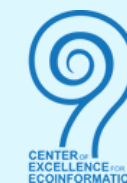# Impact of Incremental Incense Stick Consumption on PM2.5 Loading: Implications for Indoor Air Quality

Miss Montita Nanakhon, Master Thanissorn Seanpakdee, Master Paphangkorn Kaewareelap, Master Pavarut Jitprakob, Master Panat Chaowalit, Miss Achitaa Tarachusong, Miss Nawinda Keereenast, Miss Patcharaporn Udomdee, Miss Supichaya Sornjeen, Miss Alina Warawong, Master Shane Natthaphoom Garder, Miss Thipsakul Makchit, Miss Nattakan Choosang
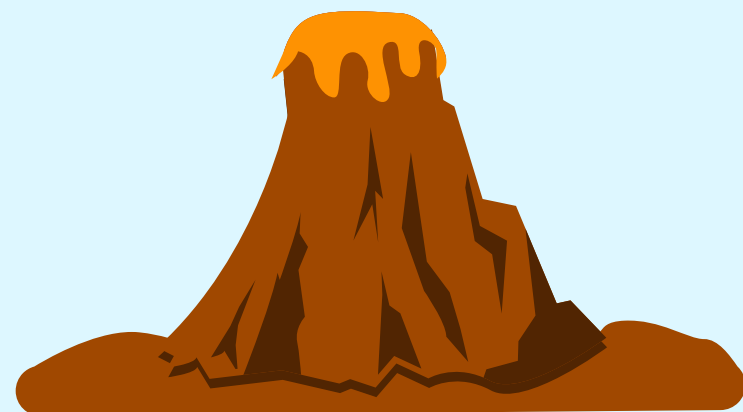
Srithammaratsuksa School
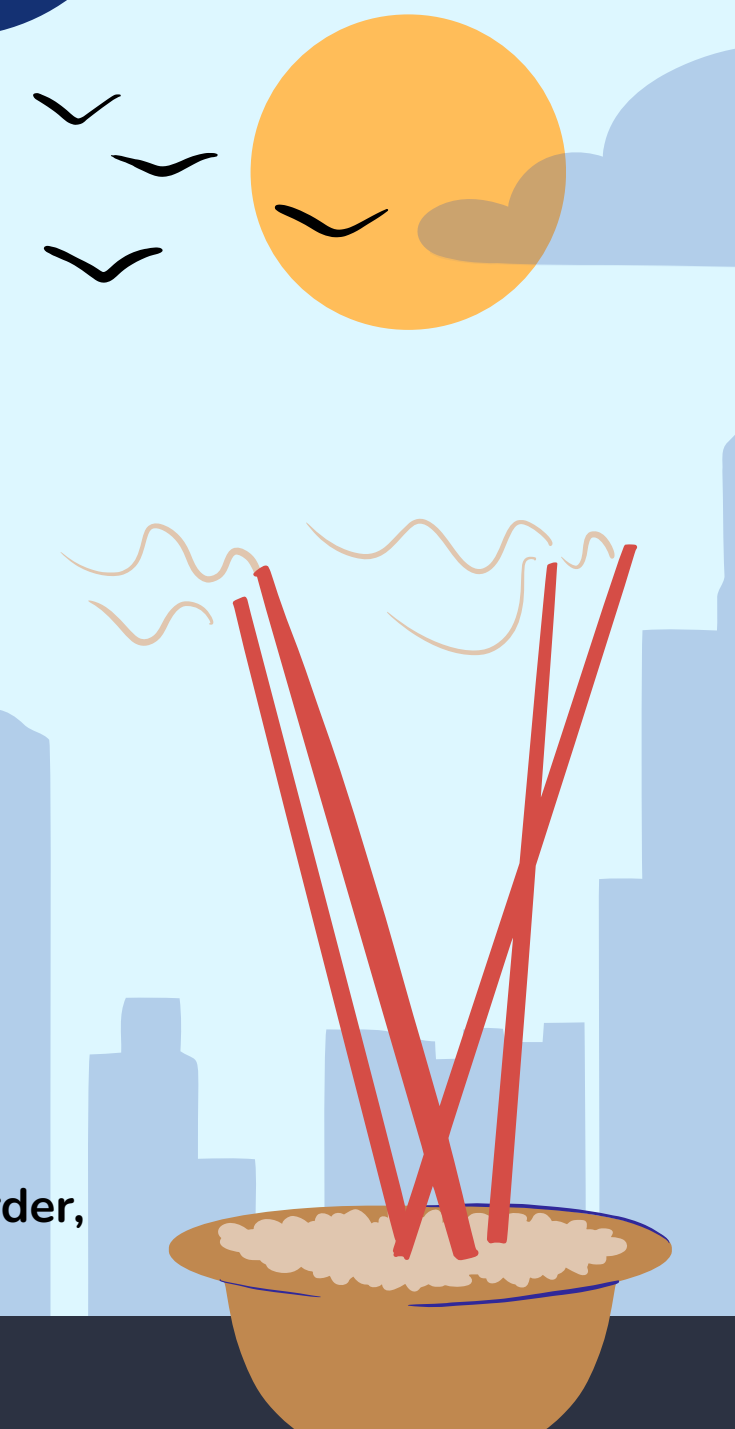
INTRODUCTION
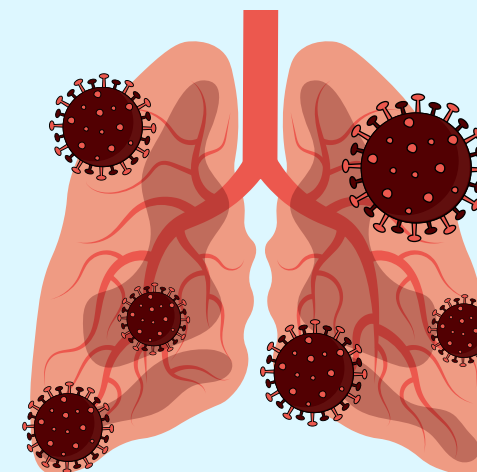
Natural Sources

Vocanic Eruptions

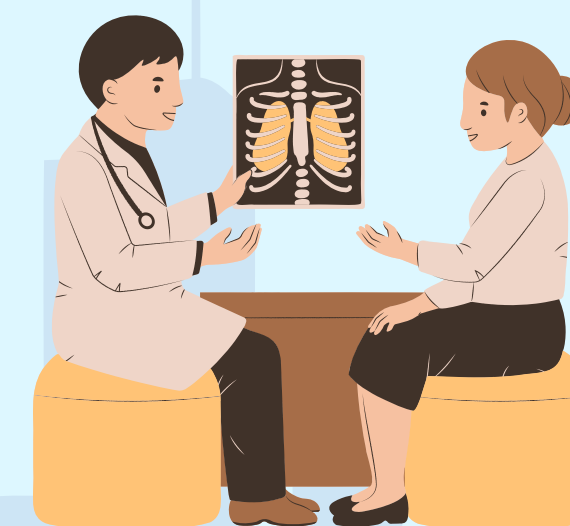**Forest Fires**

Dust Storms

Repiratory Diseases

Chronic Bronchitis

Asthma

Lung Cancer

INTRODUCTION

Man-Made Sources

Burning Fossil Fuels
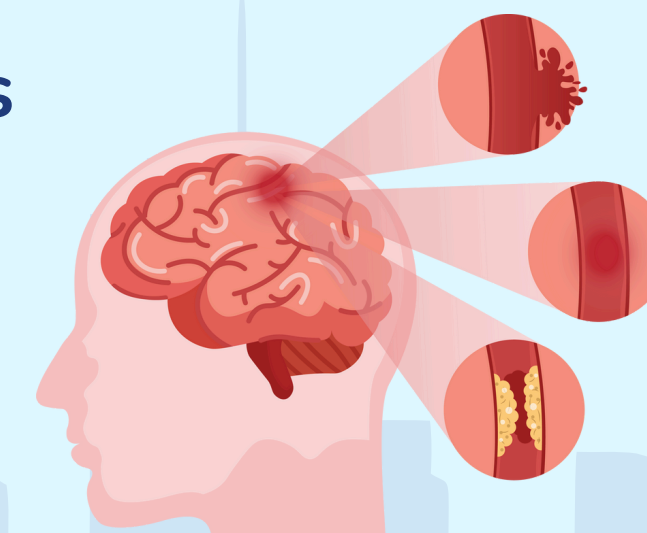
Constrution Sites

Industrial Activities

Burning Incense Sticks

Heart Diseases
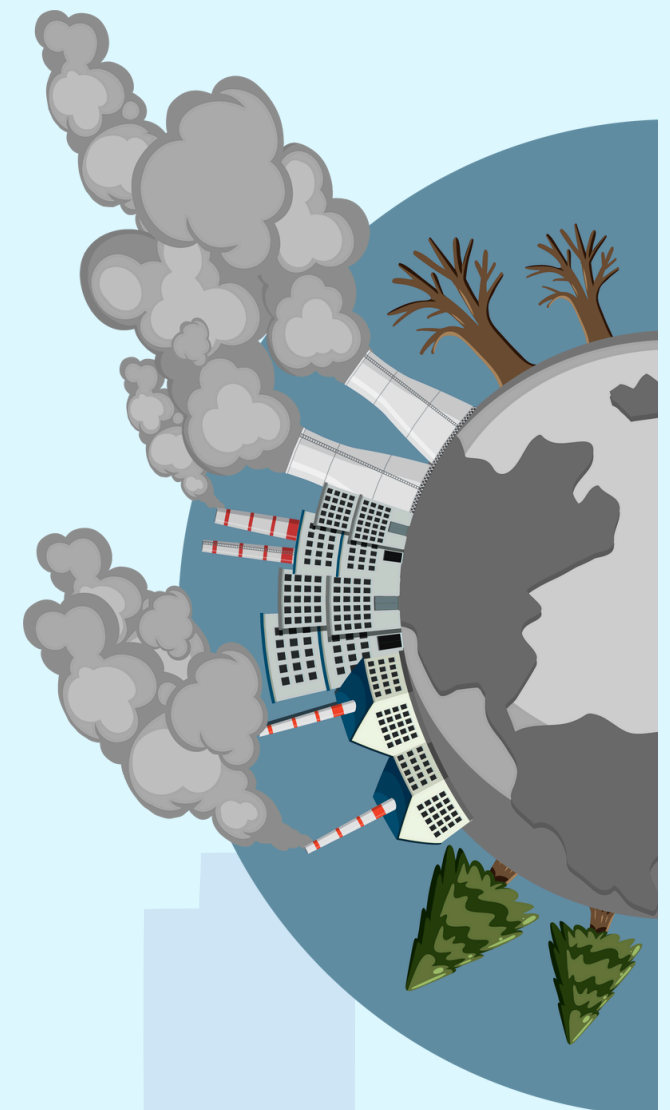
Heart Attacks

Stroke

HOW DOES PM2.5 AFFECT OUR HEALTH?

PM2.5 pollution affect 10 million people worldwide

Kill **30,000** people/year in Thailand

Thailand ranked 10th PM2.5 in Asia

HOW DOES PM2.5 AFFECT OUR HEALTH?

Lung Cancer

Pneumonia
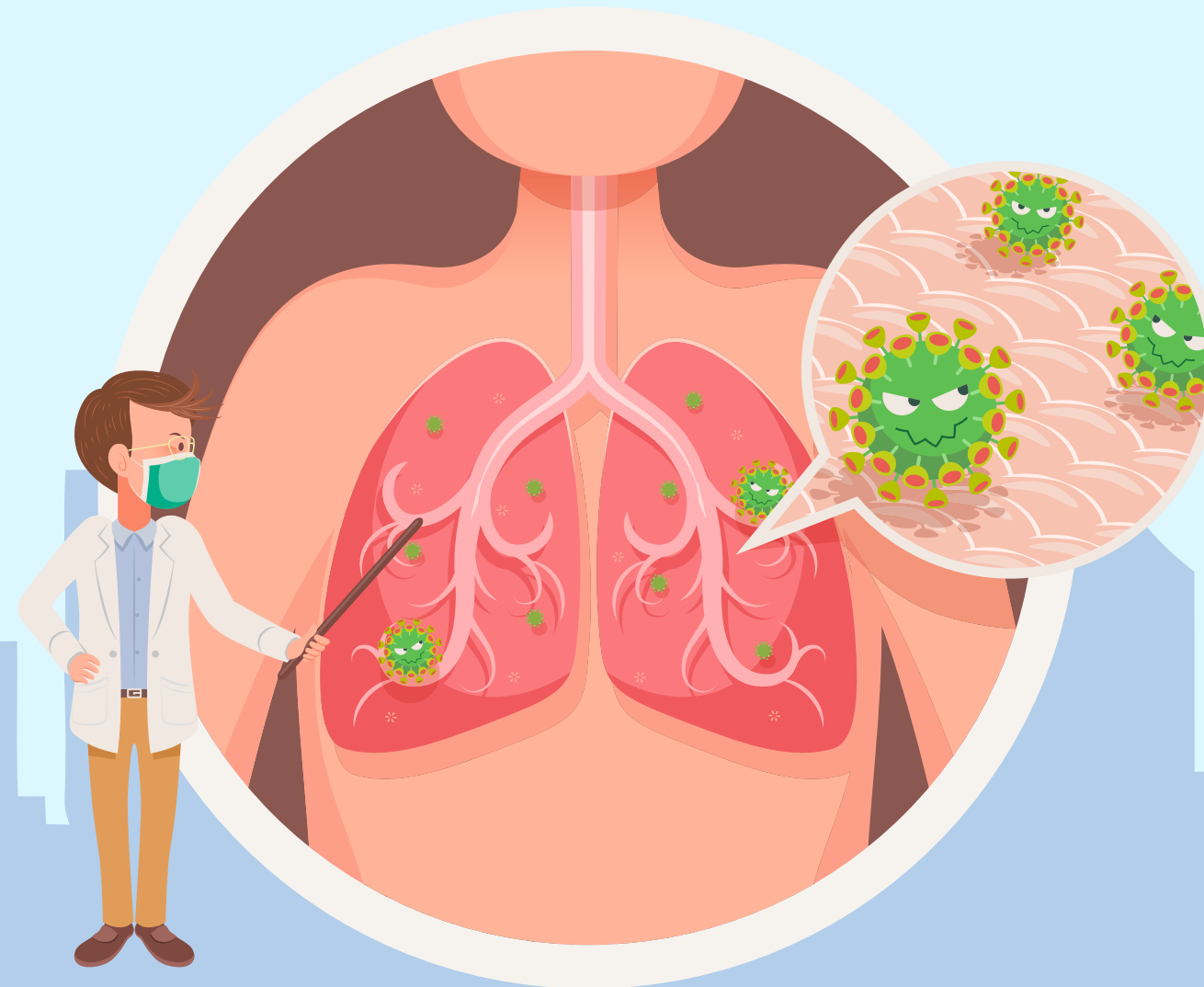
Throat Cancer

OBJECTIVES
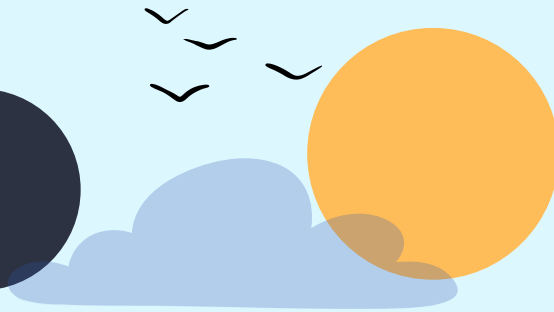
- To quantify and compare the impact of incremental incense stick consumption (2, 5, and 9 sticks) on PM2.5 mass loading within a controlled indoor environment.

- To analyze the dynamic accumulation and persistence patterns of PM2.5 over a fixed temporal scale to identify the rate of indoor air quality degradation.

- To assess the implications for indoor air quality and public health by comparing recorded concentrations against international safety standards (AQI).

EXPERIMENTAL DESIGN

HOW DOES THE NUMBER OF INCENSE STICK AFFECT THE AMOUNT OF PM2.5 IN THE AIR?

IoT PM2.5 01

IoT PM2.5 02

DATA ANALYSIS

EXPERIMENTAL DESIGN

Impact of Incremental Incense Stick Consumption on PM2.5 Loading:

Implications for Indoor Air Quality

PM2.5 Sensor 1

PM2.5 Sensor 2

Incense Sticks (2) (5) (9) Incense Sticks

Incense Sticks (2) (5) (9) Incense Sticks

- 0-15 min

1 Min reading interval

- 0-15 min

1 Min reading interval

Statistical Analysis

(1) One-way ANOVA

- 2, 5, 9 Incense Sticks
- PM2.5 Sensor 1 VS Sensor 2

(2) Regression

- Linear Regression between Time and Incense Sticks
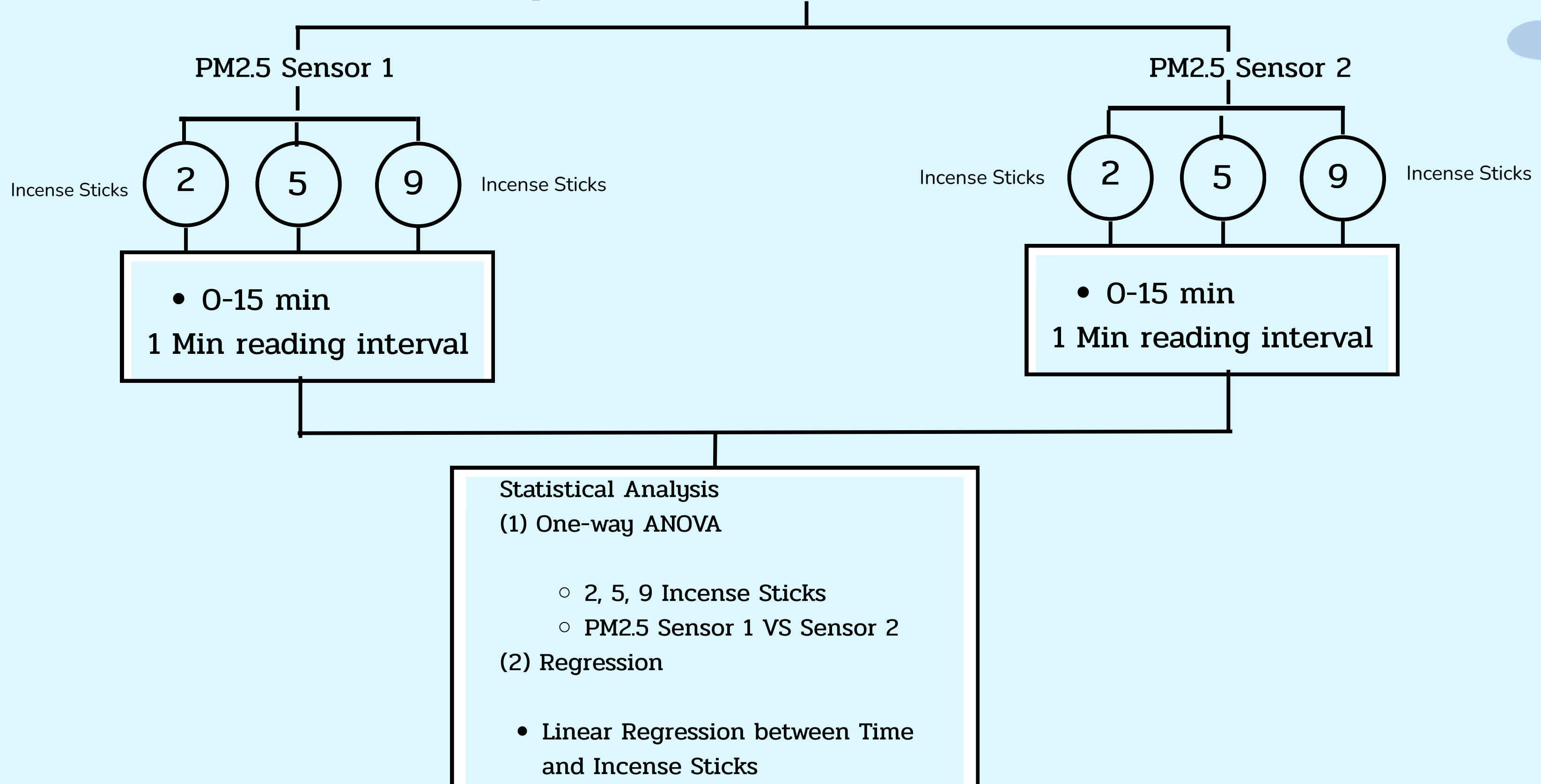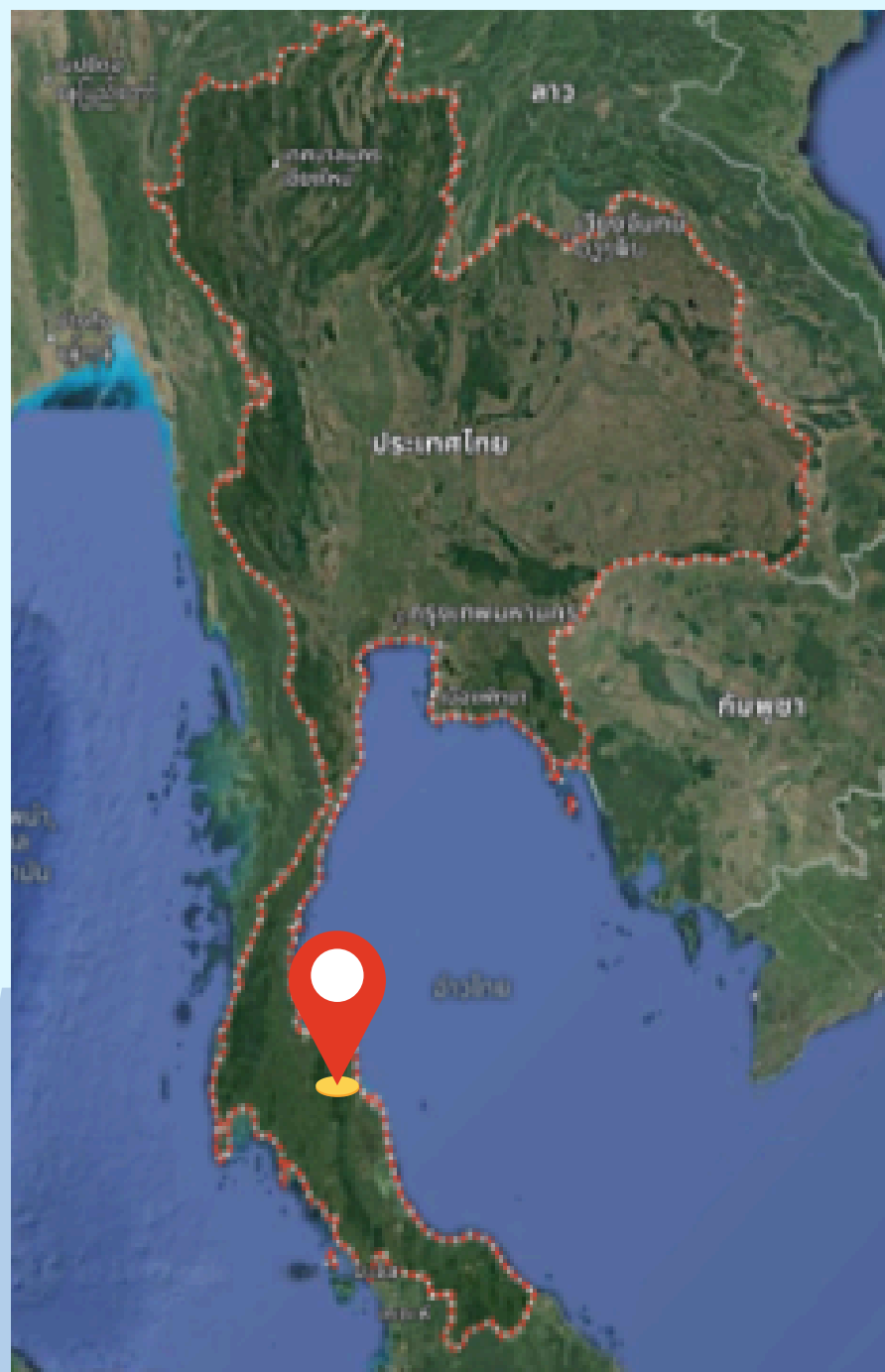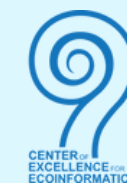
STUDY SITES

Thailand Map
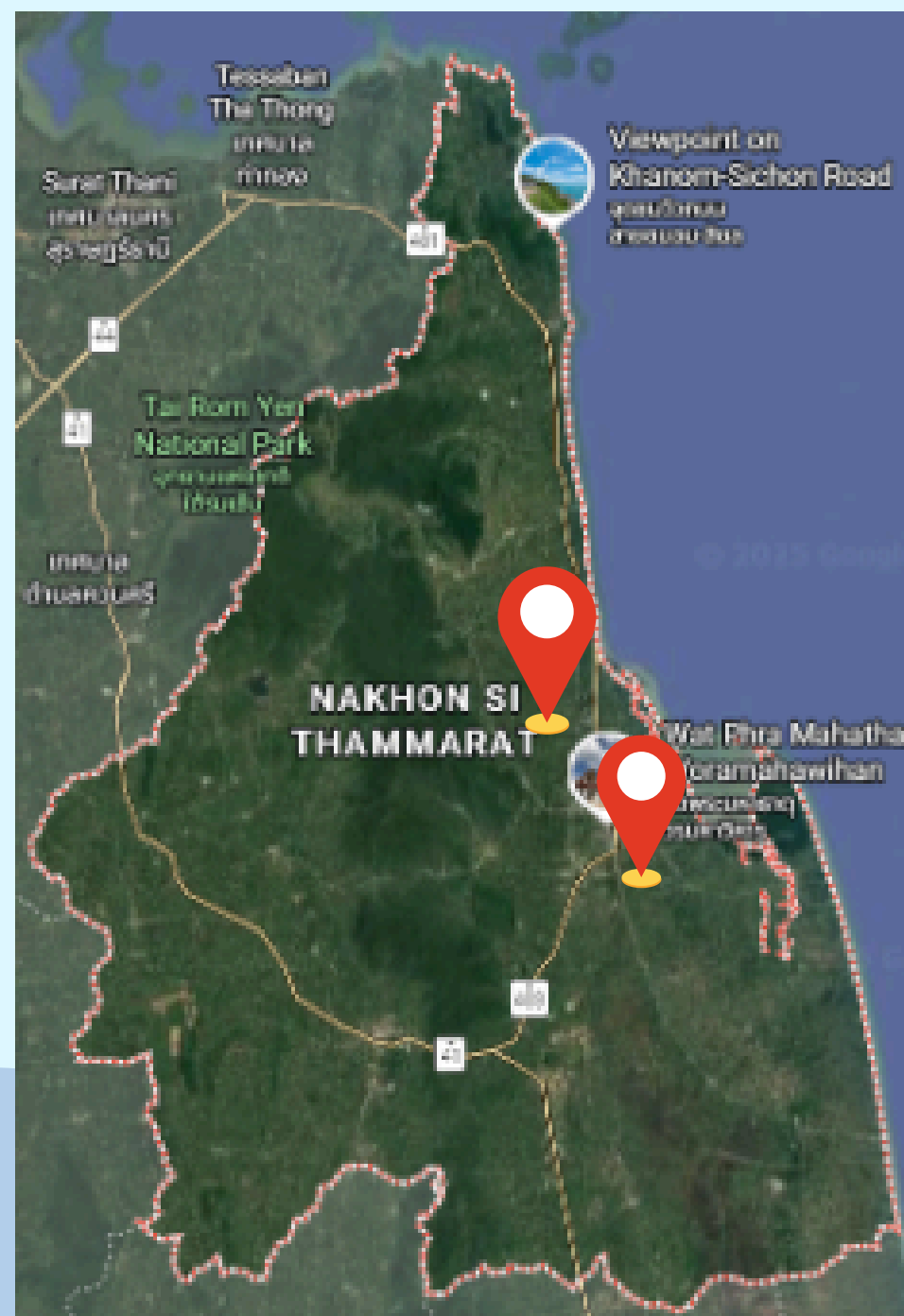
Nakhon Si Thammarat

Walailak University

PM2.5 MEASUREMENTS

Sensor Pm2.5

PM2.5 NO.02
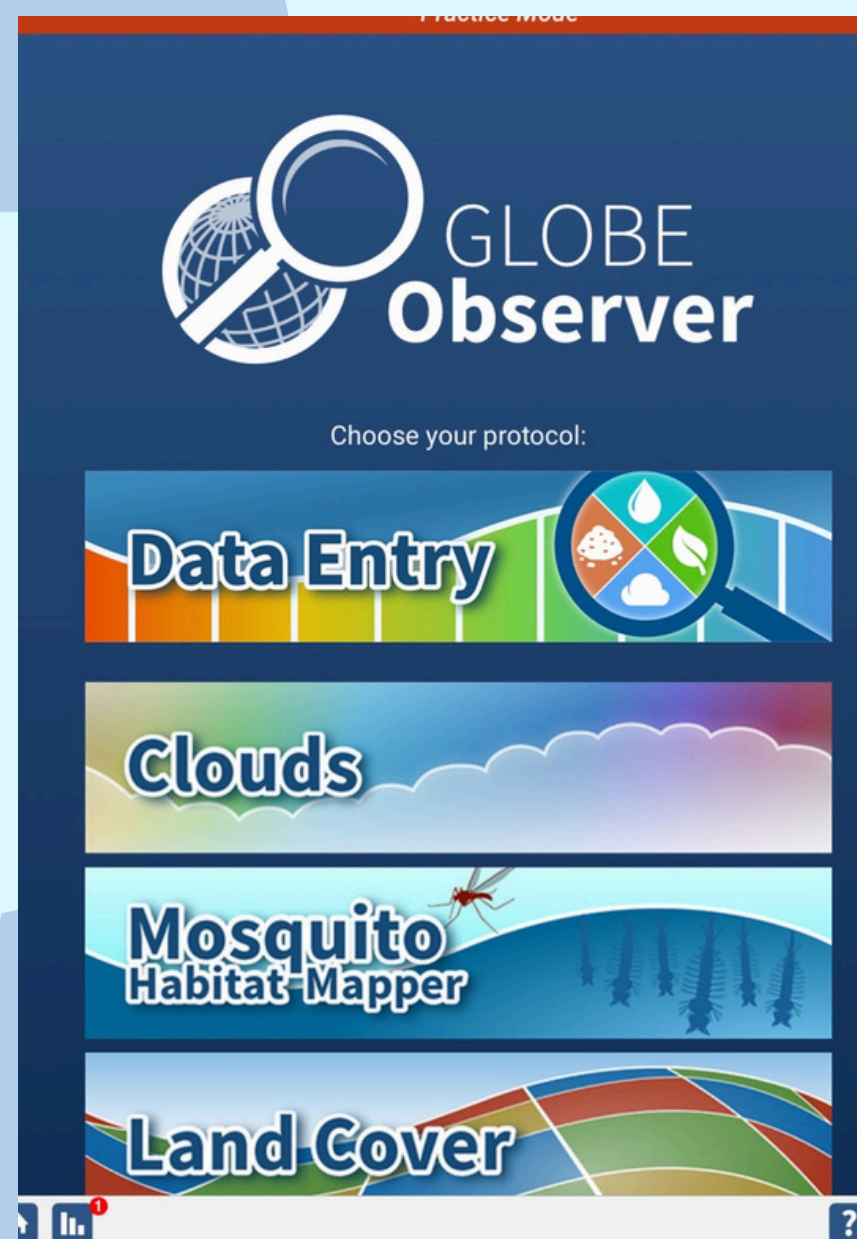
GLOBE CLOUD APP

1. Choose Cloud App
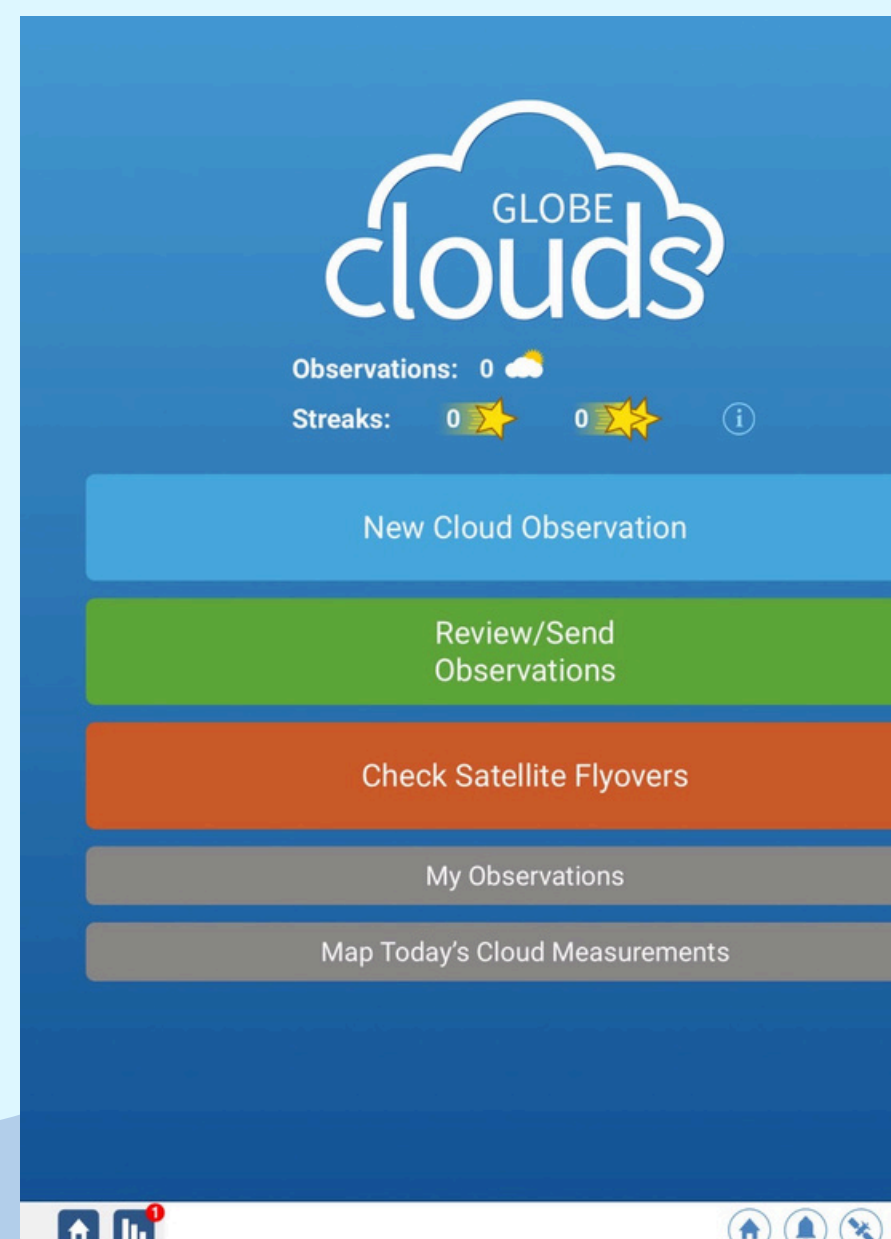
2. Choose New Cloud Observation
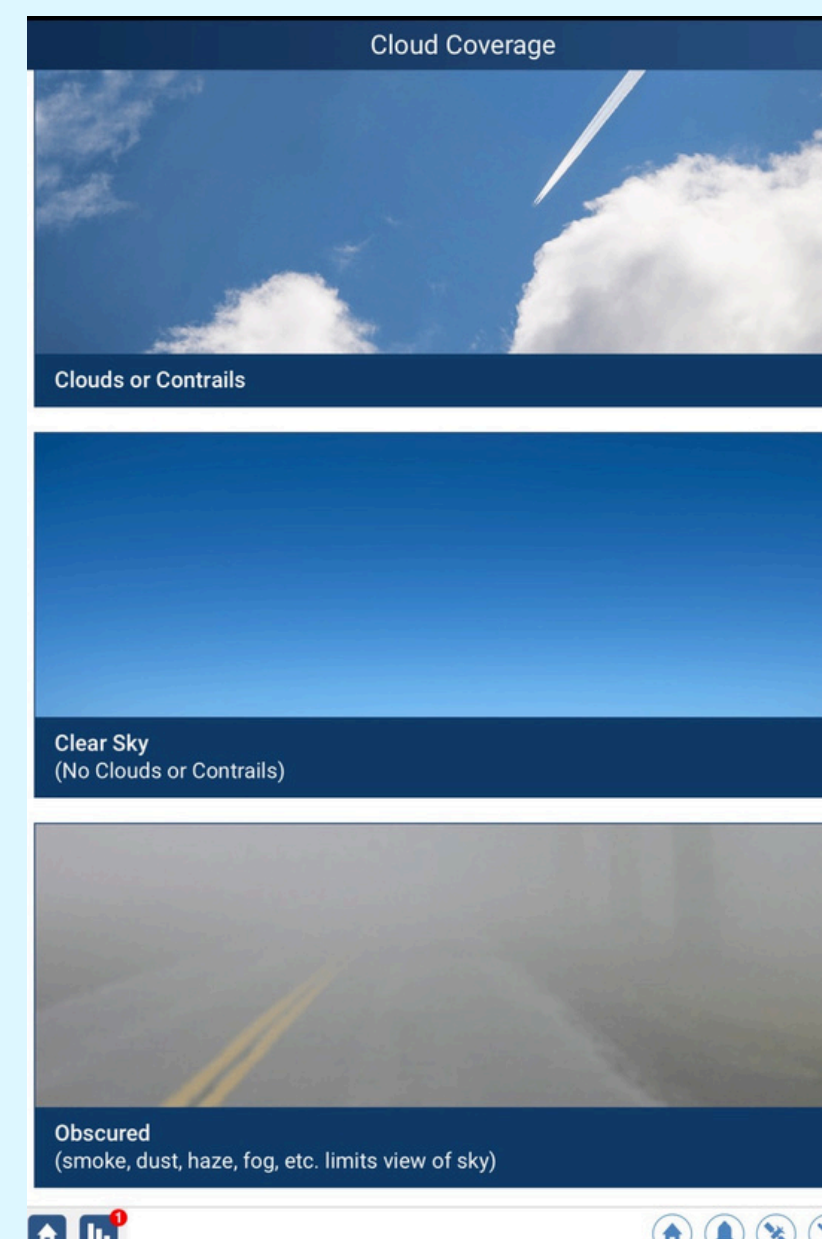
3. Observe the sky, the cloud
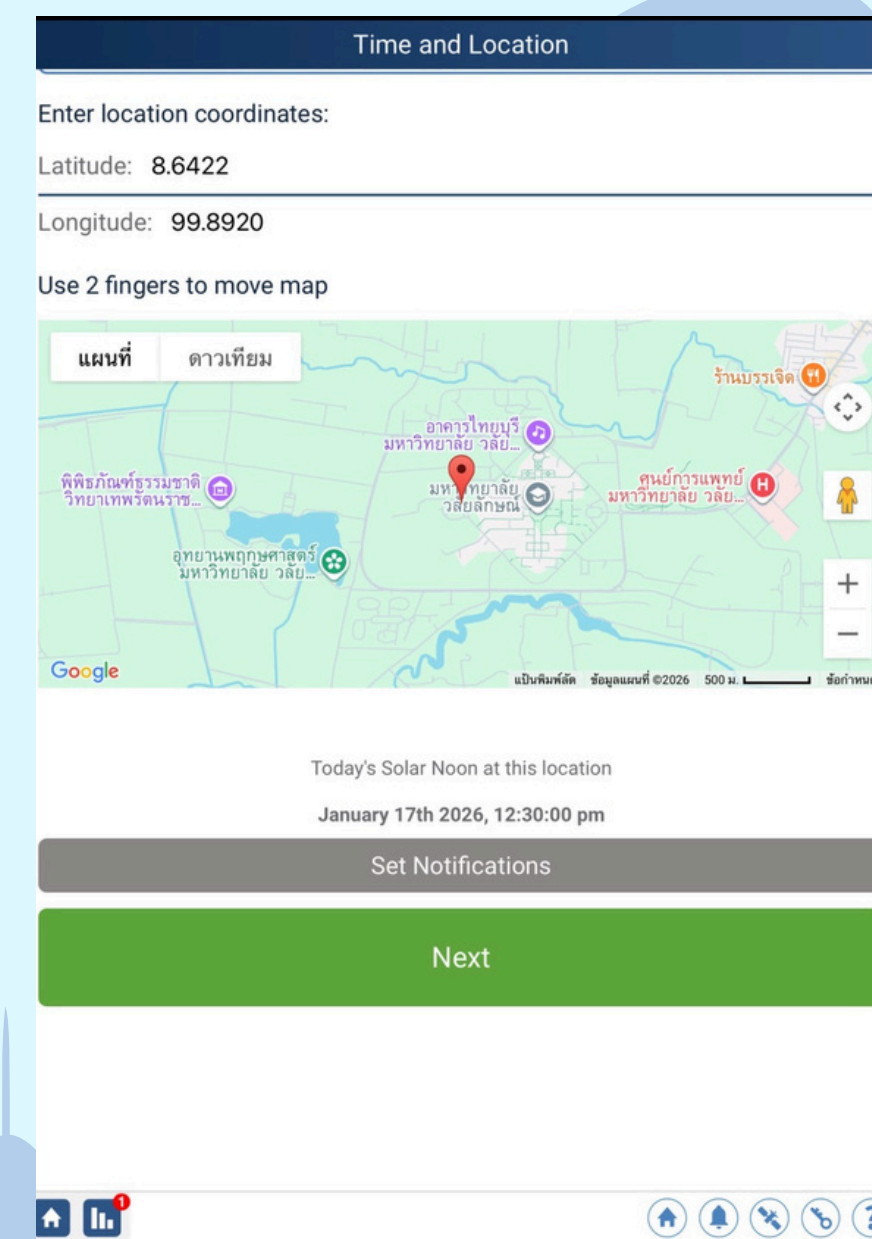
4. Latitue and Longitude of Study Sites

PM2.5 EXPERIMENT

RESULTS - EXPERIMENT 1

Experiment 1 Sensor 1.The increase in PM2.5 levels over a 15-minute period when burning different amounts

Legend:
- 2 incense sticks (µg/m³)
- 5 incense sticks (µg/m³)
- 9 incense sticks (µg/m³)

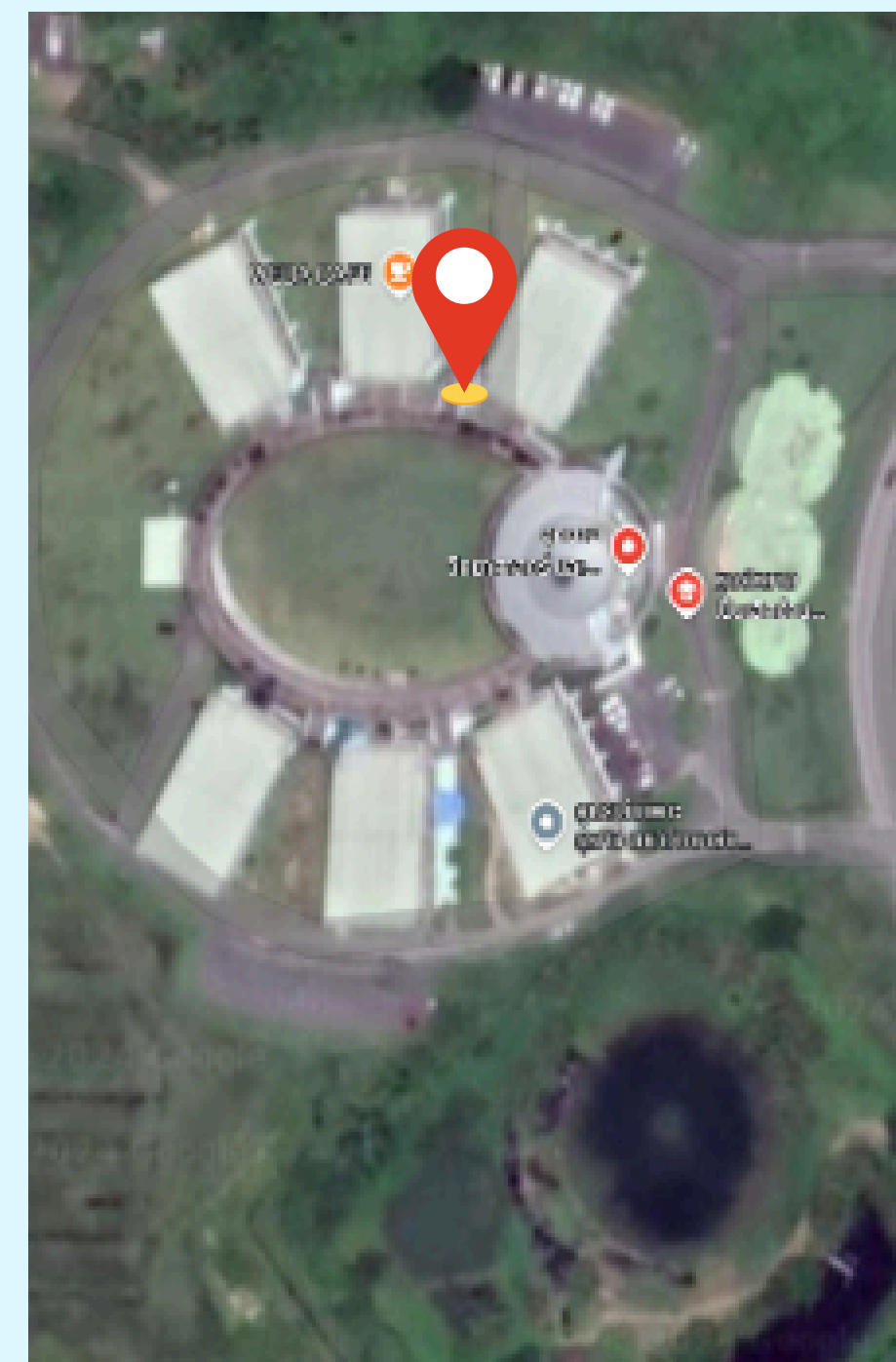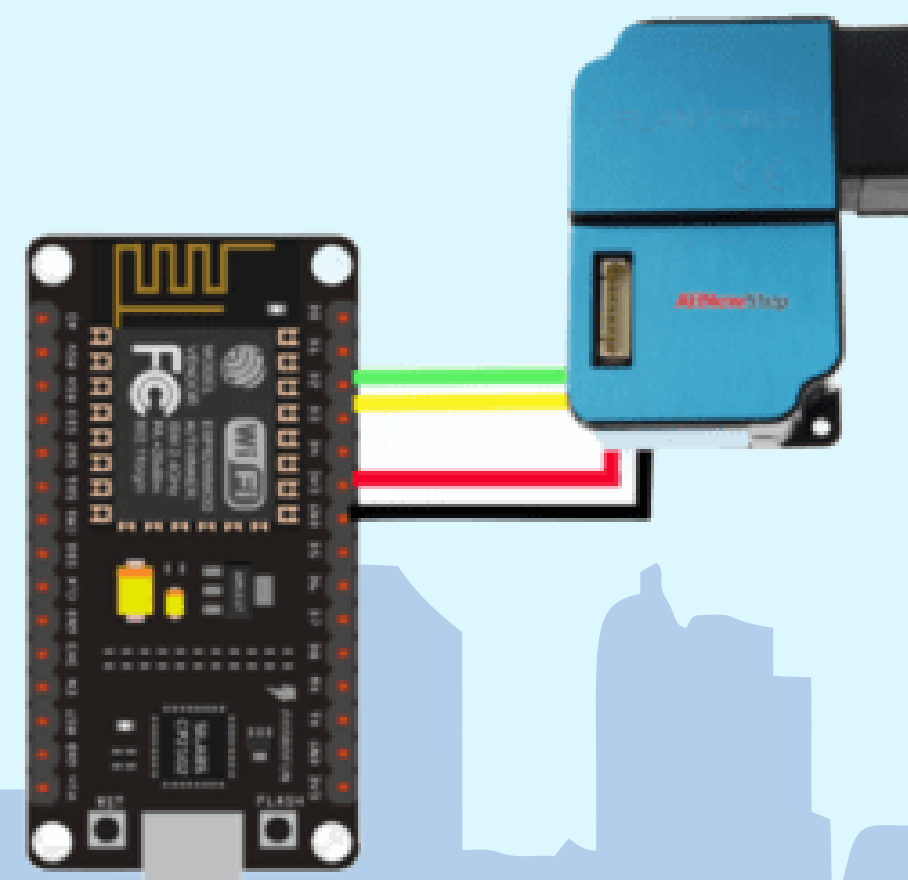Y-axis: PM 2.5 - µg/m³ (0 to 1250)

X-axis: Time (minutes) (0 to 15)
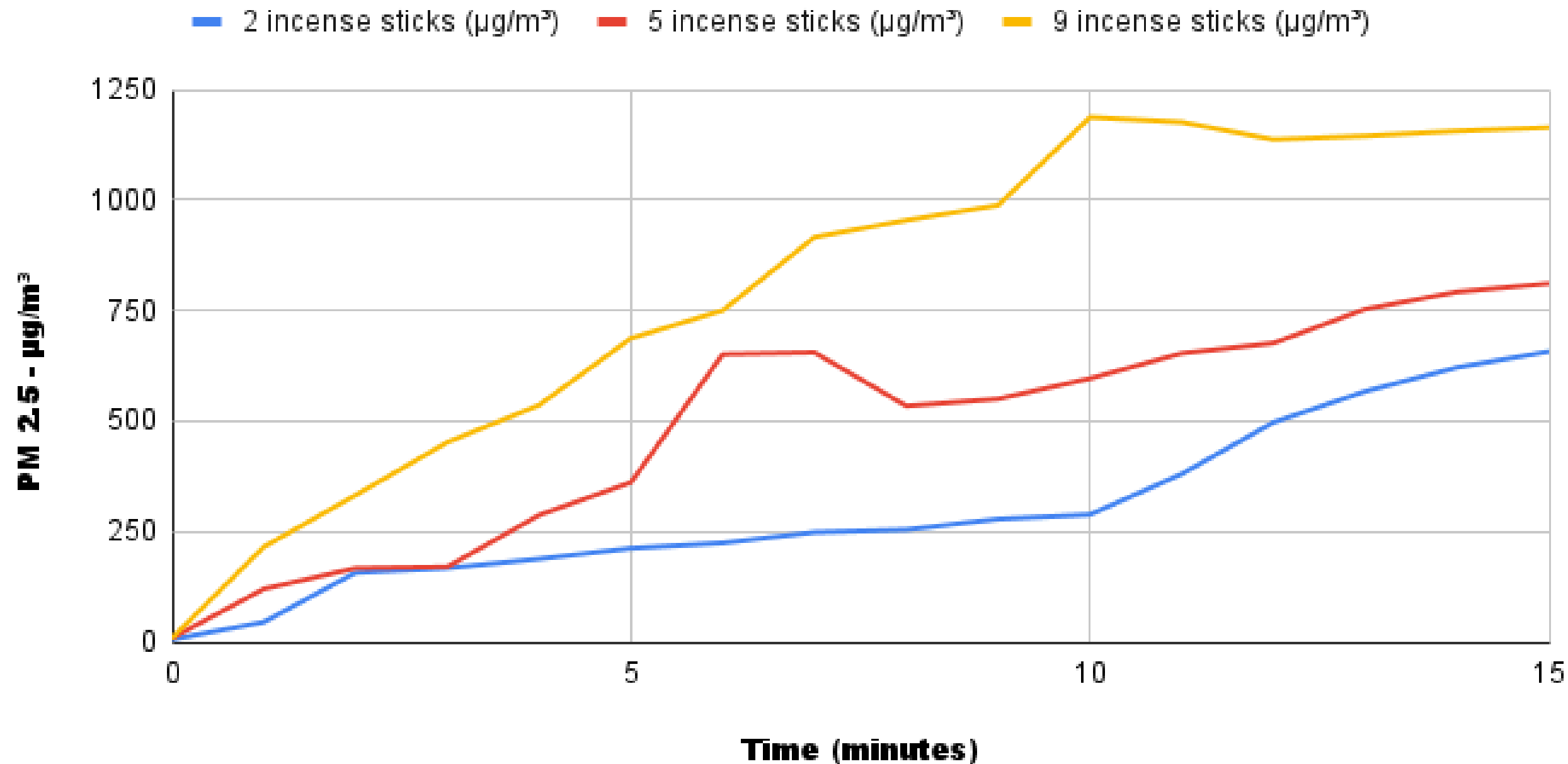
- **Rapid Increase:** PM2.5 rose sharply during the first few minutes in all groups.
- **Clear Dose Response:** 9 sticks produced the highest PM2.5, followed by 5 sticks, then 2 sticks.
- **Peak & Timing:** 9 sticks reached ~1,164 µg/m³ at ~10 minutes (about ~4× higher than 2 sticks at the same time).
- **Persistence:** PM2.5 remained elevated throughout the 15-minute measurement period, especially for 9 sticks.

RESULTS - EXPERIMENT 1

Experiment 1 Sensor 1.Average PM2.5 levels for 2,5 and 9 incense sticks.

Average PM2.5 Concentration (Sensor 1, Experiment 1)

• Clear Increase: Average PM2.5 increased with incense quantity (2 < 5 < 9).

• Magnitude: 9 sticks averaged 800.25 µg/m³, about 2.7× higher than 2 sticks (299.31 µg/m³).

• Interpretation: This supports a dose–response relationship between the number of incense sticks and indoor PM2.5.

Experiment 1 Sensor 2.The increase in PM2.5 levels over a 15 minute period when burning different amounts

- 2 incense sticks (µg/m³)
- 5 incense sticks (µg/m³)
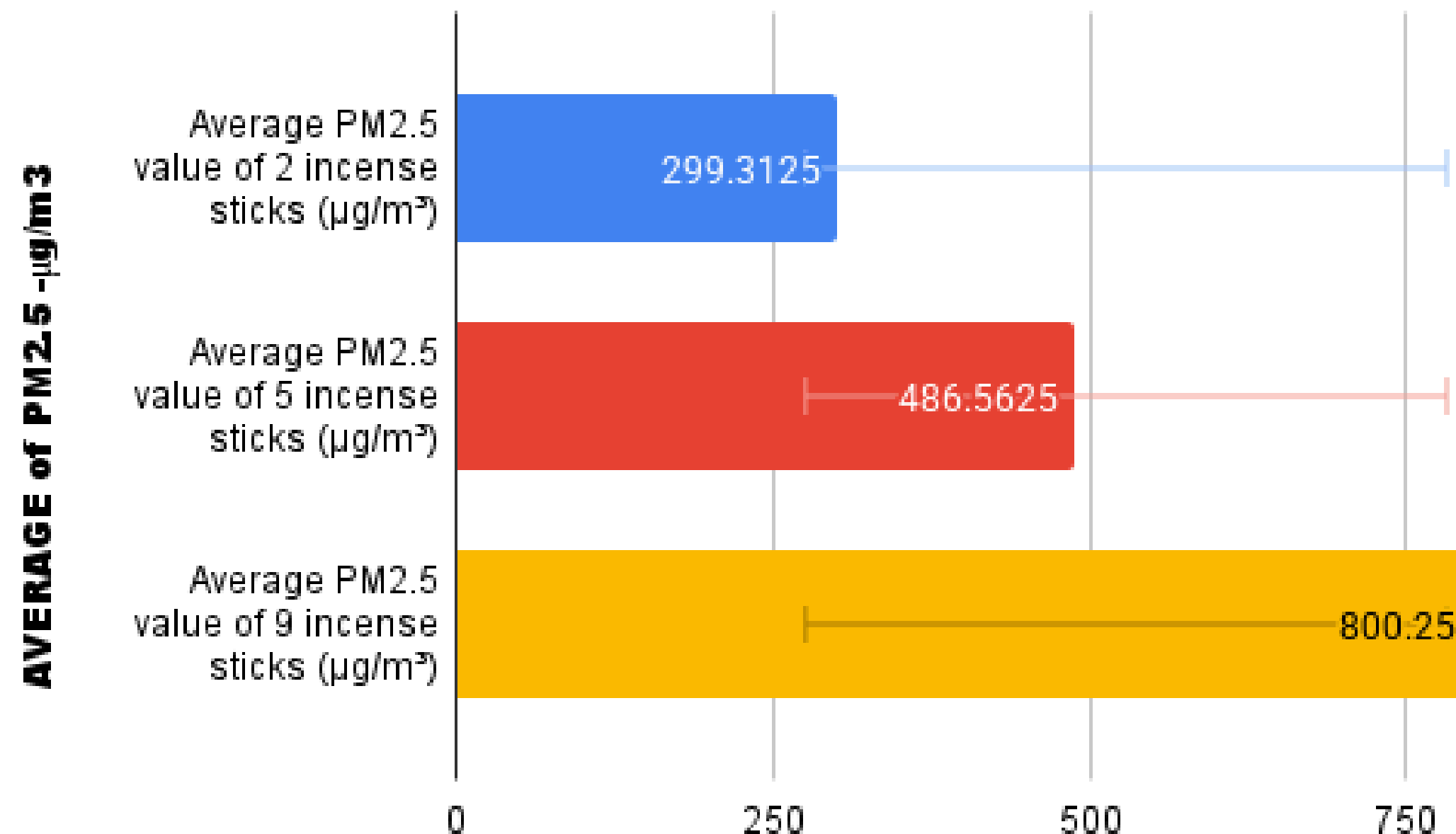- 9 incense sticks (µg/m³)

PM 2.5 - µg/m³

Time(minutes)

- Rapid Increase: PM2.5 rose quickly during the first few minutes in all groups.
- Clear Dose–Response: 9 sticks produced the highest PM2.5, followed by 5 sticks, then 2 sticks.
- Peak & Timing: 9 sticks reached ~1,256 µg/m³ at ~10 minutes and remained high through 15 minutes.
- Persistence: PM2.5 stayed elevated throughout the 15-minute measurement period, especially for 9 sticks.

Experiment 1 Sensor 2.Average PM2.5 levels for 2,5 and 9 incense sticks.
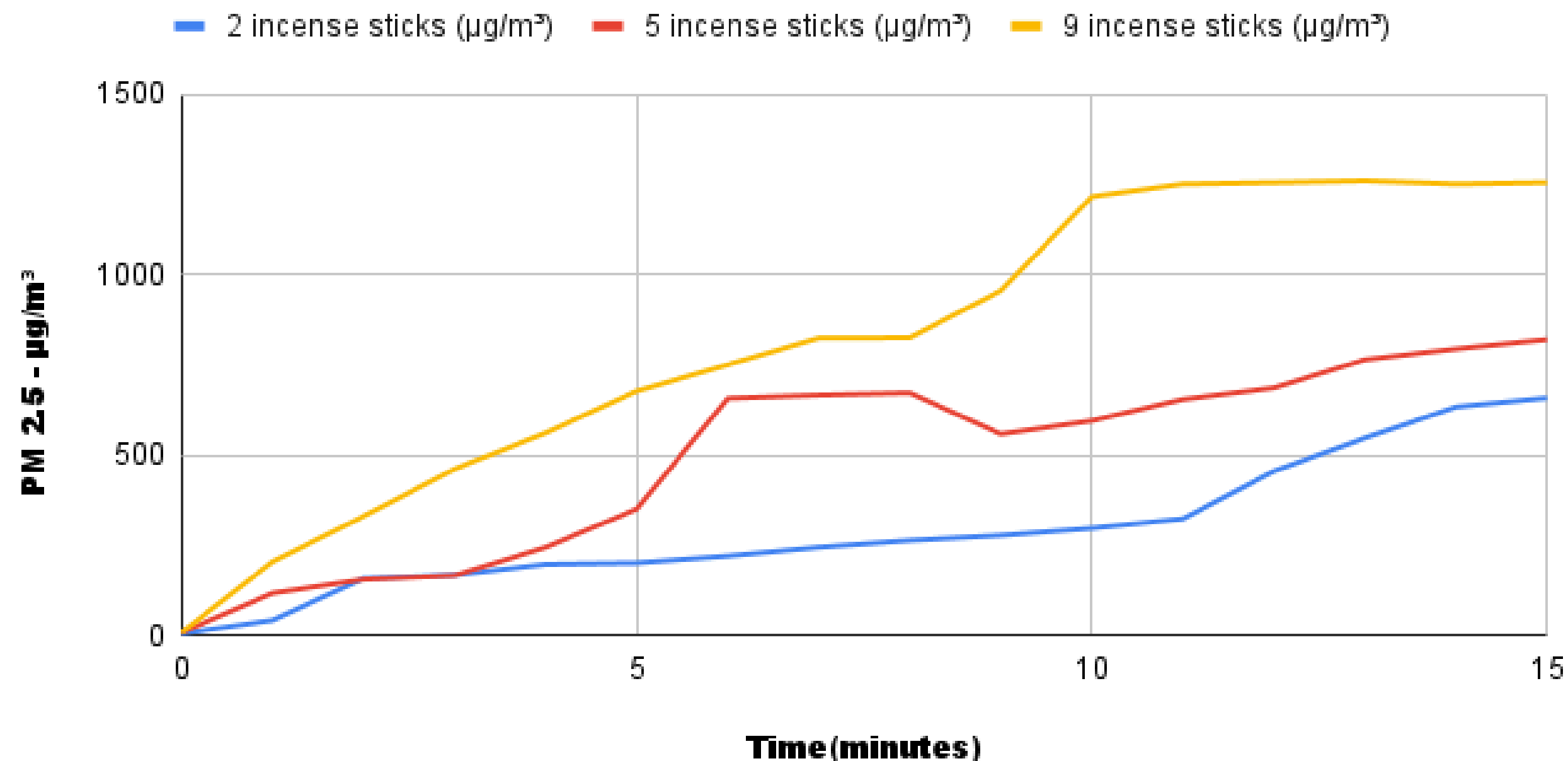

Average PM2.5 Concentration (Sensor 2, Experiment 1)

• Clear Increase: Average PM2.5 increased with incense quantity (2 < 5 < 9).

• Magnitude: 9 sticks averaged 818.69 µg/m³, about 2.8× higher than 2 sticks (293.94 µg/m³).

• Interpretation: This supports a dose–response relationship between the number of incense sticks and indoor PM2.5 concentration.

RESULTS - EXPERIMENT 2

Experiment 2 Sensor 1.The increase in PM2.5 levels over a 15 minute period when burning different amounts

Legend: 2 incense sticks (µg/m³), 5 incense sticks (µg/m³), 9 incense sticks (µg/m³)

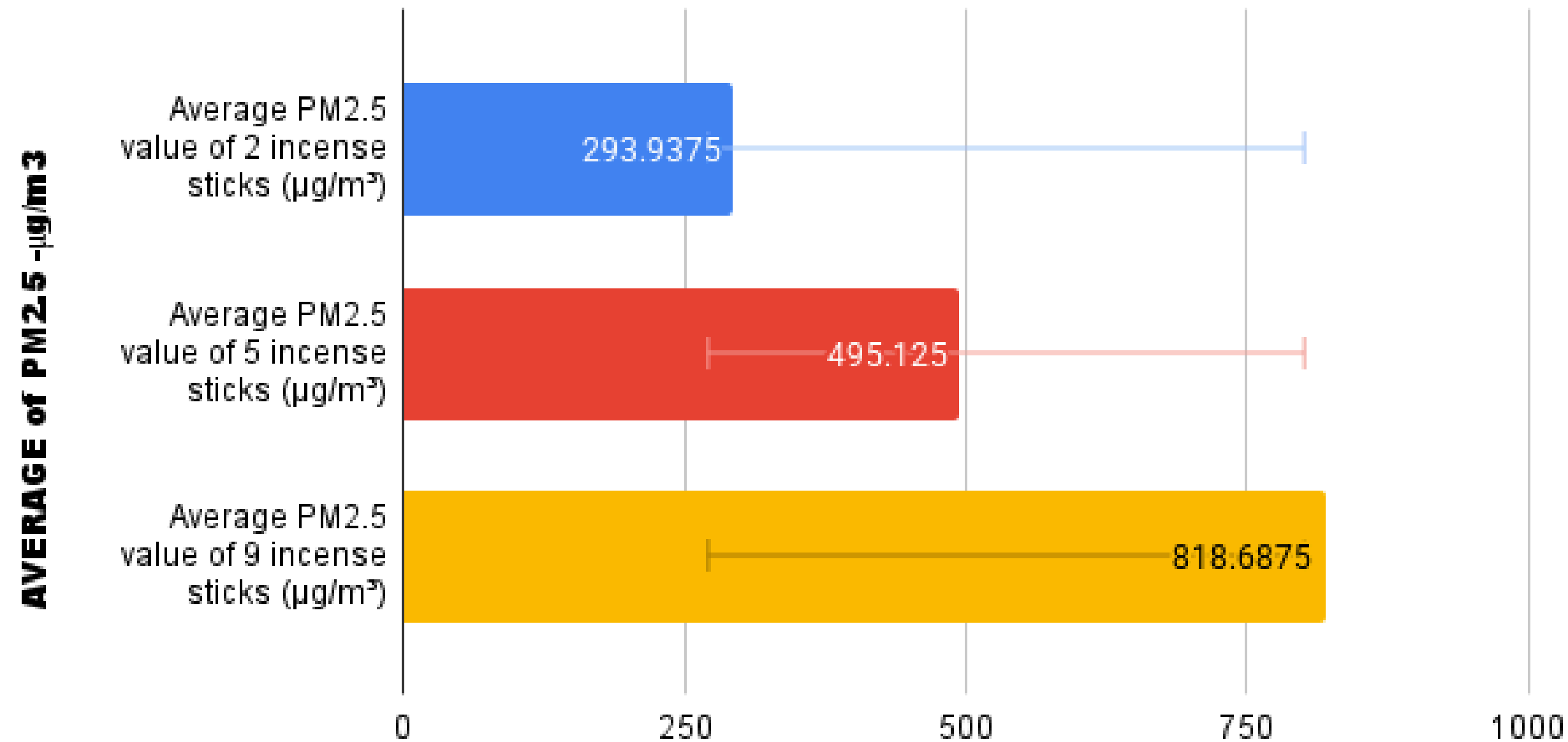Y-axis: PM 2.5 - µg/m³
X-axis: Time(minutes)

- Rapid Increase: PM2.5 rose quickly within the first few minutes in all groups.
- Clear Dose–Response: 9 sticks produced the highest PM2.5, followed by 5 sticks, then 2 sticks.
- Peak Level: 9 sticks reached ~1,464 µg/m³ by the end of the 15-minute period.
- Persistence: PM2.5 stayed elevated throughout the 15-minute measurement, especially for 9 sticks.

RESULTS - EXPERIMENT 2

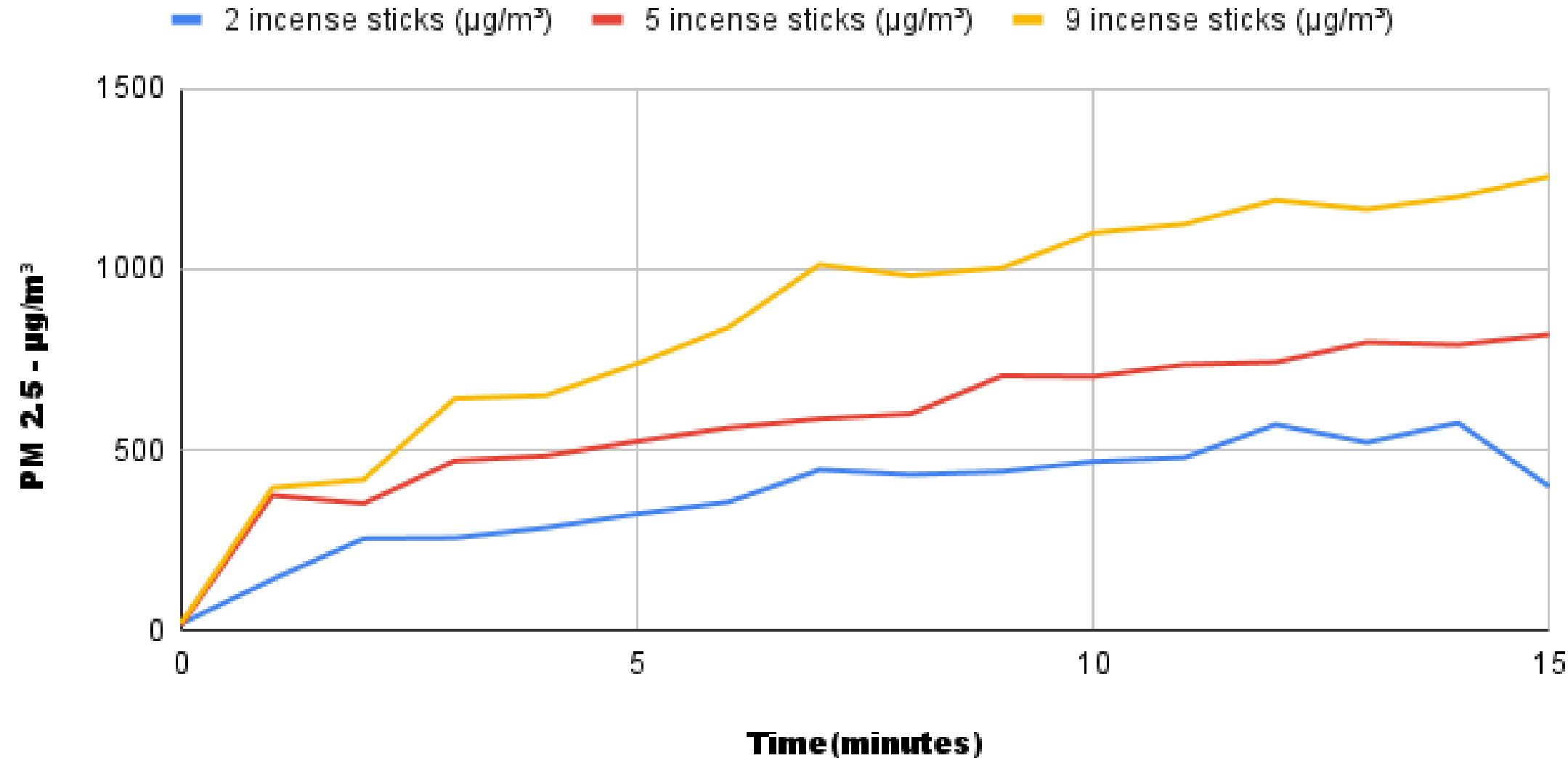Experiment 2 Sensor 1.Average PM2.5 levels for 2,5and 9 incense sticks

Average PM2.5 Concentration (Sensor 1, Experiment 2)

• Clear Increase: Average PM2.5 increased with incense quantity (2 < 5 < 9).
• Magnitude: 9 sticks averaged 853 µg/m³, about 2.9× higher than 2 sticks (291.38 µg/m³).
• Interpretation: The results support a dose–response relationship between the number of incense sticks and indoor PM2.5 concentration.
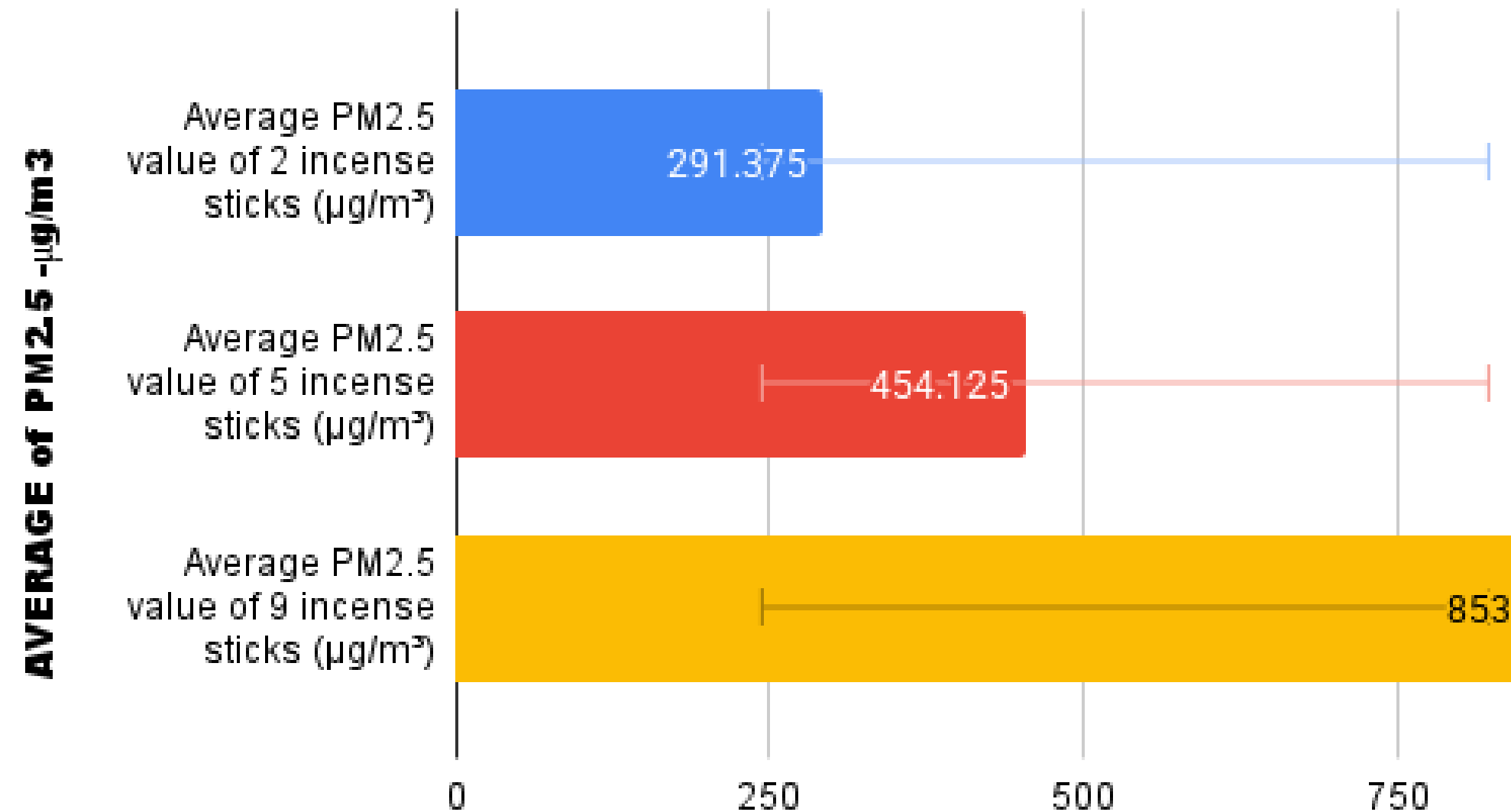
RESULTS - EXPERIMENT 2

Experiment 2 Sensor 2.The increase in PM2.5 levels over a 15 minute period when burning different amounts

Legend: ■ 2 incense sticks (μg/m³) ■ 5 incense sticks (μg/m³) ■ 9 incense sticks (μg/m³)

(Y-axis: PM 2.5 - μg/m³, X-axis: Time(minutes))

- Rapid Increase: PM2.5 rose quickly within the first few minutes in all groups.
- Clear Dose–Response: 9 sticks produced the highest PM2.5, followed by 5 sticks, then 2 sticks.
- Peak Level: 9 sticks reached ~1,257 μg/m³ near the end of the 15-minute period.
- Persistence: PM2.5 remained elevated throughout the 15-minute measurement, especially for 9 sticks.

RESULTS - EXPERIMENT 2

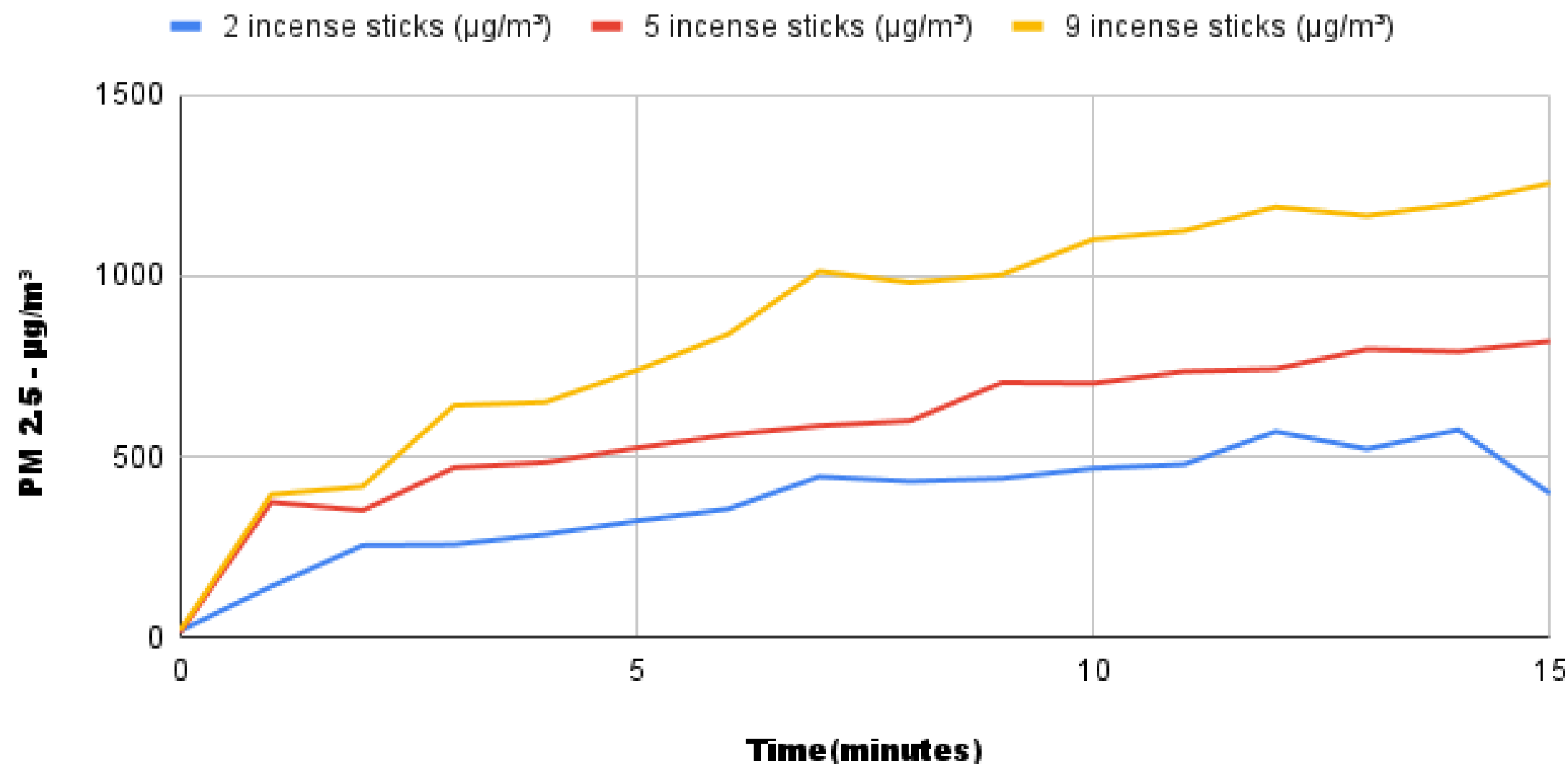## Experiment 2 Sensor 2.Average PM2.5 levels for 2,5and 9 incense sticks
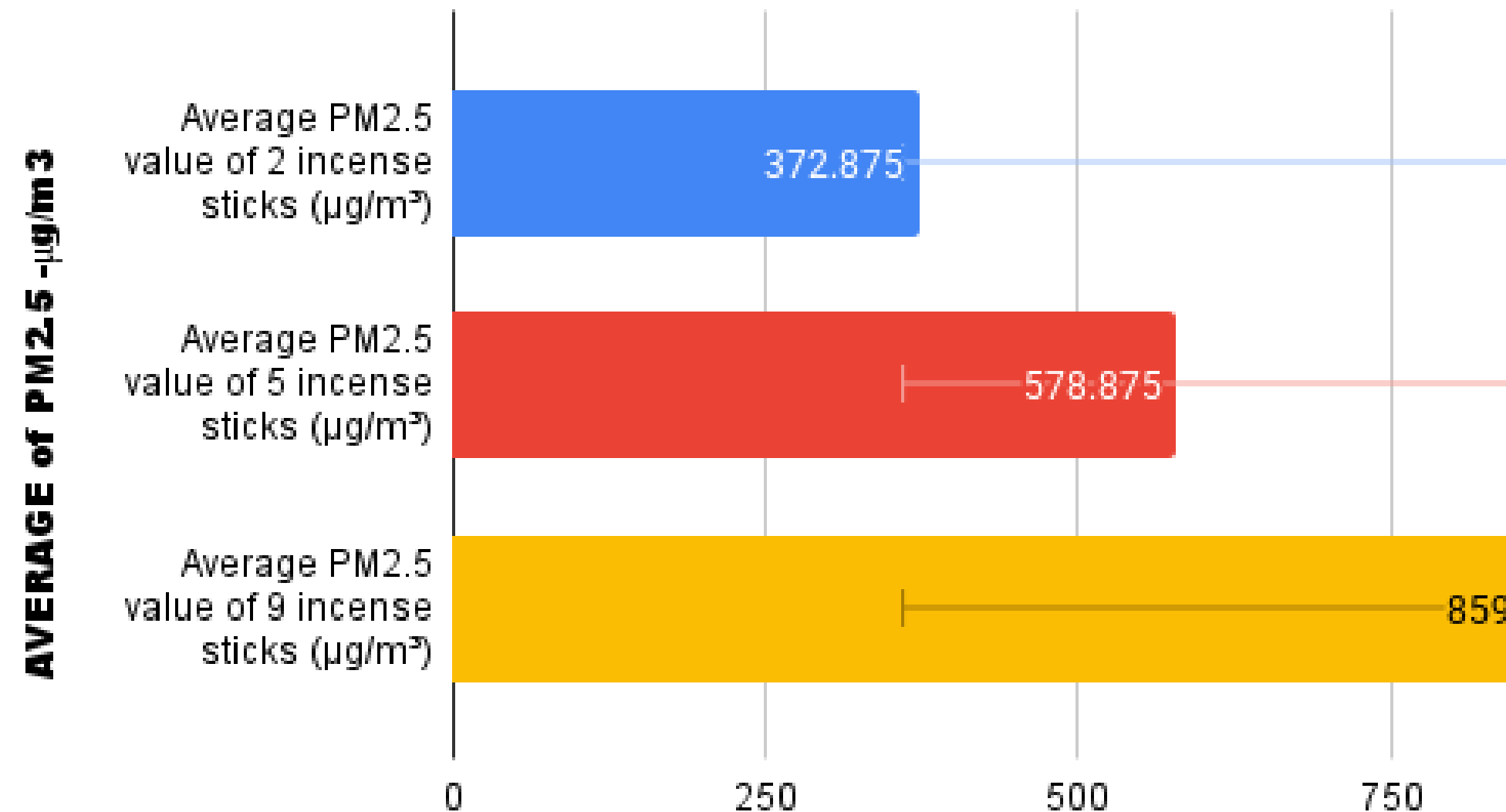
Average PM2.5 Concentration (Sensor 2)

• Mean PM2.5 increased with incense quantity: 2 sticks (372.88 µg/m³) < 5 sticks (578.88 µg/m³) < 9 sticks (859.00 µg/m³).

• Magnitude of increase: 9 sticks produced ~2.3× higher average PM2.5 than 2 sticks.

• Dose–response pattern: Results support a direct relationship between the number of incense sticks and indoor PM2.5 loading (with variability shown by error bars).

RESULTS - EXPERIMENT 3

Experiment 3 Sensor 1.The increase in PM2.5 levels over a 15 minute period when burning different amounts

Legend:
- 2 incense sticks (μg/m³)
- 5 incense sticks (μg/m³)
- 9 incense sticks (μg/m³)

Y-axis: PM 2.5 - μg/m³ (0, 500, 1000, 1500)
X-axis: Time (minutes) (0, 5, 10, 15)
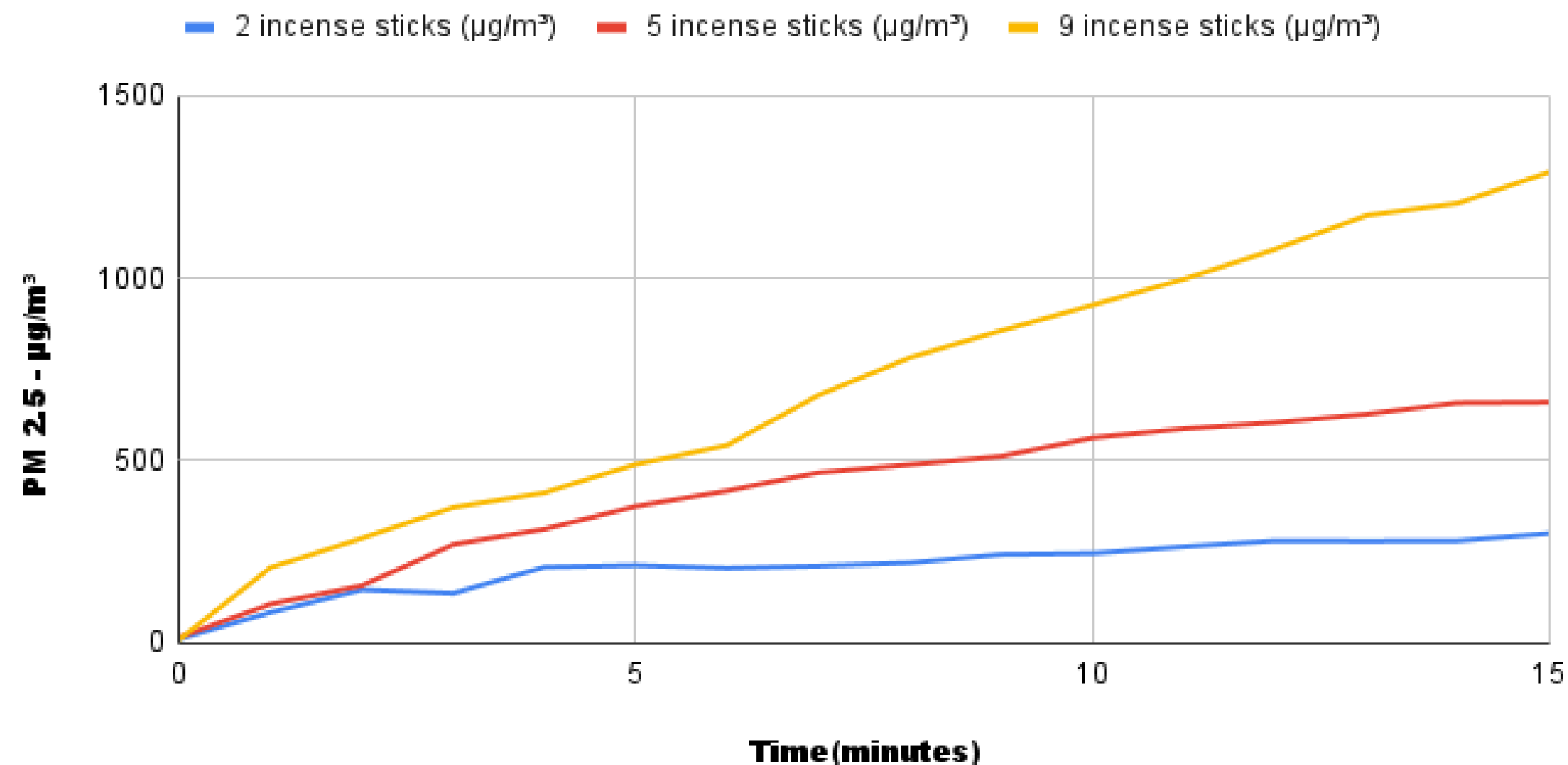
Key Findings (Experiment 3 – Sensor 1)

• Clear dose–response pattern: PM2.5 increased as incense quantity increased (2 < 5 < 9 sticks) throughout the 15-minute period.

• Peak loading: 9 sticks reached ~1,290 μg/m³, compared with ~300 μg/m³ for 2 sticks (≈4× higher).

• Faster accumulation at higher dose: The 9-stick condition climbed steeply and exceeded ~1,000 μg/m³ by around minute 11–12.

• Continued buildup: PM2.5 kept rising over time with no clear plateau in this setup, indicating ongoing accumulation in the room.

RESULTS - EXPERIMENT 3

Experiment 3 Sensor 1.Average PM2.5 levels for 2,5and 9 incense sticks

Average PM2.5 (Experiment 3 – Sensor 1)

• Dose response pattern: Mean PM2.5 increased as incense quantity increased (2 < 5 < 9 sticks).
• 15-min mean PM2.5 (µg/m³): 2 sticks = 207.88, 5 sticks = 426.19, 9 sticks = 706.56.
• Relative increase: 9 sticks produced ~3.4× higher PM2.5 than 2 sticks (and ~1.7× higher than 5 sticks).
• Variability: Error bars indicate noticeable variation across trials, but the increasing trend remains consistent.

RESULTS - EXPERIMENT 3

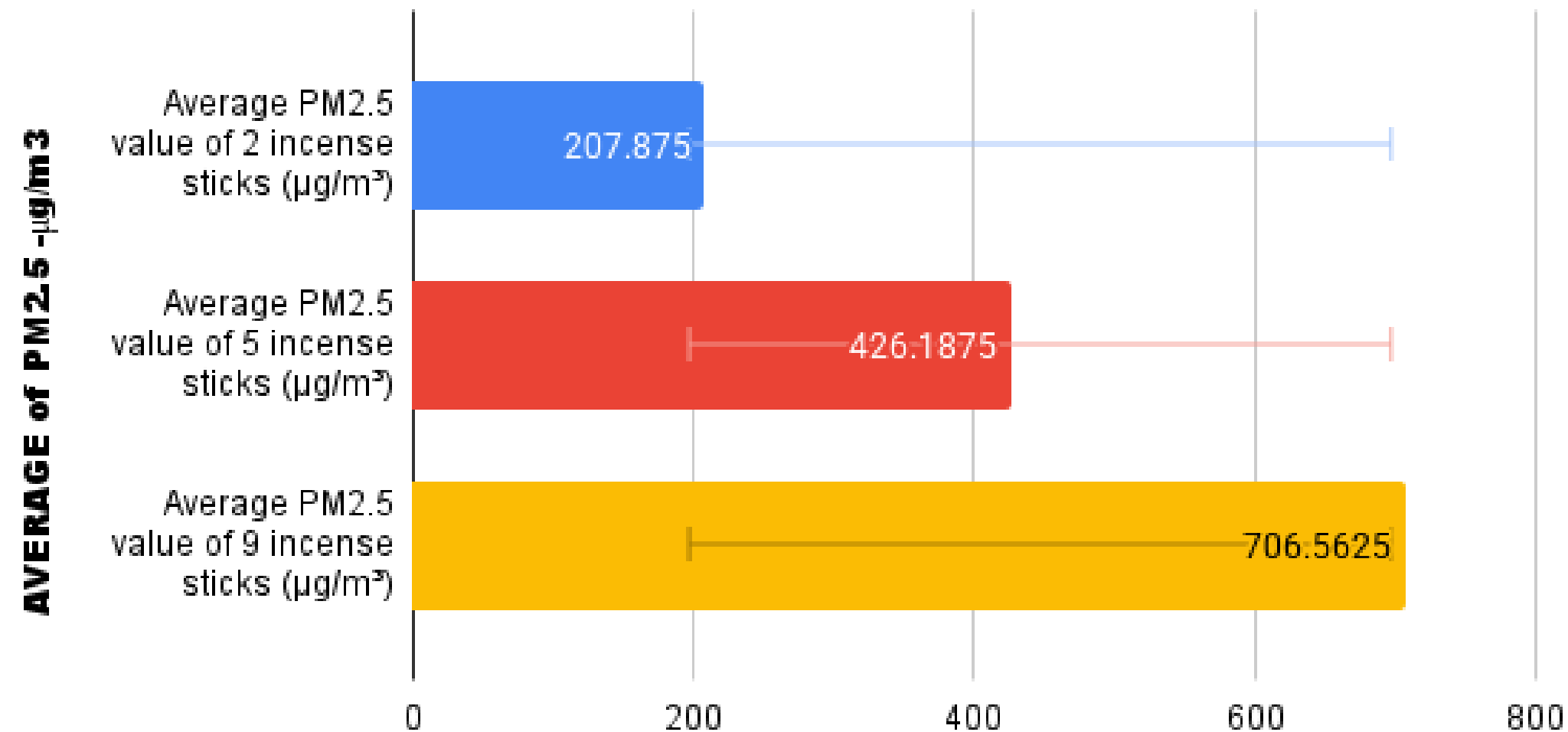Experiment 3 Sensor2.The increase in PM2.5 levels over a 15 minute period when burning different amounts

Legend: 2 incense sticks (μg/m³), 5 incense sticks (μg/m³), 9 incense sticks (μg/m³)

Y-axis: PM 2.5 - μg/m³

X-axis: Time(minutes)
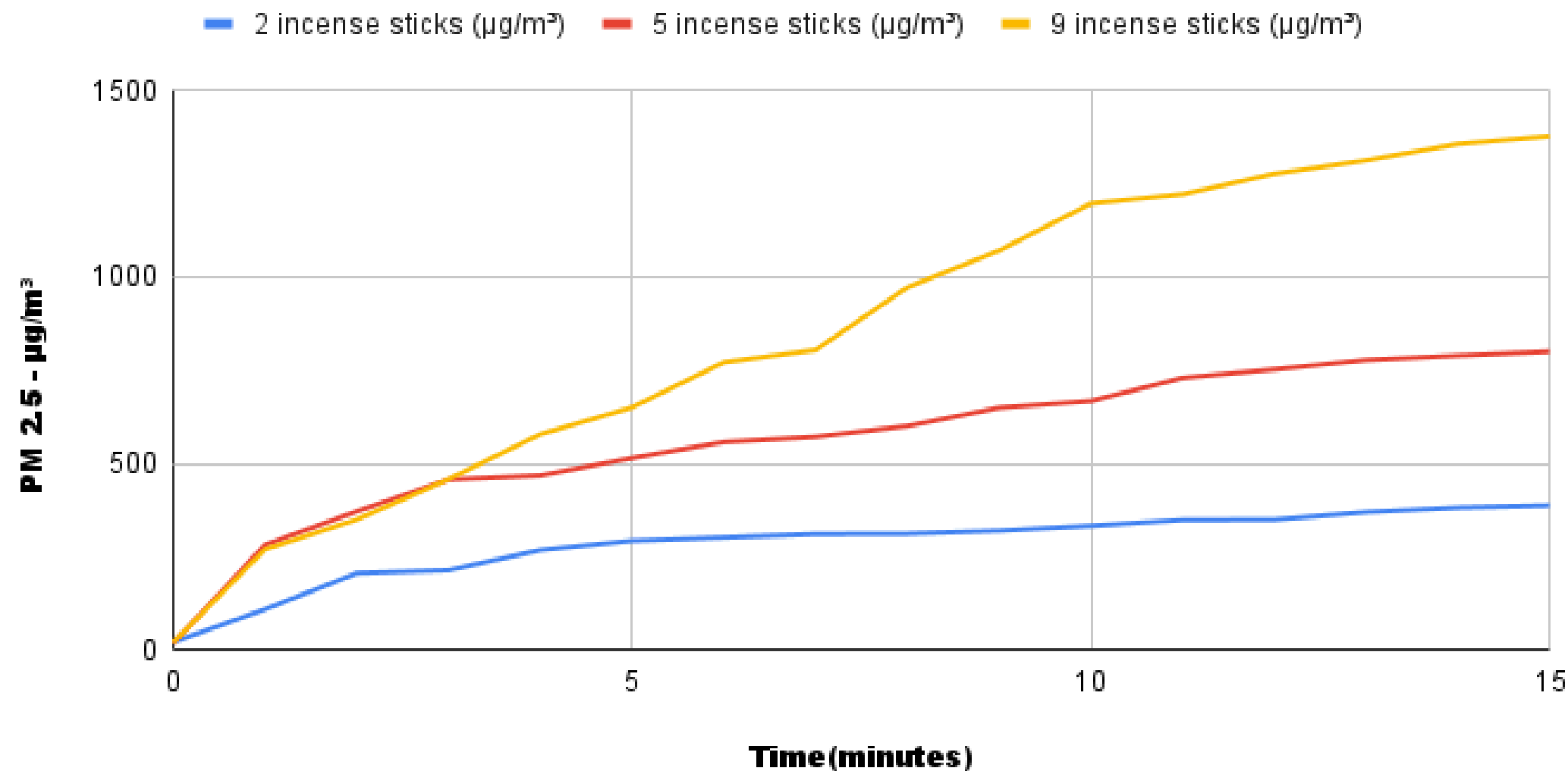
Experiment 3 – Sensor 2 (PM2.5 over 15 minutes)

• Rapid increase: PM2.5 rose sharply within the first 1–2 minutes for all groups.

• Clear dose response: 9 sticks produced the highest PM2.5, followed by 5, then 2 (9 > 5 > 2) at every time point.

• By 15 minutes, PM2.5 reached ~$1.38×10^3$ μg/m³ (9 sticks), compared with ~$8.0×10^2$ (5 sticks) and ~$3.9×10^2$ (2 sticks).

• Relative effect: 9 sticks produced ~3.5× higher PM2.5 than 2 sticks by minute 15.

• Continued accumulation: The 9-stick curve kept increasing through 15 minutes, suggesting PM2.5 was still building up.

Experiment 3 Sensor 2.Average PM2.5 levels for 2,5and 9 incense sticks
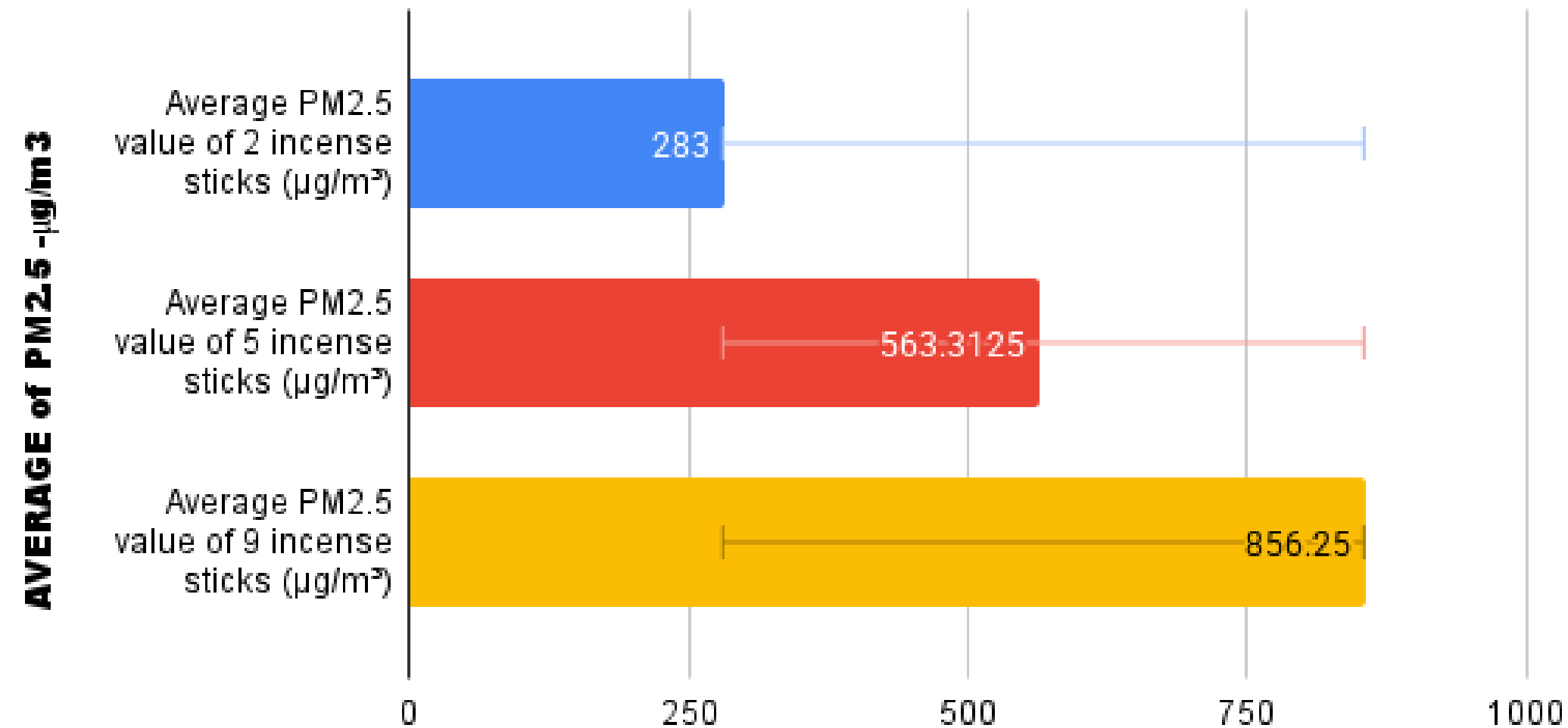
Average PM2.5 Concentration (Experiment 3 – Sensor 2)

• Mean PM2.5 increased with incense quantity (2 < 5 < 9).
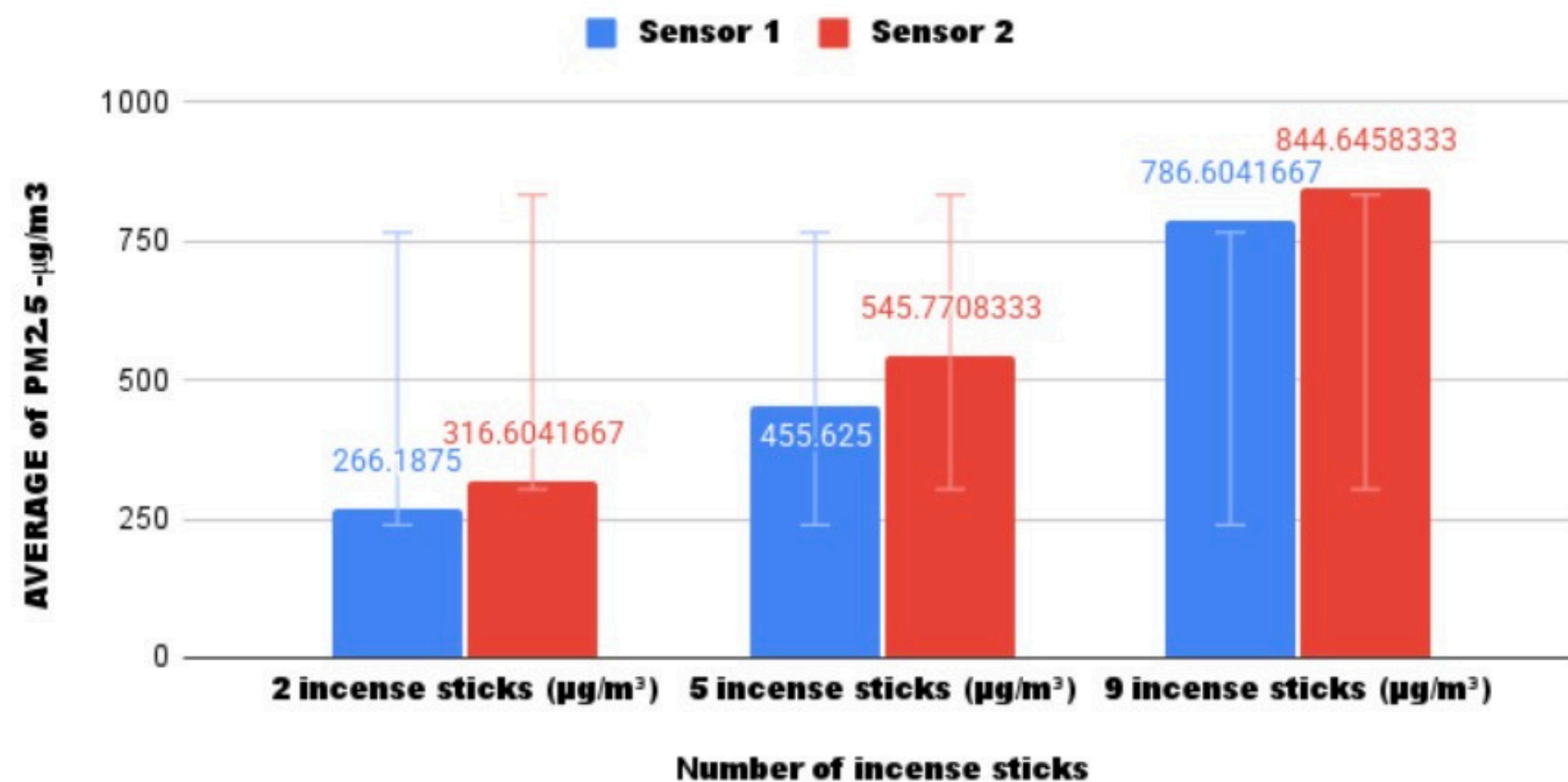• 9 sticks averaged 856.25 µg/m³ about 3.0× higher than 2 sticks (283 µg/m³).
• The consistent increase supports a clear dose–response relationship between source quantity and indoor PM2.5 loading.

RESULTS

Comparison of Average PM2.5 Concentrations from 2, 5, and 9 Incense Sticks Measured by Dual Sensors.

Sensor 1 ■ **Sensor 2** ■


Dose response Trend: Mean PM2.5 increases with incense quantity (2 < 5 < 9) in both sensors.

- Mean PM2.5 at 2 / 5 / 9 sticks (µg/m³):
- Sensor 1: 266.19 → 455.63 → 786.60
- Sensor 2: 316.60 → 545.77 → 844.65
- Strong Increase: 9 sticks is ~2.7–3.0× higher than 2 sticks (both sensors).
- Statistical Significance (One-way ANOVA): Sensor 1 $p = 0.007$, Sensor 2 $p = 0.001$ ($p < 0.05$).

RESULTS

Regression Analysis of Incremental PM2.5 Loading(Sensor 1)
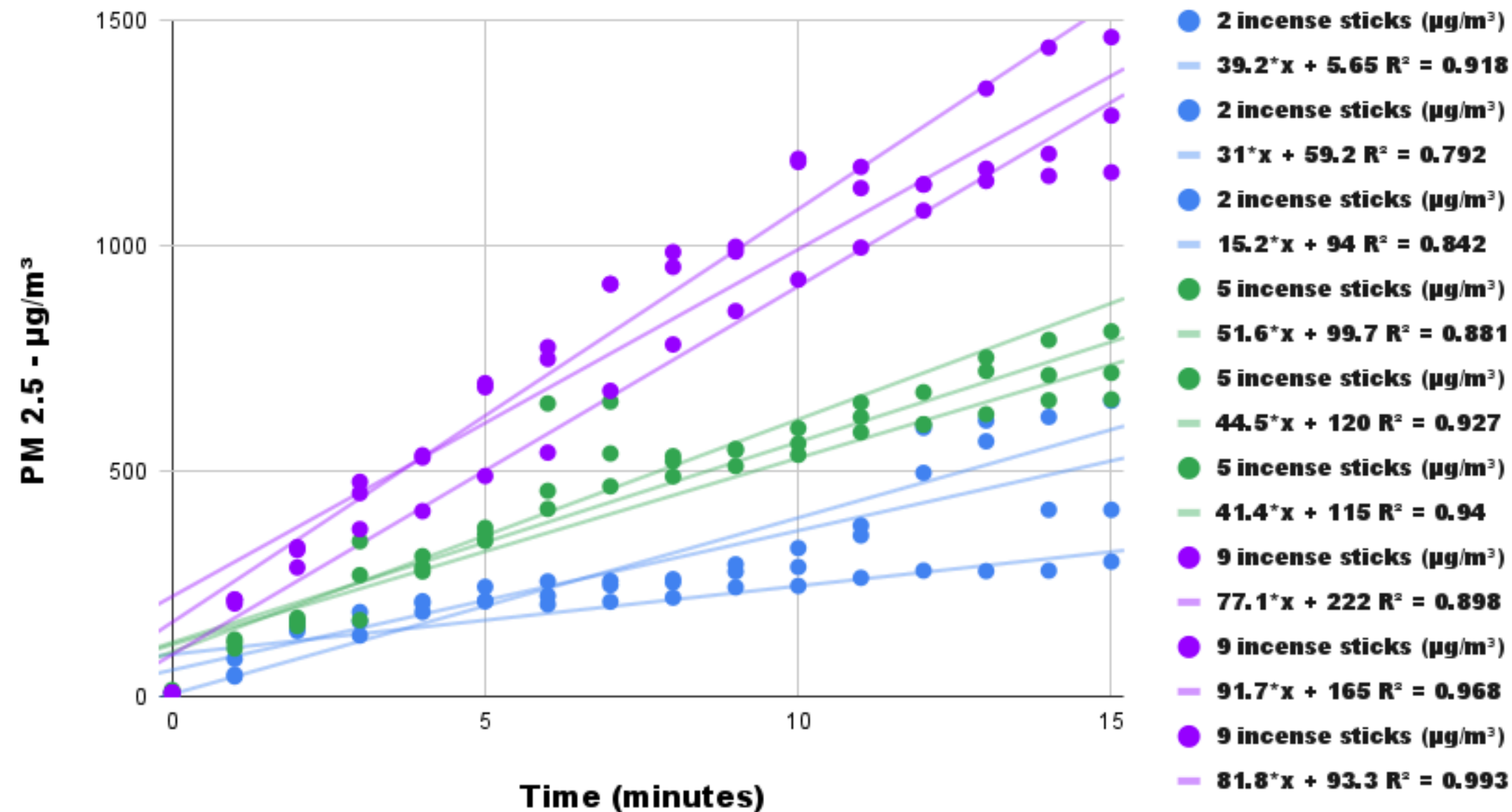
- Accelerated Loading Rate: Slopes rise with incense amount (2 sticks: 15.2–39.2, 5 sticks: 41.4–51.6, 9 sticks: 77.1–91.7 µg/m³/min).
- Strong Linearity: Linear fits are high (R^2 = 0.792–0.993), indicating PM2.5 increases almost linearly over 15 minutes.
- Highest Exposure Scenario: 9 sticks approaches ~1,400–1,500 µg/m³ by 15 minutes, far above lower dose groups.
- Data Consistency: Multiple runs per group show the same upward trend, supporting consistent Sensor 1 measurements.

RESULTS

Regression Analysis of Incremental PM2.5 Loading(Sensor 2)

Legend:
- 2 incense sticks (µg/m³)
- 38.1*x + 8.26 R² = 0.902
- 2 incense sticks (µg/m³)
- 28.5*x + 159 R² = 0.785
- 2 incense sticks (µg/m³)
- 19*x + 141 R² = 0.8
- 5 incense sticks (µg/m³)
- 53.2*x + 96.3 R² = 0.86
- 5 incense sticks (µg/m³)
- 41.1*x + 271 R² = 0.857
- 5 incense sticks (µg/m³)
- 41.7*x + 250 R² = 0.879
- 9 incense sticks (µg/m³)
- 85*x + 181 R² = 0.939
- 9 incense sticks (µg/m³)
- 70.2*x + 332 R² = 0.889
- 9 incense sticks (µg/m³)
- 89.4*x + 185 R² = 0.968
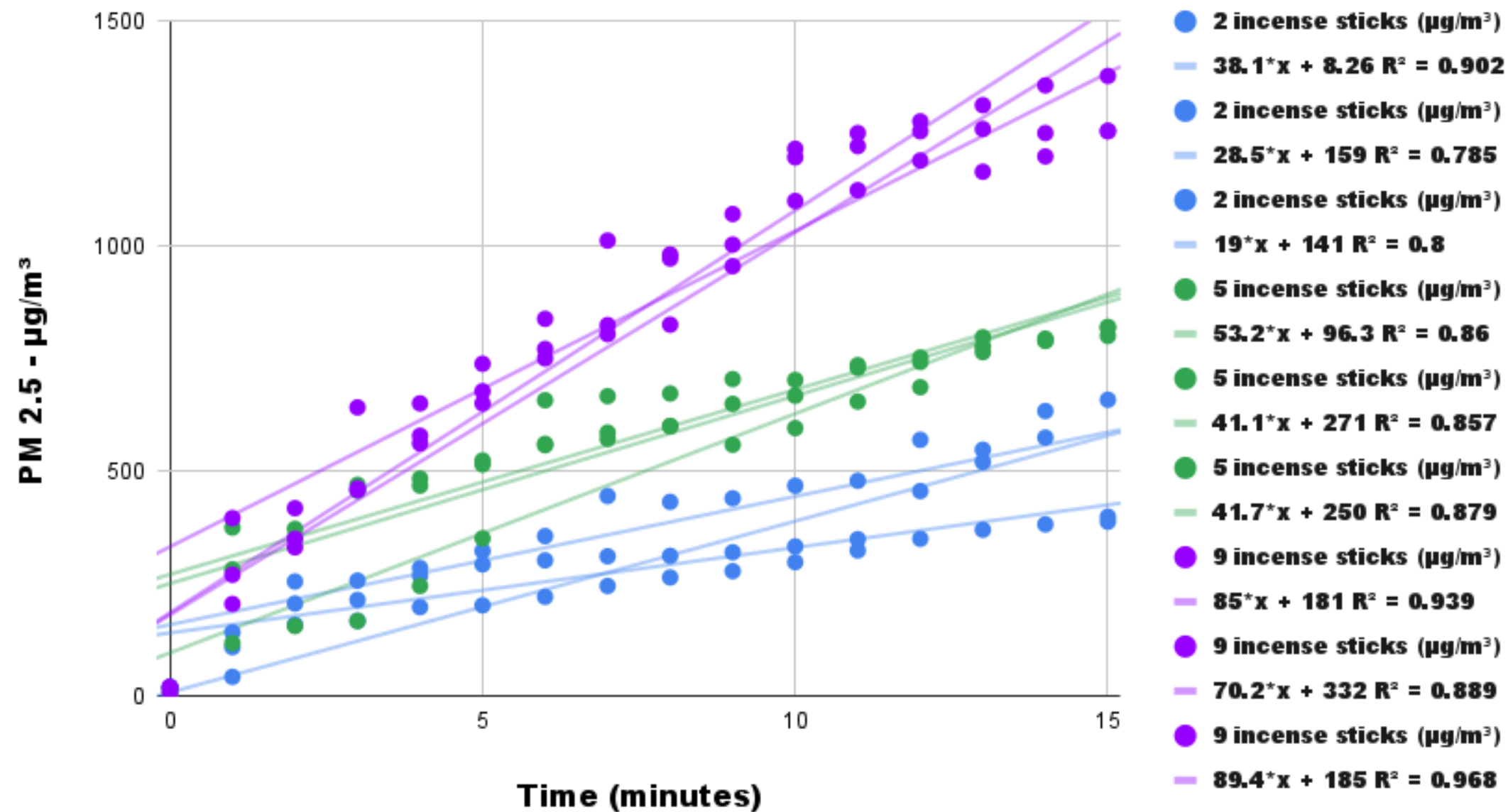
- **Growth Acceleration:** The loading rate (slope) increases sharply with more sticks, peaking at ~89.4 (µg/m³/min) for the 9 stick group.
- **Predictive Accuracy:** Strong linear fits (R² up to ~0.968) show a consistent relationship between time and PM2.5 loading.
- **Rapid Saturation:** 9 sticks drive concentrations toward ~1,500 µg/m³ within 15 minutes.
- **Cross-Sensor Consistency:** Similar dose response trends across both sensors support overall data reliability.

CONCLUSION

✅ **Both sensors show the same pattern: PM2.5 increases as more incense sticks are burned (2 < 5 < 9).**

✅ **Average PM2.5 (μg/m³):**
- Sensor 1: 266.19 → 455.63 → 786.60
- Sensor 2: 316.60 → 545.77 → 844.65

✅ **One-way ANOVA confirms incense quantity significantly affects PM2.5:**
Sensor 1: $p = 0.007$, Sensor 2: $p = 0.001$ ($p < 0.05$).

✅ **RECOMMENDATIONS :**
- Burn fewer sticks at a time and improve ventilation (open windows / doors or burn outdoors).
- Avoid burning multiple sticks in small or closed rooms, especially around children, elderly, or people with asthma.

✅ **NEXT STEP :**
Test different ventilation conditions and measure how quickly PM 2.5 drops after the incense is extinguished
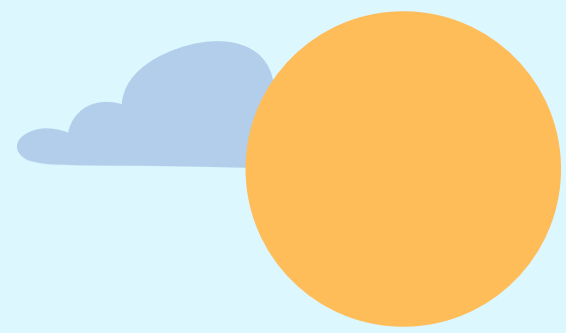
VSS BADGES

I am a data scientist

I make an impact

I am a STEM professional

REFERENCES

1. He, C., Morawska, L., & Knibbs, L. D. (2014). Modification of incense smoke emissions and their impact on indoor air quality. Atmospheric Environment, 94, 233-239.
2. Lin, T. C., Krishnaswamy, G., & Chi, D. S. (2008). Incense smoke: clinical, size-resolved, and analytical characteristics. Clinical and Molecular Allergy, 6(1), 3-10. https://doi.org/10.1186/1476-7961-6-3
3. Pollution Control Department of Thailand. (2024). Thailand Air Quality Standard for PM2.5. Ministry of Natural Resources and Environment. http://www.pcd.go.th
4. The GLOBE Program. (2025). GLOBE Observer: Cloud and Atmosphere Protocol. NASA. https://www.globe.gov
5. World Health Organization. (2021). WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide. World Health Organization. https://apps.who.int/iris/handle/10665/345329

CREDIT
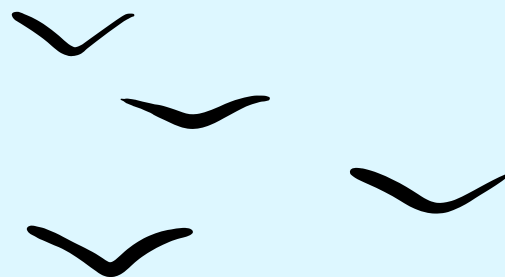
Assoc.Prof.Dr.Krisanadej Jaroensutasinee

Assoc.Prof.Dr. Mullica Jaroensutasinee

Miss Chonticha Kongthong

Mr. Tiwakorn Yaowa

Miss Thipsakul Makchit

Miss Nattakan Choosang

THANK YOU