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Study of ambient air particulates pollutants near Taichung airport sampling site in central Taiwan

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Abstract

This study monitored the atmospheric pollutants at Taichung airport (TA) sampling site during September to December of 2005 near Taiwan Strait in central Taiwan. The distributions of the particle concentrations between the TSP, coarse and fine were also displayed at TA sampling site. Analysis the average percentage of various kinds of metallic elements, the data obtained here indicated that the average percentage concentrations of metallic elements Fe and Mg were higher in fine particulate than that of the coarse particulate at Taichung airport sampling site. These foundry factories were by the TA sampling site was the possible reason responsible for this result. In addition, by a non-parametric (Spearman) correlation analysis, the results indicated that Fe, Mn and Pb have high correlation coefficients of metallic elements in different particle size. The results indicate that the airport pollutants might come from similar pollutant sources at this airport sampling site. In addition, high correlation coefficients of non-airport pollutants were observed on the ionic species of SO_4^{2-}, NH_4^+ and K^+. The r_{sp} correlate values between closed to $r_{sp} = 0.7$ and 0.9 at different particles size mode. Besides, the ionic Ca^{2+} has high negative values ($r_{sp} = -0.66$, -0.66 and 0.61) with the increasing of the temperature, relative humidity and wind speed, respectively at fine particle size.

Keywords: Meteorological condition; Percentage concentrations; Spearman; Particle size

1. Introduction

Suspended particle pollution has become a critical problem in Taiwan. Emissions of air pollutants in Asia have been increasing drastically in past decade [1]. The increase of atmospheric anthropogenic emissions of heavy metals is particularly damaging in traffic areas. In fact these pollutants, carried by atmospheric particles, may settle on the superficial air and their depositions might change the ratios among different chemical forms of heavy metals in the air. The analysis of some meteorological conditions, which may influence the fate of atmospheric particles, is useful for an improvement characterization of heavy metal comportment. In addition, temperature and rainfall were considered important factors affecting TSP levels. In fact a high ambient temperature might favor dust resuspension [2,3].

Particulate matter (PM) has been given much attention in recent decades due to its potential adverse health impact and the subsequent need to have a better control or regulate these pollutants. The sources, characteristics and potential health effects of the larger or coarse particles (>2.5 mm in diameter) and smaller or fine particles (2.5 mm in diameter) are very different; the latter can more readily penetrate into the lungs and are therefore more likely to increase respiratory and mutagenic diseases [4]. However, it is not yet known whether the health effects may be caused by the large number of particles or perhaps by some toxic components in the particulate matter. Coarse PM metal concentration trends are governed by variations in the wind speeds in each location, whereas the diurnal trends in the fine PM metal concentrations are found to be a function both of the prevailing meteorological conditions and their upwind sources. Among the many pollutants highlighted for adverse health effect, particular attention has been focused on fine particulates [5,6]. The underlying biological causes of the health effects of fine particles exposure are not clear, thus an investigation of their physical and chemical characteristics is important to elucidate particles

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toxicity. From a toxicological perspective also, airborne PM has important health implications through the inhalation of PM_{10}, which can be deposited in the tracheobronchial and alveolar regions of the lung [7]. It is well established that these inhalable particles have higher concentrations of many potentially toxic trace elements, such as Pb, Cd, V, Fe, Zn, Cr, Ni, Mn and Cu [8].

While construction of emission inventories is a well-developed science, only in combination with highly value models can emissions inventories hope to explain ambient concentrations, and construction of models giving high quality predictions of particulate matter concentrations within European urban areas has proved highly problematic. A more promising approach is through the use of receptor modeling [9], and multivariate statistical techniques applied to ambient air quality data have provided useful, and in some cases quantitative insights into the contributions of different source categories to ambient concentrations of airborne particulate matter [10].

Natural sources include dust raised by winds (resuspension of soil particles), volcanic activity, forest fires and sea salt aerosols, while industrial plants burning oils, residential heating, cement industry, smelting industry, traffic fuel combustion, industrial metal production and waste incineration are considered the main artificial sources. These artificial sources are often highly localized especially in urban and industrial areas and local high concentrations can be expected. The interaction of SO_2 and NO_2 with particles would result in the increase of secondary inorganic components, such as sulfate, nitrate and ammonium. These components can affect climate and predominantly control the aerosol acidification. Therefore, their formation mechanism and sources were intensively studied through systematic monitoring these components and their precursor gases as well as the climatic conditions [11,12].

In this study, the sampling site was selected to characterize the concentrations in Taichung Airport (TA) of central Taiwan for this study. The height of the sampling site is approximately 10 m from ground level in this study. Fig. 1 is one runway with length 3658 m, width 61 m. Aircraft parking area was 36,280 m^2 in central Taiwan. The sampling site was located in the south (about 1.5 km) of TA. There were about 25 airplanes take off and 23 airplanes landed at Taichung airport each day. The purpose of this study was to characterize the ambient air suspended, fine, coarse particulate concentrations at Taiwan Air Port in central Taiwan.

Investigated and characterized ambient air particulate matter with aerodynamic diameters 2.5 mm ($PM_{2.5}$), from 2.5 to 10 mm ($PM_{2.5–10}$) and TSP. A non-parametric (Spearman) correlation analysis was applied to derive statistical relationships between air particulate pollution and meteorological parameters during period. Beside, relative statistical equations for temperature, relative humidity, wind speed and pollutants variables were also characterized in this study. In this study, one Total Suspended Particle Sampler (PS-1) sampler Universal Air Sampler TM (UAS^{TM}) and dry deposition plates were used to collect the particulates at the same time. Meanwhile, the meteorological conditions such as sampling time, temperature, wind speed and wind direction were also monitored.

2. Experimental

2.1. Sample collection

2.1.1. PS-1 sampler

PS-1 that can collect total suspended particulate mater. So, the maximum collection particle size was appropriate 100 μm

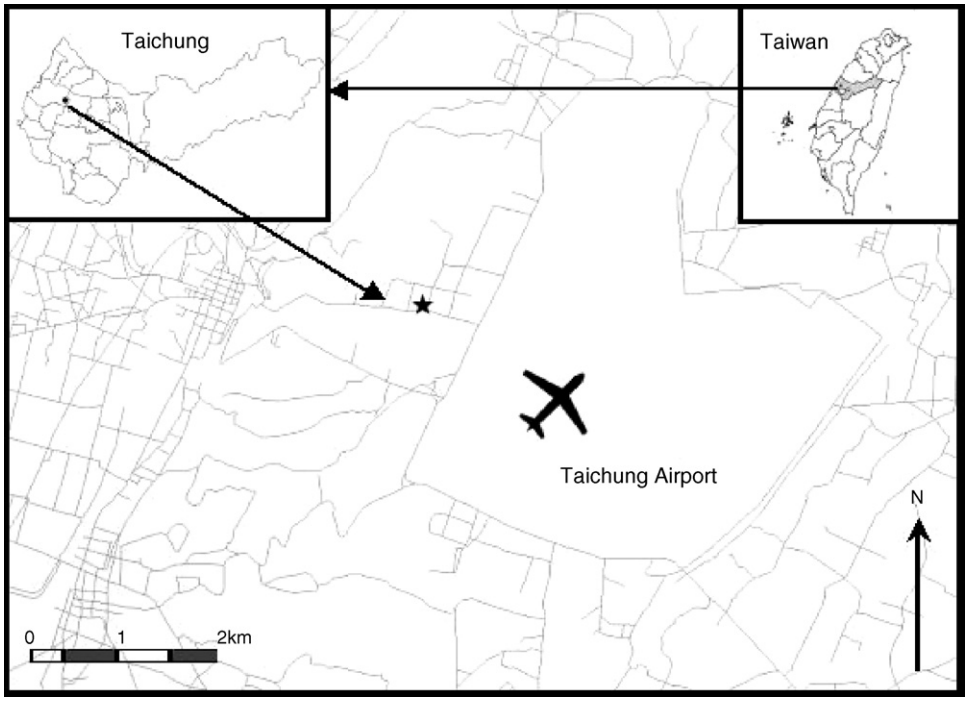

Fig. 1. The sampling positions and relative location of this study.

(Graseby-Andersen, GMW High Volume Air Sampler). The flow rate was adjusted to 200 l min^{-1} in this study. The quartz filter (diameter 10.2 cm) is used to filter the suspended particles in the study. The filters were first conditioned for 24 h in an electric chamber at humidity 50 ± 5% and temperature 25 ± 5 °C prior to weighing. Filters were placed in a sealed CD box during the transport and storage process.

2.1.2. Universal air sampler

The Model 310 UASTM is a general-purpose air sampler for airborne particles. Air is sampled at 300 l min^{-1} through an omni-directional, cylindrical inlet. Particles larger then 10 μm are separated by a virtual impactor and are discarded. Particles then pass through a 2.5 or 1.0 μm virtual impactor. Particles in the ranges of 2.5–10 or 1.0–10 μm are collected on the first filter while particles smaller then 2.5 μm are collected on the second filter. The collected particles can then be analyzed for mass or specific chemical species. Located downstream of the final filter is a holder where a standard PUF sampler can be used to collect volatile organic compounds (USATM, Model 310).

2.2. Analytical method

2.2.1. Chemical analysis

Then they were put into 200 ml bottles for each bottle sampling group. Distilled-deionizer water was added into each bottle and the bottles were sent ultrasonic process for about 120 min, and then diluted to 30 ml wish distilled-deionizer water. Ion Chromatography (DIONEX-100) was used to analyze for the anions: sulphate, chloride and nitrate in the Universal samples.

After final weighing, all quartz filters by PS-1 and UAS sampler were both cut into one-eighth. Then they were put into 200 ml bottles for each sampling group. Than 10 ml ultrapure HNO_3 was added to digest these particulates at 200–250 °C for 2 h. After above procedure this solution was added with distilled-deionized water to 30 ml. A Hitachi Z-5000 series polarized Zeeman flame atomic absorption spectrophotometer was used to measure the trace metal concentration after digestion process.

2.2.2. Quality control

Blank test background contamination was monitored by using operational blanks (unexposed projection film and quartz filter) which were processed simultaneously with field samples. The field blanks were exposed in the field when the field sampling box was opened to remove and replace field samples. Background contamination of heavy metals was accounted for by subtracting field blank values from the concentrations. Field blank values were very low, usually below or around the method detection limits. In this study, the background contamination is used to correct measurements. The results of the filter blank test are 0.43, 0.38, 0.30, 0.23, 0.26, 0.21 and 0.16 μg for Fe, Zn, Mn, Cu, Pb, Cr and Mg, respectively. In addition, the concentrations of the background contaminations are 0.02, 0.04, 0.06, 0.04, 0.03, 0.06, 0.06, 0.02 and 0.05 μg m^{-3} for Cl^-, NO_2^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+}, respectively.

2.2.3. Reproducibility test

The reproducibility test can display the stability of instruments. The procedure was to repeat the analysis of the same sample for seven times. The value of three times standard deviation for repeating analysis should not exceed the upper control limit (+10%) and lower control limit (−10%). If the value of (3 × S.D.) exceed upper and lower control limit, the experiments should be paused to examine the procedures of analysis and instruments.

2.2.4. Detection limit

Detection limit was used to determine the lowest concentration level that can be detected to be statistically different from a blank. Method detection limit (MDL) was determined from selected the concentration slightly higher than the low concentration of the standard line. Repeat this blank concentration for seven times to estimate the standard deviation (*S*). Then, the MDL was based on three times the standard deviation of the blank concentration.

3. Results and discussion

3.1. Sampling information of particulate mass and meteorological conditions

Table 1 shows the sampling information of total suspended particulate, coarse and fine particulate concentrations and meteorological conditions such as temperature, relative humidity, atmospheric pressure and prevalent wind direction at Taichung airport (TA) sampling site during September to December of 2005. The average TSP coarse and fine particulate concentrations were 120.60 ± 30.68, 24.45 ± 7.83 and 38.13 ± 8.44 μg m^{-3}, respectively. And the average temperature, relative humidity were 25.55 ± 4.80 °C and 72.15 ± 4.55%, respectively at TA sampling site. Major wind directions were ENE during the sampling period. The result also indicated that the particulate concentrations of TSP were higher than coarse and fine particulate concentrations and the order was TSP > fine > coarse particle in this study.

3.2. A non-parametric (Spearman) correlation analysis

In this section, a non-parametric (Spearman) correlation analysis is taken to investigate the Taichung airport pollutants and environment factors correlation. The correlation analysis of the elements and the data are present in the Tables 2–4. Tables 2–4 show the mass particle pollutants (TSP, coarse and fine) and ionic species (Cl^-, NO^-_3, $SO_4{}^{2-}$, $NH_4{}^+$, Mg^{2+}, Ca^{2+} and Na^+) and metal elements (Fe, Mg, Cr, Cu, Zn, Mn and Pb) correlated with the conditions of temperature, relative humidity and wind speed, respectively. The results indicated that the mass particle, metal elements and ionic species pollutants have lower correlate with the conditions of temperature, relative humidity and wind speed and atmospheric pressure, respectively. The average meteorological conditions have lower r_{sp} correlate values with mass particle and ionic species and metal elements at various particles size modes (TSP, coarse and fine). The results show

Table 1
Sampling information for TA sampling site during September to December of 2005

Date	TSP concentration ($\mu g\,m^{-3}$)	Coarse concentration ($\mu g\,m^{-3}$)	Fine concentration ($\mu g\,m^{-3}$)	Temperature (°C)	RH (%)	Wind speed ($m\,s^{-1}$)	Prevailing wind
09/26–27	120.5	24.12	40.69	28.16	69.60	2.201	NW
09/27–28	100.0	33.14	48.73	27.63	73.69	4.113	ENE
09/28–29	153.0	18.52	46.54	28.47	74.96	4.170	ENE
10/03–04	104.2	15.35	36.79	29.57	71.76	2.814	NNW
10/04–05	151.1	21.69	48.25	29.60	74.66	2.899	ENE
10/06–07	86.74	20.71	28.27	29.74	74.69	3.050	NNW
10/21–22	78.41	17.30	21.93	25.64	68.67	6.591	ENE
10/27–28	81.82	23.15	35.82	26.68	80.61	4.894	ENE
11/10–11	141.3	18.76	30.70	26.32	74.49	1.806	NNW
11/24–25	129.9	25.58	35.09	21.76	66.61	6.002	ENE
12/08–09	128.0	33.63	38.99	17.96	72.75	5.137	ENE
12/12–13	172.4	41.42	45.81	15.06	63.31	8.135	NE
Average	*120.6*	*24.45*	*38.13*	*25.55*	*72.15*	*4.320*	*ENE*
STD	*30.68*	*7.830*	*8.440*	*4.800*	*4.55*	*1.920*	

that the mass pollutants have high negative values ($r_{sp} = -0.78$) at coarse particle size with the temperature. The mass particle pollutants have lower values and increasing the temperature, the mass particle pollutants have higher values.

Table 3(a) shows that only the airport pollutant Fe has high correlate values ($r_{sp} = -0.72$ and 0.86) at TSP particle size with the Mn and Pb. Besides, the correlation coefficients of metallic elements showed an r_{sp} value between Pb and Mn of 0.73. These results indicate that most metallic Fe, Mn and Pb might come from similar pollutant sources in the form of total suspended particulates. Table 3(b) shows that the only the airport pollutant Cr has high correlate values ($r_{sp} = 0.72$ and 0.78) at coarse particle size mode with Cu and Pb. When increasing the Cu and Pb, the metal elements have lower average concentrations. These results indicate that the most Cr, Cu and Pb might come from similar pollutant sources in coarse particles. Table 3(c) shows that only the airport pollutant Mn has high correlate values ($r_{sp} = -0.74$ and 0.90) at fine particle size with the Zn and Pb. In addition, the element Fe has high correlate values ($r_{sp} = 0.71$) with the increasing of the Zn at fine particle size.

Table 4(a) shows that only the major ionic SO_4^{2-} at TSP size has higher correlate values ($r_{sp} = 0.93$ and 0.80) than the other major ions with NH_4^+ and K^+ for non-airport pollutants. These results indicate that most metallic SO_4^{2-}, NH_4^+ and K^+ might come from similar pollutant sources in the form of total suspended particulates. Table 4(b) shows that only the non-airport pollutants NO_2^- has high negative values ($r_{sp} = -0.73$ and -0.80) at coarse size with the K^+ and NH_4^+. With the increasing of the temperature, the ions have low concentration. In addition, the correlation coefficients of ionic species SO_4^{2-} showed an r_{sp} value between NH_4^+ and K^+ of 0.72. These results indicate that the most ionic species (NO_2^-, K^+, NH_4^+) and (SO_4^{2-}, NH_4^+, K^+) might come from similar pollutant sources in coarse particles. Besides, the ionic species NO_3^- has high correlate values ($r_{sp} = 0.61$) with the increasing of the temperature at coarse particle size. Table 4(c) shows that only the non-airport pollutant SO_4^{2-} has high correlate values ($r_{sp} = 0.95$ and 0.89) than the other major ionic with NH_4^+ and K^+ in fine particles. In addition, the element Mg^{2+} has high correlate values ($r_{sp} = 0.76$) with the increasing of the Na^+, at fine particle size. These results indicate that the most Mg^{2+} and Na^+ might come from similar pollutant sources in fine particles. Besides, the ionic Ca^{2+} has high negative values ($r_{sp} = -0.66$, -0.66 and 0.61) with the increasing of the temperature, relative humidity and wind speed, respectively, at fine particle size.

From Table 3, on different particle size, high correlation coefficients of metallic elements are observed for elements Fe, Mn and Pb. The results indicate that the airport pollutants might come from similar pollutant sources at this airport sampling site. From Table 4, high correlation coefficients of non-airport pollutants were observed on the ionic species of SO_4^{2-}, NH_4^+ and K^+. The r_{sp} correlate values between closed to $r_{sp} = 0.7$ and 0.9 at different particles size mode.

Table 2
Non-parametric (Spearman) correlation analysis of different particle size

	TSP	Coarse	Fine	Temperature	RH	Ws
TSP	1					
Coarse		1				
Fine	**0.60***		1			
Temperature		**−0.78****		1		
RH				**0.60***	1	
Ws				**−0.76****		1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

3.3. Different particles size range percentage of concentrations for metallic metals and ions at airport sampling site.

Fig. 2 displays the average percentage of various kinds of metallic elements in the TSP, coarse and fine particle size range modes, respectively. The results indicated the average percentage of concentrations for metallic elements Fe, Mn, Cu, Zn, Pb, Cr and Mg were 49.42%, 4.43%, 9.92%, 11.61%, 5.12%, 4.38% and 15.32%, respectively in the TSP particle size range. As for coarse particle size mode, the results showed the aver-

Table 3
(a–c) Non-parametric (Spearman) correlation analysis of different particle size for pollutants and meteorological conditions

	Fe	Mn	Cu	Zn	Pb	Cr	Mg	Temperature	RH	Ws
(a) TSP										
Fe	1									
Mn	0.72**	1								
Cu			1							
Zn				1						
Pb	0.86**	0.73**		0.66*	1					
Cr		0.60*			0.63*	1				
Mg							1			
Temperature								1		
RH								0.60*	1	
Ws								−0.76**		1
(b) Coarse										
Fe	1									
Mn	0.75**	1								
Cu	0.67*		1							
Zn		0.71**		1						
Pb					1					
Cr	0.68*		0.72**		0.78**	1				
Mg							1			
Temperature								1		
RH								0.60*	1	
Ws								−0.76*		1
(c) Fine										
Fe	1									
Mn	0.67*	1								
Cu			1							
Zn	0.71**	0.74**		1						
Pb		0.90**			1					
Cr						1				
Mg							1			
Temperature								1		
RH								0.60*	1	
Ws								−0.76**		1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

age percentage of concentrations for metallic elements Fe, Mn, Cu, Zn, Pb, Cr and Mg were 52.42%, 2.83%, 2.94%, 14.44%, 4.88%, 3.39% and 19.10%, respectively in the coarse particle size range. As for the fine particle size mode, the results also displayed the average percentage of concentrations for metallic elements Fe, Mn, Cu, Zn, Pb, Cr and Mg were 32.56%, 4.72%, 5.12%, 14.55%, 7.75%, 6.39% and 28.91%, respectively in the fine particle size mode. In general, the average percentage of concentrations for metallic elements Fe and Mg were riched in the coarse particulate than that of the fine particulate [13–15]. However, the data obtained here indicated that the average percentage concentrations of metallic elements Fe and Mg were higher in fine particulate than that of the coarse particulate. This result was similar to that of the previous study [16]. The proposed reason is that there are high densities of foundry factories near by the TA sampling site. The proposed reason is that there are high densities of foundry factories nearby the TA sampling site. These foundry factories, which contained high concentration of element Fe in the fine particulate matter during the foundry process. Thus, the element Fe has higher concentrations in the fine particulate matter than that of coarse particulate. To sum up, the previous results [14,15] combined with the results obtained in this study indicated that the metallic elements Fe, Mg and Zn occupied about 60–80% average metallic concentrations percentage out of the total metallic elements around central Taiwan.

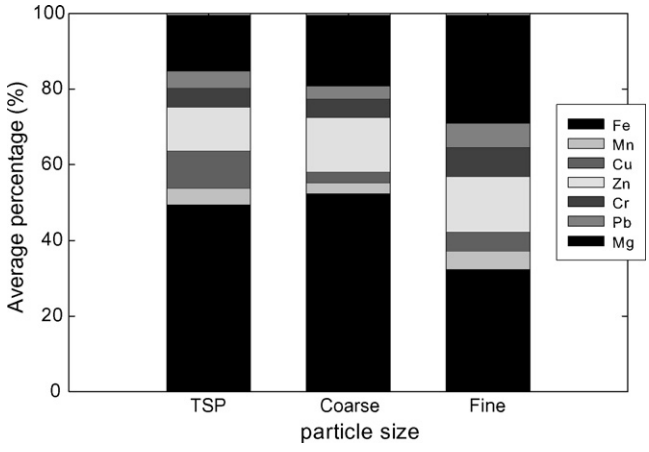

Fig. 2. Average percentage of metallic elements in various particle size (TSP, coarse, fine) at TA (airport) sampling site.

Table 4
(a–c) Non-parametric (Spearman) correlation analysis of different particle size for pollutants and meteorological conditions

	Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Temperature	RH	Ws
(a) TSP												
Cl^-	1											
NO_2^-		1										
NO_3^-			1									
SO_4^{2-}			0.77**	1								
Na^+	0.68*				1							
NH_4^+			0.69*	0.93**		1						
K^+				0.80**		0.69*	1					
Mg^{2+}	0.61*				0.83**			1				
Ca^{2+}		−0.69*							1			
Temperature										1		
RH										0.60*	1	
Ws										−0.76**		1
(b) Coarse												
Cl^-	1											
NO_2^-		1										
NO_3^-			1									
SO_4^{2-}			0.68*	1								
Na^+	0.73**	0.73**			1							
NH_4^+		−0.80**		0.72**		1						
K^+				0.72**			1					
Mg^{2+}	0.68*				0.96**			1				
Ca^{2+}			0.69*				0.73**	0.63*	1			
Temperature			0.61*							1		
RH										0.60*	1	
Ws										−0.76**		1
(c) Fine												
Cl^-	1											
NO_2^-		1										
NO_3^-		−0.61*	1									
SO_4^{2-}				1								
Na^+					1							
NH_4^+			0.68*	0.95**		1						
K^+				0.89**		0.85**	1					
Mg^{2+}					0.76**			1				
Ca^{2+}									1			
Temperature									−0.66*	1		
RH									−0.66*	0.60*	1	
Ws									0.61*	−0.76**		1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Fig. 3 displays the average percentage of various kinds of ionic species in the TSP particle size range mode. The results indicated the average percentage of concentrations for ionic species Cl^-, NO_2^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+} were 6.62%, 2.15%, 23.63%, 43.53%, 6.22%, 9.31%, 1.09%, 1.48% and 5.97%, respectively in the TSP particle size range. As for coarse particle size mode, the results showed the a average percentage of concentrations for ionic species Cl^-, NO_2^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+} were 13.32%, 3.53%, 36.73%, 22.02%, 14.1%, 3%, 0.8%, 1.7% and 4.8%, respectively in the coarse particle size range. As for fine particle size mode, the results also displayed the average percentage of concentrations for ionic species Cl^-, NO_2^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+} were 4.31%, 1.21%, 13.98%, 54.50%, 2.82%, 19.03%, 1.18%, 0.37% and 2.40%, respectively in the fine particle size mode.

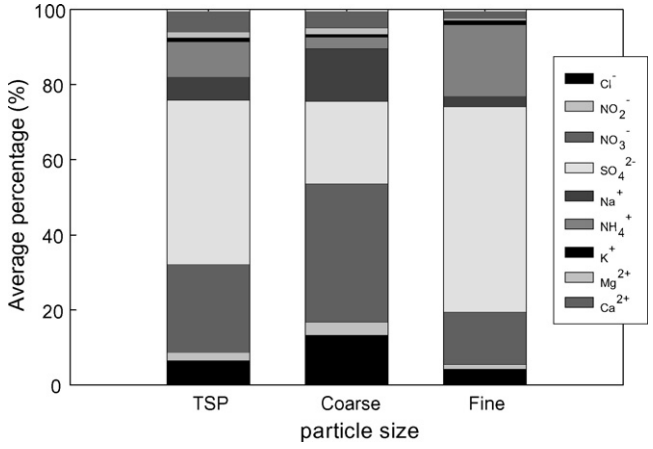

Fig. 3. Average percentage of ionic species in various particle size (TSP, coarse, fine) at TA (airport) sampling site.

4. Conclusions

The main conclusions in this study are listed as follows:

1. The average particulate concentrations of TSP were higher than coarse and fine particulate concentrations, and the order was TSP > fine > coarse particle during September to December of 2005 at Taichung airport sampling site.
2. As for the metallic concentrations in TSP, coarse and fine particulates, the metallic elements of Fe and Mg were the main metallic elements at TA sampling site. In addition, result also showed that SO_4^{2-} has the highest ionic concentrations in TSP and fine concentrations. However, the ionic species of NO_3^- was the main components in coarse particulate size mode.
3. In this study, the data obtained here indicated that the average percentage concentrations of metallic elements Fe and Mg were higher in fine particulate than that of the coarse particulate at Taichung airport sampling site. The foundry factories surrounded the TA sampling site was the possible reason responsible for this result.
4. By a non-parametric (Spearman) correlation analysis, the results indicated that Fe, Mn and Pb have high correlation coefficients of metallic elements in different particle size. The results indicate that metallic elements Fe and Mg may have similar pollutant source at Taichung airport sampling site. In addition, high correlation coefficients of non-airport pollutants were observed on the ionic species of SO_4^{2-}, NH_4^+ and K^+. The r_{sp} correlate values between closed to $r_{sp} = 0.7$ and 0.9 at different particles size mode. Besides, the ionic Ca^{2+} has high negative values ($r_{sp} = -0.66$, -0.66 and 0.61) with the increasing of the temperature, relative humidity and wind speed, respectively at fine particle size.
5. The results obtained in this study indicated that the metallic elements Fe, Mg and Zn occupied about 60–80% average metallic concentrations percentage out of the total metallic elements around traffic, Harbor and airport in central Taiwan.

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