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UTILIZING E-WASTE TO DEVELOP POLLUTION-SENSING DRONES TO MITIGATE URBAN HEAT ISLANDS IN DELHI

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Abstract - *Urban heat islands (UHIs), characterized by elevated temperatures in urban areas compared to rural surroundings, pose significant environmental challenges, especially in densely populated cities like Delhi. Some contributing factors include infrastructure that retains heat, vehicular emissions, and limited vegetation. Simultaneously, the improper disposal of electronic waste (e-waste) worsens environmental degradation. This research explores the innovative use of e-waste to develop pollution-sensing drones that monitor environmental parameters and contribute to UHI mitigation strategies in Delhi. The drones can be constructed using components reused from e-waste, such as motors, sensors, microcontrollers, and communication modules. Equipped with advanced pollution sensors, these drones can detect particulate matter (PM2.5 and PM10), greenhouse gases (CO_2, CH_4), volatile organic compounds (VOCs), and other air pollutants. Thermal imaging capabilities assess urban heat zones, vegetation health, and the efficiency of cooling interventions like green roofs and reflective materials, further helping mitigate UHI. By identifying pollution and thermal hotspots, these drones can facilitate data-driven urban planning and targeted interventions to reduce heat absorption and pollution. This paper demonstrates the feasibility of recycling e-waste to address the two crises - urban heat and pollution. This approach offers scalable solutions by integrating e-waste management, real-time monitoring, and urban planning, contributing to effective UHI mitigation in Delhi. The findings can underscore the potential of pollution-sensing drones derived from e-waste as a cost-effective, eco-friendly tool for urban resilience, especially in cities like Delhi, where rapid urbanization worsens the UHI effect.*

Key Words: **E-Waste, Pollution-Sensing Drones, Urban Heat Islands (UHIs), Air Pollutants, Delhi**.

1.INTRODUCTION

Urban Heat Islands (UHIs) are localized areas within urban environments that exhibit significantly higher temperatures compared to their rural surroundings. This phenomenon arises due to various factors such as heat-retaining infrastructure, dense vehicular emissions and limited vegetation [1] [2] . Cities such as Delhi, which are undergoing rapid urbanization coupled with a dense population, are particularly susceptible to UHIs, exacerbating adverse effects on public health, energy consumption, and environmental quality [3] .

At the same time, the improper management of electronic waste (e-waste) shows a growing environmental challenge. E-waste contains valuable materials like metals and plastics, which, if disposed improperly, release hazardous substances into the environment, contributing to pollution and resource wastage.[4] [5]

The global surge in e-waste generation has necessitated innovative approaches to its sustainable management [6].This research addresses these interconnected challenges by proposing a novel approach: the utilization of components recovered from e-waste to develop cost-effective and eco-friendly pollution-sensing drones. These drones will be designed to monitor important environmental parameters, including air pollutants such as PM2.5, PM10, greenhouse gases (CO_2, CH_4, NO_x), and volatile organic compounds (VOCs), as well as identify thermal hotspots through thermal imaging[7][8] . Such capabilities make drones a promising tool for understanding the spatial and temporal distribution of pollutants and heat anomalies that increases the UHI effect.

By using motors, sensors, microcontrollers, and communication modules recovered from e-waste, this research aims to demonstrate the feasibility of creating low-cost monitoring solutions. Also the data collected by these drones can serve as valuable and important input for urban planners to implement targeted UHI mitigation strategies, such as increasing urban vegetation, incorporating reflective building materials, and optimizing city layouts[9][10] .

This study, while theoretical, highlights a scalable and sustainable approach to addressing urban environmental issues. By bridging the gap between e-waste management and advanced monitoring technologies, this research offers a pathway to enhance urban resilience in rapidly expanding cities like Delhi [11] [12].

2. METHODOLOGY

2.1. E-Waste Sourcing and Segregation

In a crowded and busy city like Delhi, e-waste is everywhere—from old computers and smartphones gathering dust in homes to piles of discarded electronics in landfills. This study explores how these materials can be given a second life by reusing them for building drones.

The idea is simple-source e-waste from places like recycling centers, collection drives, or even large bins and landfills.

Once collected, the focus shifts to identifying components that can be salvaged like motors, circuit boards, sensors, batteries, and microcontroller parts that can be extracted and transformed into essential building materials for drones. As highlighted by Cucchiella[13] recycling not only reduces the burden on landfills but also creates an opportunity to recover valuable resources in a cost-effective way.

Then, these components must be sorted out based on their functionality and compatibility with the drone's design and structure. This ensures that every piece, no matter how small or big it is, plays its part in creating a fully functional drone. It's about finding value in what's been discarded and turning waste into something that helps us solve real-world problems, like pollution and urban heat islands, which Delhi struggles with daily.

Figure – Collection of E-Waste in East Delhi

Figure 1 -shows e-waste collection in East Delhi. (Source-indianexpress)[Ewaste collection, Delhi, indianexpress

2.2. Drone Design and Assembly

This conceptual stage involves designing the drone's framework and integrating the components salvaged from e-waste.

- **Frame Design:** Lightweight materials like repurposed aluminum and plastic from e-waste can be proposed for constructing the frame.
- **Component Integration:** Theoretical integration of motors, sensors (air quality, thermal imaging), microcontrollers, and communication modules into the drone design.
- **Power Supply:** Recycled batteries from e-waste may serve as the primary energy source for the drone.

Figure 2- A sensor based drone for pollutants detection

[A Sensor-Based Drone for Pollutants Detection... Roberto De Fazio, Leonardo Matteo Dinoi, Massimo De Vittorio Paolo Visconti] **[14]**

In the above Figure 2, the lower end of the drone is used to host a Sensing Section. That section incorporates advanced sensors that are sensitive to particulate pollutants, including PM2.5, CO_2, NO_x, CH_4, and SO_x. These sensors can be used to produce maps of the spatial distribution of pollution alongside the mobility of drones. Air Intakes (2) play a very important role in sampling ambient air during the flight. Thus, at different heights and zones of interest such as industrial, traffic-dense areas, and residential societies, the pollutant levels are being recorded accurately. The IR Camera (3) further adds functionality for thermal imaging for heat mapping, directly related with the effects of Urban Heat Island (UHI) [15]. The IR camera can capture temperature variations across zones and identify hotspots worsened by pollution and heat retention in materials like asphalt and concrete. Moreover, the integration of sensors into drones to monitor UHIs and analyze temperature patterns is built on the research by Santamouris [16] This ensures that the drone design not only can capture pollution levels but also contributes to a more comprehensive understanding of urban environmental challenges. Also, the Electret Microphone (4) helps to monitor noise pollution, which often coincides with vehicular density and industrial zones that are key contributors to overall environmental degradation especially in Delhi.

2.3. Calibration of Sensors

To ensure the drones give accurate and reliable data, it's very important to properly set up and maintain their sensors. These drones use a variety of sensors, like air quality sensors to measure air pollutants like PM2.5 and PM10, gas sensors to detect harmful gases such as CO, SOx, and NOx, and thermal sensors to identify heat-retention

areas in urban land. Each sensor plays an important role in painting a complete picture of environmental challenges like pollution and urban heat.

Calibration is the process of fine-tuning these sensors so they give precise readings. For example, in Delhi's winter months, pollution (especially air) increases due to stubble burning in Punjab which causes smoke to travel in Delhi through air pressure and weather conditions like smog. If the air quality sensors on drones aren't calibrated correctly, they might underestimate or overestimate pollutant levels, leading to poor decision-making. Similarly, thermal sensors used to map and identify heat-stressed zones in cities need to be regularly adjusted, especially in extreme weather. Guttikunda and Gurjar [17] highlighted the critical role of accurate data in understanding urban air pollution dynamics, particularly in cities like Delhi, where complex air pollution sources such as stubble burning and vehicular emissions interact. A real-world example can be seen in cities like Los Angeles, where drones equipped with gas sensors have been used to detect methane leaks. The success of such projects shows the importance of well-calibrated sensors that deliver actionable, real-time data.

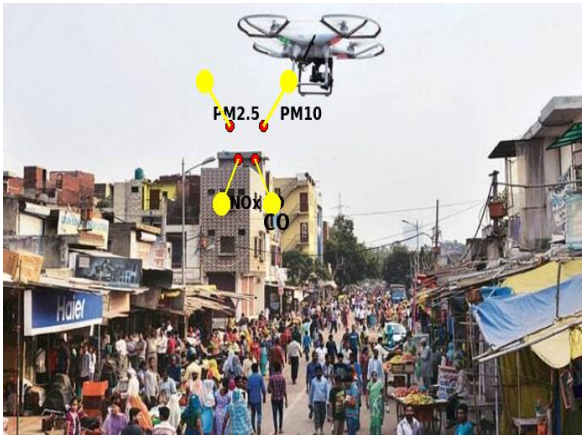
2.4. Simulated Environmental Testing

To evaluate the potential performance of the drone design, theoretical simulations could be conducted in virtual or controlled environments.

Data Collection: Propose methods for the drone to gather data on air pollution levels & thermal imaging.

Simulation Setup: Hypothetical creation of a small-scale urban layout with heat sources, vegetation patches, and pollution emitters.

Figure 3 – Deployment of pollution sensing drones



The above Figure3 depicts a view of the deployment of pollution-sensing drones whose objective is to monitor and analyze atmospheric pollutants, which include carbon monoxide (CO), particulate matter 2.5 (PM 2.5), particulate matter 10(PM 10) nitrogen oxides (NO_x), etc by using thermal and gas sensors. In the context of Delhi- a city facing severe air pollution due to vehicular emissions, industrial activities, and seasonal impacts like stubble burning, this simulation is a very important method for obtaining data that could be used by policy makers and environmental engineers to combat UHIs effect in Delhi.

Drones with gas detection sensors and infrared imaging sensors in this controlled testing environment are able to fly at varied altitudes over the key hotspots, such as industrial areas (Narela, Bawana), congested roads (Ring Road, Anand Vihar), and even residential neighborhoods. These drones can produce spatial heat maps showing the pollutant distribution, which can be then visually represented, to pinpoint local sources of pollution. For example, high levels of NO_x and CO_2 in highly trafficked areas/regions or industrial centers may indicate significant emissions, and therefore, policymakers can target their interventions at traffic management or emission reduction. Studies, such as those by Li and Bou-Zeid [18], shows the importance of leveraging such data to understand urban microclimates and heat retention, while we also see the role of drones in providing real-time localized insights for urban environmental management [19]

2.5. Cost Analysis and Sustainability Assessment

When looking at the costs involved in this project, it's important to break things down step by step. First, we can think about the expenses to collect e-waste, building the drone, and adding the necessary sensors. While this is just a hypothetical scenario, these figures give a sense of what similar efforts might require in the real world. Addressing UHI through targeted methods like green infrastructure and sustainable urban planning is important for improving the comfort and environmental health of cities. [20]

On the sustainability side, we can look at measurable impacts, like the percentage of recycled materials used in the drone and how much e-waste is being diverted from landfills in Delhi. Additionally, there's the potential environmental benefit i.e. reducing the Urban Heat Island (UHI) effect and air pollution in a way that directly impacts urban living conditions.

3. Results and Discussion

This section delves into the theoretical outcomes derived from the proposed methodology for designing pollution-sensing drones using e-waste. These outcomes provide insights into the effectiveness of the approach in addressing urban environmental challenges like air pollution and urban heat islands (UHIs).

3.1. Expected Outcomes

3.1.1. Air Pollution Monitoring

The theoretical deployment of drones equipped with air quality sensors could provide granular data on pollutant concentrations (e.g., PM2.5, PM10, CO_2, CH_4, VOCs) across different areas of a city like Delhi. This data can help identify high-risk zones with poor air quality and sources of pollution.

Figure 4 – Bar graph of PM2.5 pollutant conc. In Delhi

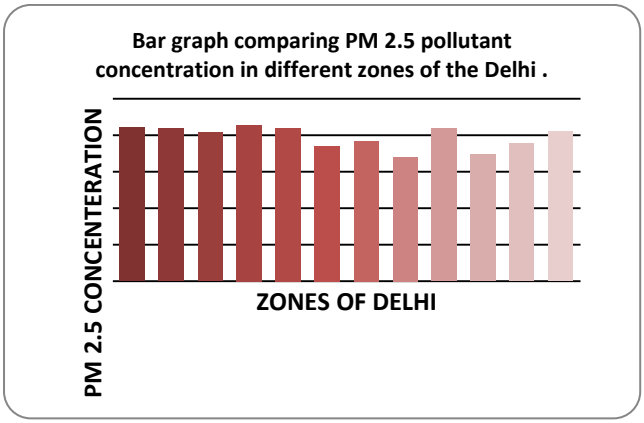


Figure 4- A bar graph comparing PM2.5 pollutants in different zones of Delhi

(Data derived from AccuWeather on December 2024)

A key example is the bar graph (Data derived from AccuWeather on December 2024) [Figure 4] PM2.5 pollutant concentrations across various zones of Delhi reveals critical insights into air quality disparities in the region. The **PM 2.5 concentration bar graph** highlights a concerning reality for Delhi- air pollution levels remain critically high across all zones. With PM 2.5 values ranging from **170 µg/m³** in North Shahdara to a staggering **214 µg/m³** in Karol Bagh, every part of the city far exceeds safe air quality limits. Areas like **Karol Bagh**, **Central Zone**, and **Keshav Puram** stand out as some of the worst affected, reflecting the impact of heavy traffic, construction dust, and industrial emissions. This is where **pollution-sensing drones** could make a real difference. Equipped with **air quality sensors** derived from **e-waste**, these drones can fly across Delhi's zones and measure PM 2.5 concentrations in real time. Unlike static monitoring systems, drones can cover a **wider area** quickly and identify pollution hotspots that are often missed, such as congested roads, construction sites, and industrial pockets. The data collected by these drones can be turned into **pollution heat maps**, offering a clear, visual representation of which areas need urgent attention. For example, zones like Karol Bagh and West Zone—where pollution levels are consistently high—could be prioritized for measures like better traffic control, dust management, and creating more green spaces.

These drones could also help us understand how pollution behaves across different parts of the city by capturing data at different altitudes, providing a more complete picture of the air we breathe. By giving policymakers this kind of actionable, real-time data, pollution-sensing drones could play a key role in tackling Delhi's air quality crisis and improving the lives of its residents.

3.1.2. Urban Heat Island Analysis

The integration of thermal imaging sensors within the proposed pollution-sensing drones,aims at supporting *comprehensive* hotspot *temperature* exploration *in* cities, which can then aid in adequate *urban heat island analysis. The* designed *drones* can recognize *and map* high- *land, surface* temperature regions, giving useful information *for planners* on interventions *such as* enhanced greenery *or reflective* materials to mitigate heat stress.*A* strong evidence for the growth *of UHI is* provided *in* land surface temperature maps of Delhi from the years 2014 to 2022 (Figure 5). These are obtained from the Centre of Environment Sciences, which exhibit *the* growing strength *of UHIs overtime* along *with* increasing size *and* area *of* hot *zones. Such data* underlines *the need* to develop *real-time monitoring systems* such as *pollution-sensing drones* which complement existing research and drive *mitigation measures.* LST *Progression in Delhi 2014–2022:* Graphical *representation of UHI intensification* Source:
CSE urban heat stress Delhi

[Figure 5] - Urban heat stress over a period of 5 years

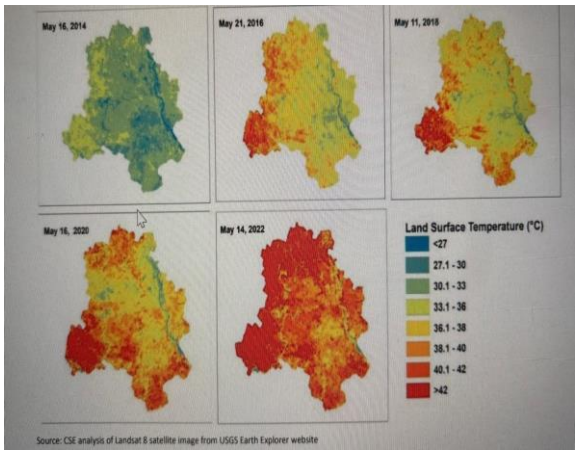


Figure 5 – Urban stress heat map in Delhi over 5 years

3.2. Feasibility and Practicality

The proposed methodology is feasible and scalable. The method applied here uses parts from electronic wastes, hence addressing financial constraints while advancing environmental sustainability. Drones made of recycled materials offer inexpensive yet functional means of intensive environmental monitoring, especially about the Delhi case. Applications of low-cost drones already exist in developing countries, like India and Kenya, where air quality measurement in informal settlements is observed, which proves the functionality of drone designs based on e-waste.

This further means that the scalability of drone systems can cut across cities with different monitoring needs. The adaptability of e-waste components will ensure that the system is specialized to collect environmental and meteorological data for certain urban heat zones. Some examples are the drones that monitor UHI patterns in cities like Tokyo in Japan have shown how local temperature data can be used to inform mitigation strategies like urban greening and reflective surfaces.

3.3. Theoretical Implications

This research can change the manner in which we practice urban management and can also improve environmental conservation practices. For example, information gathered by these drones could help urban planners determine regions with the highest pollution levels and heat. After that, they can design various strategies such as increasing the coverage of tree canopy or reducing vehicular traffic at specific locations or adopting green roofing systems to reduce temperatures. Cities like New York have already used similar ideas and started to cut down the heat in their urban areas by focusing on green projects.

The drones can also help in making better laws and rules. Since the data they provide is real-time and specific to each location, it can guide policymakers to design smarter rules for different zones. For example, if a drone indicates elevated pollution levels in a specific location, traffic restrictions or more strict pollution regulations may be implemented precisely where they are most required. This type of strategy can enhance the effectiveness of urban management practices.

3.4. Challenges and Limitations

Incorporation of components from electronic waste into pollution sensing drone systems is filled with many challenges, particularly regarding the compatibility of such components. For example, electronic waste recovered from obsolete devices often has variable quality, which can lead to failure during operation. Another instance is that drones may be deployed in the pollution hotspots of Delhi in which PM2.5 and PM10, and harmful gases like SO_2 and NO_2, increase the degradation of recovered material. Also, the issue of precision of sensors has been observed since environmental monitoring is heavily reliant on fine calibration. Various Studies in Delhi have also shown that repeated temperature fluctuations and high humidity levels can also distort sensor readings which result in data that is not reliable. Moreover, this research is still largely theoretical, and it needs pilot tests to establish the feasibility and practicality of such systems in real life. One example is the thick urban texture and high electromagnetic interference in the industrial zones of Delhi would make it even more challenging to deploy such drones in practice.

3.5. Future Directions

This proposed approach in my opinion holds a huge potential for innovation, which can open up vast development opportunities in urban environmental management sectors of city and eventually the country.

Imagine the busy streets of Delhi and industrial areas of the city that are filled with AI- powered drones, sensing pollution metrics, and even maki ng predictions. These smart drones might be able to help the administration prepare and solve issues even before they even escalate, like reducing dips in air quality during the smoggy winter season, managing heat stress in the most populous areas or developing tactics to control air pollution during Diwali Finally, why stop at Delhi? We can extend this concept to other cities like Mumbai or Bengaluru, and the difference could be transformational. Each city has its own challenges- from the coastal humidity of Mumbai to the tech-driven sprawl of Bengaluru. Testing these drones in all these cities will help develop the technology enough to make it versatile for use in cities around the world, building a future where urban life and environmental health can go hand in hand.

Data Availability

The data supporting the findings of this study are available upon request from the corresponding author, subject to reasonable requests.

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