OPEN ACCESS
Journal of Environmental Science and Technology

ISSN 1994-7887
DOI: 10.3923/jest.2017.

Research Article
Environmetric Study on Air Quality Pattern for Assessment in Northern Region of Peninsular Malaysia

[1]Azman Shah Ismail, [1]Ahmad Makmom Abdullah and [2]Mohd Armi Abu Samah

[1]Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[2]Kulliyyah of Science, International Islamic University Malaysia, 25200 Kuantan Campus, Pahang, Malaysia

Abstract
Background and Objective: Causes of air quality problems detected are emission from vehicles, industrial emissions and open burning. The objective of this study was to determine the significant pollutant parameters contributing to air quality problems and also to look at air quality pattern at 12 air monitoring stations in the Northern region of Peninsular Malaysia (Perlis, Kedah, Pulau Pinang and Perak). **Methodology:** The data set was given from the Department of Environment, Malaysia (DOE) for the years 2002-2012 (11 years). Basically, air pollution index (API) parameters such as O_3, SO_2, CO, NO_2 and PM_{10} were involved in this study. Therefore, environmental metric techniques used such as cluster analysis (CA), perform three smaller groups compared 12 stations which has a same characteristic. This clusterization was also used to look air quality pattern based on yearly and specific monthly basis. It were shown that, 2005 and 2006 has a more stand out and different pattern. The third quarter of these years showed predominant and different pattern due to transboundary pollution. Discriminant analysis (DA) was used for differentiating each class. The study found that there were establish different variables, between each class. Principal component analysis (PCA), combined with factor analysis (FA), was used to know significant pollutant parameters based on five pollutants/gases in the air pollution index (API) which cause many activities either internal or external factors. **Results:** The study found that SO_2, NO_2 and O_3 are the major pollutants contributing to degradation of air quality in the Northern region due to the combustion process from vehicles and industries. **Conclusion:** As a result of using the envirometric technique for analyzing huge data sets become better understanding air quality pattern and more clearly identify significant air pollutant parameters.

Key words: Air pollutants, pollution parameters, environmetric techniques, combustion process, meteorological factors

Received: Accepted: Published:

Citation: Azman Shah Ismail, Ahmad Makmom Abdullah and Mohd Armi Abu Samah, 2017. Environmetric study on air quality pattern for assessment in Northern region of Peninsular Malaysia. J. Environ. Sci. Technol., CC: CC-CC.

Corresponding Author: Azman Shah Ismail, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
Tel: 04-9793100

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

After independence from the British in 1957, Malaysia started strengthens their policy of development. As a result, many areas developed into urban and industrial regions. From an agricultural base, reform led to industrialization, with a negative impact on the environment. Industrial expansion, rapid urbanization and increase high volume of vehicles caused air quality problems and are threats to both the natural environment and public health[1]. It may decrease the quality of life of residents[2].

The main cities contribute one of the factors of air quality problems through their rapid urbanization[3].I n 2010, Malaysia's population was approximately 28,588,600 people, focused on the Northern regions such as Perlis (235,800), Kedah (1,949,300), Pulau Pinang (1,575,900) and Perak (2,379,000), but currently in 2012 has increased to 29,336,800, focusing on Perlis (239,400), Kedah (1,996,800), Pulau Pinang (1,611,100) and Perak (2,416,700). Most people migrate to urban and industrial areas for job opportunities. The population in urban and industrial areas was increased[4]. Through the urbanization process will contribute a decreasing number of good days, based on API indicator[3].The urbanization process led to changes in meteorological parameters[5].

Public complains in environmental issues are the one significant indicator of concern and worry about quality of life. They exist to channel frustrations to the authorities. In 2002, the DOE received public complaints in 2,204 cases. The 74% (1631 cases) were air pollution complaints[6]. In 2012, this increased to 6,062 cases, 1465 (24.2%) cases from the Northern region. Air pollution complaints contributed 4,467 cases (73.7%)[6].

Most air quality studies have focused on urban areas such as Kuala Lumpur, because those areas have physically shown a high number in term of population, transport, industrial, commercial and residential factors. Air quality causes depending on economic, political and technological development, climate and topography. In another study, meteorological factors were determined to affect air pollution quality directly[7].

Degradation of air quality in Southern Thailand (August, 2005) is caused from wind movement carrying particulate matter from Sumatera Island, Indonesia[8]. This means that air pollutant movement can cross not only Malaysia, especially the Northern region, but may reach as far as Southern Thailand. Air pollutants such as ozone can reach across the Pacific Ocean from Asian source regions and be deposited in the Western U.S.[9].

Among the causes of the air quality problems detected are emission from vehicles, industrial emissions and open burning. This is especially in urban areas such as Klang Valley, Ipoh and Georgetown, Penang[10]. Malaysia is the largest user of motor vehicles in Asia[11]. The gases emitted from motor vehicles are hydrocarbon, carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen dioxide[11].

In 2002, there were 11,975,641 units of registered vehicles in Malaysia. From that figure, 3,136,109 units were registered in the Northern region. Currently, 22,702,221 vehicles are registered in Malaysia, with 5,540,864 in the Northern region of Peninsular Malaysia[6].Urban population growth leads to an increasing number of vehicles[12].

In Malaysia, the number of industries keeps increasing. There are 15,481 industries in Malaysia in 2012 subjected to Environmental Regulation (Clean Air) 1978 only. The distribution number of industries was in Northern region as in Perlis (54), Kedah (898), Penang (1,169) and Perak (1,521). This regulation reflects to the inventory of chimney from industries[6].

In 2012, CO produced was 1,873,730 MT (Vehicles: 94.97%, power plants: 3.85% and industries: 0.5%). The NO_2 877,364 MT (Power plants: 60%, vehicles: 26% and industries: 6%). The SO_2 198,519 MT (Power plants: 48%, vehicles: 7% and industries: 10%). The PM_{10} 6,049 MT (Vehicles: 76%, power plants: 15% and industries: 4%)[6].

The air pollution index (API) has become an important indicator of the air quality. There were used over the entire world. It is easy to understand and clear communicate to the stakeholders. The Malaysia air pollution index (MAPI) has been through modification[13].

Until now, it is still important to provide air quality readings to the public. The challenges of environmental data interpretation include a huge amount of samples, timeliness, availability, gaps, classification, reliable and representative factors.

The amount of sample refers to the quantity of data collected. If more data collected it will increase of efficiency. Both might be facing the problem of lots of information. As a result, it can be biased in the evaluation. To perform good interpretation result through huge of data need suitable statistic method based on the objective. The messy information is more valuable and interesting if analysis result presented in drawing view[14].

Currently, there are many statistical analysis techniques to interpret environmental data using envirometric techniques. It uses multivariate analysis such as cluster, discriminant and principal components.

The study objective is to look at air quality pattern and determined significant air pollutant parameters in the Northern region of Peninsular Malaysia.

MATERIALS AND METHODS

Location: Malaysia is 329,960.22 km^2 in area. It consisted of two major landmasses, Peninsular Malaysia and the North Borneo territories of Sabah and Sarawak. The area of Peninsular Malaysia[15] is 131,798 km^2. Northern Peninsular Malaysia area consisted of 32,331 km^2 with Perlis, Kedah, Pulau Pinang and Perak[15].

The Department of Environment, Malaysia (DOE) had classified air monitoring stations based on land use characteristics. One consideration was being near residential houses for protecting human health. The sources of pollutant might be from industrial estates and high volume of traffic.

In the Northern region of Peninsular Malaysia, there were four states: Perlis (1 station), Kedah (3 stations), Penang (3 stations) and Perak (5 stations). The totals of air monitoring stations were 12 out of 52 in the whole of Malaysia under National Continuous Air Quality Monitoring Network. Most air monitoring stations located in sub-urban, urban and industrial areas[6]. Table 1 showed detailed information about air monitoring stations location and Fig. 1 showed their map in the Northern region of Peninsular Malaysia.

Frame of data: Alam Sekitar Malaysia Berhad (ASMA) was appointed by the Department of Environment (DOE) to run the air monitoring program in Malaysia. They had used a gas analyzer for capturing CO, O_3, SO_2 and NO_2. Particulate matter with diameter size below 10 μm (PM_{10}) were using manual high volume sampler. In Northern region, Manjung air monitoring station (CA0041) only measured PM_{10}. The 14 out 52 air monitoring stations in Malaysia measured PM_{10} only using a high volume sampler. Other stations were complete with all parameters needed in the air pollution index (API) units. The data produced by AlamSekitar Malaysia Berhad (ASMA) will be examined and validated by the Department of Environment (DOE) as an authority before giving to the stakeholders.

Table 1: Location air monitoring stations in Northern region Peninsular Malaysia

States	St. ID	Air monitoring stations	Representative names	Latitude (N)	Longitude (E)
Perlis	CA0033	ILP Kangar, Kangar	Kangar	6°42.395	100°18.406
Kedah	CA0017	Sekolah Kebangsan Bakar Arang	Sungai Petani	5°37.888	100°28.182
	CA0032	Kompleks Sukan Langkawi	Langkawi	6°43.007	100°21.088
	CA0040	Sekolah Menengah (A) Mergong	Alor Star	6°13.710	100°34.686
P. Pinang	CA0003	Sekolah Kebangsan Cenderawasih	Perai	5°22.265	100°23.344
	CA0009	Sekolah Kebangsaan Seberang Jaya II	Seberang Jaya	5°23.893	100°24.235
	CA0038	Universiti Sains Malaysia	USM, Penang	5°21.372	100°18.476
Perak	CA0008	Sekolah Menengah Jalan Tasek	Tasek	4°62.939	101°11.659
	CA0020	Sekolah Kebangsaan Air Puteh	Taiping	4°89.881	100°67.912
	CA0041	Pejabat Daerah Manjung	Manjung	4°12.020	100°39.800
	CA0045	UPSI	T. Malim	3°68.758	101°52.438
	CA0046	Sekolah Menengah Pegoh	Ipoh	4°55.330	101°08.017

Source: Department of Environment (2012)

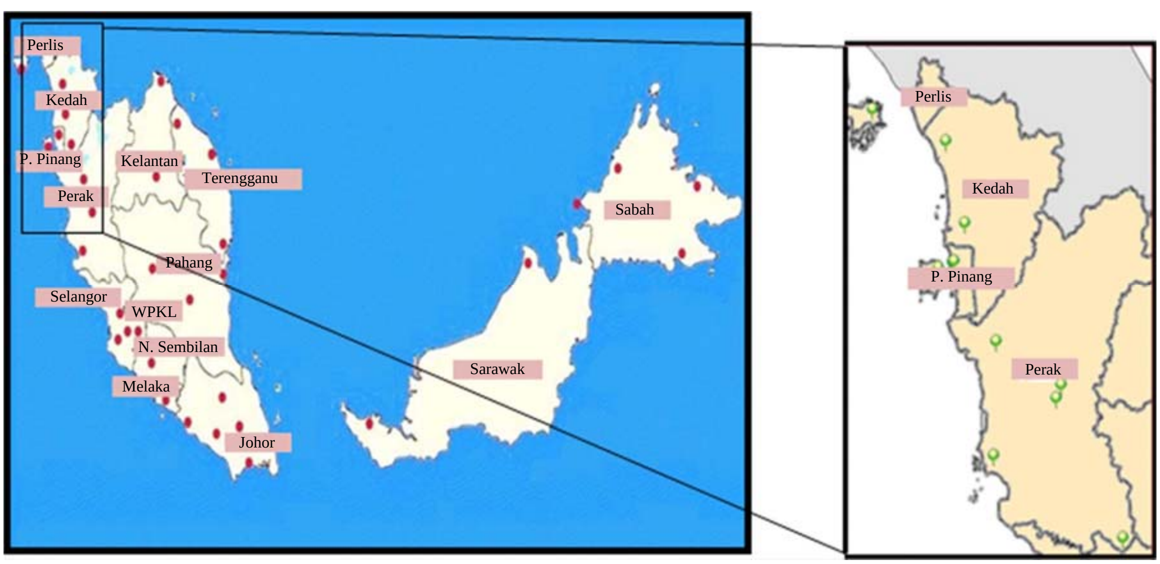

Fig. 1: Location map for air monitoring stations in Northern region of Peninsular Malaysia

The students were used five pollutants consist in basic parameters air pollution index (API) for all Northern region air monitoring stations except Manjung station (CA0041). The parameters were ground level ozone (O_3), carbon monoxide (CO), particulate matters (PM_{10}), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2).

The data collected hourly and were used to form a daily average. The data set runs from January, 2002 until December, 2012 (11 years). Total data sets were 48,216 at 12 air monitoring stations in four states: Perlis, Kedah, Pulau Pinang and Perak.

Statistical analysis method: This study identified three methods for achieving the objective. There were cluster analysis (CA), discriminant analysis (DA) and principal component analysis (PCA) via XLSTAT software version 2003. Using this statistic approach, we were able to determine the selected parameters and find a pattern.

Cluster analyses (CA) were used to establish the uniform characteristic of air pollution parameter. Cluster analysis played a very important role to create dissimilarity from large samples or group and make profiling.

This approach was very important when handle huge of data. Make it simple and easy to understand which the technique comprises the set of data[16]. So, for this case it needed to classify 12 air monitoring stations, which were located in different places for a small group.

Normally, hierarchical agglomerative used cluster analysis (HACA) as an approach to find dissimilarity relationship and illustrated as a dendrogram graph. This is the best approach and easy for understanding[17]. This technique also was applied to identify air quality patterns from 2002 until 2012. Discriminant analysis (DA) introduced in this study for validation.

After clusterization, it needed to determine the total percentage corrected cases or efficiency how much the result reliable. It also can show level of relationship between the variables. Principal component analysis (PCA)/factor analysis (FA) was very important to summarize the pattern of data. This technique created a new variable.

To get much better result, it supported rotation algorithm. This technique used to determine the source of pollutants. Principle component analysis combined with factor analysis can perform strong relationship each component.

RESULTS AND DISCUSSION

Descriptive analysis of air quality: Descriptive analysis is the basic statistical method to show the exact reading for all parameters of the air pollution index (API). This study puts a basic descriptive such as mean, median, mode, maximum, standard deviation and skewness. It is based on average starting on year 2002 until 2012 (11 years) and compared with Recommended Malaysia Air Quality Guideline. This guideline sets a standard 150 $\mu g\ m^{-3}$ for PM_{10}, CO (9 ppm), O_3 (0.1 ppm), NO_2 (0.17 ppm) and SO_2 (0.04 ppm).

Categorized of air quality pattern using cluster analysis (CA): There are 52 air monitoring stations in Malaysia. In the Northern region there are 12 monitoring stations located various sources of pollution. Currently DOE categorized based on industrial, sub-urban and urban. Figure 2 shows three pattern groups which classified as class 1, class 2 and class 3. This classes carrying dissimilarity characteristic of the air pollution index (API). Class 1 refers to the air monitoring station in Sekolah Kebangsaan Cenderawasih, Perai, Penang (CA0003).

This station contributed highest number of dissimilarity to the graph. It is performed alone and gives a significant indicator of air quality. It can be presented as a not good air condition (NGAC). Within the air monitoring station was the Prai Free Trade Zone.

Nowadays, 1,066 out of 4,838 industries have potential to contribute air pollution in Penang, most located in Prai area. The major pollution in Prai areas from wood industries (2.75%), electronics (27.52%), metals (39.45%), chemical industries (24.77%) and rubber industries (5.50%)[6].

Class 2 covered air monitoring stations in USM (CA0028), Langkawi (CA0032), Alor Star (CA0040), Perlis (CA0033) and Taiping (CA0020). This class showed lowest dissimilarity level compared class 1 and 3. Many areas in class 2 had no congested traffic. The number of industrial areas was under control. It can be stated as ideal air condition (IAC).

Within the USM air monitoring station are Bayan Lepas Free Trade Zone Phase 1, 2, 3, 4 and Sungai Pinang Industrial Area. Major pollutant sources come from quarries (6.21%), wood base industries (7.59%), textiles (41.38%) and electronics (44.83%)[6]. Within three kilometers from Taiping air monitoring station is the Kemunting Industrial Area. This area has type of industry such as rubber gloves, metals, non-metals, printings, textiles, foods and plastics. Oil palm mill industry and pulp and paper mill are among the heavy industry located nearby.

Within three kilometers from Alor Star air monitoring station are Mergong Industrial Areas Phase 1 and 2, Mergong Barrage Industrial Area. This area has various type and mix industries. This air monitoring station is located nearby residential, academic complex and near public transport terminal.

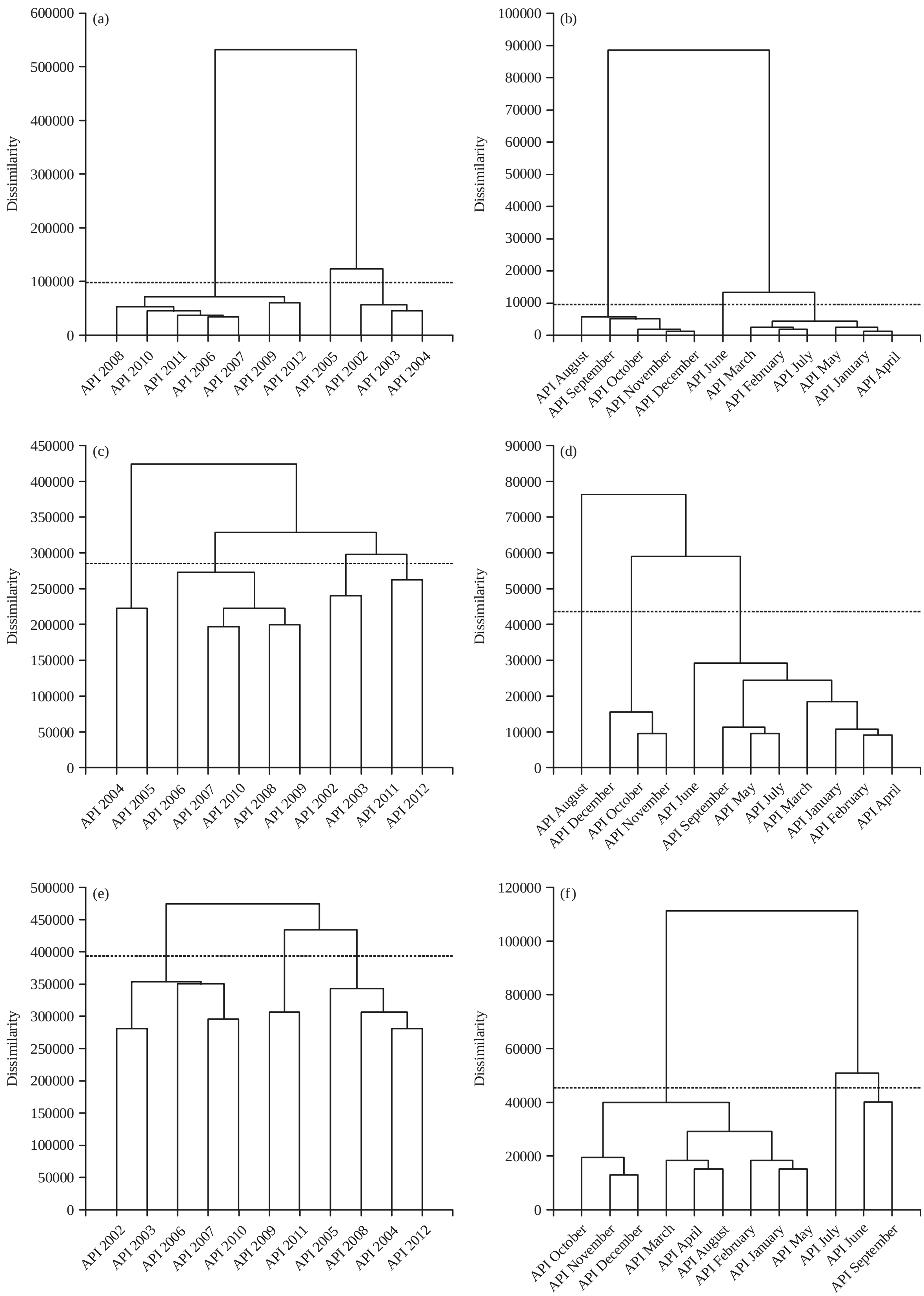

Fig. 2(a-f): Patterns of API Based on yearly and specific monthly, (a) Class 1 (Yearly), (b) Class 1 (Monthly-2005), (c) Class 2 (Yearly), (d) Class 2 (Monthly-2005), (e) Class 3 (Yearly) and (f) Class 3 (Monthly-2006)

In Langkawi, within 3 km radius area from air monitoring station located residential and commercial areas including Kuah town and the main jetties for the ferry terminal. Also there are five marine base industries.

There are power plant and cement plant located at TelukEwa, which 10 km from air monitoring station. Within more than 3 km, major potential air pollution sources are six quarries and two solid waste disposal sites. Besides that, there are marina bays/areas for marine industries and water transportation such as shipyards and cargo barges at Tanjung Lembung, Jejawi and Kuala Perlis Industrial area is the main industrial area in Perlis. These two industrial areas located 5-6 km from air monitoring station. Most industry players in that area are food and marine based, except one rubber glove industry in Jejawi.

In Perlis there are two big industries. One is the Cement Industries of Malaysia Berhad (CIMA) and the other Kilang Gula Felda Perlis Sdn. Bhd. (sugarcanes) but they are far apart. Within 3 km radius of the air monitoring station there is only one rice mill industry and wood industry.

Surrounding the area are residential and commercial areas. Major industries within Taiping air monitoring station are an oil palm mill, lime manufacturing and metal. Industrial area nearby are Kamunting and Kamunting Raya Industrial Area, Kg. Boyan and Tupai Industrial Area located 9 km from air monitoring station.

Class 3 involved four (4) air monitoring stations located in TanjungMalim (CA0045), Manjung (CA0041) and Tasek (CA0008) and Pegoh (CA0046). Perak has 106 gazetted industrial areas. Within Tanjung Malim (CA0045) air monitoring station are Proton City area are approximately 5 km away. Proton vendors are also located nearby. Most of air pollution comes from spray booth activities.

Within 3 km there have located Taman Kota Malim Prima Industrial Area, residential houses and commercials. Within 3 km from Manjung (CA 0041) air monitoring station have Seri Manjung and Lumut Port Industrial Area. Oil palm mill, refineries and sawmills among industries located there. Outside than 3 km, can find Kg Acheh Industrial Area, ports, cargoes, quarries and marine base activities.

In Tasek area there are many heavy industries, such as Tasek, Bercham and IGB Industrial Areas. Tasek Industrial Area has various industry such as plastics, non-metal, rubber bases, food, printing and wood bases. In Bercham and IGB Industrial Area they have many textiles, metal and wood industries. Within three kilometers from air monitoring station are located two landfill disposal quarries.

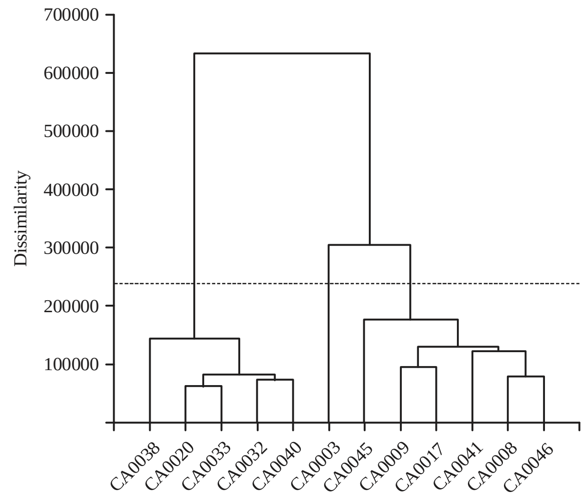

Fig. 3: Cluster analysis in dendrogram view

There are many residential and commercial areas and also North-South highway also located nearby. One of the biggest industries is Tasek Cement Corporation Berhad. Pegoh (CA0046) air monitoring station is located within the airport area.

This area also has a high population with a high number of vehicles. Within 3 km also have three biggest industry areas such as Pegoh, Sri Rapat, Zarib and Menglembu. Most of industries focusing on metal, wood, plastic and paper production. There were 17.86% rubber mill and 82.14% oil palm mills surrounding in Perak territories.

Besides that, two air monitoring stations are in Seberang Jaya (CA0009) and Sungai Petani, Kedah (CA0017). Within Seberang Jaya air monitoring station are residential and commercial areas such as Seberang Jaya town. Seberang Jaya is a popular area and the heart of Penang which is located in the center of the Penang mainland. The resident population is the among the highest because having road networks which connect to the North, South, East and Penang island.

Traffic movement very congested, especially during morning and late afternoon. Seberang Jaya air monitoring station located 2 km from Perai air monitoring station. Within Sungai Petani air monitoring station are Bakar Arang Industrial Area and Tikam Batu Industrial Area. This two industry area becomes mix industry. From the Fig. 3, seen that class 3 located at moderate condition compared to class 1 and 2. It can be signed as moderate air condition (MAC).

All listed above are the major industrial areas in the Northern region. There are also has a lot of number industries in scattered areas in Northern region such oil palm industries, rubber industries and recovery industries.

Table 2: Descriptive analysis of API parameter based on class of air monitoring station

		Parameters					
Station ID	Statistic Items	API	PM_{10} (µg m^{-3})	CO (ppm)	O_3 (ppm)	NO_2 (ppm)	SO_2 (ppm)
Class 1	Mean	57.759	96.243	1.431	0.040	0.026	0.020
	Median	55.000	77.000	1.370	0.041	0.026	0.009
	Mode	52.000	57.000	0.000	0.000	0.027	0.004
	Max	155.000	540.000	4.910	0.120	0.080	0.170
	Std. Dev	17.227	52.163	0.558	0.020	0.008	0.024
	Skewness	0.598	1.466	0.671	-0.170	0.343	2.049
Class 2	Mean	45.653	76.132	1.103	0.037	0.016	0.003
	Median	45.000	66.000	1.050	0.036	0.015	0.002
	Mode	51.000	54.000	1.010	0.036	0.014	0.002
	Max	149.000	578.000	4.97	0.120	0.070	0.050
	Std. Dev	13.087	42.545	0.442	0.015	0.007	0.003
	Skewness	0.622	2.378	0.793	0.301	0.817	4.542
Class 3	Mean	54.805	85.068	1.069	0.040	0.018	0.004
	Median	53.000	77.000	1.060	0.042	0.019	0.003
	Mode	52.000	65.000	0.000	0.000	0.000	0.000
	Max	213.000	673.000	5.980	0.170	0.100	0.170
	Std. Dev	15.471	38.158	0.718	0.025	0.011	0.005
	Skewness	0.967	2.702	0.490	-0.097	-0.099	5.772
	Recommended Malaysia air quality guideline		150.00	9.00	0.10	0.17	0.04

Besides that, nearby air monitoring stations also have many residential houses and commercial buildings supported with heavy traffic, especially in urban areas such as Ipoh, Seberang Jaya, USM and Perai. Status on the same class pattern does not mean stay in the same area. Most of the patterns depend on source availability either internal or external.

Location status does not mean anything and should not be as indicated. It is very difficult to distinguish urban and industrial, especially sub-urban, as these terms subjected to qualitative measurement. But cluster analysis can be performed through pattern dissimilarity for better understanding.

Class 1 shown the maximum values for PM_{10} compared with the Recommended Malaysia Air Quality Guideline which are around 540 µg m^{-3}. The average is 96.243 µg m^{-3}. Average values for CO, O_3, NO_2 and SO_2 are 1.431 ppm, 0.040 ppm, 0.026 ppm and 0.020 ppm, respectively. All the parameters still under the limit.

The maximum values for O_3 (0.120 p.m.) and SO_2 (0.170 ppm) are above the limit compared CO (4.910 ppm) and NO_2 (0.080 ppm). Standard deviation for PM_{10} is quite high, 52.163 µg m^{-3} and other gasses below than 1.0 ppm. Class 2 gives a higher reading for PM_{10}which come out 578 µg m^{-3}. The O_3 and SO_2 cross the border line, both perform 0.120 ppm and 0.050 ppm. Others two parameters CO and NO_2 still under the recommended. The average values for all parameters are under the limit stated as PM_{10} (76.132 µg m^{-3}), CO (1.103 ppm), O_3 (0.037 ppm), NO_2 (0.016 ppm) and SO_2 (0.003 ppm). Standard deviation for PM_{10} also high, 42.545 µg m^{-3} and other pollutants less than 1 ppm.

Class 3, PM_{10} gives a maximum reading 673 µg m^{-3} and the average below than 100 µg m^{-3}. Maximum values for O_3 (0.170 ppm) and SO_2 (0.170 ppm)are higher than standard. NO_2 and CO still under control which come out 0.1 ppm and 5.980 ppm. The average values for O_3, NO_2 and SO_2 less than 1 ppm. Meanwhile, CO is shown 1.069 ppm.

From Table 2, the study found that average values for all parameters are under the Recommended Malaysian Air Quality Guideline for the entire 11 years period. There were certain time or period contribute higher values (maximum values) especially for PM_{10}, O_3, SO_2, CO and NO_2 still under the limit.

There was having huge difference between average and maximum values. The API values, average shown Class 2 stayed in a good condition compared to Class 1 and 3, in a moderate condition for the past 11 years (2002-2012).

Air quality pattern by using cluster analysis (CA): This analysis produced to identify patterns of air quality in Northern region. It is based on an air pollution index (API) trend and pattern from 2002 until 2012 and following with monthly variation from January until December which refer to the selected reading at that particular of the years. The analysis discussed based on classes and look at the group or cluster produced. The HACA choose to study on pattern of air pollution. Figure 2 shows the pattern of air pollution index (API) based on yearly and specific monthly.

Table 3: Discriminant analysis for all classes (standard, forward and backward stepwise)

Classes	Class 1	Class 2	Class 3	Total	Correction (%)
Class 1	1234	725	2059	4018	30.71
Class 2	79	12535	7476	20090	62.39
Class 3	482	6566	17060	24108	70.76
Total/average	1795	19826	26595	48216	63.94
			F1		F2
Eigenvalue			0.39		0.12
Discrimination (%)			76.39		23.61
Cumulative (%)			76.39		100.00

From 2002-2012, Class 1 produced three pattern groups. Group 1 (2006, 2007, 2008, 2009, 2010, 2011 and 2012). Group 2 (2005) and group 3 (2002, 2003 and 2004). The study found 2005 is the highest dissimilarity reading of the air pollution index (API). Based on month in 2005, there were perform three patterns of the group. Group 1 (August, September, October, November and December), group 2 (June) and group 3 (January, February, March, April, May and July). Figure 2a and b show for class 1 based on yearly (2002-2012) and months (2005).

Based on 2002 until 2012, Class 2 created four pattern groups. Group 1 (2004 and 2005), group 2 (2006, 2007, 2008, 2009 and 2010), group 3 (2002 and 2003) and group 4 (2011 and 2012). In monthly basis, 2005 the graph performs three patterns of the group. Group 1 (August), group 2 (October, November and December) and group 3 (January, February, March, April, May, June, July and September).

Class 2 refers to five air monitoring stations located in low density of development compared class 1 and 3. Based on National Oceanic Atmospheric Administration (NOAA) satellite during August, 2005 recorded total hotspots in Sumatera, Borneo and Peninsular Malaysia with 6,378, 2260, 252, respectively[18].

This haze period was more severe than 1997[6]. During August, 2005, this area was critically affected by transboundary pollution (external sources). This transboundary pollution comes from Sumatera, Indonesia, especially Riau province. All neighbors in Southeast Asian countries affected. The study has not denied that internal sources also contribute to the low air quality and have become a part of hazzy statistic.

Class 3 performs 3 patterns. Group 1 (2002, 2003, 2006, 2007 and 2010), group 2 (2009 and 2011) and group 3 (2004, 2005, 2008 and 2012). Refering to the monthly basis (2006), it has shown three patterns. Group 1 (January, February, Mar, April, May, August, October, November and December) group 2 (July) and group 3 (June and September) showed an air pollution index (API) in July 2006 give a highest dissimilarity reading following June and September.

Class 3 involved four (4) air monitoring stations which located in TanjungMalim (CA0045), Manjung (CA0041) and Tasek (CA0008) and Pegoh (CA0046). This means four out of six air monitoring station located in Perak. Two air monitoring station in Seberang Jaya (CA0009) and Sungai Petani (CA0017). Figure 2e and f show for class 3 based on yearly (2002-2012) and monthly (2006).

From the observation, it has been shown that 2005 and 2006 had different patterns than the predominant one from 2002 until 2012. Specifically, the third quarter of that years shown different pattern due to trans boundary pollution. The study found that meteorological factor also contributed the air quality and haze phenomena during dry months starting from February until March and Jun until October.

This is based on monthly set of arrangement. Southwest monsoon wind (June-September) can blow the pollutant cross the boundary. It is one added factor contributing to the haze phenomena from neighboring country. Northeast monsoon (November-Mar) bringing the wet season with the high raining occasion. As a result, the number of burning activities could be reduced. From 2002 until 2012, the years 2005 and 2006 were critically affected by transboundary pollution for all classes.

Differentiate between classes using discriminant analysis (DA): The study tries to look different for classes by using discriminant analysis (DA). DA uses standard, backward and forward stepwise technique. From the Table 3, there were shown the analysis involved all the data sets which has 48,216 samples. The percentage correction for class 1 (30.71%), class 2 (62.39%) and class 3 (70.76%). The analysis produced similar result for standard, backward and stepwise and backward stepwise due to deal with a limited number of variables.

From this Table 3 also, Factor 1 (F1) contributes 76.39% and Factor 2 (F2) gives 23.61% of discrimination. The result shown that in Table 3, there were perform accuracy 63.94% of the average value of percentage correction at more than 50%.

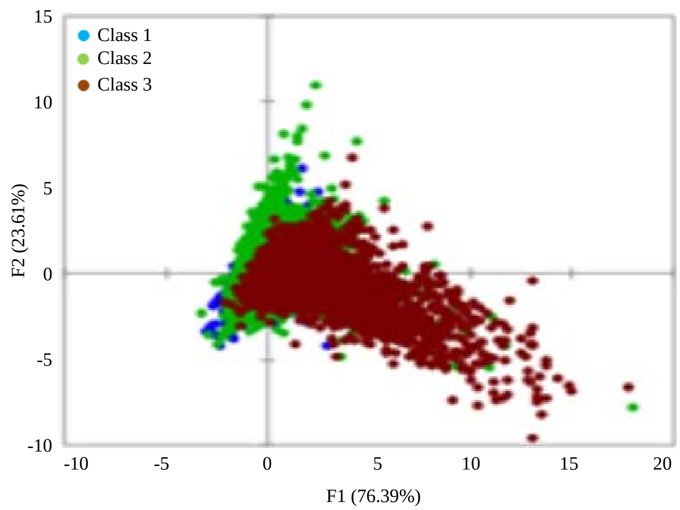

Fig. 4: Observation dots based on facts at three classes

Table 4: Identification pollution source of classes (after PCA varimax rotation)

	Class 1		Class 2		Class 3	
Parameters	F1	F2	F1	F2	F1	F2
SO_2	0.714	-0.459	0.480	0.643	0.676	0.335
NO_2	0.719	0.402	0.693	0.396	0.894	-0.192
O_3	0.401	0.393	0.764	-0.204	0.702	-0.423
CO	0.253	0.712	0.504	0.332	0.836	-0.005
PM_{10}	0.766	-0.390	0.607	-0.470	0.292	0.844
Eigenvalue	1.839	1.187	2.638	1.076	2.533	1.040
Variability (%)	36.778	23.738	43.961	17.939	50.658	20.805
Cumulative (%)	36.778	60.516	43.961	61.900	50.658	71.463

The observations based on Factor 1 (F1) and Factor 2 (F2) as distribution dots among the classes presented in Fig. 4. The figure showed class three more dominant in term of colors. This is because the high percentage correction compared class 2 and class 1. Class 1 showed a less number of observation dots, with blue color. Based on the Wilks lambda test, the study found a lambda value of 0.642, refer $p<0.0001$ and $\alpha = 0.05$.

The hypothesis is stated as below:

H_o: The mean vectors of three classes are equal
H_a: At least one of the means vector is different from another

Computed $p<\alpha$, one should reject the null hypothesis (H_o) and accept the alternative (H_a). The risk to reject H_o, while it is true, is lower than 0.01%. Therefore, there was having different class each. From the analysis, DA were able to discriminate all variables which stated as class 1, 2 and 3 representing for all numbers of air monitoring station in the Northern region.

Identify air pollution source using principal component analysis (PCA): Principle component analysis (PCA) was applied to identify the most and the less significant pollutant contribute to the air quality in the Northern region Peninsular Malaysia. It is based on classes which already clustered at three patterns. Referring to Table 4, the study discussed factor loading. It also interpreted highest and descending values. From the analysis, found that there were produced eight values more than 1.0 which maximum 2.638. The cumulative on percentage values each class are Class 1 (60.516%), Class 2 (61.9%) and Class 3 (71.463%).

From the analysis, the study found that all the classes have been impacted from anthropogenic activities. As seen, for the F1 for the all the classes the major contributions are SO_2, NO_2 and O_3 and followed by PM_{10}. This means that over the past 11 years ago until now, these parameters have contributed a major problem to the air quality in the Northern region and at the same time PM_{10} will be affected seasonally. The dot matrix position based on factor loading for each class was presented in Fig. 5.

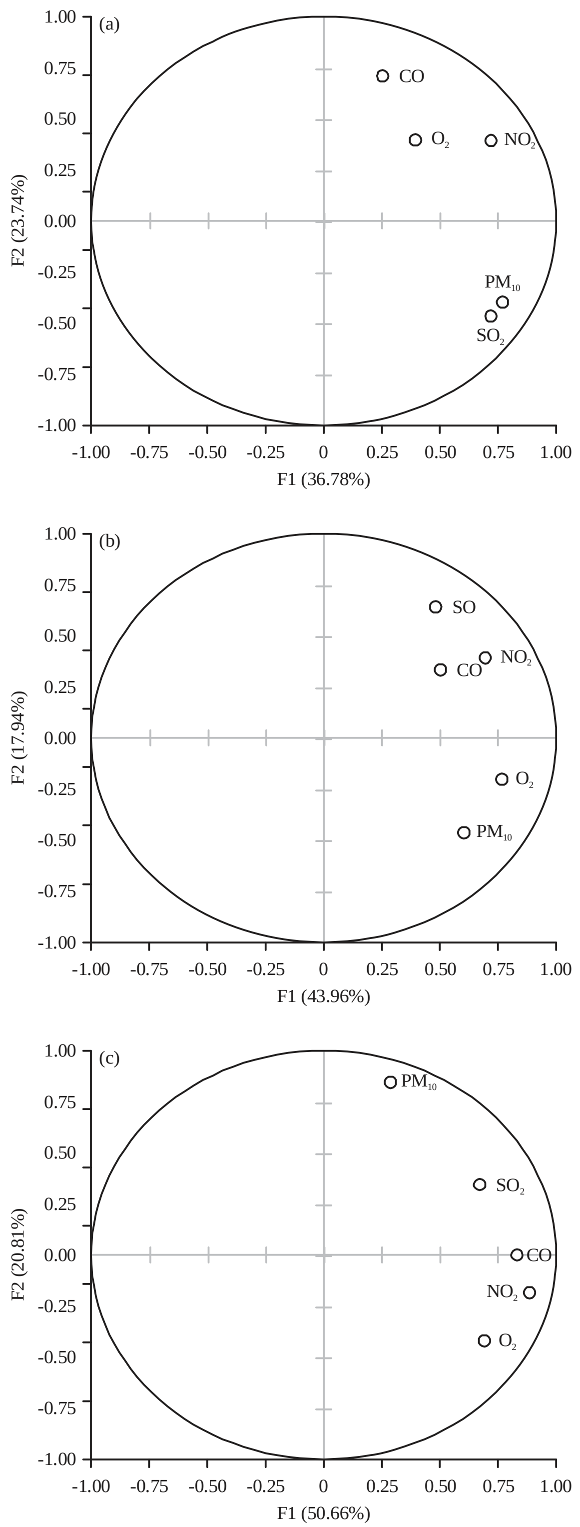

Fig. 5(a-c): Factor loading all classes by using PCA, (a) Class 1, (b) Class 2 and (c) Class 3

Ozone (O_3) occurs due to a lot of potential source precursors such as carbon monoxide (CO), nitrogen dioxide (NO_x), methane (CH_4) and volatile organic compound (VOCs). All these chemicals will react in the presence of sunlight, producing ground level ozone (O_3). The main factor contributing to an increase in ozone level is combustion of fuel. It might be from vehicles or industries. Anthropogenic and naturally activities is the main contributor to the ozone precursor[19]. Urban areas are more exposed to ozone pollution compared to rural areas[20]. High concentration ozone in ambient air can affect to human beings and ecosystems. Increasing ozone (O_3) in the ambient can be affected also to the crop production[21]. Carbon monoxide (CO) is a poisonous gas. These gases are from incomplete combustion from vehicles, industries and open burning activities. High level concentration in the ambient air will lead a cardiovascular disease. Particulate matters of less than 10µm (PM_{10}) are sourced from vehicles, marine, traffic, non-engine combustion aerosol, soil, dust and burning plantations[22]. Increasing number of vehicles on the road will increment of dust concentration[23]. Sulfur dioxide (SO_2) forms during the combustion process, which contains sulfur. This sulfur occurs naturally in coal and fossil fuels. High concentration in the ambient air will lead to respiratory system problems and affect the ecosystem. These gasses also can cause acid rain. Nitrogen dioxide (NO_2) from nitrogen oxide (NO_x) through oxidation process. Nitrogen oxide (NO_x) is produced from a combustion process with a high temperature. These gasses are readily converted to the nitrogen dioxide (NO_2) in ambient air. The vehicles, industries especially power plant are the leading activities contributed to the nitrogen dioxide (NO_2). These gasses are very toxic to human being and the environment, including the formation of acid rain[24].

CONCLUSION

Based on the results, an environmetric technique for environmental measurement was better able to identify selected air quality parameters and pattern of air monitoring stations in the Northern region Peninsular Malaysia. Discriminant analysis (DA) has shown reliable result after clustered which were established significant variable and for principal component analysis (PCA) were able to identify major air pollutants in the Northern region of Peninsular Malaysia. The study found that SO_2, NO_2 and O_3 are the major pollutants that have contributed to degrade air quality in the Northern region due to the combustion process from vehicles and industries.

SIGNIFICANCE STATEMENTS

This study discovers the pattern of air quality at Northern region of Peninsular Malaysia area by using environmetric technique that can be beneficial as the reference for current and future. Basically this study also refer to new establishment of different variables between each class based on principal component analysis (PCA) and combined factor analysis (FA) in order to determine of significant pollutant parameter in Northern Region.

ACKNOWLEDGMENTS

This acknowledgment is dedicated to the Department of Environment, Malaysia and Department of Public Service, Malaysia for all their support and assistance to complete this journal successfully. We are also very thankful to all lecturers, Faculty of Environmental Studies, Universiti Putra Malaysia and our families and friends.

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