STATISTICAL ANALYSES OF THE WET AND BULK DEPOSITION OF ISTANBUL, TURKEY

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ABSTRACT

The aim of this study is analyze wet and bulk deposition collected on both sides of Istanbul with the help of statistical techniques. Altogether, 137 wet deposition and 47 bulk samples were collected. The overall mean value of pH of wet deposition samples was found to be 5.85. Maximum and minimum values of pH were 7.51 and 4.27, respectively. Concentrations of SO_4^{2-} and Ca^{2+} in the stations of European side were found to be higher than those of the Asian side for the two consecutive precipitation periods. Statistical data analyses together with principle component analysis were carried out for the two sampling periods. NH_4^+, NO_3^- and K^+ ions and $NH_4^+$and SO_4^{2-} ions were found to have significant factor loadings for the first period and the second period, respectively. Ca^{2+} and SO_4^{2-} ions relatively have higher t statistic with respect to other ions on the two parts of Istanbul.

INTRODUCTION

Many studies on precipitation chemistry have been carried out using statistical and meteorological analyses to understand the characteristics and causes of acidic precipitation. Principle component and factor analysis are useful tools for the determination of ion sources and examining the spatial and temporal variations of certain ions [1, 2].

The objectives of this study are to determine spatial distribution and statistical interrelationships of chemical components of wet deposition that was collected at different regions of Istanbul for the two consecutive precipitation periods and to investigate bulk deposition in one region. By using principal component analysis it may be possible to describe a set of variables in terms of a smaller number of indices of factors, and hence elucidate the relationship between these variables [3]. This work presents results of principal component analysis of the ions in precipitation leading to the construction of factors of these ions. t test was applied to find any differences between the two parts of Istanbul, European Side and Asian Side, that were significant. Furthermore, spatial analysis was performed for pH and ions in wet deposition for the two parts of Istanbul.

Besides daily analysis of wet deposition, inspection of bulk deposition for the period of January 2001 - April 2003 is important in terms of providing longer term averages. Time variability of major anion and cation concentrations in bulk and wet deposition were also studied for Göztepe.

SAMPLING SITE AND EXPERIMENTAL

The Bosphorus strait, approximately 30 km long, connects the Black Sea and

Marmara Sea, dividing Istanbul into two parts, a European Side and Asian Side. This study presents the chemical composition of wet deposition that occurred at different regions of both parts of Istanbul during the period of January 2001 - May 2001 and September 2001 - May 2002. During the period of January 2001 - May 2001 wet deposition samples were collected in Topkapı, Bağcılar, which are located on the European side, in Maltepe and Göztepe which can be found on the Asian side. During the September 2001 -May 2002 wet deposition was sampled in Zeytinburnu, Bakırköy which are located on the Europen side, Maltepe, Göztepe, and Sarıgazi, which are located on the Asian side.

Bulk deposition was collected together with wet deposition at only one station (Göztepe) during the period of January 2001 - April 2003. 137 wet deposition samples and 47 bulk samples were collected during the study period. The methods of collection, storing and chemical analysis can be obtained from [4].

RESULTS AND DISCUSION

Statistical analysis of wet deposition

Principal component analysis is an interdependence technique in which all variables simultaneously considered each related to all others. Factor loadings are the correlations of each variable with each other. These loadings indicate the degree of correspondence between the variable and the factor, with higher loadings greater than ± 0.30 are considered to meet the minimal level; loading of ± 0.40 is considered to be more important; and if the loadings are 0.50 or greater, they are considered practically significant [5]. Owing to our objective of summarizing the characteristics, the factor analysis were applied to a correlation matrix of concentrations of the ions.

b)	Component		
	1	2	3
	0.73	0.41	0.22
	0.92	-0.01	0.24
	0.87 -	0.07	0.18
	0.14	0.94	0.05
	0.21	0.19	0.74
	0.38	0.75	0.28
	0.02	0.06	0.02
	0.87	0.13	0.04

a)	Component	
	1	2
Ca^{2+}	0.84	0.24
Mg^{2+}	0.85	0.14
Na^{+}	0.72	0.09
NH_4^{+}	0.29	0.53
K^{+}	0.21	0.69
SO_4^{2-}	0.77 -	0.34
NO_3^{-}	0.17	0.76
Cl^{-}	0.81	0.12

Table1. Principle component loadings (varimax rotation) of ion substances in rainwater.

Table1 provides for principle component loadings (varimax rotation) of ion substances in rainwater during the period of a) January 2001 - May 2001 and b) September 2001 -May 2002, separately. The components belonging part "a" explain % 60.7 of the total variance of the data set of the first period and the components belonging part "b" explain % 58.6 of the total variance of the data set of the second period, altogether representing the mean tendency of the variance of the precipitation chemistry. Ca^{2+} Mg^{2+} Na^{+} and Cl^{-} ions have the significant factor loadings for the first components in the both of periods. In the second component of the first period, factor loadings of NH_4^{+}, NO_3^{-} and K^{+} ion substances reaches their maximum values. In the second period, the loading values of $NH_4^{+}$and SO_4^{2-} was significantly high for the second component. SO_4^{2-} and NO_3^{-} could exist in the atmosphere as $(NH_4)_2SO_4$ and NH_4NO_3 aerosols [6]. This may be the reason of having significant factor loadings of NH_4^{+}, SO_4^{2-} and NO_3^{-} together in various components.

The t test assesses the statistical significance of the difference between two independent sample means. t critical value depends on the degrees of freedom which is equal to N_1+N_2-2 , where N_1 and N_2 denote the sizes of two independent samples.

	First period			***Second period***		
	Mean	Stan. dev.	t statistic	Mean	Stan. dev.	t statistic
SO_4^{2-}	7.47	7.19	1.56	4.60	5.11	1.88
Ca^{2+}	3.48	2.84	2.26	2.70	2.58	0.87
Cl^{-}	2.59	2.41	-0.14	4.30	3.42	-1.63
NO_3^{-}	1.36	0.45	0.52	1.73	0.79	0.11
Na^{+}	1.45	1.14	0.30	1.48	1.40	-0.44
NH_4^{+}	0.60	0.34	-0.38	0.46	0.33	1.32
K^{+}	0.76	1.16	1.52	0.25	0.49	-1.44
Mg^{2+}	0.35.	0.36	0.62	0.26	0.43	-1.17

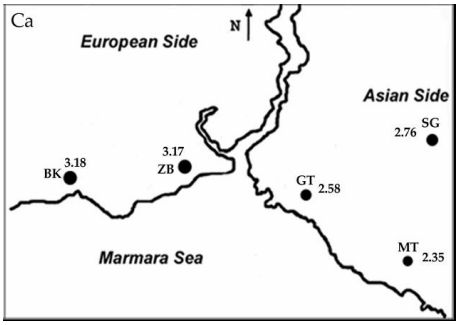
Table 2. Mean values, standard deviation and t distribution of the ions in the rain events for the two periods and for the two sites of Istanbul.

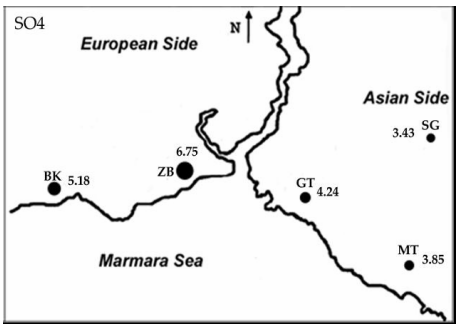
In this study, N_1 and N_2 are the number of rain events occurred on European and Asian sites, respectively. Table 2 shows t statistic distribution of the ions in the rain events for the first period, January 2001 -May 2001 and the second period, September 2001 - May 2002. Standard deviation and mean values of the ion concentrations were also provided in this table. Degree of freedom was calculated as 59 for first period. According to this degree of freedom, critical t value was 1.67 corresponding to 90% confidence level. Ca^{2+} and SO_4^{2-} ions relatively have higher t values with respect to the other ions as 2.26 and 1.56 in this period. This result shows us that there was a 90% significant difference between the Ca^{2+} wet deposition values of European and Asian sides of Istanbul. Analogous to the result of Ca^{2+}, SO_4^{2-} also shows difference between the two sites but it was not significant at the 90% confidence level. For the 90% confidence level the t statistic was calculated as 1.66 for the second period. t value of SO_4^{2-} ion was found to be high once again as 1.88 for this period. For the remaining ions it was not possible to talk about a large difference between the two parts of Istanbul for both of the two periods.

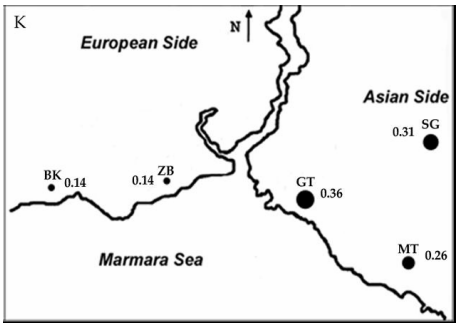
Standard deviation was calculated among the individual samples of wet deposition for each ion. It is a measure of how widely values were dispersed from the average value. SO_4^{2-} has the maximum mean value and standard deviation for both of the two periods. The standard deviation values for SO_4^{2-} were 7.19 and 5.11 corresponding to the two sampling periods, in order. Minimum standard deviation values were found for NH_4^+as 0.34, 0.33. These values prove that the highest and lowest variability in the ion concentrations belong to SO_4^{2-} and NH_4^+, respectively. Anthropogenic source of SO_4^{2-} was considered to be highly variable, mainly depending on the usage of high sulfur containing fossil fuels in domestic heating, controlled by temperature and wind velocity and in industrial production.

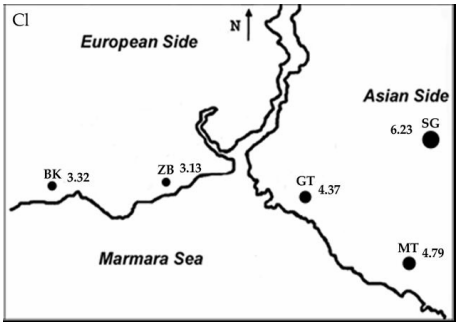
Concentrations of ions and pH with respect to the sampling locations

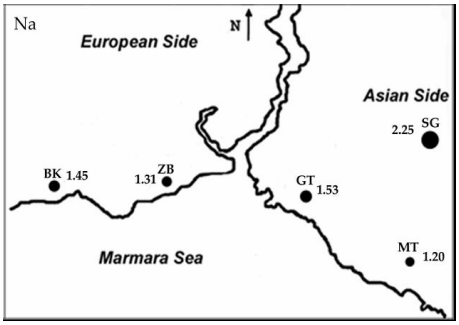
Spatial distribution of pH and ions in wet deposition for different five regions, Sarıgazi, Zeytinburnu, Bakırköy, Maltepe and Göztepe during the period of September 2001 - May 2002 were depicted in Figure 1. Concentrations of SO_4^{2-} and Ca^{2+} in the stations of European side were found to be higher than those of the Asian side. For NO_3^- it is not possible to talk about a large difference between the sampling locations.

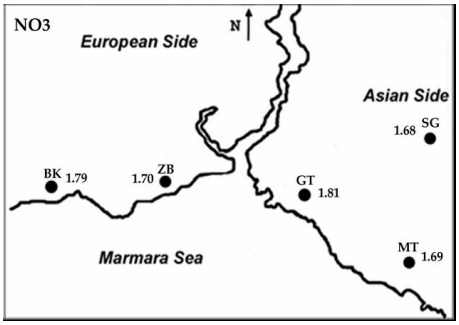

Ca
N
European Side
Asian Side
2.76 SG
3.17
ZB
3.18
BK
GT 2.58
MT 2.35
Marmara Sea

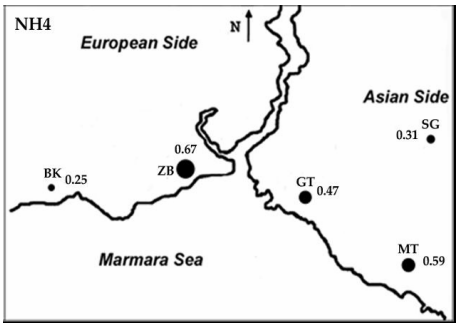

SO4
N
European Side
Asian Side
3.43 SG
6.75
ZB
BK 5.18
GT 4.24
MT 3.85
Marmara Sea

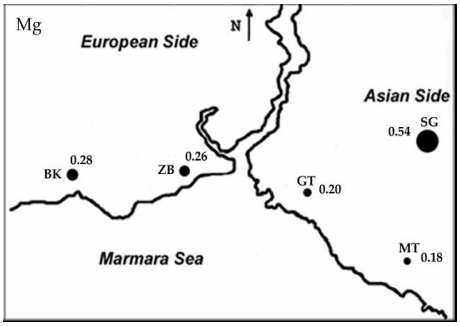

K
N
European Side
Asian Side
0.31 SG
BK 0.14
0.14 ZB
GT 0.36
MT 0.26
Marmara Sea


Cl
N
European Side
Asian Side
6.23 SG
BK 3.32
ZB 3.13
GT 4.37
MT 4.79
Marmara Sea


Na
N
European Side
Asian Side
2.25 SG
BK 1.45
1.31 ZB
GT 1.53
MT 1.20
Marmara Sea


NO3
N
European Side
Asian Side
1.68 SG
BK 1.79
1.70 ZB
GT 1.81
MT 1.69
Marmara Sea


NH4
N
European Side
Asian Side
0.31 SG
0.67
ZB
BK 0.25
GT 0.47
MT 0.59
Marmara Sea


Mg
N
European Side
Asian Side
0.54 SG
0.28
BK
0.26
ZB
GT 0.20
MT 0.18
Marmara Sea

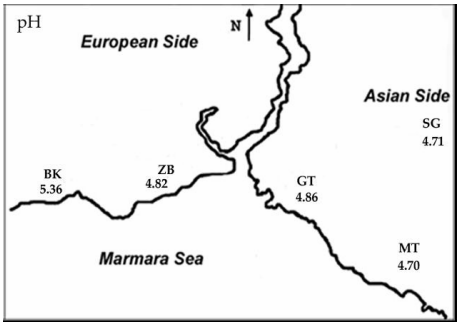


Figure 1. Spatial distribution of pH and ions over Istanbul. (SG: Sarıgazi, MT: Maltepe, GT: Göztepe, ZB: Zeytinburnu, BK: Bakırköy)

Owing to higher population density and industrial activity on the European side than on the Asian side, SO_4^{2-} concentrations were found to be higher in rain water sampled on the European side with respect to the Asian Side. The results of spatial distribution analysis of pH and the ions in wet deposition for different four regions, during the period of January 2001 - May 2001 was given in the study of [7] and the concentration distribution on both parts of Istanbul shows great resemblance to the findings of this study.

Bulk Deposition

Seasonal average concentration of ions in wet and bulk deposition were illustrated in Figure 2. Amount of ions in bulk deposition depends on the dry deposition rate and also the concentration of ions in the wet deposition. There are three main reasons to increase the dry deposition rate:

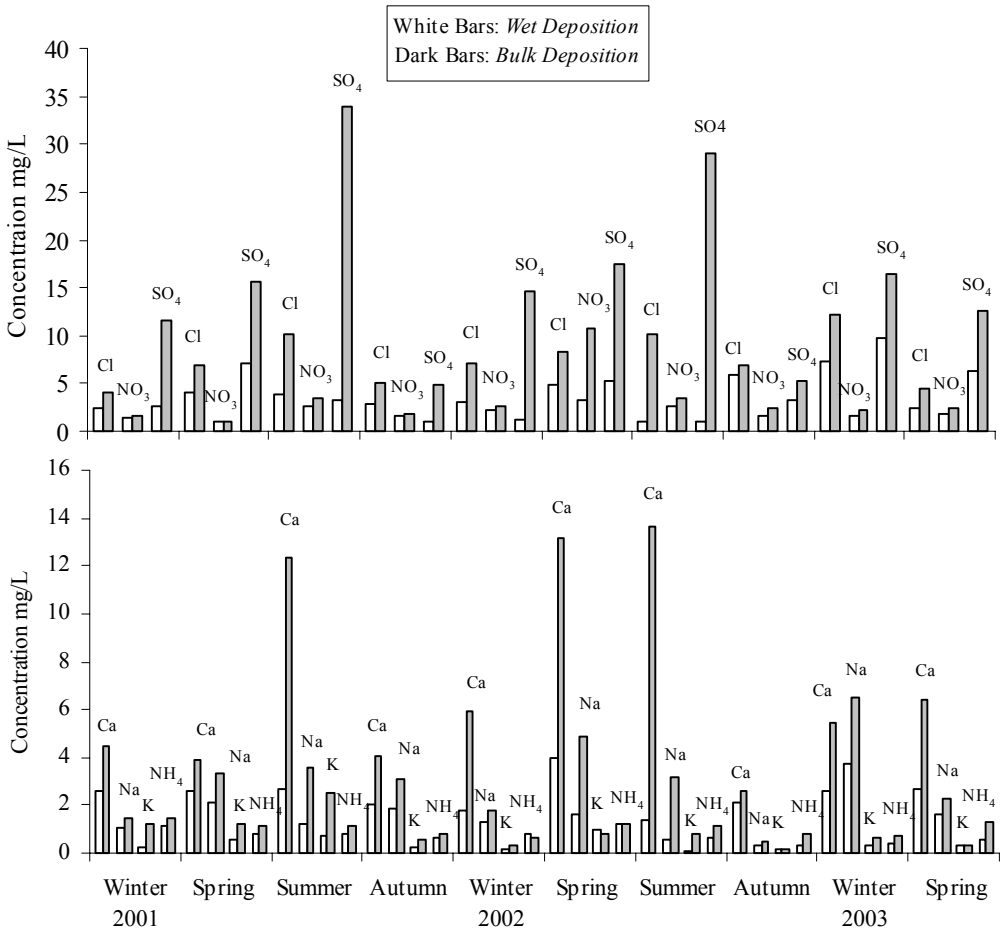


Figure 2. Seasonal average concentration values of anions and cations in wet and bulk deposition.

1) Coarse mode of particles in the atmosphere, having a main source as the wind blow dust, tend to settle down more readily than the fine particles. The main source of Ca^{2+} in Turkey is soil, thus this ion can present dominantly as large particles in the lower troposphere and can undergo dry deposition.

2) Also the amount of dry deposition of a chemical species can be related to the concentration of that chemical species in the atmosphere. Therefore, the chemical species having high concentrations in the wet deposition was also found to have high concentrations in the bulk deposition. Ca^{2+} and have higher concentration in wet deposition compared with the concentrations of the other ions. The difference between bulk and wet deposition levels, i.e., dry deposition was found to be highest for SO_4^{2-} and Ca^{2+}. Differences between bulk and wet normalized with the overall concentration (wet+bulk) were lower than 19.6% for NH_4^+, while the differences of SO_4^{2-}, Ca^{2+}, K^+, Cl^-, Na^+ NO_3^- vary between 55% and 24.2%.

3) Lowest frequency of rain events occurred in summer and many dry days in this season is expected to increase the amount of dry deposition accumulated on the funnel. Owing to this reason, the highest difference between wet and bulk deposition samples for all ions

were measured in the bulk deposition samples during the long dry summer seasons except NH_4^- in 2001 and Na^+, NO_3^- in 2002. Ca^{2+} and SO_4^{2-} were found to have the highest concentrations for the dry deposition in the summer seasons (Figure 2).

SUMMARY AND CONCLUSIONS

In this work, two and three components using principle component analysis for the two consecutive precipitation periods were found in different regions of Istanbul. NH_4^+, NO_3^- and K^+ ions have the significant factor loadings for the second component of the first period. In the second period, the loading values of $NH_4^+$and SO_4^{2-} was significantly high for the second component. This may be the reason of having significant factor loadings of NH_4^+, SO_4^{2-} and NO_3^- together in various components as $(NH_4)_2SO_4$ and NH_4NO_3 aerosols.

Spatial distribution of pH and ions revealed higher SO_4^{2-} concentrations on the European side than on the Asian Side for both of the precipitation periods. This can be bound to the fact that Istanbul has higher population density and industrial activity on the European side than on the Asian side. t statistical technique was applied to the ion concentrations obtained for the European and the Asian sides of Istanbul to find any significant differences between them. t values of Ca^{2+} and SO_4^{2-} ions were found to be higher than the other ions for the two consecutive precipitation periods.

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