



Particular Matter Monitoring at a Local Quarry

FLIGHT RESOURCE CENTER

Training 2000



Co-funded by
the European Union

Table of Contents

Table of Contents

SHORT DESCRIPTION

SUBJECT AREA

TYPE

DRONE USED

DURATION

LEARNING OBJECTIVES

KEY COMPETENCES DEVELOPED

1. Communication and Languages
2. Mathematical, Scientific, Technical and Professional Skills
3. Digital Competences
4. Personal, Social and Professional Competences
5. Safety, Quality and Sustainability
6. Citizenship and Cultural Competence
7. Creativity, Problem-Solving and Entrepreneurship
8. Work-Based Learning and Workplace Integration

Prior Knowledge

Project Outline

Phase 1 – Introduction (Engage & Contextualize)

Phase 3 – Application (Hands-On Practice)

Phase 4 – Reflection & Consolidation (Present & Connect)

Assessment Criteria

Teaching Materials

External Resources

Particulate Matter (PM) Basics

References



SHORT DESCRIPTION

This project guides students in deploying a commercial DJI drone equipped with a specialized payload to evaluate particulate matter distribution across an active surface excavation site specialized in extracting gravel, sand, clay, and kaolin.

Students investigate air quality across three specific areas of interest: the entrance buffer zone located just outside the working perimeter, the central transport corridor where heavy haul trucks stage and transit, and the perimeter around one of the excavated ground pits. Using a commercial drone with a custom-attached sensor enclosure allows students to safely collect real-time particulate data (PM1.0, PM2.5, PM10) above hazardous terrain while assessing how operational site conditions, stationary machinery, and material extraction influence localized dust levels.

TARGET

- 15
- 16
- 17
- 18
- Over 18

SUBJECT AREA

- Agriculture
- Disaster Response
- Constructions
- Water Management
- Environmental Protection
- Other



TYPE

- Lesson Plan
- Project
- Activity

DRONE USED

- Custom Drone
- Commercial drone (DJI)

DURATION

- 1 x 45-minute class
- 1 x 60-minute class
- 1 x 90-minute block
- 2 x 45-minute classes
- 2 x 60-minute classes
- Double session (2 × 60 minutes) optional project-based homework.

LEARNING OBJECTIVES

O1: Measure and compare particulate matter concentrations (PM1.0, PM2.5, PM10) across distinct quarry operational zones.

O2: Execute a safe, manual flight path around industrial infrastructure.

O3: Process and visualize sensor data collected with the payload.

O4: Evaluate industrial dust generation and site containment performance.



KEY COMPETENCES DEVELOPED

1. Communication and Languages

- Literacy competence (understanding and producing written/oral texts)
- Communication in professional contexts
- Multilingual competence

2. Mathematical, Scientific, Technical and Professional Skills

- Mathematical competence
- Scientific, technological and engineering competence (STEM)
- Numeracy applied to work tasks
- Interpretation of technical information (manuals, diagrams, standards)
- Professional/technical skills
- Execution of practical tasks

3. Digital Competences

- Digital competence (general digital literacy)
- Use of digital tools in workplace settings

4. Personal, Social and Professional Competences

- Personal, social and learning-to-learn competence
- Teamwork and collaboration
- Autonomy and responsibility
- Work ethics and professional behaviour
- Adaptability and flexibility
- Cooperation with supervisors and colleagues



5. Safety, Quality and Sustainability

- Application of health and safety standards (OHS/SST)
- Quality procedures and workplace norms
- Environmental and sustainability awareness

6. Citizenship and Cultural Competence

- Citizenship competence
- Cultural awareness and expression competence

7. Creativity, Problem-Solving and Entrepreneurship

- Problem-solving and critical thinking
- Entrepreneurship competence
- Initiative and creativity
- Decision-making in real work situations

8. Work-Based Learning and Workplace Integration

- Integration into workplace routines
- Following professional instructions and procedures
- Use of tools, equipment and technology

This checklist merges the EU Key Competences for Lifelong Learning with the core competences expected in European Vocational Education and Training (VET).

Prior Knowledge

Students should have a foundational understanding of drone piloting safety protocols and basic electronics, including experience with connecting components on a breadboard. While advanced programming knowledge is not required for this project, a working familiarity with the Arduino IDE is highly recommended. Specifically, students should be comfortable setting up the IDE for the ESP8266 board and uploading code to a microcontroller, as detailed in the FLIGHT KIT handbook materials.

Basic understanding of Particulate Matter and concentration levels ($\mu\text{g}/\text{m}^3$) will help students interpret their data.



Project Outline

Phase 1 – Introduction (Engage & Contextualize)

Students examine the core sensing payload: a Laser PM2.5 Sensor. This device utilizes light scattering technology inside an optical sampling chamber to determine the mass concentration of airborne particulates ranging from 0.3 to 10 micrometers μm in diameter. The sensor evaluates three distinct particle size fractions simultaneously:

- PM1.0: Ultrafine particles (0.3 to 1.0 μm)
- PM2.5: Fine particles (1.0 to 2.5 μm)
- PM10: Coarse particles (2.5 to 10.0 μm)

An internal microprocessor decodes the scattered laser signals via an embedded algorithm, translating the raw optical counts into calibrated mass concentration values. These values are transmitted as standard metrics ($\mu\text{g}/\text{m}^3$) within a fixed 32-byte serial data frame.

By executing a manual drone survey across three strategically selected flight points within an active excavation site, students safely capture real-time spatial data on particulate matter pollution. This field exercise provides a clear, practical example of how drone technology and environmental monitoring intersect to map public health safety zones.



Aerial view of the excavation site(Italy). Source: DJI Mini Pro 4

Guiding Questions:

1. How does particulate matter (PM) pollution pose a distinct hazard to human health based on particle size?



Co-funded by
the European Union

2. Why is using a drone to sample multiple points more effective for mapping PM pollution than relying on a single, static ground station?
3. What environmental and operational challenges might a flight team face when operating a drone inside an open excavation area?

4. Phase 2 – Exploration (Investigate & Compare)

In this phase, students move from a general discussion of how particulate matter (PM) pollution is generated and how drones and sensors are used to collect environmental data safely. The goal is to understand the capabilities and limitations of using a drone equipped with an environmental logger.

Students are first introduced to the components of the payload. The trainer explains the role of each element: the Laser PM2.5 sensor, the GPS module and the ESP8266 microcontroller manages data collection, and the SD card stores the data. The following handbooks are good for a better understanding:

- [2.2.1. Getting Started with NodeMCU](#)
- [2.2.2. Environmental Sensing Modules](#)
- [2.2.3 Data Acquisition, Logging and Field Operations](#)

The trainer then introduces the commercial drone and its application for environmental protection using the Laser PM2.5 sensor. Attention is then given to the challenges of attaching a custom payload to a drone. The importance of keeping all safety systems enabled is emphasized, reinforcing responsible and professional drone operation.

Using Google Maps, students identify specific operational target zones to plan an optimized flight route.



Flight plan. Source: Google Earth



In the selected environment, students plan a strategic flight route to capture the particulate matter concentration levels.

- Observation Point 1: Entrance**
 Located just outside the working perimeter, this checkpoint serves as the baseline reference for ambient background air quality before any direct influence from on-site operations. Hovering here allows the system to capture undisturbed environmental conditions and verify whether airborne dust migrates beyond the site's outer boundaries.
- Observation Point 2: Internal crossroads**
 Situated in the middle of the excavation grounds, this area covers the main internal crossroads and staging corridors where heavy haul trucks transit to connect different parts of the facility. Monitoring this point provides data on surface dust generation along unpaved gravel and clay tracks, illustrating the direct air-quality impact of vehicle corridors under operational or idle conditions.
- Observation Point 3: Ground Pit Extraction Crater**
 Positioned directly above and around the deep excavation pit, this point targets active material extraction zones where gravel, sand, clay, and kaolin are cut and removed. Sampling within this area measures the direct airborne release of fine mineral particles from mechanical digging while evaluating how the pit topography helps contain dust plumes locally.

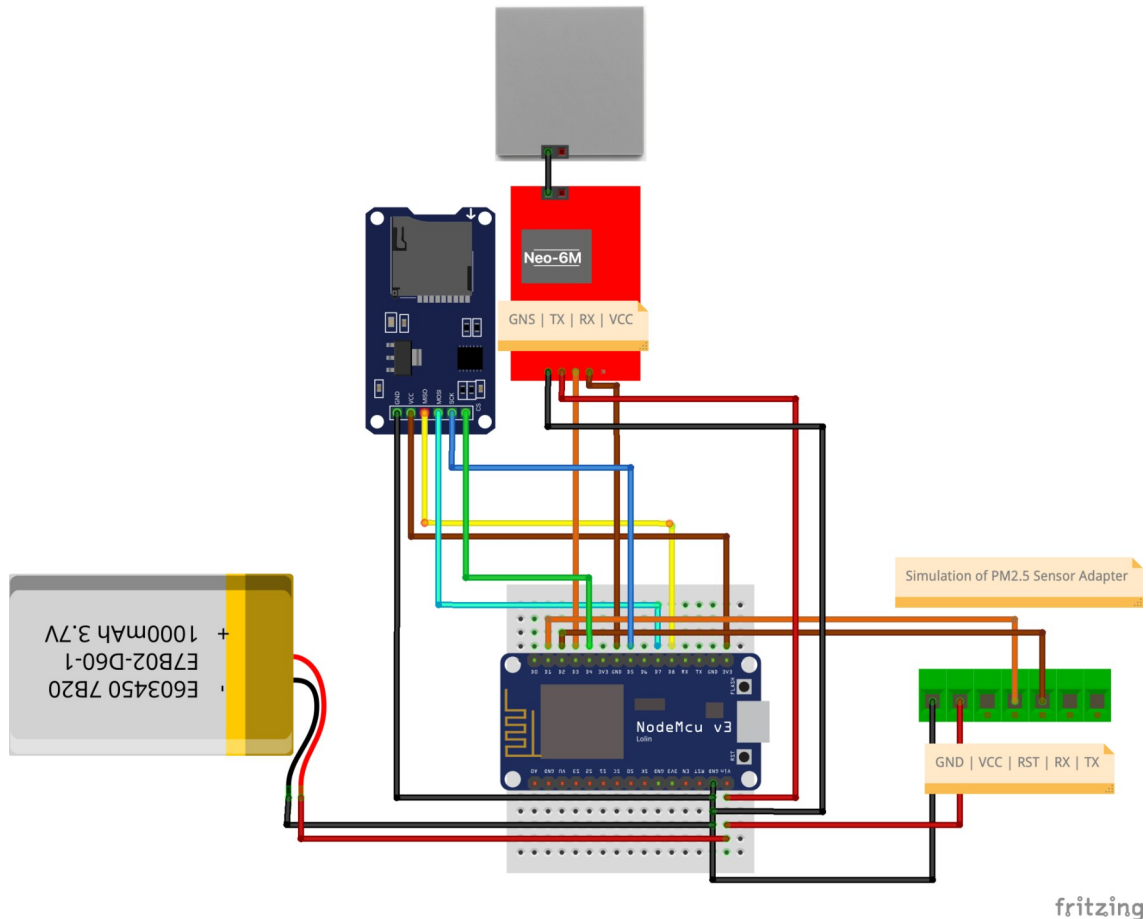


Excavation site panoramic view.

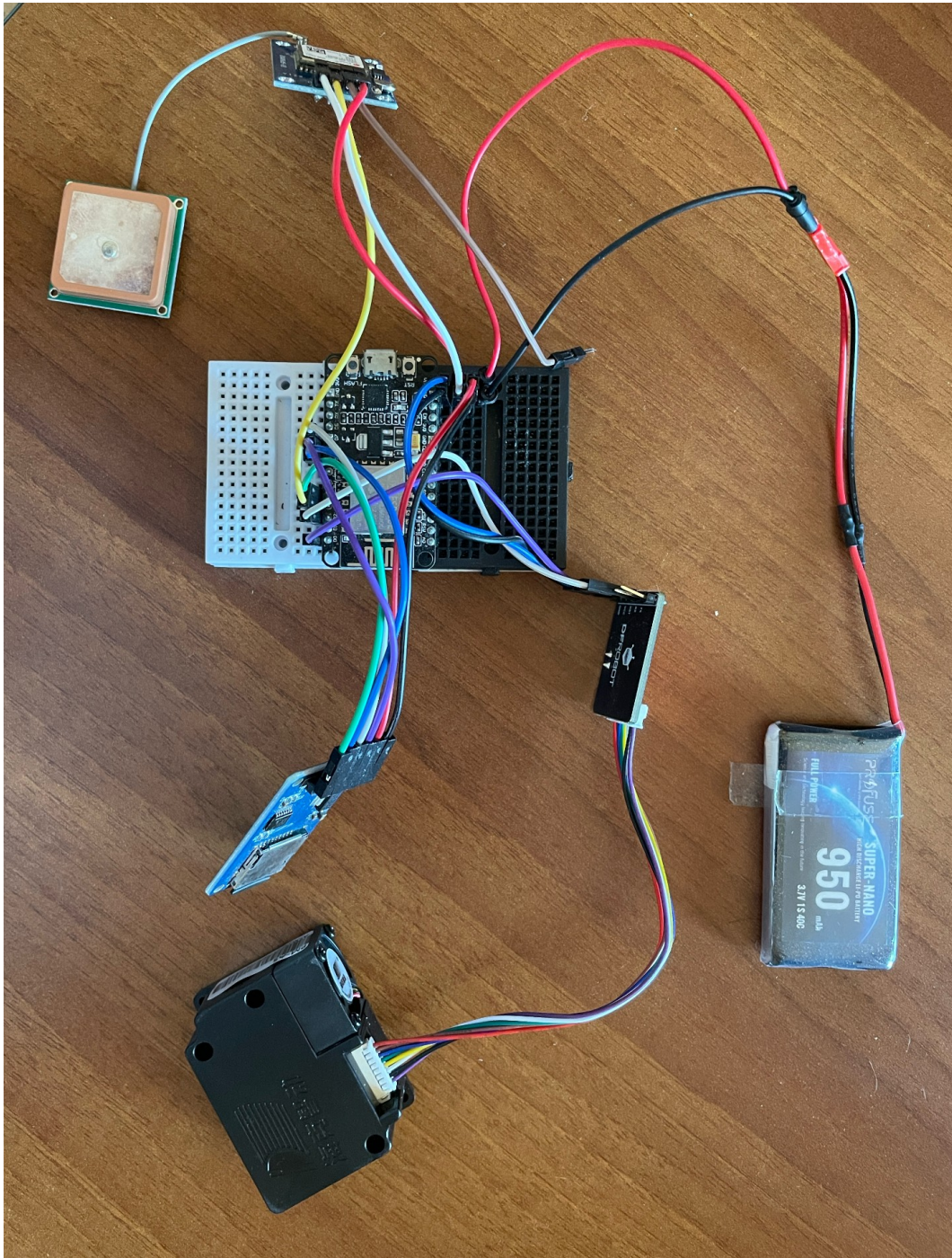
Groups discuss flight height, direction of movement, and points where slower flight may be needed to improve data quality and reduce payload swing. The trainer reminds students to respect EASA limitations for drone flights in “open category”.

Phase 3 – Application (Hands-On Practice)

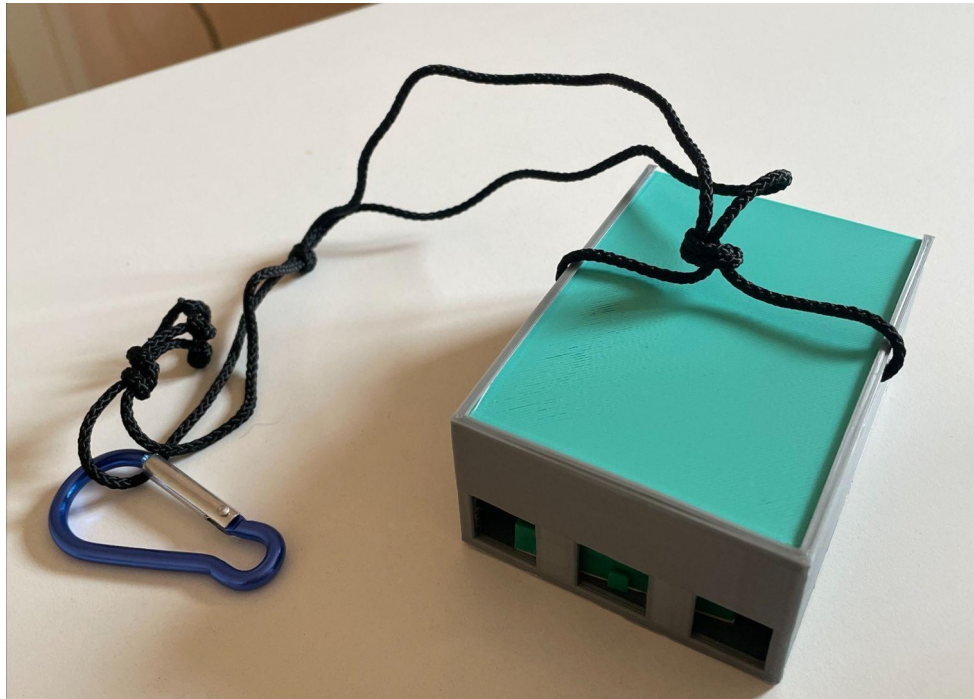
The session begins with a brief introduction to the technical handbooks, which guide students through the setup of the ESP8266, basic sensor testing, and SD card preparation. Using the provided circuit diagram and source code, the trainer explains how ESP8266 connects to the Laser PM2.5 sensor, the GPS module and SD card, focusing on the purpose of each component. Students upload the code and verify that data is being recorded correctly before integrating the system with the drone.



The circuit diagram provided is for illustrative purposes. Due to market availability and different manufacturers, the physical components in your kit may vary slightly in color, shape, or pin arrangement compared to the images. Do not rely solely on visual matching; always read the silkscreen labels printed on your specific modules to ensure correct wiring.



Integration of Laser PM2.5 sensor and assemble drone payload (below)



Assembled drone payload

Students then assemble the payload system to the commercial drone. The payload is secure under the drone with a rope. Another option is to use a plastic threat with a clip to attach the payload to the custom drone.

A pre-flight check is carried out to ensure that the payload suspension is secured, and active data logging.

Field operations are conducted slowly and smoothly along the planned route, using gentle, progressive movements to minimize payload swing. The drone hovers safely at a regulated distance over each designated operational zone to let the sensor stabilize. It is recommended to hold a steady 15-second hover during data logging for more accurate air samples.



Commercial drone with payload.*Observation point 1 - Facility entrance**Observation point 2 - Internal crossroads**Observation point 2 - Drove hovering on the facility internal crossroads*



Observation point 3 - Excavated ground pit



Observation point 3 - Drone hovering on the ground pit

After the flight, the payload is detached, the drone is landed safely, and the SD card is removed. Students transfer the recorded data to a computer.

The following table illustrates the monitoring results recorded in August 2026. The data, recorded by the Laser PM2.5 Sensor, includes PM1.0, PM2.5 and PM10 readings, and is provided to support the creation of a worksheet for trainers to use with students.

Observation Point	PM1.0	PM2.5	PM10
-------------------	-------	-------	------



**Co-funded by
the European Union**

Observation Point 1	2	4	6
	4	4	5
	4	4	5
	5	5	6
	5	5	6
Observation Point 2	4	4	5
	5	5	6
	5	5	6
	3	4	4
	3	3	4
Observation Point 3	4	5	7
	3	4	5
	3	3	3
	4	4	4
	5	5	6
Observation Point	PM1.0 Average	PM2.5 Average	PM10 Average
1	3,310,344,828	4,034,482,759	5,137,931,034



2	3,266,666,667	3,733,333,333	4,633,333,333
3	3,7	4,1	5,166,666,667

The recorded averages indicate low particulate levels across all three observation points, remaining close to clean ambient background conditions throughout the survey. Across Observation Points 1, 2, and 3, values range within narrow intervals for all fractions - approximately 3.3 to PM1.0 for PM₁, 3.7 to 4.1 for PM_{2.5} and 4.6 to 5.2 for PM₁₀.

Phase 4 – Reflection & Consolidation (Present & Connect)

Group Presentations

Each group prepares a short presentation reviewing the main stages of their fieldwork. Students explain the excavation site survey route and present the particulate matter (PM_{1.0}, PM_{2.5}, PM₁₀) data collected across the three monitoring zones. Using comparative tables and charts, they describe the concentration patterns observed, discussing why the entrance baseline, the internal crossroads for trucks, and the extraction pit produced different readings. The focus remains on evaluating localized dust distribution rather than drawing definitive long-term air quality conclusions.

Class Discussion:

After the presentations, the trainer leads a group discussion. Students compare their data logs and identify similarities and differences in the particulate concentration curves across the study zones.

Reflection Activity:

To conclude the project, students complete a short individual reflection supported by written prompts. They reflect on both their technical and environmental learning, including:

- What they learned about mapping airborne particulate matter pollution using drone payloads.
- How piloting with a payload influence flight dynamics, stability, and speed control.
- The role of teamwork, data logging, and systematic data cleaning in successful environmental fieldwork.
- How industrial dust-suppression measures (such as road watering and vegetative buffers) can mitigate health risks for site workers and surrounding communities

Quiz

1. How do optical particulate matter sensors like the Laser PM_{2.5} Sensor detect and quantify suspended dust particles in the air?



- a) a) By passing air through a heated chemical coil and measuring electrical resistance
- b) b) By measuring light scattered by passing particles inside an optical laser chamber
- c) c) By taking high-resolution digital photographs and counting visible pixels
- d) d) By calculating changes in ambient barometric pressure and humidity

2. What does an increase in the output reading expressed in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) indicate?

- a) An increase in flight speed
- b) A decrease in battery voltage
- c) A higher mass concentration of dust suspended in that volume of air
- d) A sudden drop in air temperature

3. Which particle fraction is small enough to travel deep into the lungs and enter the bloodstream?

- a) Coarse gravel dust
- b) Ultrafine particles (PM1.0)
- c) Large pollen grains
- d) Visible sand grains

4. Why must the sensor intake be shielded from direct propeller downwash?

- a) High-velocity rotor airflow disrupts the intake fan's calibrated flow rate
- b) Cold rotor airflow switches off the laser diode
- c) Airflow drains the microcontroller battery prematurely
- d) Propeller draft prevents the SD card from saving data

5. What is the operational purpose of holding a steady 15-second hover during data logging?

- a) To send measurement values to the cloud via Wi-Fi
- b) To stabilize the aircraft and collect an unperturbed, representative air sample
- c) To allow the payload battery to recharge from the drone
- d) To recalibrate the aircraft compass

6. Why was a measurement taken in the buffer zone outside the site boundary?

- a) To establish a clean background baseline before industrial activity influences the air
- b) To verify that the MicroSD card is completely empty
- c) To locate the windiest corridor across the site
- d) To test the maximum flight range of the drone

7. Why is it valuable to measure PM1.0, PM2.5, PM10 simultaneously?

- a) It cuts the sensor's power consumption in half
- b) It helps distinguish between coarse mechanical dust and fine mineral or exhaust emissions
- c) It calculates ambient wind direction automatically
- d) It allows the drone to carry a heavier battery



8. What role does the internal micro-fan play inside the optical laser dust sensor?

- a) It cools the drone's flight controller board during operation
- b) It draws ambient air through the sampling chamber at a constant, calibrated flow rate
- c) It blows dust away from the sensor's external casing
- d) It generates aerodynamic lift to keep the payload balanced

9. Why do analysts filter the raw .csv log to isolate steady hover periods before calculating average concentrations?

- a) Spreadsheet software cannot calculate averages on moving objects
- b) It removes erratic readings caused by drone acceleration and payload tilt during transit
- c) It artificially reduces the final reported pollution levels
- d) It changes the units from parts per million into micrograms per cubic meter

10. What conclusion can be drawn when PM levels across the entire site remain close to baseline levels during a flight audit?

- a) The optical sensor is unable to detect mineral dust like sand and clay
- b) Without active vehicle movement or ongoing mechanical disturbance, surface dust remains well-contained
- c) Airborne dust levels are only influenced by solar radiation and air temperature
- d) The drone hovered too high to encounter any particulate matter

Answers

b — By measuring light scattered by passing particles inside an optical laser chamber

c — A higher mass concentration of dust suspended in that volume of air

b — Ultrafine particles (PM1.0)

a — High-velocity rotor airflow disrupts the intake fan's calibrated flow rate

b — To stabilize the aircraft and collect an unperturbed, representative air sample

a — To establish a clean background baseline before industrial activity influences the air

b — It helps distinguish between coarse mechanical dust and fine mineral or exhaust emissions

b — It draws ambient air through the sampling chamber at a constant, calibrated flow rate

b — It removes erratic readings caused by drone acceleration and payload tilt during transit

b — Without active vehicle movement or ongoing mechanical disturbance, surface dust remains well-contained



Assessment Criteria

Student learning is assessed using the following criteria:

- The student demonstrates a clear understanding that the optical sensor measures suspended particulate matter via laser light scattering, outputting digital mass concentration values directly in $\mu\text{g}/\text{m}^3$. They can explain how sudden increases in readings reflect localized dust generation and distinguish between coarse particles PM10 from mechanical ground disturbance and fine or ultrafine particles PM2.5 and PM1.0 that pose greater health risks.
- The student successfully manages the raw sensor .csv log recorded on the MicroSD card. They correctly filter the dataset to isolate steady 15-second hover timestamps, remove transitional flight turbulence noise, compute arithmetic averages for each monitoring phase, and compare the resulting values.
- The student participates effectively in group work, respecting assigned roles, handling timing logs synchronously, and contributing to shared tasks during field operations and data analysis.
- The student presents information clearly, using visual maps, graphs, and structured data to support their explanations of spatial pollution patterns.
- The student correctly evaluates the potential, environmental implications, and practical limitations of using targeted aerial screening tools to audit industrial dust emissions and assess containment performance.

Teaching Materials

Resource	Link
1. Commercial drone DJI Mini Pro 4	https://docs.google.com/document/d/1WKZLmW6b800Wqem2UvJzkMqQ1JuvwxX/edit#heading=h.ks3mojoi01w6
2.2.1. Getting Started with NodeMCU	https://docs.google.com/document/d/1kQglg533Jtssm3LG2PeQFb5h1b1OKwSLQl-dx8GvcHM/edit?usp=drive_link
2.2.2. Environmental Sensing Modules	https://docs.google.com/document/d/1TaEKu4fmXjR0nPVU_rB5BKxXWu_l-oj9cHaotPzbTBc/edit?usp=drive_link
2.2.3 Data Acquisition, Logging and Field Operations	https://docs.google.com/document/d/19S4BqSk_Rdi75qzwWkpkeVnbtte9otIEB-O9kfYv9Ww/edit?usp=drive_link



2- FLIGHT Kit (custom drone components) used:

- BME680 – Temperature, Humidity, Pressure, VOCs
- Laser PM2.5 Sensor – Particulate Matter
- MQ7 Gas Sensor – CO Detection
- GUVA-S12SD – UV Intensity

External Resources

Resource	Link
Particulate Matter (PM) Basics	https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

References

