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To cite this article: M S Samsudin *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **810** 012052

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Source of apportionment of Air Quality Parameters at Federal Port of Malaysia with Emphasis on Ship Emission

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Abstract. Air pollution is becoming a major environmental issue in Malaysia. Centered on data obtained from the Malaysian Department of Environment (DOE), this analysis focused on identifying possible causes of air quality heterogeneity across the research area. 14 air quality parameters in 7 monitoring stations for ten years (2009 – 2018) were gathered. To determine the source of air pollution around the study region, the Principal Component Analysis (PCA) approach from a chemometric methodology was applied. The PCA method has identified three varimax factor (VF) with 11 air quality parameters are the most significant parameters around the study area. It can be inferred from the analysis that the use of the PCA approach in chemometric techniques can be applied for the purpose of source apportionment. Accordingly, this study suggested that efforts should be put as a priority in the monitoring of ships emissions sources in Malaysia Federal Ports area and successful management of Malaysian air quality.

1. Introduction

In shipping goods and people around the world, the maritime sector is becoming increasingly essential. Indeed, more than 80% of global trade by volume and more than 70% of its value is borne on board ships and handled by seaports around the world [1]. The effect of emissions from ships on air quality has numerous factors and can be analysed on a worldwide or local perspective. The worldwide influence is primarily focused on pollution during ports-to-ports navigation, while the local impacts are mainly dependent on emissions in and near ports [2]. Emissions of CO_2 pledge greatly to global warming, whereas NO_x, SO_x, PM and VOC principally impact port cities' human health. [2].

In view of the significant contribution of ship emissions to air pollution emissions in Malaysian ports, it is necessary to quantify the contribution of that source. Data on air quality were collected between 2009 and 2018 to fill this information gap for subsequent source-apportionment analysis. In this study, air quality parameters were first briefly characterised and source factors contributing to air quality were quantified using main component analysis. Implications are then provided for future research and policy activities.

2. Methodology
2.1. Study Area

Seven continuous air monitoring stations were chosen near Federal Ports. The stations are Pasir Gudang (1° 26' 21.4008" N, 103° 53' 26.5956" E), Klang (2° 59' 8.7792" N, 101° 22' 29.7624" E), Kuantan (3° 58' 39.6012" N, 103° 24' 36.8928" E), Penang (5° 24' 43.1244" N, 100° 20' 23.9388" E), Tanjung Pelepas (1° 21' 58.9536" N, 103° 33' 31.6152" E), Kemaman (4° 15' 19.8252" N, 103° 28' 22.296" E) and Bintulu (3° 16' 8.094" N, 113° 4' 0.0012" E). Figure 1 shows air quality monitoring station locations which consist of six stations in Peninsular Malaysia and one in East Malaysia. There are no significant climate catastrophes in these regions (like volcanic eruptions, typhoons, and earthquakes) [6].
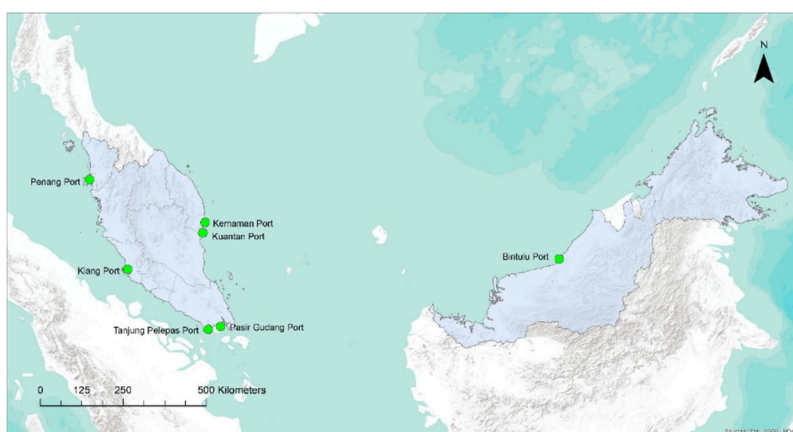

Figure 1. Location of the Malaysia Federal Ports

2.2. Data Collection

Air quality data was provided from Air Quality Division, Department of Environment (DOE) Malaysia. Alam Sekitar Malaysia Sdn. Bhd. (ASMA) collected and monitored data, as a DOE-authorized agency. All selected stations were determined based on data from 1st January 2009 to 31st December 2018. The parameters of air quality as used in this analysis include wind speed (Ws), wind direction (Wd), UVB, humidity, nitrogen oxides (NO_x), nitric oxide (NO), methane (CH_4), non-methane hydrocarbon (NmHC), total hydrocarbon (THC), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and particulate matter below 10 microns (PM_{10}). The measurements for these variables are hourly.

2.3. Data Pre-treatment

896 data points were used in this study (14 variables x 64 data set). From the overall results, the total amount of missing data was very small (~3 percent). In order to promote the inaccessible or incomplete data, the closest neighbouring approach [6]-[7] was implemented using XLSTAT 2019 add-in tools. The nearest neighbour method was based on Equation 1 gap endpoints:

$$y = y_1 \, if \, x \leq x_1 + [(x_1 - x_2)/2] \, or \, y = y_1 \, if \, x > x_1 + [(x_1 - x_2)/2] \tag{1}$$

where; y is the interpolant, x is the time point of the interpolant, y_1 and x_1 are the coordinates of the starting point of the gap, and y_2 and x_2 are the endpoints of the gap.

2.4. Principal Component Analysis

Principal Component Analysis (PCA) used on the standardised data set to observe and recognise factors influencing each parameter in contrast to the compositional pattern among the air quality parameters [8]. The new variable known as Principal Components (PCs) are linear combinations of original variables [9]. PCs can be expressed as follows [8], [11]:

$$y_{ij} = b_{1i}x_{1j} + bx_{2j} + \ldots + b_{mi}x_{mj} \qquad\qquad (2)$$

where y is a component score, b is the component loading, x is the measured value of the variable, i is the component number, j is the sample number, and m is the total number of variables.

The matrix of covariance was analyzed, generating Eigenvalues known as a root characteristic [11]. This analysis is based on eigenvalue criteria by which a value > 1 is intentionally essential and a new set of variables has been developed on the basis of the similarities of the entire data set [8]. Factor loading provides the association among the initial factors and the VFs, while the actual transformed annotations are considered factor scores. VF coefficients with a 0.49–0.30 correlation is examined 'weak' significant factor loadings, correlations within the range of 0.74–0.50 are examined 'moderate' and those within the range of >0.75 are examined 'strong' [6, 10, 12].

3. Result and Discussion

This study used a 9-year daily average secondary data. The database consists of 14 variables. Figure 2 summarises overall descriptive statistics of air pollutant variables. Multiple parameter average values are within New Malaysian Ambient Air Quality Standards (NMAAQS). This means Malaysia's air quality remains in controlled conditions. There are some parameters not listed in NMAAQS including Ws, Wd, UVB, Humidity, NO_x, NO, CH_4, NmHc and Thc.
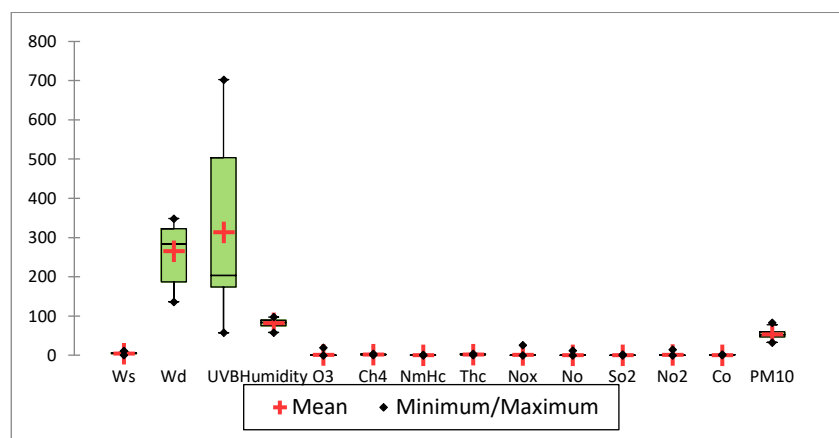

Figure 2. Overall descriptive statistics of daily average air quality parameters in the study areas, 2009-2018

To test associations between air quality variables and derived factors, factor loading estimation was carried out. After varimax rotation, there are only two VFs from three PCs that represent 87.87% of the data variance selected due to higher-than-one (> 1.0) values. Using the scree plot graph, the cut-off point was established (Figure 3). The values below one (< 1.0) are neglected due to redundancy with more significant factors. Multicollearity was among the original variables. In this analysis, since these values are solid and stable, with moderate to strong loading on the derived variables, VFs with absolute values over 0.75 were set as the selection threshold. Table 1 and Figure 4 highlight that 11 of the 14 parameters used in this study meet the threshold of 0.75 factor loads. These are Ws, UVB, NO_x, NO, CH_4, Thc, SO_2, NO_2, O_3, PM_{10}. These contaminants in the Federal Ports of Malaysia are then identified as possible pollutants.
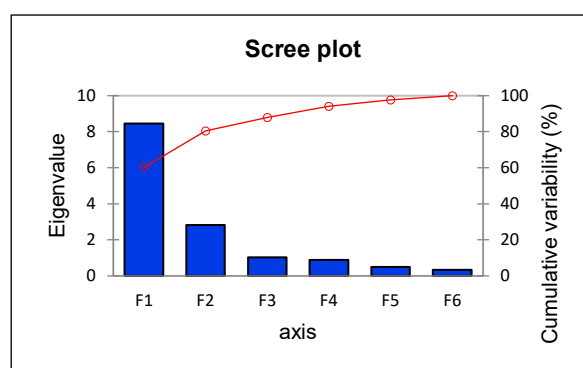
Figure 3. Screen plots for PCA

Table 1. Varifactors in the research area after varimax rotation and the potential source group

Parameter	VF1	VF2	VF3
Ws	0.205	0.872	-0.169
Wd	-0.653	-0.515	0.258
UVB	0.068	0.758	-0.445
Humidity	0.484	-0.404	0.708
NO_x	0.929	0.313	0.077
NO	0.887	0.299	0.168
CH_4	0.391	0.849	0.004
NmHc	0.632	0.715	0.069
Thc	0.452	0.837	0.012
SO_2	0.751	0.171	0.553
NO_2	0.960	0.258	-0.069
O_3	0.194	0.088	-0.816
CO	0.968	0.192	-0.124
PM_{10}	0.793	0.488	-0.100
Eigenvalue	8.444	2.826	1.031
Variability (%)	60.317	20.189	7.364
Cumulative %	60.317	80.506	87.870

The VF1 contributes 60.317% of air quality data variation. High loads from six parameters are NO_x (0.929), NO (0.887), SO_2 (0.751), NO_2 (0.960), CO (0.968) and PM_{10} (0.793). This VF is aligning with Johansson study [13], for all model pollutants, considering the emission rates of these sea areas, the Singapore Strait has by far the largest concentration of pollutants.

Even, for other sources of contaminations other than NO_x, the Malacca Strait, the Eastern China Sea and the Yellow Sea have elevated emission concentrations. Emission Control Areas (ECAs) are easily visible because, in terms of relative NO_x emissions, they have low emissions of SO_x and PM. On the basis of the emissions totals of the current study, the worldwide average of the marine fuel sulphur gratified of IMO registered traffic was 1.9% (by mass) in 2015, but there are significant regional differences instigated by several sulphur regulations [13].
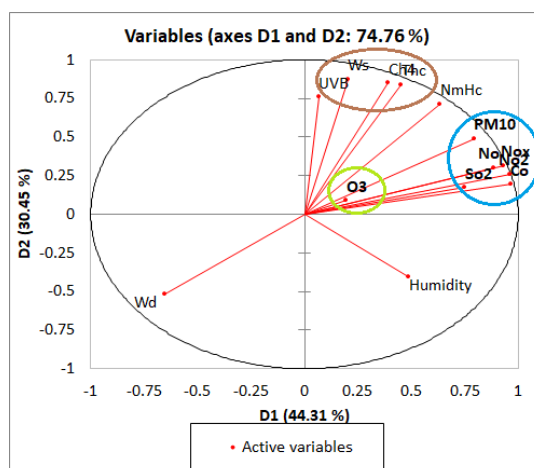
Figure 4. Factor loading plot after varimax rotation (Blue: VF1; Brown: VF2; Green: VF3)

The VF2 demonstrates 20.189% of data variance. It has high Ws (0.872), UVB (0.758), CH_4 (0.849) and Thc (0.837) loads. Based on Eyring research [23], the calculation of total hydrocarbons is based on shipping combustion on the fraction between CH_4 and the other parameters from fuel combustion in 25 groups. A differentiation is made between gas oil and fuel oil as fuel types compounds have been tested. Evaporation during tanker loading and shipment of crude oil is a major source of hydrocarbons, in addition to fuel combustion emissions.

The VF3 demonstrates 7.364% of data variance with high negative loading from O_3 (-0.816). O_3 is a heavy oxidising gas with a particular odour, often distributed in the stratosphere. Ultraviolet radiation can be removed and stopped from reaching the earth, ensuring that humans and the atmosphere are harmless. O_3 is also involved in the heterogeneous reaction on the surface of particles that accelerates the conversion and development of PM and other air pollutants. The negative loading of O_3 from Table 2 is significant with Jia et al (2020) [14]. In field studies conducted, O_3 concentrations in the troposphere have a negative correlation with atmospheric particle concentrations. Since O_3 and H_2O occur in the atmosphere, SO_2 is stimulated on the soil to generate calcium carbonate sulphate, thus reducing ozone levels.

4. Conclusion

The goal of this study, which is to determine the chemical fingerprints of possible sources of air pollution in the Malaysian Federal Ports, has also been accomplished through this research, and the PCA can be used to permit variations between the types of sources of pollutants and the dissimilarity of the main potential sources of pollution. This study confirmed that regional and local sources of emissions contributed concurrently and tended to discriminate against the dominant sources at each site, and showed that the operation of these ports had a direct and indirect impact on the parameters of air quality levels.

The key role of reliable and quantitative information of pollution sources in enforcing the Guidelines on air quality. Implementing such mitigation measures to control air pollution from shipping industry, with an emphasis on emissions from shipping, will have possible advantages in terms of air quality. The Malaysia Federal Ports source allocation results are intended to integrate scientific studies in surrounding port cities with natural, economic and urban developments. As a conclusion, continuous monitoring should be carried out in the area and the authority will concentrate on the most relevant parameters that led to air pollution from this study. This study therefore suggested that attempts to regulate point and non-point emissions sources should be prioritised for the potential and successful management of Malaysian air quality.

Acknowledgments

References

[1]   UNCTAD 2017 Review of Maritime Transport 2017
[2]   Toscano D and Murena F 2019 Atmospheric ship emissions in ports: A review. Correlation with data of ship traffic *Atmospheric Environment: X*, 4, 100050
[3]   UNCTAD 2018 Review of Maritime Transport 2018 New York October 2018 https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf
[4]   Pallis A A and Vaggelas G K 2019 *Cruise shipping and green ports: a strategic challenge* In Green Ports (pp. 255-273) Elsevier
[5]   Peisley T 2014 *End of the Beginning for Cruising* (Colchester: Seatrade Communications Ltd.)
[6]   Azid A, Juahir H, Toriman M E, Endut A, Kamarudin M K A, Rahman M N A, Hasnam C N C, Saudi A S M and Yunus K 2015 Source apportionment of air pollution: a case study in Malaysia *Jurnal Teknologi* 72(1)
[7]   Azmi S Z, Latif M T, Ismail A S, Juneng L and Jemain A A 2010 Trend and status of air quality at three different monitoring stations in the Klang Valley, Malaysia *Air Quality, Atmosphere & Health* 3(1), 53-64
[8]   Dominick D, Juahir H, Latif M T, Zain S M and Aris A Z 2012 Spatial assessment of air quality patterns in Malaysia using multivariate analysis *Atmospheric environment* 60, 172-81
[9]   Sousa S I V, Martins F G, Alvim-Ferraz M C M and Pereira M C 2007 Multiple linear regression and artificial neural networks based on principal components to predict ozone concentrations *Environmental Modelling & Software* 22(1) 97-103
[10]   Samsudin M S, Azid A, Khalit S I, Saudi A S M and Zaudi M A 2017 river water quality assessment using APCS-MLR and statistical process control in Johor river basin *Malaysia Int. J. Adv. Appl. Sci.* 4(8), 84-97
[11]   Vega M, Pardo R, Barrado E and Debán L 1998 Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis *Water research* 32(12), 3581-592
[12]   Retnam A, Zakaria M P, Juahir H, Aris A Z, Zali M A and Kasim M F 2013 Chemometric techniques in distribution, characterisation and source apportionment of polycyclic aromatic hydrocarbons (PAHS) in aquaculture sediments in Malaysia *Marine pollution bulletin* 69(1-2), 55-66
[13]   Johansson L, Jalkanen J P and Kukkonen J 2017 Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution. *Atmospheric Environment* 167 403-15
[14]   Jia B, Dong R and Du J 2020 Ozone concentrations prediction in Lanzhou, China, using chaotic artificial neural network. *Chemometrics and Intelligent Laboratory Systems* 204 104098