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# Forecasting and Component Investigation of Respirable Particulate Matter ($PM_{10}$ and $PM_{2.5}$) from Dust Dispersion


Presented by:

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# PRESENTATION OUTLINE

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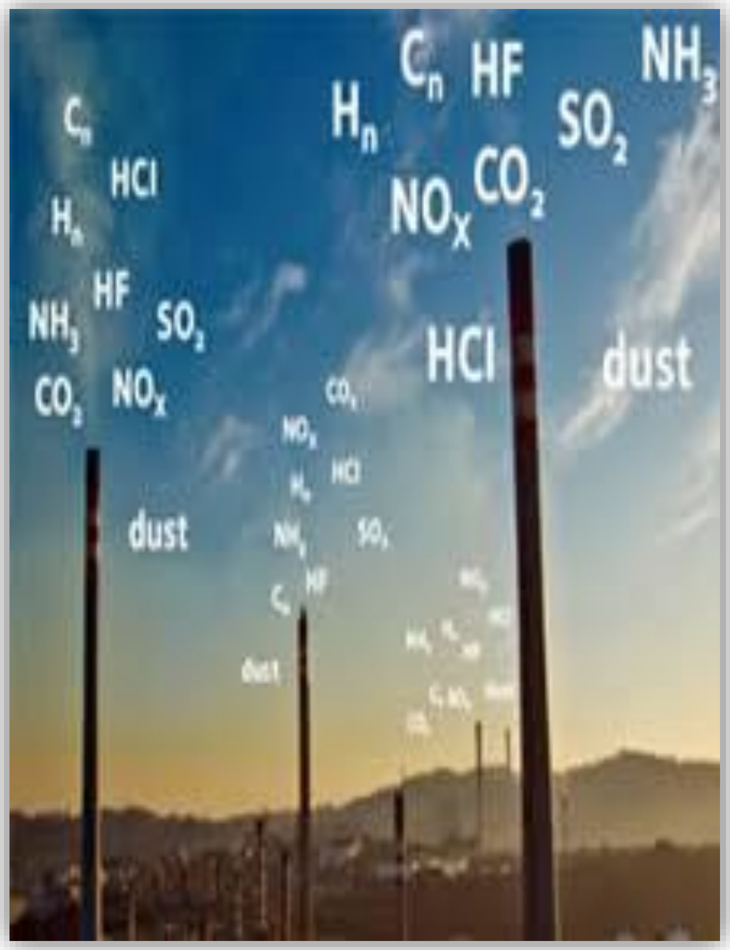
# INTRODUCTION

- "Particulate Matter" (PM), is a complex mixture of physical and chemical characteristics that varies depending on location and time.

- Common chemical constituents include:
  - Sulphates, nitrates, ammonium.
  - Inorganic ions - sodium, potassium, calcium, magnesium and chloride, crustal material, particle-bound water, metals (including cadmium, copper, nickel, vanadium, and zinc).
  - Elemental carbon and organic compounds (WHO,2013).

- The size of particles is directly linked to their potential for causing health problems.



# INTRODUCTION

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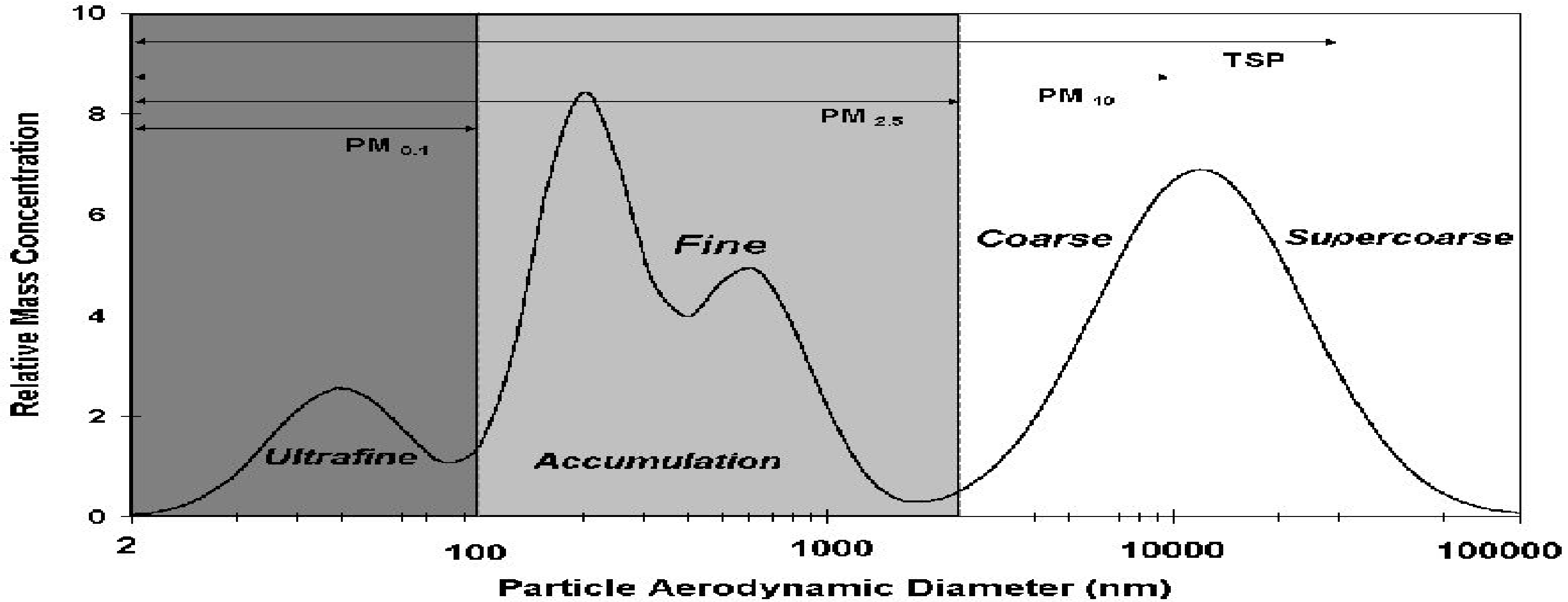
## Size Distribution Characteristics of PM

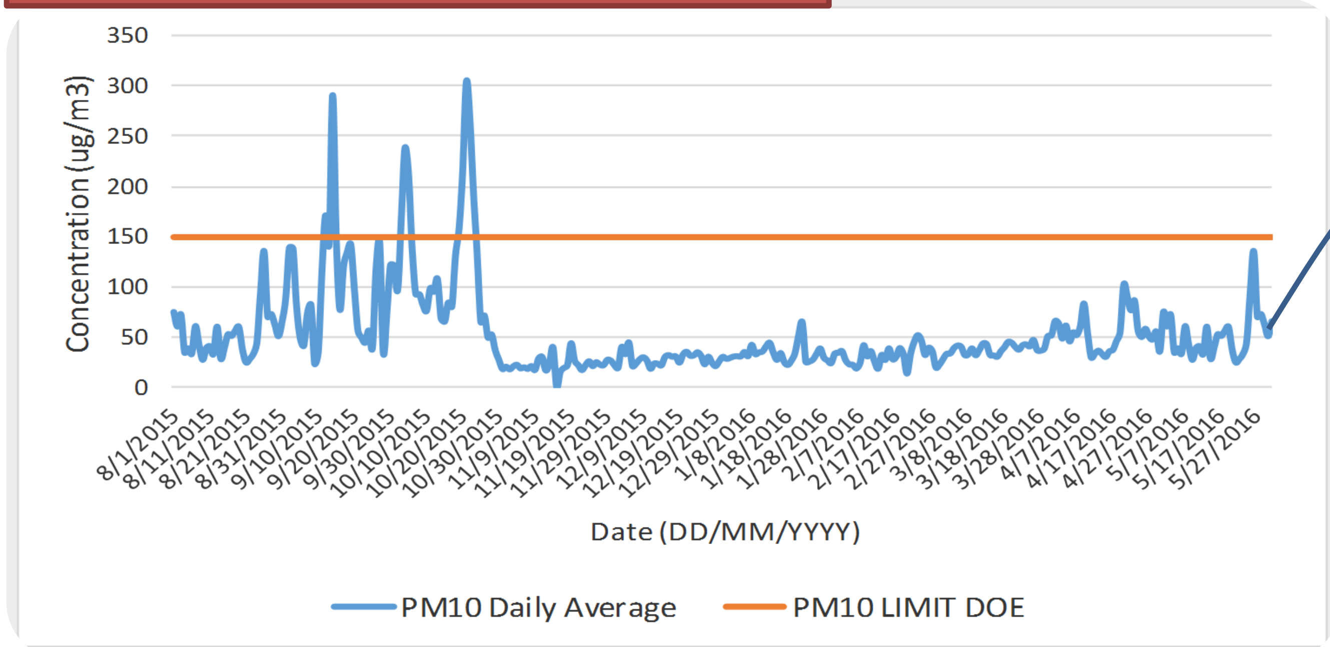



Source: Sioutas et al., 2005

Moreover, PM is defined according to the aerodynamic diameter - as this is **what determines how long they will reside in the air, how far they may be transported and, in terms of health, how they will be deposited in the respiratory system** (Wiseman, & Zereini 2009).

# INTRODUCTION – TIME SERIES AND FORECASTING OF PM

Time Series of Daily Average of $PM_{10}$




Forecast of Daily Average of $PM_{10}$

Daily concentrations of DOE measurement shows higher $PM_{10}$ mass concentrations for the period of Sept – Oct. 2015.

*Malaysia had experienced the haze episode from 22 August until 26 October 2015. This resulted in deterioration of air quality in the country.*

The early detection of poor air quality might be known by having forecasting models. Particulates concentration forecasting has two main advantages:

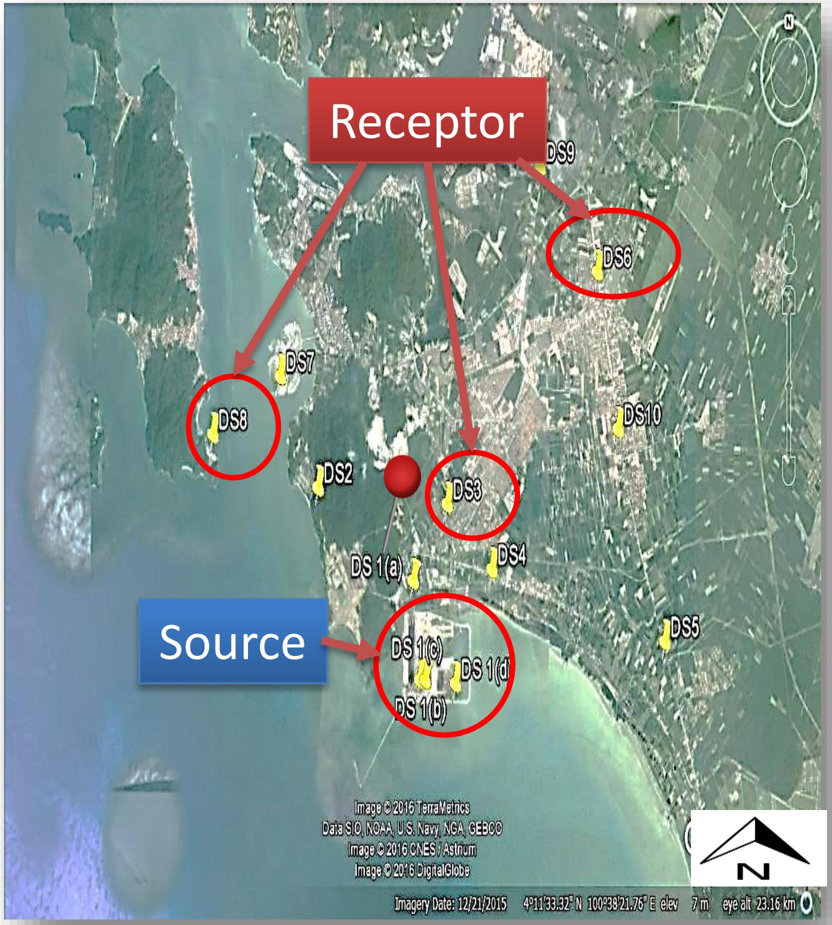
- First is for local authorities, whereby the government can take any suitable action.
- Second was that for community itself. The early detection might warn the community.

# OBJECTIVES AND RESEARCH AREA

Objectives

1. To formulate algorithms based on chemical species and PM concentrations.
2. To develop the Forecasting Tool to forecast consequent month status of $PM_{10}$ and $PM_{2.5}$

- This research focusing on 10 km radius of the area from the power station (Source).
- It consists of industrial area, villages, commercial and tourism area.
- Sampling were carried out for twelve (12) months.
- Only four (4) sites were selected to monitor the $PM_{10}$ and $PM_{2.5}$ and the time series.



# RESEARCH METHODOLOGY
## - Measurement of PM mass concentration

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**High Volume Sampler (HVS)**

- Collected using High Volume Sampler.
- Method determines average dust concentrations which comprises the collection of dust by drawing a constant flow rate of ambient air through a filter.

-Data were collected over a 24 hrs period and results are expressed in µg/m$^3$/24hrs (ie. mass of dust per volume of air per 24 hrs).

**Portable Particle Counter**

-Portable Particle Counter Analyser (GRIMM) is a real-time dust monitor.

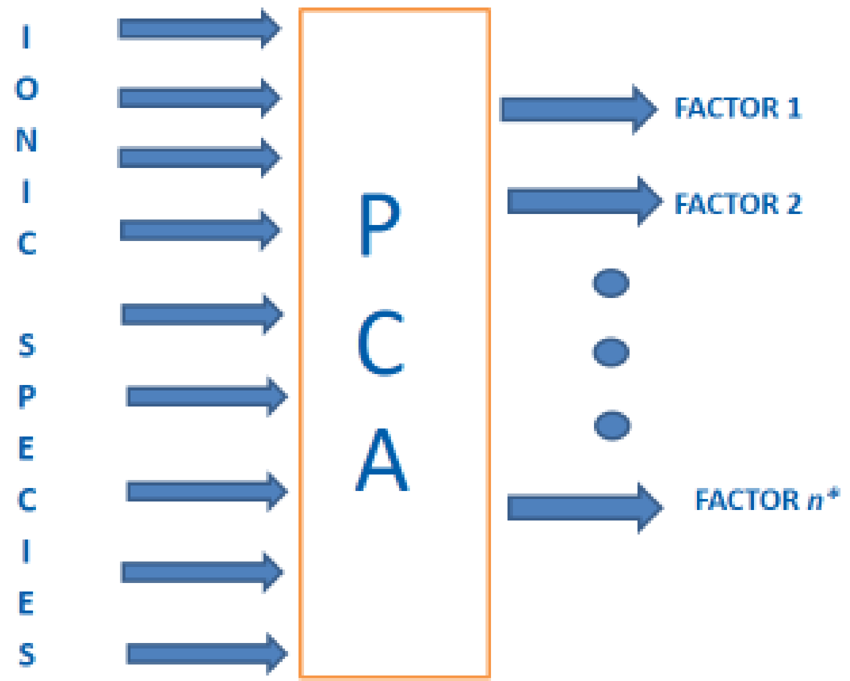
-The real time dust monitor was based on measuring principle of multi-channel light scattering optics.

- Data were collected hourly, over a 24 hrs period for 12 months.

# RESEARCH METHODOLOGY
# - PRINCIPAL COMPONENT ANALYSIS (PCA)

- PCA identifies the contributions of the major sources to the particulate pollution at a particular site

- Primary purpose of factor analysis:
  1. Data Reduction
  2. Summarization




PCA ARCHITECTURE

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## Linear Model - MLR

- Model relationship -
  - Between 2 or more explanatory variables and response variables by fitting equation.

$$y = b_0 + \sum_{i=1}^{n} b_i X_i + \varepsilon$$

$X_i$ are the independent variables and ε is stochastic error associated with the regression.

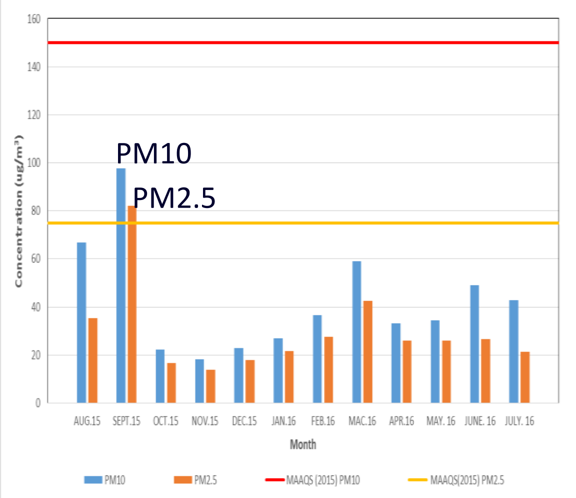
## PM Forecasting

- SPSS version 22 - developing the equation by MLR.
- Stepwise MLR was chosen as the regression method.

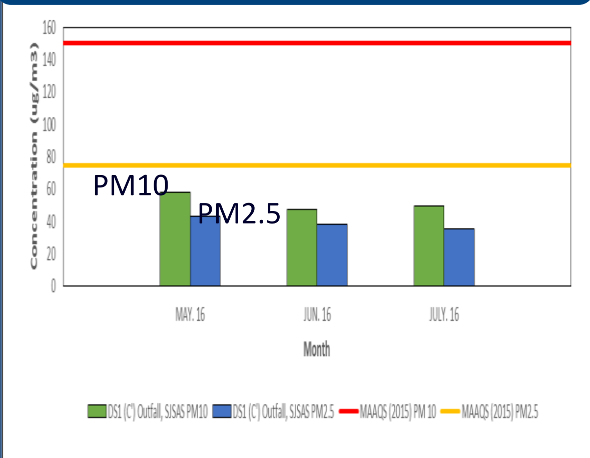
- Prediction →
  - Chemical species (independent variable)
  - PM concentrations (dependent variable).

# RESULTS AND DISCUSSION
# - $PM_{10}$ & $PM_{2.5}$ CONCENTRATIONS

### DS8: Receptor Site



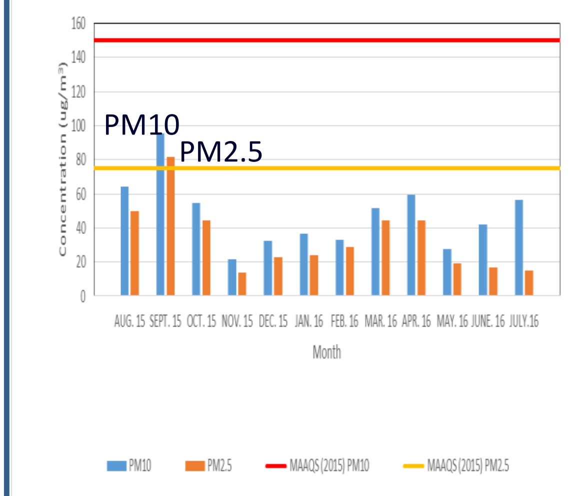

### DS1 : Source Site



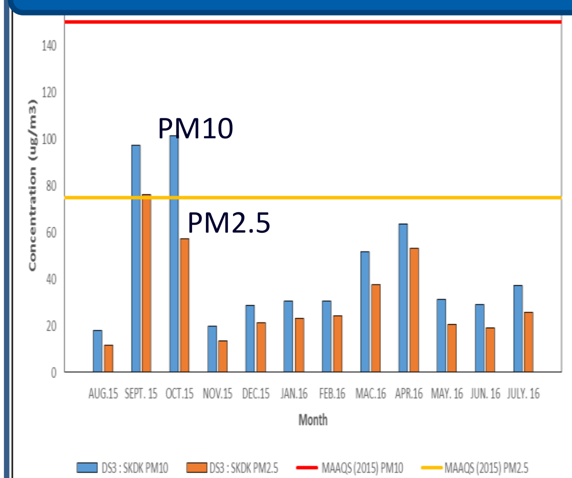

- $PM_{10}$ levels are well below the allowable limits of 150 ug/m³.
- Receptor Sites recorded $PM_{2.5}$ exceeded the Standard.
- Haze episode happened during Aug. – Sept. 2015 which might affect the $PM_{2.5}$ concentration.
- It is suspected that combination of local source and trans-boundary.

Note: MAAQS 2015
– PM10 : 150ug/m³
– PM2.5: 75ug/m³

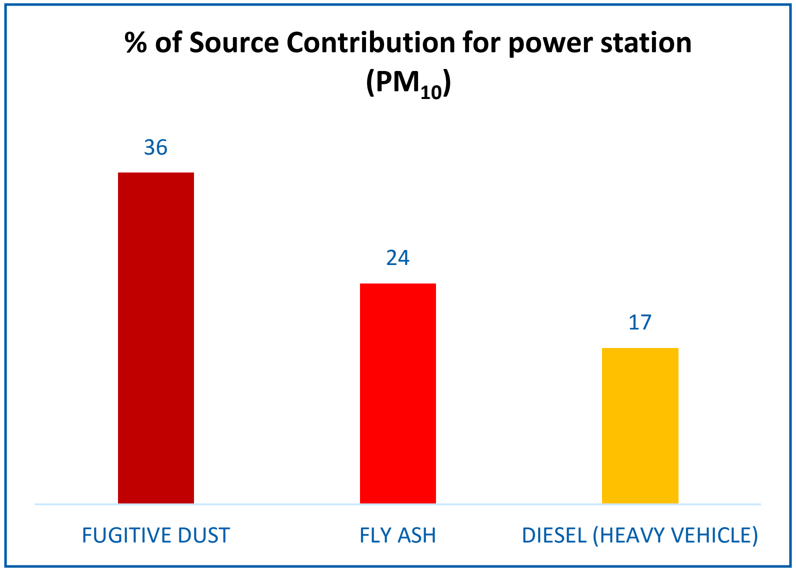
### DS6: Receptor Site



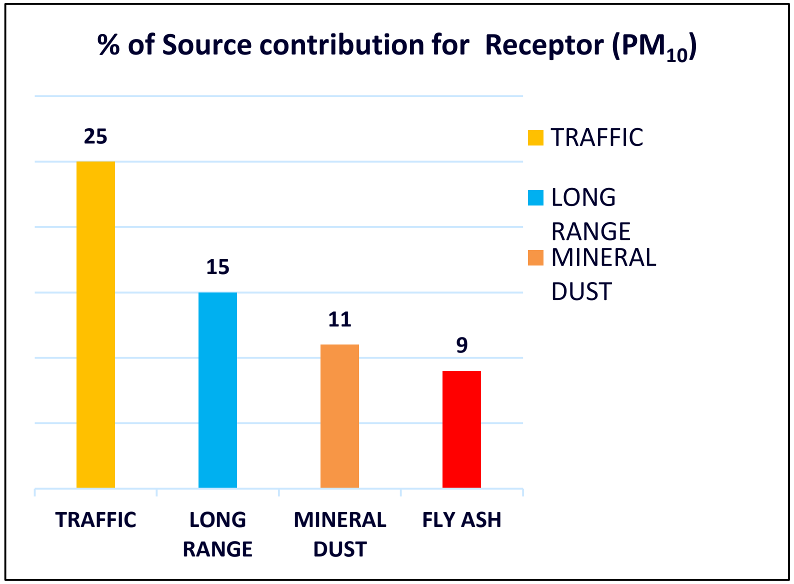

### DS3: Receptor Site



# RESULTS AND DISCUSSION - MAIN CONTRIBUTORS OF $PM_{10}$

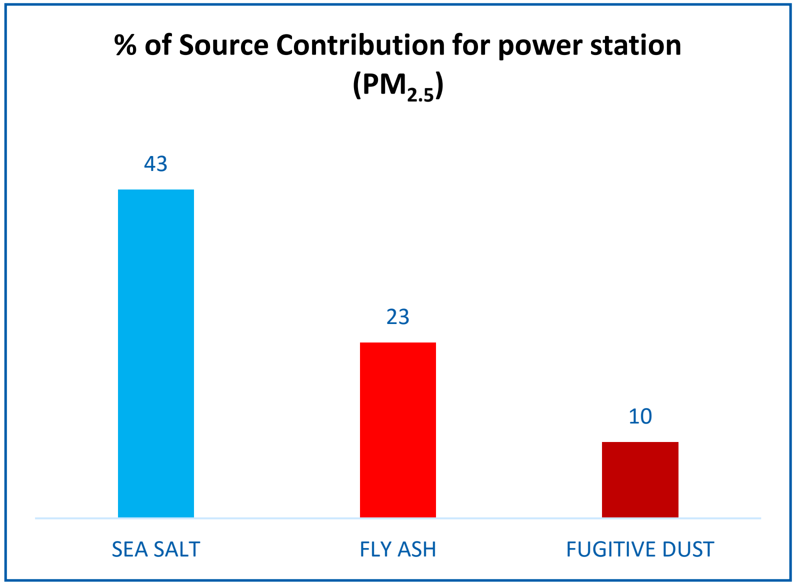


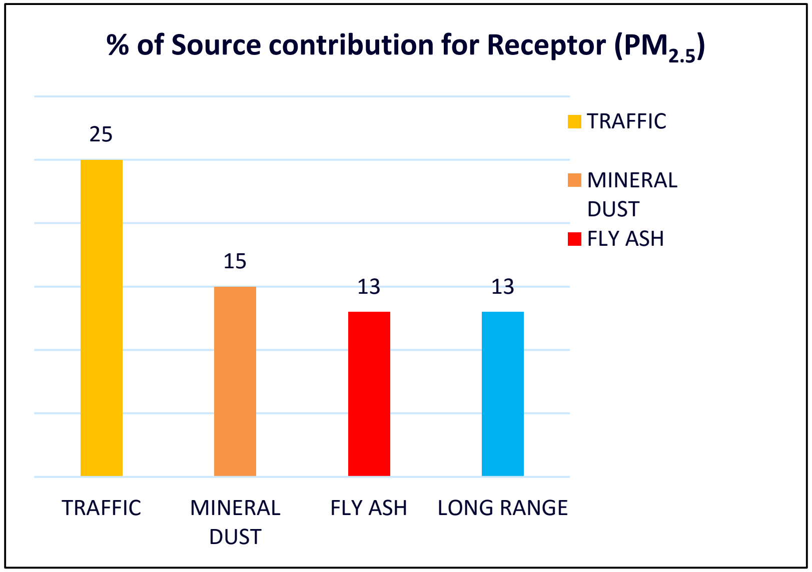

- Power Station - 3 main sources for $PM_{10}$
  - Fugitive dust, 36%
  - Fly ash, 24%
  - Motor vehicle, 17%




- Receptor sites - 3 other stations;
  - Traffic emission, 25%,
  - Long range/trans-boundary source 15%,
  - Mineral dust, 11%
  - Fly ash, 9%.

# RESULTS AND DISCUSSION - MAIN CONTRIBUTORS OF $PM_{2.5}$




- Power Station – 3 main sources, $PM_{2.5}$
  - Marine aerosol, 43%
  - Fly ash, 23%
  - Fugitive dust, 10%

- Receptor sites -
  - Traffic, 25%
  - Mineral dust, 15%
  - Fly ash and long range/transboundary sources, 13%

# Models Development for Forecasting of PM10 & PM2.5 Concentrations

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- Forecasting is based on the monthly basis, whereby the concentration of particulates ($PM_{10}$ and $PM_{2.5}$) of the next month at the power station and surrounding area is forecasted.

MLR Model

1

The prediction

- Chemical species (independent variable)

- PM concentrations (dependent variable).

2

-The ionic species used were Cl, S, Na, K, Ca, Mg, Ba, Cu, Mn, Ni, Pb, As, Ti, Th, Al, Fe, and Zn.

-MLR model consists of chemical elements that contribute to the formation of particulate matters.

Forecasting Model

3

Stepwise method was utilized, and if not having significant (>0.05) influence on the particulate matter, it will be excluded from the model.

# Models Development for Forecasting of PM10 & PM2.5 Concentrations -Forecasting Formula for PM10

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**Coefficients[a]**

| Model | | Unstandardized Coefficients B | Unstandardized Coefficients Std. Error | Standardized Coefficients Beta | t | Sig. | Collinearity Statistics Tolerance | Collinearity Statistics VIF |
|---|---|---|---|---|---|---|---|---|
| 1 | (Constant) | .043 | .057 | | .750 | .459 | | |
| | Ca | .739 | .130 | .704 | 5.697 | .000 | 1.000 | 1.000 |
| 2 | (Constant) | -.006 | .055 | | -.107 | .915 | | |
| | Ca | .561 | .132 | .535 | 4.235 | .000 | .784 | 1.276 |
| | LAGS(PM10,1) | .368 | .128 | .364 | 2.883 | .007 | .784 | 1.276 |
| 3 | (Constant) | -.066 | .059 | | -1.124 | .270 | | |
| | Ca | .529 | .126 | .504 | 4.190 | .000 | .773 | 1.293 |
| | LAGS(PM10,1) | .337 | .121 | .334 | 2.778 | .009 | .774 | 1.293 |
| | S | .301 | .138 | .237 | 2.181 | .037 | .951 | 1.051 |

a. Dependent Variable: PM10

**The Formula for SOURCE SITE:**

$$PM_{10} = 0.529(Ca) + 0.337(\text{Previous month of } PM_{10}) + 0.301(S) - 0.066$$

# Models Development for Forecasting of PM10 & PM2.5 Concentrations -Forecasting Formula for PM10

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**Coefficients**[a]

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Tolerance | VIF |
| 1 | (Constant) | .048 | .013 | | 3.603 | .000 | | |
| | S | .731 | .051 | .816 | 14.442 | .000 | 1.000 | 1.000 |
| 2 | (Constant) | .004 | .015 | | .266 | .791 | | |
| | S | .796 | .048 | .888 | 16.623 | .000 | .922 | 1.085 |
| | Al | .141 | .029 | .258 | 4.833 | .000 | .922 | 1.085 |
| 3 | (Constant) | .023 | .016 | | 1.447 | .151 | | |
| | S | .823 | .047 | .918 | 17.651 | .000 | .892 | 1.121 |
| | Al | .154 | .028 | .283 | 5.466 | .000 | .902 | 1.109 |
| | Na | -.173 | .054 | -.162 | -3.220 | .002 | .958 | 1.044 |
| 4 | (Constant) | .018 | .015 | | 1.227 | .223 | | |
| | S | .818 | .044 | .913 | 18.395 | .000 | .891 | 1.122 |
| | Al | .562 | .124 | 1.031 | 4.514 | .000 | .042 | 23.795 |
| | Na | -.200 | .052 | -.186 | -3.846 | .000 | .936 | 1.068 |
| | Ba | -.495 | .147 | -.764 | -3.356 | .001 | .042 | 23.654 |
| 5 | (Constant) | .023 | .015 | | 1.536 | .128 | | |
| | S | .849 | .046 | .947 | 18.295 | .000 | .795 | 1.258 |
| | Al | .702 | .141 | 1.290 | 4.978 | .000 | .032 | 31.532 |
| | Na | -.213 | .052 | -.199 | -4.132 | .000 | .920 | 1.087 |
| | Ba | -.612 | .156 | -.946 | -3.912 | .000 | .036 | 27.463 |
| | Nickel | -.091 | .045 | -.127 | -2.015 | .047 | .537 | 1.863 |

a. Dependent Variable: PM10

**The Formula for RECEPTOR SITE:**

$$PM_{10} = 0.849(S) + 0.702(Al) - 0.213(Na) - 0.612(Ba) - 0.091(Ni) + 0.023$$

# Forecasting Model


Multiple Linear Regression (MLR) Models for [PM10] Forecasting Based on Significant Ionic Species.

- Source Site; [PM10] = 0.529(Ca) + 0.337(PM10,lag) + 0.301(S) – 0.066

  ($R^2$ = 0.653)

- Receptor Site; [PM10] = 0.849(S) + 0.702(Al) – 0.213(Na) – 0.612(Ba) – 0.091(Ni) + 0.023

  ($R^2$ = 0.785)

**Highest $R^2$ is considered as the best model for forecasting [$PM_{10}$]

# Models Development for Forecasting of PM10 & PM2.5 Concentrations - Forecasting Formula for PM2.5

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**Coefficients**[a]

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Tolerance | VIF |
| 1 | (Constant) | .013 | .029 | | .431 | .669 | | |
| | Ca | 1.169 | .114 | .872 | 10.226 | .000 | 1.000 | 1.000 |
| 2 | (Constant) | .004 | .027 | | .146 | .885 | | |
| | Ca | .685 | .201 | .511 | 3.408 | .002 | .267 | 3.739 |
| | Mg | .570 | .203 | .422 | 2.813 | .008 | .267 | 3.739 |

a. Dependent Variable: PM2.5

**The Formula for SOURCE SITE:**

$$PM_{2.5} = 0.685(Ca) + 0.570(Mg) + 0.004$$

## Models Development for Forecasting of PM10 & PM2.5 Concentrations - Forecasting Formula for PM2.5

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**Coefficients**[a]

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Tolerance | VIF |
| 1 | (Constant) | .046 | .017 | | 2.729 | .007 | | |
| | S | .412 | .064 | .535 | 6.493 | .000 | 1.000 | 1.000 |
| 2 | (Constant) | .006 | .022 | | .247 | .806 | | |
| | S | .412 | .062 | .535 | 6.681 | .000 | 1.000 | 1.000 |
| | As | .118 | .044 | .216 | 2.702 | .008 | 1.000 | 1.000 |
| 3 | (Constant) | -.039 | .031 | | -1.286 | .201 | | |
| | S | .422 | .061 | .548 | 6.933 | .000 | .994 | 1.006 |
| | As | .107 | .043 | .195 | 2.456 | .016 | .984 | 1.016 |
| | Mg | .150 | .071 | .168 | 2.110 | .037 | .978 | 1.022 |

a. Dependent Variable: PM2.5

**The Formula for RECEPTOR SITE:**

**$PM_{2.5} = 0.422(S) + 0.107(As) + 0.150(Mg) - 0.039$**

# Forecasting Model


Multiple Linear Regression (MLR) Models for [PM2.5] Forecasting Based on Significant Ionic Species.

Source Site; [PM2.5] = 0.685(Ca) + 0.570(Mg) + 0.004

($R^2$ = 0.808)

Receptor Site; [PM2.5] = 0.422(S) + 0.107(As) + 0.150(Mg) – 0.039

($R^2$ = 0.361)

**Highest $R^2$ is considered as the best model for forecasting [$PM_{2.5}$]

# CONCLUSION

- **Dust prediction software** developed is useful for improving air quality and as an early warning to inform the community for them to reduce the outdoor activities.

- Determination of $PM_{10}$ and $PM_{2.5}$, by knowing the ionic species of interest.

- **PM Forecasting Model** established that fly ash is not the dominant source of PM pollutants ($PM_{10}$ and $PM_{2.5}$) within the 10 km radius of area; only within the vicinity of the power station.

- For that reason, the source site (power station) is not the main contributor to the dust pollution in the area.

# Thank You

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