.

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