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Chemical Composition, Characterization and Factors Affecting Household Dust (<20 μm) in Greater Cairo, Egypt

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Abstract

Adverse health and environmental effects of household dust are derived from their chemical composition and properties. In this study, household, stairs and entryway dust (<20 μm) samples from homes located in urban, residential and residential near to industrial area in Greater Cairo during summer 2013 were collected to study their chemical composition, characterization and factors affecting them. Results indicate that the levels of measured anions and cations were higher in the household compared to stairs and entryway dust. The highest concentration of SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} in the household and entryway dust was found in urban area. SO_4^{2-} was abundant in household, entryway and stairs dust followed by Cl^- and NO_3^-. Its average concentrations were 21.38, 14.57 and 15.83 mg/g, respectively. The household/entryway (I/O) concentration ratios of measured ion components indicate that these species might derive from indoor sources, although outdoor sources could be present as well. pH values of household, stairs and entryway dust ranged from 6.43 to 8.53, indicating that these dusts brought a large amount of crustal species, and might alleviate the tendency of acidification. The relationships between the concentrations of acidic components (NO_3^- and SO_4^{2-}) and basic components (NH_4^+, Ca^{2+} and Mg^{2+}) in household, stairs and entryway dust confirm that the acidity of dust is neutralized. Ca^{2+} and NH_4^+ in household and stairs dust and Ca^{2+} and Mg^{2+} in entryway dust are the most dominant neutralization substances.

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Keywords

Household, Stairs and Entryway Dust, Chemical Composition and Characterization, Greater Cairo, Egypt

1. Introduction

Time people spend indoor is influenced by several factors, like gender, occupation, and age. People tend to spend between 85% and 90% of their time exposed to the indoor rather than the outdoor atmosphere [1] [2]. Interest in indoor air chemistry and variations of airborne particles between indoor and outdoor atmospheres is mainly fueled by the fact that humans spend most of their time indoors [3]. House dust can be a major exposure route for some hazardous substances, leading to potential health risks [3]. Young children ingest considerable amounts of house dust via hand-to-mouth and object-to-mouth behaviour. The ingestion of house dust by children is particularly high relatively to their lower body weight. Adverse health and environmental effects of particulate are derived from their chemical components and properties [4] [5]. Inorganic water-soluble ions of dust are associated with the adverse human health effects [6], acidity of precipitation [7] [8], and soiling of the monuments [9]. They cause terrestrial and aquatic ecosystems damage [10]. In indoor environment, the deposition of "acidified" particles on a susceptible material surface is capable of accelerating chemical degradation of the material. Acid particles can severely deteriorate cultural heritage and reduce its aesthetic appearance and life span [11] [12]. On the other hand, alkaline dust damages painted surfaces such as walls, doors and automobiles [13]. Therefore, evaluation of chemical composition and characterization of household dust is important.

There are many indoor sources of particulate matter (PM) in homes. These include combustion processes, clothing fibers, human skin scales, building materials and furnishings, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for house hold cleaning and maintenance, personal care or hobbies detergent solution and pesticides; central heating and cooling systems and humidification devices; ventilation systems, resuspended dust from surfaces and outdoor sources [14]-[19]. Indoor particles vary in size and shape [20]. They represent a large surface area suitable for adsorption of volatile organic compounds present in the environment [21]. Indoor concentrations can be influenced by outdoor levels and by particle generation indoors [22] [23].

Indoor floor dust is composed of material derived from a variety of interior and exterior sources [24]. The unintentional collection of outside soil on footwear followed by subsequent deposition indoors is a principal route of soil ingress. The introduction of exterior soil into the interior environment is a significant element of the exposure pathway. Estimates of the exterior soil contributions have been proposed in the ranges from 20% - 30% [25]-[29]. It has, however, been estimated that as much as 85% of indoor dust is from outside home [30].

Indoor floor dust is a heterogeneous melange of organic and inorganic PM [31]. The inorganic components of indoor settled dust can arise from both natural sources e.g. oceans, dust storms and anthropogenic such as, biomass combustion, construction, road traffic, industrial activities or even indoor activities [32]-[38]. Particulate sulfate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+) and chloride (Cl^-) are formed from gaseous SO_2, NO_x, NH_3 and HCl, respectively, and represent the major water-soluble components of this dust [39]-[42]. SO_4^{2-} and NO_3^- are often higher in PM collected from urban areas and more related to combustion activities [43] [44]. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) may indicate a crustal source, while potassium (K^+) is a tracer for biomass burning and meat cooking [45]. Cations such as K^+, Ca^{2+}, Na^+ and Mg^{2+} are the main components of soil [46]-[51]. The components of these elements in household dust are expected to originate from outdoor surface soil and dust. NH_4^+ is a secondary product of NH_3 [52].

In many developing countries like Egypt where outdoor dust pollution is increasing, the impact of outdoor dust on the indoor environment is particularly important. In the indoor environment, removal of entrained outdoor PM occurs through ventilation and deposition. Studying the chemical characteristics and composition of house dust plays an important role in determining the types of contaminants associated with dust particles. It is a function of numerous factors including environmental and seasonal factors, ventilation and air filtration, homeowner activities, and indoor and outdoor source activities. Therefore, the main purpose of this study is to determine the composition and chemical characterization of household, stairs and entryway dust with particle size less than 20 µm in Greater Cairo.

2. Materials and Methods

2.1. Sites Description and Samples Collection

The household, stairs and entryway dust samples were collected from 16 homes located in urban (Dokki and El haram), residential (Faysal and Hadek Elahram) and residential near to industrial (Dar Elsalam) areas in Greater Cairo during the summer season of 2013. Dokki, El haram and Faisal areas are characterized by heavy traffic and high population density. Hadek Elahram is a new and low population density area. Dar Elsalam is characterized by heavy traffic, high population density and surrounded by an industrial area. **Table 1** shows the characteristics of each home. The household dust samples in each home were collected from living rooms using a vacuum cleaner equipped with a changeable (every two weeks) dust bag as described by Rasmussen *et al*. [53]; Lindern *et al*. [54]; Bai *et al*. [55] and Hassan [56]. Stairs dust samples were collected by sweeping from the edge to the other edge every two weeks. Entryway dust samples were collected every two weeks by sweeping dust from the house (dust collections were carried out inside the house not outside it) where the children usually play. The samples were dried at room temperature for 24 h, sieved using stainless steel sieves, and the <20 µm were obtained [57]. To eliminate cross contamination of the samples, the dust bag was changed and the vacuum cleaner and other sampling equipment were cleaned after each sampling. Gloves were worn during all sampling and laboratory procedures.

2.2. Sampling Analysis

For the analysis of water-soluble components, 0.50 gm of dust was dissolved in distilled water on hot plate and then filtered through a filter paper (Whatman No. 42). The water-soluble fraction was completed to a known volume, then its pH value measured. Its Na^+, K^+, Ca^{2+} and Mg^{2+} content were analyzed by atomic absorption spectrophotometry. NO_3^-, SO_4^{2-}, NH_4^+ and Cl^- were measured spectrophotometrically according to Harrison and Perry [58].

3. Results and Discussion

3.1. Anions and Cations Concentration Levels in Household, Stairs and Entryway Dust

The concentrations of anions and cations in household, stairs and entryway dust samples (<20 µm) in different areas in Greater Cairo are presented in **Tables 2-4** and **Figure 1**. The levels of anions (SO_4^{2-}, NO_3^- and Cl^- were relatively higher in the household dust compared to the stairs and entryway dusts (**Figure 1**). The sequence of anions concentration: household, entryway and stairs were as follows: SO_4^{2-} (21.38, 14.57 and 15.83 mg/g), Cl^- (10.91, 7.67 and 8.07 mg/g) and NO_3^- (4.37, 3.01 and 3.24 mg/g). The highest levels of the measured components in household dust indicate the presence of indoor sources such as combustion activities, building materials, detergents, and furniture beside the influence of the external particles that penetrate from outdoor sources and accumulate in an indoor environment. However, the indoor (household)-outdoor (entryway) relationship of water-soluble ions was not statistically significant. This indicates that the indoor and outdoor water-soluble ion components had different sources, although outdoor air penetration might play a role in delivering indoor water-soluble components. These results are in agreement with those reported in many studies [15]

Table 1. Characterization of sampling sites in Greater Cairo.

Site	No. of homes	Area	City	Home age	Size/m^2	Floor	No. of Occupant's	Smoking allowed	Type of fuel	Street
Faysal	4	Residential	Giza	14 - 29 years	115 - 130	2nd	6	Yes	LPG	Unpaved
Dar Elsalam	2	Residential	Cairo	19 - 34 years	65 - 85	2nd	4	Yes	LPG	Unpaved
El Dokki	4	Urban	Giza	44 - 64 years	35 - 75	3rd	4	Yes	LPG	Paved
El Haram	4	Urban	Giza	24 - 34 years	110 - 140	4th	6	Yes	LPG	Unpaved
Hadaek Elahram	2	Residential	Giza	9 years	135 - 150	3rd	4	No	LPG	Paved

Table 2. Ionic concentrations of household dust at different locations.

Site		SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Ca^{2+}	Na^+	K^+	Mg^{2+}	pH
Faysal	Minimum	11.70	2.63	5.29	1.13	5.85	5.10	0.90	0.61	7.57
	Maximum	28.96	5.58	13.08	2.85	14.48	13.43	8.08	5.27	8.03
	Median	21.06	4.25	9.35	2.03	10.53	9.30	3.86	2.51	7.84
	Mean	21.09	4.16	9.27	2.09	10.46	9.25	4.22	2.64	7.82
	S.D.	5.56	1.01	2.42	0.60	3.53	2.69	2.18	1.41	0.16
Dar Elsalam	Minimum	11.48	2.65	4.88	1.11	5.47	5.62	2.00	1.30	7.39
	Maximum	30.87	6.40	16.54	3.04	15.43	16.05	8.41	5.29	7.71
	Median	20.55	4.55	10.01	1.98	10.27	10.49	4.85	2.95	7.57
	Mean	20.84	4.42	9.88	2.06	10.34	10.53	4.98	3.00	7.56
	S.D.	5.56	1.09	3.08	0.59	4.07	3.05	1.69	1.08	0.13
Dokki	Minimum	12.20	2.64	8.40	1.22	6.10	5.30	2.67	1.87	7.41
	Maximum	35.59	6.61	19.03	3.64	17.79	14.52	7.34	4.97	8.12
	Median	24.15	4.63	13.54	2.41	11.95	9.89	5.81	3.72	7.75
	Mean	24.02	4.57	13.53	2.46	11.92	9.83	5.47	3.55	7.74
	S.D.	6.92	1.22	3.68	0.76	4.77	2.82	1.45	1.03	0.28
El haram	Minimum	8.88	2.15	7.19	0.96	4.61	5.85	4.04	2.69	7.5
	Maximum	52.26	10.85	19.31	5.75	27.14	15.52	10.21	7.44	7.75
	Median	22.37	4.82	13.26	2.53	11.62	10.72	8.29	5.37	7.58
	Mean	25.80	5.49	13.26	2.85	13.29	10.65	7.79	5.13	7.61
	S.D.	12.05	2.49	3.79	1.37	9.43	3.11	2.06	1.54	0.11
Hadek Elahram	Minimum	7.92	2.08	5.02	0.95	4.27	4.03	1.73	1.26	7.39
	Maximum	21.32	4.43	11.77	2.23	11.48	13.97	4.91	3.44	8.55
	Median	15.11	3.23	8.64	1.57	8.14	8.72	3.76	2.50	8.54
	Mean	15.16	3.22	8.60	1.61	8.10	8.63	3.54	2.38	8.15
	S.D.	3.98	0.78	2.27	0.46	2.95	2.70	0.97	0.71	0.57

[20] [34] [56] [59]-[64]. The high Cl^- levels in household dust might be due to cooking activities, such as cooking ingredients, cleaning agents and chlorinated tap water [61] [64]. The higher concentration of the SO_4^{2-} and NO_3^- in the household dust could be a result of smoking and cooking activities [65].

The average concentration of NH_4^+ (2.21 mg/g), K^+ (5.2 mg/g), Na^+ (9.78 mg/g), Ca^{2+} (10.82 mg/g) and Mg^{2+} (3.34 mg/g) in household dust were significantly higher than those found in both entryway and stairs. The average concentration of NH_4^+ (1.62 mg/g) and Ca^{2+} (7.85 mg/g) in stairs dust were relatively higher than entryway dust (1.53 mg/g for NH_4^+ and 7.58 mg/g for Ca^{2+}). The higher concentration of Na^+, K^+, Ca^{2+} and Mg^{2+} in the household dust indicate that they originated mainly of detrited building materials such as cement and gypsum, earth crust material from tracked-in soil [61] [66]. However, the average concentration of K^+ (3.99 mg/g), Na^+ (7.42 mg/g) and Mg^{2+} (2.57 mg/g) in entryway dust were relatively higher than those found in stairs dust (3.88 mg/g for K^+, 7.19 mg/g for Na^+ and 2.47 mg/g Mg^{2+}). From the above, we can conclude that the analyzed cations can originate from indoor sources themselves.

Among all the water-soluble ions determined in household dust, SO_4^{2-} was found to be the largest ionic contributor to the total ion mass (31.44%), followed by Cl^- (16.04%), Ca^{2+} (15.91%), Na^+ (14.38%), K^+ (7.65%), NO_3^- (6.43%), Mg^{2+} (4.91%), and NH_4^+ (3.25%) (**Figure 2**). A similar pattern was found in the stairs dust samples, SO_4^{2-} (31.57%), followed by Cl^- (16.09%), Ca^{2+} (15.65%), Na^+ (14.34%), K^+ (7.74%), NO_3^- (6.46%),

Table 3. Ionic concentrations of stairs dust at different locations.

Site		SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Ca^{2+}	Na^+	K^+	Mg^{2+}	pH
Faysal	Minimum	8.35	1.95	4.07	0.84	4.18	3.77	0.64	0.45	7.22
	Maximum	20.68	4.14	10.06	2.11	10.34	9.95	5.77	3.91	7.55
	Median	15.05	3.15	7.19	1.50	7.52	6.89	2.76	1.86	7.44
	Mean	15.07	3.09	7.13	1.54	7.47	6.85	3.01	1.96	7.40
	S.D.	3.97	0.75	1.86	0.44	2.52	1.99	1.56	1.04	0.12
Dar Elsalam	Minimum	8.50	1.89	3.75	0.85	4.05	4.02	1.43	1.00	7.31
	Maximum	22.86	4.57	12.72	2.34	11.43	11.46	6.01	4.07	7.82
	Median	15.22	3.25	7.70	1.52	7.61	7.49	3.46	2.27	7.67
	Mean	15.44	3.16	7.60	1.58	7.66	7.52	3.56	2.31	7.61
	S.D.	4.12	0.78	2.37	0.46	3.01	2.18	1.20	0.83	0.22
Dokki	Minimum	8.72	2.03	6.00	0.87	4.36	4.08	2.05	1.44	7.35
	Maximum	25.42	5.08	13.59	2.60	12.71	11.17	5.65	3.82	7.54
	Median	17.25	3.56	9.67	1.72	8.53	7.61	4.47	2.87	7.42
	Mean	17.16	3.51	9.66	1.76	8.51	7.56	4.21	2.73	7.43
	S.D.	4.94	0.94	2.63	0.54	3.41	2.17	1.11	0.79	0.27
El Haram	Minimum	6.83	1.59	5.33	0.68	3.41	4.18	3.11	1.92	6.43
	Maximum	40.20	8.04	14.30	4.11	20.10	11.08	7.86	5.32	7.47
	Median	17.21	3.57	9.82	1.81	8.60	7.65	6.38	3.83	6.70
	Mean	19.84	4.06	9.82	2.03	9.84	7.61	5.99	3.66	6.56
	S.D.	9.27	1.85	2.80	0.98	6.99	2.22	1.59	1.10	0.43
Hadek Elahram	Minimum	6.09	1.54	3.59	0.70	3.05	2.98	1.28	0.90	6.59
	Maximum	16.40	3.28	8.41	1.65	8.20	10.35	3.64	2.46	7.29
	Median	11.63	2.39	6.17	1.16	5.81	6.46	2.78	1.78	6.63
	Mean	11.66	2.39	6.14	1.20	5.79	6.39	2.62	1.70	6.85
	S.D.	3.06	0.58	1.62	0.34	2.11	2.00	0.72	0.51	0.34

Mg^{2+} (4.93%), and NH_4^+ (3.25%) (**Figure 3**). regarding to the entryway dust samples, SO_4^{2-} (30.14%), followed by Cl^- (15.87%), Ca^{2+} (15.68%), Na^+ (15.35%), K^+ (8.25%), NO_3^- (6.23%), Mg^{2+} (5.32%), and NH_4^+ (3.17%) (**Figure 4**).

3.2. Spatial Variations of Anions and Cations in Household Dust

Variations of anions and cations levels in household dust of different areas are affected by indoor activities and outdoor pollution sources. In the present study, the highest concentrations of SO_4^{2-}, NO_3^- and Cl^- in household dust were found at the urban areas followed by the residential areas (**Tables 2-4**). This may be due to the presence of internal sources such as, smoking and cooking activities beside high traffic volume in urban areas which added much more to the indoor levels [52] [65]. In addition, the highest concentration of NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} in household dust at the urban and residential areas may be due to deterioration of interior surfaces, warped windows and doors, and crevices in floors and walls as well as the effect of unpaved roads and heavy constriction activates of new buildings.

3.3. Correlation between Ionic Species in Household and Entryway Dust

Correlation coefficients between the ionic concentrations of the entryway dust are presented in **Table 5**. Significant

Table 4. Ionic concentrations of entryway dust at different locations.

Site		SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Ca^{2+}	Na^+	K^+	Mg^{2+}	pH
Faysal	Minimum	7.52	1.85	3.87	0.75	4.05	3.85	0.65	0.47	7.45
	Maximum	18.62	3.93	9.56	1.90	10.03	10.15	5.89	4.10	7.77
	Median	13.54	2.99	6.84	1.35	7.30	7.03	2.82	1.95	7.60
	Mean	13.56	2.93	6.77	1.39	7.25	6.99	3.07	2.05	7.55
	S.D.	3.57	0.71	1.77	0.40	2.45	2.03	1.59	1.09	0.30
Dar Elsalam	Minimum	8.08	1.70	3.56	0.81	3.89	4.14	1.47	1.04	7.44
	Maximum	21.72	4.12	12.09	2.22	10.98	11.81	6.19	4.23	8.12
	Median	14.46	2.93	7.31	1.45	7.31	7.72	3.57	2.36	7.68
	Mean	14.66	2.84	7.22	1.50	7.35	7.75	3.66	2.40	7.62
	S.D.	3.91	0.70	2.25	0.43	2.89	2.25	1.24	0.86	0.23
Dokki	Minimum	7.76	1.93	5.70	0.83	4.23	4.24	2.14	1.52	7.59
	Maximum	22.62	4.83	12.91	2.47	12.33	11.61	5.87	4.05	7.94
	Median	15.35	3.38	9.19	1.64	8.28	7.91	4.65	3.04	7.74
	Mean	15.27	3.34	9.18	1.67	8.26	7.86	4.38	2.90	7.70
	S.D.	4.40	0.89	2.50	0.52	3.31	2.26	1.16	0.84	0.32
El Haram	Minimum	6.49	1.43	5.06	0.65	3.28	4.39	3.20	1.96	6.63
	Maximum	38.19	7.24	13.59	3.90	19.30	11.64	8.09	5.42	7.87
	Median	16.35	3.21	9.33	1.72	8.26	8.04	6.57	3.91	7.24
	Mean	18.85	3.66	9.33	1.93	9.45	7.99	6.17	3.74	7.21
	S.D.	8.80	1.66	2.66	0.93	6.71	2.33	1.63	1.12	0.43
Hadek Elahram	Minimum	5.49	1.47	3.41	0.67	2.96	3.04	1.31	0.92	6.89
	Maximum	14.76	3.12	7.99	1.57	7.96	10.56	3.71	2.53	7.59
	Median	10.46	2.27	5.87	1.10	5.64	6.59	2.84	1.84	7.22
	Mean	10.50	2.27	5.84	1.14	5.61	6.52	2.67	1.75	7.20
	S.D.	2.75	0.55	1.54	0.32	2.04	2.04	0.73	0.52	0.36

Table 5. Correlation coefficients between the ionic concentrations of entryway and household dusts.

	SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Ca^{2+}	Na^+	K^+	Mg^{2+}
Entryway								
SO_4^{2-}	1.00							
NO_3^-	**0.41**	1.00						
Cl^-	**0.65**	**0.67**	1.00					
NH_4^+	**0.84**	0.38	**0.57**	1.00				
Ca^{2+}	**0.91**	**0.81**	**0.69**	**0.64**	1.00			
Na^+	**0.74**	**0.84**	**0.81**	**0.50**	**0.88**	1.00		
K^+	**0.72**	**0.42**	**0.51**	**0.83**	**0.62**	**0.62**	1.00	
Mg^{2+}	**0.83**	**0.75**	**0.79**	**0.71**	**0.89**	**0.86**	**0.73**	1.00
Household								
SO_4^{2-}	1.00							
NO_3^-	**0.69**	1.00						
Cl^-	0.35	0.30	1.00					
NH_4^+	**0.70**	**0.71**	0.37	1.00				
Ca^{2+}	**0.72**	**0.61**	0.39	0.39	1.00			
Na^+	0.34	**0.46**	**0.45**	0.35	0.38	1.00		
K^+	**0.52**	**0.53**	**0.41**	**0.43**	0.35	0.32	1.00	
Mg^{2+}	**0.63**	**0.55**	0.39	**0.41**	**0.49**	**0.46**	**0.50**	1.00

Bold: significant ($p < 0.001$).

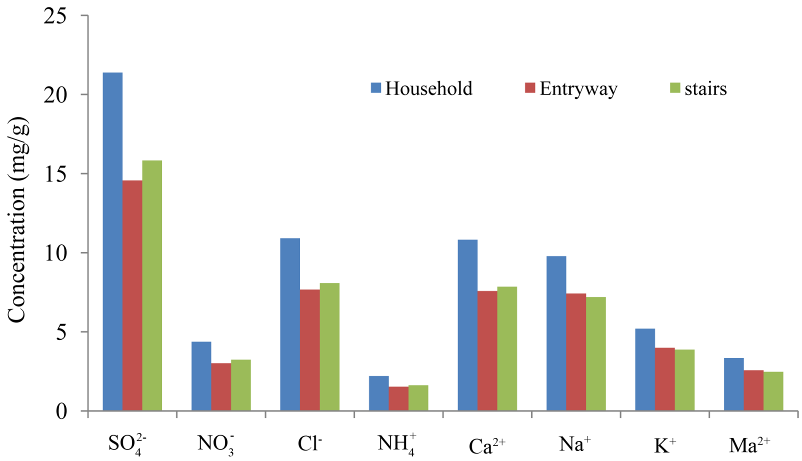

Figure 1. Concentrations of water-soluble componants in household, stairs and entryway dust.

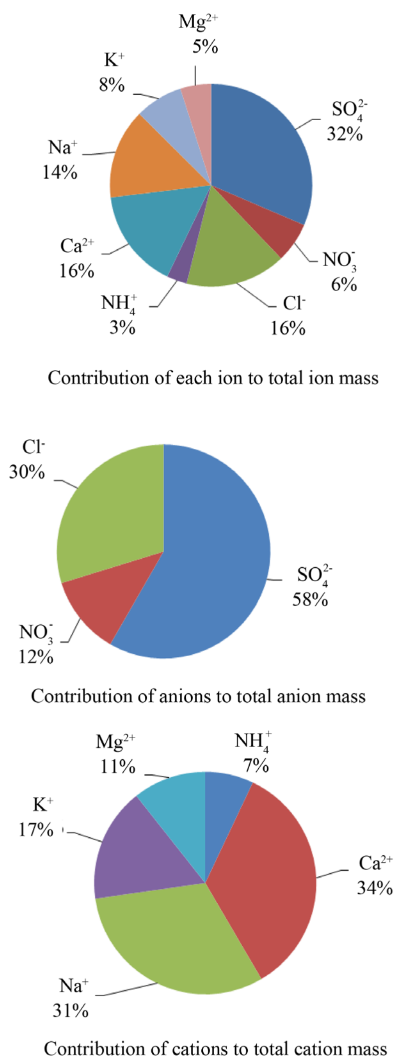

Figure 2. The contribution of ions to total cation/anion and total ion mass in the household dust.

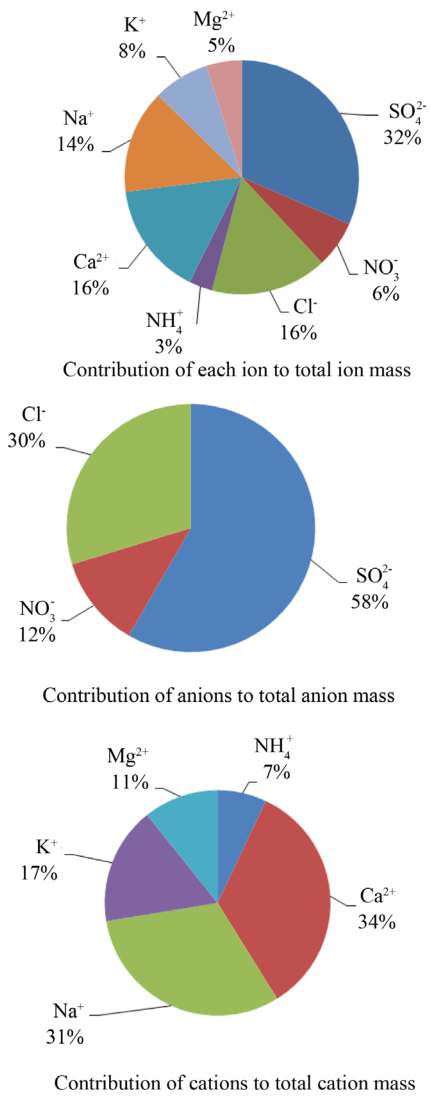

Figure 3. The contribution of ions to total cation/anion and total ion mass in the stairs dust.

positive correlation coefficients were found between the concentrations of Ca^{2+} and SO_4^{2-}, Mg^{2+} and SO_4^{2-}, and Na^+ and SO_4^{2-}. These relationships could be explained by the reaction of H_2SO_4, results from the oxidation of atmospheric SO_2, with alkaline components of dust rich in Ca^{2+}, Mg^{2+} and Na^+. SO_2 or H_2SO_4 can react with aqueous carbonates such as dissolved $CaCO_3$ and $MgCO_3$ on soil particles to form a coarse mode sulfate [37] [67] [68]. In the present study, the concentration of SO_4^{2-} was also found to be significantly positively correlated with NH_4^+ concentration (**Table 5**), suggesting neutralization by ammonia gas and the forms of $(NH_4)_2SO_4$ and/or NH_4HSO_4 and $CaSO_4$ do exist in the entryway dust. Strong positive correlation coefficient between SO_4^{2-} and NH_4^+ concentration indicate that SO_4^{2-} is present as $(NH_4)_2SO_4$ and/or NH_4HSO_4 [46] [69].

In Cairo, the summer season is characterized by high temperature. Therefore, the fine mode nitrate (NH_4NO_3) is volatilized and forms gaseous nitric acid and ammonia gas. A portion of the nitric acid which is volatilized from the fine mode nitrate particles is adsorbed by the coarse particles with alkaline components of mineral aerosols, and form the coarse mode nitrate through the gas-to-particle reaction, such as $Ca(NO_3)_2$, $Mg(NO_3)_2$ and $NaNO_3$. This is confirmed by insignificant positive correlations between NH_4^+ and NO_3^- and significant positive correlations between Ca^{2+} and NO_3^-, Mg^{2+} and NO_3^-, and Na^+ and NO_3^- concentrations in the present study (**Table 5**). The production of particulate NH_4NO_3 is favored by the low temperatures and high relative

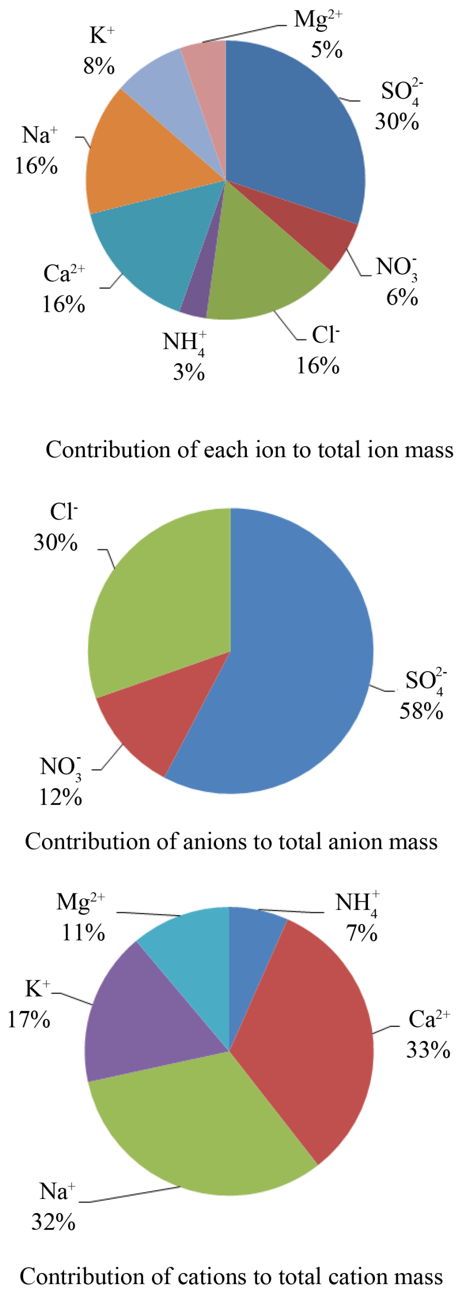

Figure 4. The contribution of ions to total cation/anion and total ion mass in the entryway dust.

humidity typical of high atmospheric stability episodes [37]. Nitrate mainly exists in coarse particles together with alkaline ions, such as calcium and potassium [70] [71]. The correlation among NO_3^-, Mg^{2+} and Ca^{2+} suggests a nitrate salt formation on coarse particle [72]. In the present study, the lack of strong positive correlations between SO_4^{2-} and NO_3^- concentrations may be attributed to the effect of different sources of SO_4^{2-} other than traffic sources, such as Shoubra-El Kheima industrial area in the north, Mokattam hills in the east and southeast, and cement factories in the south of Cairo city centre.

The correlation coefficient matrices for water-soluble ions in the household dust are shown in **Table 5**. These correlations were not as strong as that entryway, and there were only significant between NH_4^+, Ca^{2+}, Mg^{2+}, K^+ and NO_3^- and SO_4^{2-}. The relative lack of correlation between ion species indicates different emission sources and/or removal mechanism, and possibly different transport patterns for indoor water-soluble ions. This would be consistent with the weak and unrelated indoor-outdoor relationship of water-soluble ions.

3.4. The Acidity of Household, Stairs and Entryway Dust

3.4.1. Equivalent Concentrations of Total Cations and Anions

The ratios of the sum of the equivalent concentration (meq/g) of cations to anions in the household, stairs and entryway dust were calculated. These ratios were 1.83 in household, 1.93 in stairs and 1.80 in entryway dust. Moreover, significant positive correlation coefficients ($p < 0.001$) were found between the sum of the equivalent concentrations of all cations and that of all anions ($r = 0.83$ in household, $r = 0.93$ in stairs and $r = 0.94$ in entryway dust). The difference between the sum of cations and the sum of anions in the household, stairs and entryway dust is an indicator for the completeness of the measures parameters. The anions deficiency in dust samples may be attributed to the exclusion of some anions. The main anions which may cause the imbalance are bicarbonate, organic ions (formate and acetate), F^-, NO_2^-, PO_4^{3-} and Br^-.

3.4.2. pH

The pH of the dust filtrate is a parameter to directly denote the acidity of the dust collected. The mean pH values of the household, stairs and entryway dust were nearly similar. They were 7.83 (household), 7.35 (stairs) and 7.27 (entryway). Compared with the blank value of 5.65, household, stairs and entryway dust of Greater Cairo brought a large amount of crustal species, and might alleviate the tendency of acidification of the these dusts.

3.5. Neutralization Factors

In order to know the neutralization of acidic components of household, stairs and entryway dust by crustal components and ammonia, neutralization factors (NF) for NH_4^+, Ca^{2+} and Mg^{2+} have been calculated using the following formula [73]:

$$NF_{NH_4^+} = \left[NH_4^+\right] \Big/ \left\{2\left[SO_4^{2-}\right] + \left[NO_3^-\right]\right\}$$

$$NF_{Ca^{2+}} = \left[Ca^{2+}\right] \Big/ \left\{\left[SO_4^{2-}\right] + 2\left[NO_3^-\right]\right\}$$

$$NF_{Mg^{2+}} = \left[Mg^{2+}\right] \Big/ \left\{\left[SO_4^{2-}\right] + 2\left[NO_3^-\right]\right\}$$

The order of NF is $Ca^{2+} > Mg^{2+} > NH_4^+$ for household dust and stairs dust (**Table 6**). This feature suggests that the major neutralization of acidic components of dust samples collected from household, entryway and stairs had occurred through Ca^{2+} and Mg^{2+}.

4. Conclusion

The present study reports the chemical composition and characterization of household, stairs and entryway dust with particle size less than 20 µm collected from 16 homes located in urban and residential areas in Greater Cairo and factors affecting them during the summer of 2013. The levels of measured anions and cations were higher in the household compared to stairs and entryway dust. The highest concentration of SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} in the household dust and entryway were found in urban followed by residential areas. SO_4^{2-} was the abundant in household, entryway and stairs dust followed by Cl^- and NO_3^-. The water-soluble ion components of household dust was partially delivered by outdoor air penetration, but mainly originated from indoor sources such as, smoking and cooking activities, deterioration of interior surfaces, warped

Table 6. Neutralization factors for NH_4^+, Ca^{2+} and Mg^{2+}.

	NH_4^+	Ca^{2+}	Mg^{2+}
Household	0.12	0.92	0.47
Stairs	0.13	0.91	0.49
Entryway	0.15	0.95	0.53

windows and doors, and crevices in floors. Household, entryway and stairs dusts bought a large amount of crustal species, and might alleviate the tendency of acidification. The relationships between the concentrations of acidic components (NO_3^- and SO_4^{2-}) and basic components (NH_4^+, Ca^{2+} and Mg^{2+}) in household, stairs and entryway dust confirmed that the acidity of dust is neutralized, and Ca^{2+} and NH_4^+ in household and stairs dust and Ca^{2+} and Mg^{2+} in entryway dust are the most dominant neutralization substances.

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