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Ambient Air Ionic Species (F^-, Cl^-, NO_3^-, SO_4^{2-}) Compositions Study at a Semi-Open/Outdoor Concrete Processing Factory in Changhua County, Taiwan

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Research Article

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Abstract

This study was to collect ambient air TSP, dry depositions, PM_{10}, $PM_{2.5}$ compositions and analyze the ionic species (F^-, Cl^-, NO_3^-, SO_4^{2-}) compositions which attached in TSP, dry depositions, PM_{10}, $PM_{2.5}$ for these semi-open/outdoor environments at a concrete processing factory in ChangHua Coastal Park. And the comparisons of ambient air ionic species (F^-, Cl^-, NO_3^-, SO_4^{2-}) in TSP, dry depositions, PM_{10}, $PM_{2.5}$ compositions for these semi-open/outdoor environments were also discussed during the year of 2017-half year observations. And the results indicated that the average ionic species SO_4^{2-} was ranked highest average compositions in dry depositions, PM_{10}, $PM_{2.5}$ when compared with those of the other ionic species (F^-, Cl^-, NO_3^-) while the ionic species for Cl^- was ranked highest average compositions in TSP when compared with those of the other ionic species (F^-, NO_3^-, SO_4^{2-}) at this semi-open/outdoor environments sampling site at a concrete processing factory in Changhua Coastal Park. In addition, the average ionic SO_4^{2-} compositions in semi-open environment were higher than that of outdoor environment. In addition, ionic species SO_4^{2-} occupied were than 60% of the compositions percentages when compared with all the ionic species at both PM_{10} and $PM_{2.5}$. And ionic species SO_4^{2-} compositions in TSP was occupied more than 50% of than concentrations percentages when compared with all the ionic species. Finally, ionic species SO_4^{2-} compositions in dry depositions was occupied more than 40% of compositions percentages when compared with all the other ionic species in this study.

Keywords: Ambient Air Particles; Dry Depositions; Concrete Processing Factory; Semi-Open/Outdoor; Ionic Species Compositions

Abbreviations: MOE: Ministry of the Environment; DDP: Dry Deposition Plates; PVC: Polyvinyl Chloride; MDL: Method Detection Limit

Introduction

Ambient aerosol particles consist of carbonaceous species, ionic species, elemental species, and water [1]. They have attracted much attention due to their influence on air quality, visibility, human health effects and radioactive climate forcing.

And fine with aerodynamic diameters under 2.5μm (termed $PM_{2.5}$) have drawn much attention due to their effect on human health and the environment. Exposure to $PM_{2.5}$ has been associated with increases in mortality and hospital admissions due to respiratory and cardiovascular disease [2-5].

Submicron aerosol particles are considered to be hazardous due to their small size, high number concentration and ability to penetrate deeply into the alveoli, and the amounts of ultrafine particles deposited on alveolar surface area can be as high as 89.2$\mu m^2/cm^3$ during typical weekday in urban area [6-10]. Many recent studies demonstrated that the toxicological effects of the inhaled particles mainly depend on the particle size, and ultrafine aerosol particles may cause more severe health effect than fine particles [6].

Recent measurements in Fort, Meade, MD, USA show a strong correlation between elemental carbon (EC, often defined as black carbon) and carbon monoxide (CO), implying that there is a possibility that CO can be used as surrogate for estimating emission inventory of EC [11]. The ability to estimate EC from ambient CO measurement is highly promising because of the ease of measuring CO compared to EC. According to the Korea Ministry of the Environment (MOE, 2001) [12], the emission inventories of air pollutants (TSP, CO, NO_x, SO_2, and HC) by traffic exhausts constitute 40-85% of the total emission inventories in urban areas depending on site conditions. The urban areas in which industrial facilities are populated are reported to have less emission inventory of the vehicles, ~40% of the total emission inventory [13].

The coastal atmosphere adjacent to large urban and industrial centers can be strongly impacted by the emissions of air pollutants [14-19]. The airborne pollutants include the ionic species, such as sulfate, nitrate, and ammonium, etc. associated with suspended particulates from various pollution sources. High concentrations of certain ionic species in the airborne particles of coastal air could not only enhance the air-to-sea ionic deposition fluxes to coastal waters, consequently affect the coastal ecosystem, but could also be transported over the open ocean and affect the compositions of remote marine atmosphere [20]. In addition, high concentrations of airborne ionic species seriously influence the air quality and human health. Fine particles produced predominantly from high-temperature sources or gas-to-particle conversion processes within the atmosphere. The major components of $PM_{2.5}$ were sulfate (SO_4^{2-}), nitrate (NO_3^-), ammonia (NH_4^+) [21,22]. This ChangHua Coastal Park was just located along the coast area of ChangHua County. Therefore, the main goals of this study were to 1). Measure ionic species (F-, Cl^-, NO_3^-, SO_4^{2-}) which attached on total suspended particulates, PM_{10}, $PM_{2.5}$, dry depositions compositions. 2). Comparisons of ambient air ionic species (F-, Cl^-, NO_3^-, SO_4^{2-}) compositions on total suspended particulates, PM_{10}, $PM_{2.5}$, dry depositions for this semi-open/outdoor environment. 3). Calculate the individual ionic species (F-, Cl^-, NO_3^-, SO_4^{2-}) compositions percentages in the different particulates sizes modes (TSP, dry depositions, PM_{10}, $PM_{2.5}$) at this semi-open/outdoor sampling site.

Methodology

Sampling Sites

Figure 1 displayed the characteristics sampling site at a concrete processing factory in Changhua Coastal Park. And this sampling site was located in the ChangHua Coastal Park, ChangHua County and west coast of central Taiwan. Agriculture and small scale of fishery were the main living characters for Xianxi Township. It was also belong to remote area of Xianxi Township, ChangHua County. The total area were about 3,643 acre and there were about 321 factories which included food, glass, textile, plastic, chemical, metal, electricity, steel, machinery, hardware, wood, gas enterprises. This study selected a concrete processing factory as the sampling site. This factory was mainly recover slag as the elements and combined with cement to serve as the building materials.

Figure 1: Characteristics sampling site at a concrete processing factory in Changhua Coastal Park.

Sampling Device

PS-1 Sampler: PS-1 is a device for sampling ambient air particulates and was used to collect suspended airborne particles (GMW High-Volume Air Sampler; Grase by-Andersen, USA). The largest particles that can be collected using this device have a diameter of about 100μm. The PS-1 sampler was calibrated about 24 hr before each sampling and its flow rate was set up at 200L/min. A quartz filter with a diameter 10.2cm and a pore size 25μm was used as the sampling medium. All of the samples were stored at a temperature of 25±5°C and a humidity of 35±5%. The PS-1 and a dry deposition plate were placed on the highest building (about 15m) in the area. The site is located in a wide, open space without any nearby shelters [23].

Dry Deposition Plates (DDP): The dry deposition plate that was used herein is similar to those used in wind tunnel studies, but with a slight modification; it was made from polyvinyl chloride (PVC), was 21.5cm long, 7.6cm wide and 0.65cm thick with a sharp leading edge (with an angle of less than 10 degree), which was pointed into the wind using a wind vane. The top and bottom of each plate were covered with a thick projection film on which was coated about 20mg of silicone grease to collect the particles upon impact. Each thick projection film was 8cm long, 5.5cm wide and 8 mm thick, and held onto the plate at its edges using a thick plastic template, which was secured at each end using acrylic slats that were screwed into the plate. The plates were cut to slide between two rods with a diameter of 0.7cm, and two screws fastened the plate to a wind vane, allowing it to swing freely into the wind. The wind vane was made of aluminum, and was 21.5cm long and 17.5cm wide. The height of the stand was adjusted to between 130cm and 200cm. This sampling device has been used in a previous study [24].

Wilbur Sampler

The Wilbur sampler is a new high-volume air sampling system that is designed to collect fine particulates. This ambient air sampler device can be used to collect ambient air particulates with diameters of under 2.5 and 10μm. The maximum pressure drop of a clean filter with at 16.67Lmin^{-1} clean air flow is 30cm of a water column. The allowed working temperature range was -25°C~50°C. Automatic sampling was performed for 24 working hours. Sampling conditions were all kept well air ambient and there were use shelters nearby. Quartz filters were used at the medium the collect the ambient air $PM_{2.5}$ and PM_{10} all the samples were placed on the equilibrium box for 24 hrs after sampled [25].

Versatile Air Pollutant Sampler: The Versatile air pollutant sampler (VAPs, URG-3000K, URG, Chapel Hill, NC) was used to collect the $PM_{2.5}$ (fine, mass concentration of particles with aerodynamic diameter ≤2.5 μm) and $PM_{2.5-10}$ (coarse, mass concentration of particles with aerodynamic diameter from 2.5 to 10μm) particulates simultaneously. Sampling conditions were described as followed: Quartz filter was cored to collect ambient air particulates with 32L/min (water-soluble ionic with 15 L/min, coarse with 2 L/min, fine with 15L/min) flow rate. The sample filter was kept at humidity with 45±5% for 48 hrs. And weighing precedence was processed at temperature 25±5°C and humidity 45±5% with 0.001 mg as the minimum balance recorded number. Field blank was also placed in the sample site to ensure sample quality when sample program was conducted. The detail of the VAP sampler was described in previous study [26].

Chemical Analysis

All filters were put into 50mL bottles and immersed in distilled-deionized water. And the bottles were sent to ultrasonic process for about 99 min. Ion Chromatography (DIONEX-100) was used to analyze the water-soluble ions (F^-, Cl^-, SO_4^{2-} and NO_3^-) in the samples.

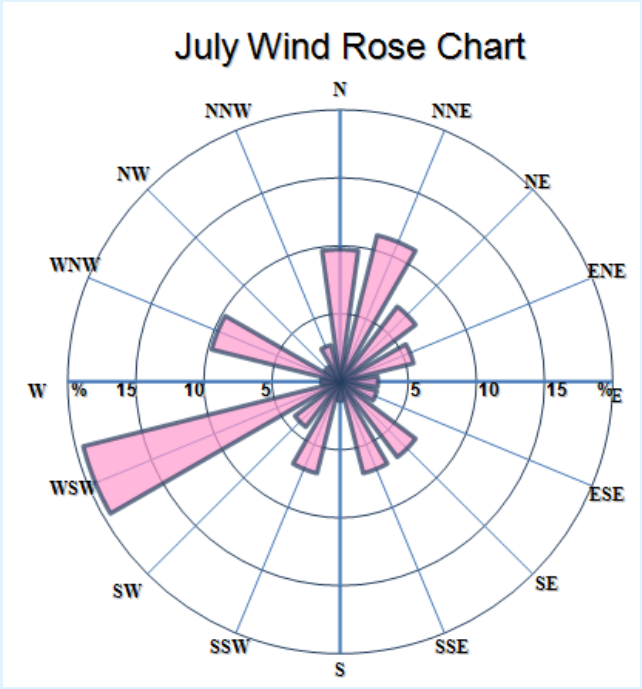
Quality Control

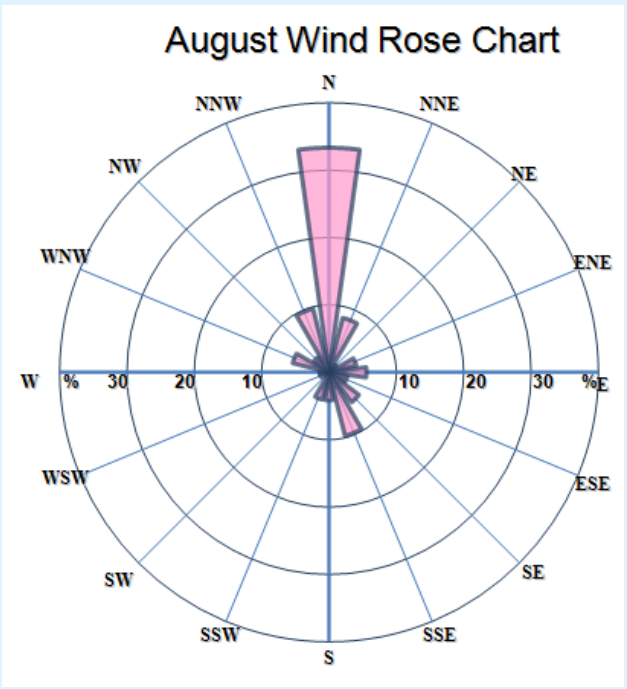
The method detection limit (MDL) was determined from 3×S, where S is the standard deviation (S) estimated from repeating the concentration slightly higher than the lowest concentration of standard line for 7 times. The detection limit was used to determine the lowest concentration level that can be detected to be statistically different from a blank.

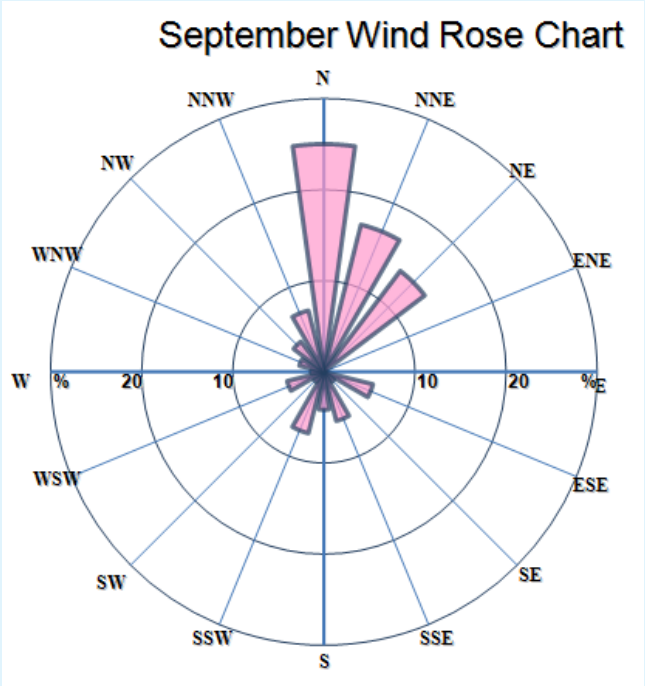
Results and Discussion

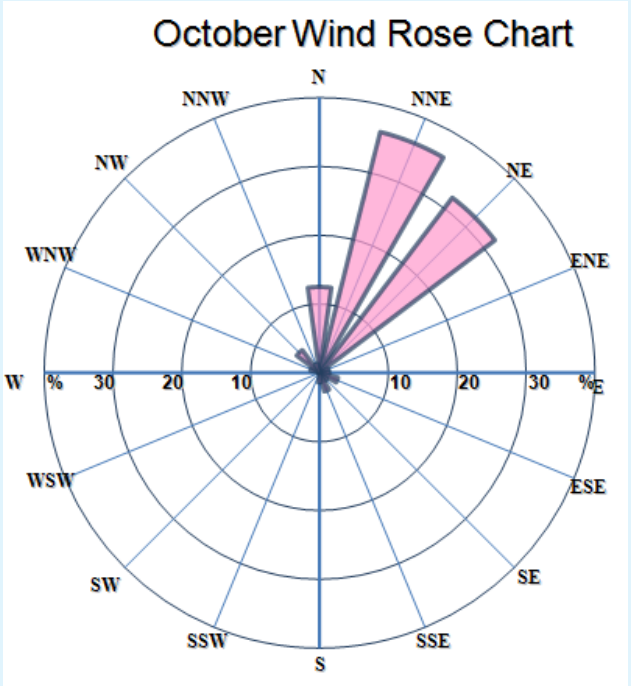
Atmospheric Meteorological Conditions in Changhua Coastal Park

Figure 2 displayed the Wind-rose chart at Changhua Coastal Park sampling site during the year of 2017-half year observations. The results indicated that the Wind direction in July, August, September, October, November and December were came from southwest, north, northeast, northeast and east during the year of 2017-half year observations, respectively. And the average wind direction was come from northeast.









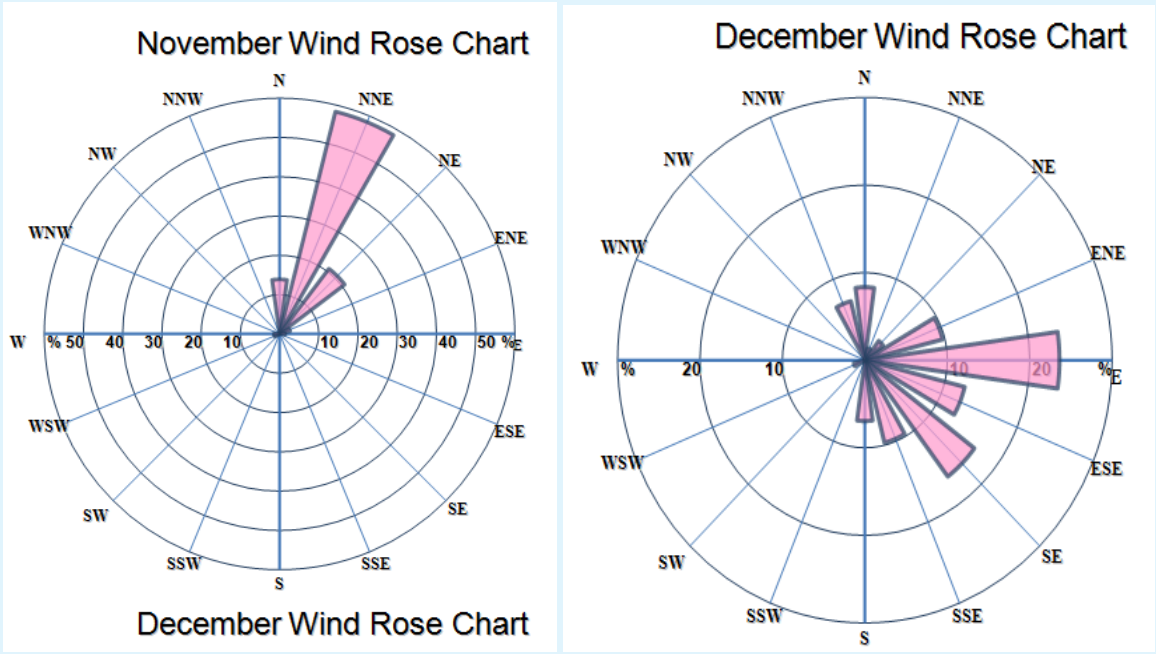


Figure 2: Wind-rose chart at Changhua Coastal Park sampling site during the year of 2017-half year observations.

In addition, the figure 3 displayed the atmospheric temperature, humidity, wind speed at this concrete processing factory in Changhua Coastal Park sampling site during the year of 2017-half year observations. The results also indicated that the highest temperature, humidity, wind speed were occurred in August, October, October, and the value were 31.7ºC, 86.4%, 6.2m/sec, respectively. Moreover, the lowest temperature, humidity, wind speed were occurred in December and the value were 17.8ºC, 67.9 %, 1.0 m/sec, respectively.

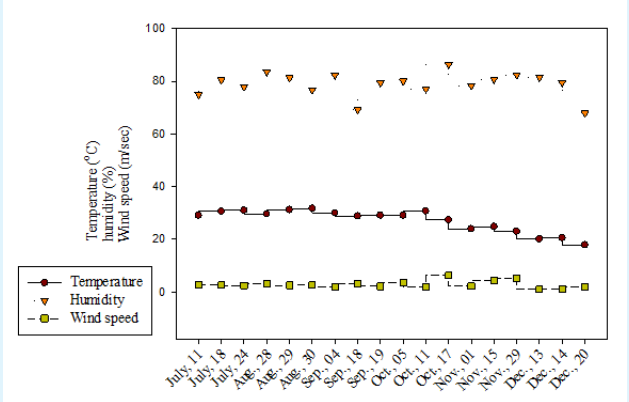


Figure 3: Atmospheric temperature, humidity, wind speed at a concrete processing factory in Changhua Coastal Park sampling site during the year of 2017-half year observations.

Ionic Species (F^-, Cl^-, NO_3^-, SO_4^{2-}) Compositions at a Concrete Processing Factory in Changhua Coastal Park during the Year of 2017

Table 1 displayed the average comparisons for ionic species (F^-, Cl^-, NO_3^-, SO_4^{2-}) compositions in dry depositions, TSP, PM_{10}, $PM_{2.5}$ with semi-open environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations. And the results also indicated that the highest average ionic F^-, Cl^-, NO_3^-, SO_4^{2-} compositions for TSP were occurred in August and the values were 2.593, 70.956, 76.711, 52.456 mg/g, respectively. In addition, the highest average ionic F^-, Cl^-, NO_3^-, SO_4^{2-}compositions for dry deposition were occurred in December and the values of F^-, Cl^-, NO_3^-, SO_4^{2-} were 17.11, 30.10, 119.49, 69.74 mg/g, respectively. Moreover, the highest average ionic F^-, SO_4^{2-} compositions for PM_{10}were occurred in November while the highest average ionic Cl^-, NO_3^- were occurred in August and the F^-, Cl^-, NO_3^-, SO_4^{2-} value were 0.157, 0.17, 0.306, 1.476 mg/g, respectively. Finally, the highest average ionic F^-, Cl^-, NO_3^-, SO_4^{2-} compositions for $PM_{2.5}$ were occurred in September, October and the value were 1.101, 0.248, 0.427, 1.02 mg/g for semi-open environment sampling site at a concrete processing factory in Changhua Coastal Park.

Data	Semi-Open Sampling Site															
	TSP				Dry depositions				PM_{10}				$PM_{2.5}$			
	F^-	Cl^-	NO_3^-	SO_4^{2-}	F^-	Cl^-	NO_3^-	SO_4^{2-}	F^-	Cl^-	NO_3^-	SO_4^{2-}	F^-	Cl^-	NO_3^-	SO_4^{2-}
07.11.17	0.385	16.954	3.944	11.827	14.042	3.389	3.949	29.887	0.051	0.045	0.169	0.312	0.038	0.043	0.150	0.276
07.18.17	1.229	6.310	22.898	33.260	4.486	1.264	1.779	9.601	0.035	0.112	0.245	0.459	0.028	0.095	0.184	0.357
07.24.17	0.537	1.189	3.056	8.197	4.283	1.197	1.349	10.119	0.034	0.074	0.284	0.484	0.024	0.061	0.213	0.376
Average	**0.717**	**8.151**	**9.966**	**17.761**	**7.604**	**1.950**	**2.359**	**16.536**	**0.040**	**0.077**	**0.232**	**0.418**	**0.030**	**0.066**	**0.182**	**0.336**
08.28.17	1.612	16.139	31.689	52.957	8.830	0.837	6.362	6.331	0.172	0.360	0.519	0.851	0.165	0.348	0.490	0.815
08.29.17	1.046	41.709	30.868	33.216	2.890	1.476	1.522	6.886	0.062	0.058	0.113	0.385	0.057	0.037	0.088	0.357
08.30.17	5.120	155.020	167.575	71.195	17.621	6.791	9.453	47.051	0.145	0.092	0.285	0.410	0.141	0.063	0.243	0.375
Average	**2.593**	**70.956**	**76.711**	**52.456**	**9.780**	**3.035**	**5.779**	**20.089**	**0.126**	**0.170**	**0.306**	**0.549**	**0.121**	**0.149**	**0.274**	**0.516**
09.04.17	3.302	12.618	47.404	61.581	2.079	1.256	1.441	5.667	0.150	0.072	0.253	1.222	0.807	0.498	0.783	0.496
09.18.17	0.851	5.616	7.204	12.185	3.694	1.139	1.685	11.303	0.106	0.014	0.117	1.218	2.357	0.102	0.011	0.094
09.19.17	3.213	16.362	12.915	36.231	24.652	8.015	15.642	4.367	0.145	0.177	0.530	1.140	0.138	0.145	0.488	1.069
Average	**2.455**	**11.532**	**22.508**	**36.666**	**10.141**	**3.470**	**6.256**	**7.112**	**0.134**	**0.088**	**0.300**	**1.193**	**1.101**	**0.248**	**0.427**	**0.553**
10.05.17	2.340	10.250	39.540	65.210	9.130	2.210	2.080	6.150	0.216	0.015	0.113	1.036	0.984	0.246	0.641	0.954
10.11.17	1.310	5.510	9.210	10.240	10.280	3.460	2.970	4.250	0.103	0.054	0.521	1.602	0.325	0.254	0.421	0.854
10.17.17	1.370	16.610	10.080	20.890	5.490	3.150	3.090	3.090	0.109	0.031	0.231	0.901	0.821	0.132	0.120	1.254
Average	**1.673**	**10.790**	**19.610**	**32.113**	**8.300**	**2.940**	**2.713**	**4.497**	**0.143**	**0.033**	**0.288**	**1.180**	**0.710**	**0.211**	**0.394**	**1.021**
11.1.17	3.124	9.215	37.210	40.360	8.240	2.120	3.950	5.210	0.236	0.035	0.201	1.123	0.413	0.521	0.091	0.954
11.15.17	2.013	8.452	20.160	11.260	11.020	3.190	3.060	5.620	0.125	0.095	0.352	1.354	0.958	0.953	0.521	0.857
11.29.17	1.245	5.120	19.970	20.350	7.320	6.540	3.520	4.970	0.110	0.054	0.132	1.952	0.365	0.258	0.621	0.452
Average	**2.127**	**7.596**	**25.780**	**23.990**	**8.860**	**3.950**	**3.510**	**5.267**	**0.157**	**0.061**	**0.228**	**1.476**	**0.579**	**0.577**	**0.411**	**0.754**
12.13.17	0.630	29.580	3.820	13.040	13.280	28.880	249.750	23.780	0.060	0.168	0.238	0.470	0.056	0.132	0.226	0.436
12.14.17	0.420	19.800	5.370	13.540	7.980	13.590	20.890	25.060	0.051	0.131	0.181	0.235	0.046	0.103	0.170	0.207
12.20.17	1.380	0.030	0.890	58.320	32.060	47.840	87.820	160.370	0.046	0.167	0.191	0.412	0.042	0.132	0.174	0.380
Average	**0.81**	**16.47**	**3.36**	**28.30**	**17.77**	**30.10**	**119.49**	**69.74**	**0.05**	**0.16**	**0.20**	**0.37**	**0.05**	**0.12**	**0.19**	**0.34**

Unit: mg/g

Table 1: Average comparisons for ionic species (F^-, Cl^-, NO_3^-, SO_4^{2-}) compositions in dry depositions, TSP, PM10, PM2.5 (mg/g) for semi-open environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations.

Furthermore, Figure 4 displayed the average ionic species (F^-, Cl^-, NO_3^-, SO_4^{2-}) compositions in dry depositions, TSP, PM_{10}, $PM_{2.5}$ for semi-open environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations. And the results indicated that the ionic species SO_4^{2-} was ranked highest average compositions in TSP, PM_{10}, $PM_{2.5}$ when compared with those of the other ionic species (F^-, Cl^-, NO_3^-) and the value were 31.88, 0.86, 0.587mg/g, respectively while the ionic species for $NO_3^-$was ranked

highest average compositions in dry depositions when compared with those of the other ionic species (F^-, Cl^- ,SO_4^{2-}) and the value was 23.35 mg/g at this semi-open environment sampling site at a concrete processing factory in Changhua Coastal Park.

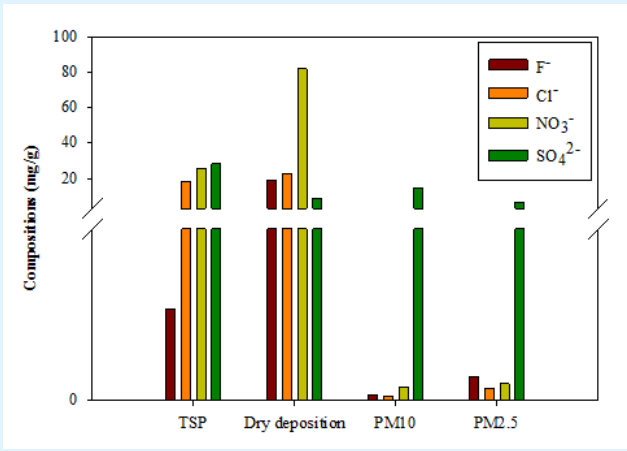


Figure 4: Average ionic species (F^-, Cl^-, NO_3^-, SO_4^{2-}) compositions in dry depositions, TSP, PM10, PM2.5 for semi-open environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations.

Table 2 displayed the average comparisons for ionic species (F^-, Cl^-, NO_3^-, SO_4^{2-}) compositions in dry depositions, TSP, PM_{10}, $PM_{2.5}$ with outdoor environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations. And the results also indicated that the highest average ionic F^-, Cl^-, SO_4^{2-}compositions for TSP were occurred in December while the highest average ionic NO_3^-compositions for TSP were occurred in September and the values of F^-, Cl^-, NO_3^-, SO_4^{2-} were 1.84,187.22, 64.04, 73.74 mg/g, respectively. In addition, the highest average ionic F^-, SO_4^{2-} compositions for dry deposition were occurred in July while the highest average ionic Cl^-, NO_3^- compositions for dry deposition were occurred in December and the values of F^-, Cl^-, NO_3^-, SO_4^{2-} were 17.415, 19.50, 13.84, 41.17 mg/g, respectively. Moreover, the highest average ionic F^-, Cl^-, NO_3^-, SO_4^{2-} compositions for PM_{10} was occurred in December while the highest ionic Cl^- compositions for PM_{10} were occurred in December and the values were 0.083, 0.277, 0.527, 0.894 mg/g, respectively. Finally, the highest average ionic F^-, Cl^-, NO_3^-, SO_4^{2-} compositions for $PM_{2.5}$ were occurred in September, December, October, December and the values were 0.136, 0.196, 0.424, 58.536 mg/g for outdoor environment sampling site at a concrete processing factory in Changhua Coastal Park.

Data	Outdoor Sampling Site															
	TSP				Dry depositions				PM_{10}				$PM_{2.5}$			
	F-	Cl^-	NO_3^-	SO_4^{2-}	F-	Cl^-	NO_3^-	SO_4^{2-}	F-	Cl^-	NO_3^-	SO_4^{2-}	F-	Cl^-	NO_3^-	SO_4^{2-}
07.11.17	0.571	10.428	24.491	23.210	47.550	25.532	4.919	113.722	0.060	0.092	0.391	0.678	0.046	0.086	0.357	0.618
07.18.17	0.455	23.529	21.093	21.149	2.126	4.054	1.102	4.607	0.129	0.153	0.627	1.054	0.112	0.122	0.420	0.736
07.24.17	0.589	23.944	26.351	12.580	2.569	0.303	1.278	5.197	0.059	0.140	0.564	0.950	0.030	0.087	0.310	0.546
Average	**0.538**	**19.300**	**23.978**	**18.980**	**17.415**	**9.963**	**2.433**	**41.175**	**0.083**	**0.128**	**0.527**	**0.894**	**0.063**	**0.098**	**0.362**	**0.633**
08.28.17	0.290	5.250	12.320	11.680	2.385	2.492	1.469	4.121	0.019	0.032	0.084	0.122	0.222	0.037	0.114	0.722
08.29.17	0.320	16.390	14.690	14.730	3.978	3.907	4.113	7.603	0.020	0.056	0.081	0.083	0.088	0.023	0.026	0.421
08.30.17	0.310	12.500	13.760	6.570	0.765	0.600	0.791	1.852	0.028	0.080	0.131	0.176	0.097	0.021	0.128	0.336
Average	**0.307**	**11.380**	**13.590**	**10.993**	**2.376**	**2.333**	**2.124**	**4.526**	**0.022**	**0.056**	**0.099**	**0.127**	**0.136**	**0.027**	**0.089**	**0.493**
09.04.17	0.588	6.816	21.327	25.937	1.947	1.314	1.984	7.554	0.016	0.035	0.117	0.211	0.073	0.079	0.236	1.105
09.18.17	0.951	40.541	69.970	54.504	2.711	4.131	3.082	10.717	0.010	0.080	0.190	0.203	0.042	0.053	0.219	0.755
09.19.17	1.266	29.854	100.822	79.438	0.799	0.491	0.757	0.459	0.017	0.048	0.191	0.272	0.139	0.040	0.114	0.296
Average	**0.935**	**25.737**	**64.040**	**53.293**	**1.819**	**1.979**	**1.941**	**6.243**	**0.014**	**0.054**	**0.166**	**0.229**	**0.084**	**0.057**	**0.190**	**0.719**

10.05.17	0.580	4.560	19.250	20.250	1.360	4.260	1.970	5.620	0.021	0.029	0.125	0.352	0.039	0.015	0.361	0.975
10.11.17	0.360	20.150	15.300	17.350	3.210	3.150	0.960	9.120	0.053	0.025	0.136	0.359	0.085	0.032	0.258	1.354
10.17.17	0.520	11.360	9.280	25.130	0.950	0.810	0.860	4.260	0.034	0.024	0.185	0.397	0.048	0.059	0.654	1.952
Average	**0.487**	**12.023**	**14.610**	**20.910**	**1.840**	**2.740**	**1.263**	**6.333**	**0.036**	**0.026**	**0.149**	**0.369**	**0.057**	**0.035**	**0.424**	**1.427**
11.1.17	1.210	5.210	15.390	17.520	5.690	4.230	0.930	7.650	0.062	0.052	0.159	0.516	0.065	0.015	0.054	1.985
11.15.17	1.920	10.260	10.540	15.290	4.650	4.690	0.820	5.190	0.036	0.036	0.365	0.621	0.039	0.021	0.123	1.152
11.29.17	1.140	20.310	5.120	10.350	8.260	5.610	1.920	4.890	0.052	0.045	0.212	0.851	0.052	0.063	0.092	0.751
Average	**1.423**	**11.927**	**10.350**	**14.387**	**6.200**	**4.843**	**1.223**	**5.910**	**0.050**	**0.044**	**0.245**	**0.663**	**0.052**	**0.033**	**0.090**	**1.296**
12.13.17	1.170	118.340	18.700	45.180	2.110	3.700	5.870	12.470	0.018	0.176	0.071	0.122	0.013	0.111	0.054	0.113
12.14.17	0.140	24.420	7.360	0.360	5.050	16.960	11.180	29.420	0.007	0.089	0.051	0.095	0.016	0.067	0.098	175.000
12.20.17	0.700	63.880	14.220	37.150	2.570	26.740	6.880	16.920	0.003	0.037	0.023	0.043	0.014	0.076	0.078	0.156
Average	**1.840**	**187.220**	**32.127**	**72.743**	**5.353**	**19.500**	**13.847**	**32.073**	**0.027**	**0.277**	**0.119**	**0.209**	**0.027**	**0.196**	**0.131**	**58.536**

Unit: mg/g

Table 2: Average comparisons for ionic species (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) compositions (mg/g) in dry depositions, TSP, PM10, PM2.5 for outdoor environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations.

Furthermore, Figure 5 displayed the average ionic species (F^-, Cl^-, NO_3^-, SO_4^{2-}) compositions in dry depositions, TSP, PM_{10}, $PM_{2.5}$ for outdoor environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations. And the results indicated that the ionic species SO_4^{2-} was ranked highest average compositions in dry deposition, PM_{10}, $PM_{2.5}$ when compared with those of other ionic species (F^-, Cl^-, NO_3^-) and the value were 16.043, 0.415, 10.517 mg/g, respectively while the ionic species was Cl^- was ranked highest average compositions in TSP when compared with those of other ionic species (F^-, Cl^-, SO_4^{2-}) and the value was 44.59 mg/g at this outdoor environment sampling site at a concrete processing factory in Changhua Coastal Park.

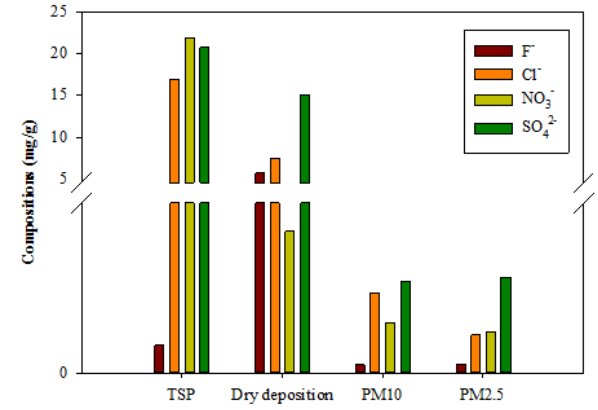


Figure 5: Average ionic species (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) compositions in dry depositions, TSP, PM10, PM2.5 for outdoor environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations.

To sum up, the highest average ionic species compositions was SO_4^{2-} for dry deposition, PM_{10}, $PM_{2.5}$ at this concrete processing factory in Changhua Coastal Park. In addition, the highest average ionic species composition was Cl^- for TSP at this concrete processing factory in Changhua Coastal Park in this study.

Ambient Air Particles Compositions and Dry Depositions Average Percentages of Water-Soluble Ionic (F^-, Cl^-, NO_3^- and SO_4^{2-}) with Semi-Open and Outdoor Environments.

Figure 6 displayed the average compositions percentages of ionic species (F-, Cl^-, NO_3^-, SO_4^{2-}) in TSP, dry depositions, PM_{10}, $PM_{2.5}$ for semi-open environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations. The results indicated that the average compositions percentages for ionic (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) proportion in TSP were 2.02, 20.98, 17.59 and 58.07%, respectively. In addition, the average compositions percentages for ionic (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) proportion in dry deposition 15.46, 10.45, 24.06 and 49.50% respectively. Moreover, the average compositions percentages for (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) proportion in PM_{10}were 7.29, 10.35, 13.84 and 63.22%, respectively. Finally, the average compositions percentages for ionic (F^-,Cl^-, $NO_3^-$and SO_4^{2-}) proportion $PM_{2.5}$ proportion were 8.12, 8.44 , 15.63 and 62.10%, respectively at this concrete processing factory environments.

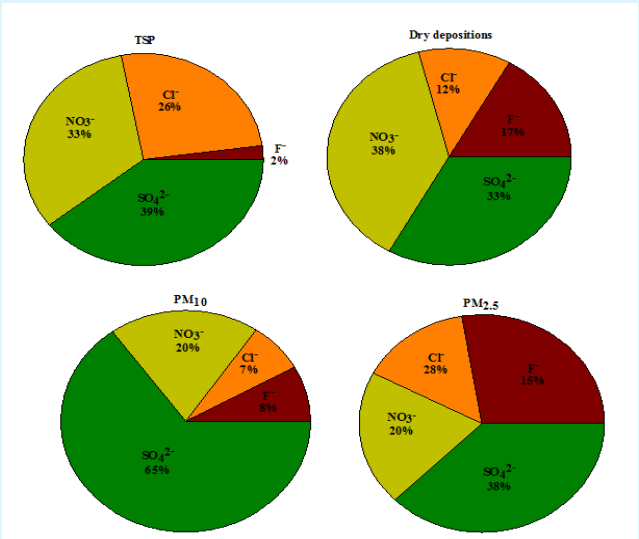


Figure 6: Average compositions percentages of ionic species (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) in TSP, dry depositions, PM10, PM2.5 for semi-open environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations.

Figure 7 displayed the average compositions percentages of ionic (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) in TSP, dry depositions, PM_{10}, $PM_{2.5}$ for outdoor environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations. The results indicated that the average compositions percentages for compositions ionic (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) proportion in TSP were 0.78, 19.70, 25.46 and 52.56%, respectively. In addition, the average compositions percentages for ionic (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) proportion in dry deposition 9.23, 19.71, 29.58 and 40.94%, respectively. Moreover, the average compositions percentages for ionic (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) proportion in PM_{10} were 5.12, 13.42, 17.11 and 61.06%, respectively. Finally, the average compositions percentages for ionic (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) proportion $PM_{2.5}$ proportion were 0.91, 8.48, 11.23 and 61.13%, respectively at this concrete processing factory environments.

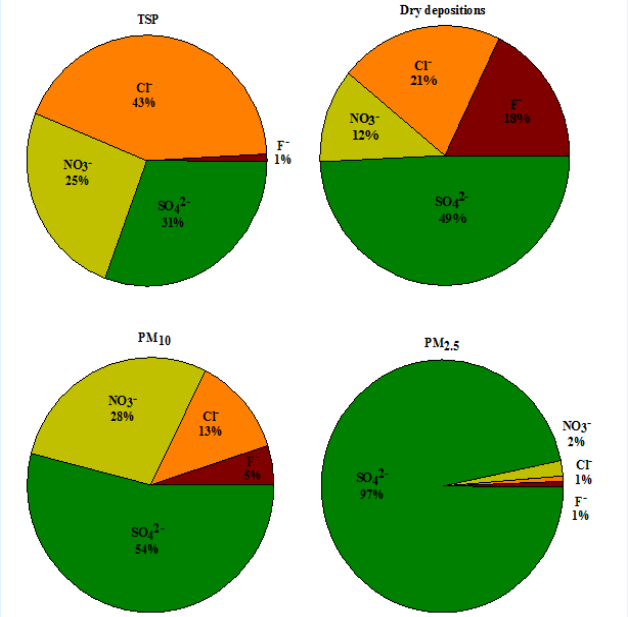


Figure 7: Average compositions percentages of ionic species (F^-, Cl^-, $NO_3^-$and SO_4^{2-}) in TSP, dry depositions, PM10, PM2.5 for outdoor environment at a concrete processing factory in Changhua Coastal Park during the year of 2017-half year observations.

To sum up, the main average compositions percentages for ionic species was SO_4^{2-} followed by $Cl^-$and $NO_3^-$for TSP, PM_{10}, $PM_{2.5}$ and dry depositions at semi-open and outdoor environments. Note worthy, ionic species SO_4^{2-}occupied were than 60%of the compositions percentages when compared with all the ionic species at both PM_{10} and

$PM_{2.5}$. And ionic species SO_4^{2-} compositions in TSP was occupied more than 50% of than concentrations percentages when compared with all the ionic species. Finally, ionic species SO_4^{2-} compositions in dry depositions was occupied more than 40% of than compositions percentages when compared with all the ionic species.

Conclusions

The main conclusions were shown as followed:

- The average ionic species compositions ratios for SO_4^{2-} in TSP to that of the F^-, Cl^-, NO_3^- were 18.43, 1.53, 1.211 at this semi-open environment sampling site. In addition, the average ionic species NO_3^-compositions ratios for in TSP to that of the F^-, Cl^-, SO_4^{2-} were 48.38, 1.68, 1.39 at this outdoor environment sampling site at this concrete processing factory in Changhua Coastal Park.
- The average ionic species compositions ratios for SO_4^{2-} in PM_{10} to that of the F^-, Cl^-, NO_3^- were 7.95, 8.87, 3.33 at this semi-open environment sampling site. In addition, the average ionic species compositions ratios for SO_4^{2-} in PM_{10} to that of the F^-, Cl^-, NO_3^- were 10.72, 4.25, 1.90 at this outdoor environment sampling site at this concrete processing factory in Changhua Coastal Park.
- The average ionic species compositions ratios for SO_4^{2-} in $PM_{2.5}$ to that of the F^-, Cl^-, NO_3^- were 1.36, 2.56, 1.87 at this semi-open environment sampling site. In addition, the average ionic species compositions ratios for SO_4^{2-} in $PM_{2.5}$ to that of the F^-, Cl^-, NO_3^- were 150.48, 141.59, 49.08 at this outdoor environment sampling site at this concrete processing factory in Changhua Coastal Park.
- The average ionic species compositions ratios for NO_3^- in dry depositions to that of the F^-, Cl^-, SO_4^{2-} were 2.24, 3.08, 1.13 at this semi-open environment sampling site. In addition, the average ionic species compositions ratios for SO_4^{2-} in dry deposition to that of the F^-, Cl^-, NO_3^- were 2.75, 2.32, 4.21 at this outdoor environment sampling sit at a concrete processing factory in Changhua Coastal Park.

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