Eight years studing bulk and wet deposition in the Spanish Basque Country

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Abstract

Chemical characteristics of bulk and wet deposition collected on six sites in the Basque Country (Spain) from 1986 to 1993 are discussed.

Wet deposition ($kg.ha^{-1}.y^{-1}$) is included between: Cl^- = 118.5 and 5.0, NO_3^- = 27.7 and 7.4, SO_4^{2-} = 60.6 and 14.0, NH_4^+ = 18.0 and 3.7 and Ca^{2+} = 23.3 and 5.1.

Mean rainwater pH fluctuates strongly from a site to another between 5.3 and 4.4.

Maximum Cl^-/Na^+ ratio has a value of 3 denoting the influence of a waste incinerator.

Wet deposition variation throughout precipitation process presents different trends for H^+ and for the remaining ions.

Bulk deposition is clearly dominated by SO_4^{2-} with 51.3 $kg.ha^{-1}.y^{-1}$.

1. INTRODUCTION

As a part of the EPOCA programme (Estudios en el Pirineo Occidental de la Contaminación Acida) [1-3], the results between 1986 and 1993 concerning the wet deposition of six sites in the Basque Country are presented in this paper. Moreover, scavenging process by means a sequential collector is studied in four sites. Finally, the bulk deposition of a forested area in the Basque Country is presented.

2. EXPERIMENTAL

The Basque Country is located in the north of the Iberian Peninsula, next to the Cantabric Sea, between the Western Pyrenees and the Cantabrian region. It covers an area of 7261 km^2 and is an highly industrialized region but with half of its area covered with woods (Figure 1).

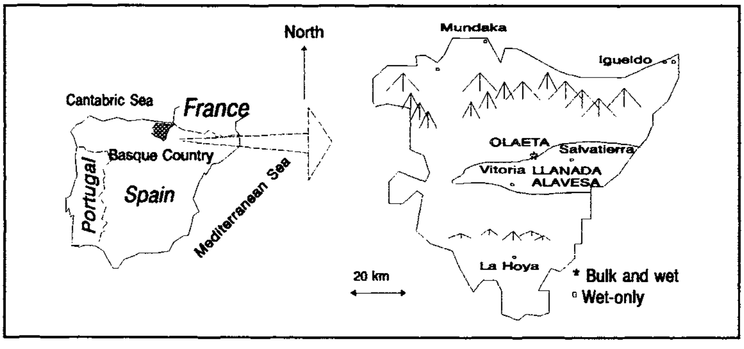

Figure 1. Map of the Basque Country showing the location of the precipitation collectors.

3. RESULTS AND DISCUSSION

3.1. Average chemical characteristics of wet deposition

Table 1 shows the spatial distribution of the ionic wet deposition on each site.

Table 1
Average wet deposition recorded in the rainwater collecting sites. Units: $kg.ha^{-1}.y^{-1}$.

Site	Cl^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}
Vitoria	11.7	7.9	15.2	5.2	3.8	0.8	6.4	1.0
Igueldo	118.5	27.7	60.6	55.0	18.0	5.8	23.1	7.6
Mundaka	103.2	16.7	38.9	57.1	7.1	6.4	11.9	8.2
Salvatierra	24.8	12.8	23.9	10.0	8.87	2.5	13.2	1.5
La Hoya	5.0	7.4	14.0	2.3	3.7	2.2	5.1	0.6
Olaeta	45.4	13.9	25.9	9.9	13.2	2.4	13.8	1.2

Molar Cl^-/Na^+ ratio varies between 1.1 and 1.5 at both coastal sites and at the southern sites. However, this ratio takes higher values at the central sites: 1.8 at Salvatierra and 3.0 at Olaeta. These results show the influence of a waste incinerator. The incinerator is located 11 km north-easterly from Olaeta, which affects the ionic composition and the pH of the precipitation at the nearest sites, especially at Olaeta.

3.2. Rain acidity

Table 2 gives the volume weighted mean concentration of H^+ for each site. The corresponding average pH is also included in it.

Table 2
Average H^+ concentration and pH in the precipitation collected at each site. Units: $\mu eq.l^{-1}$.

Site	Vitoria	Igueldo	Mundaka	Salvatierra	La Hoya	Olaeta
H^+	10.9	12.8	18.3	5.4	8.5	41.0
pH	5.0	4.9	4.7	5.3	5.1	4.4

In general, these pH values are higher than those found in different areas of central Europe [4,5] which have similar concentrations of acid anions, SO_4^{2-} and NO_3^-. This is due to the importance of the CO_3Ca, which acts as a neutralizing element at the study area [3].

The precipitation of Olaeta has very acid characteristics which are typical of very industrialized areas. This can be explained by the influence of the mentioned waste incinerator.

3.3. Variation of wet deposition with meteorological class

Four types of back-trajectories have been distinguished, as shown in Figure 2: - Local trajectories: They do not exceed 200 km.- Iberian trajectories: They come from the Peninsula inland. - Marine trajectories: They come from the Cantabric Sea. - Continental trajectories: They come from the Europe.

Figure 3 shows the mean wet deposition of the different species at each site, according to back-trajectories.

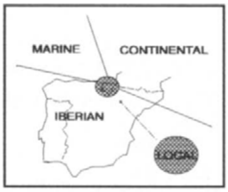

Figure 2. Examples of the four sectors types.

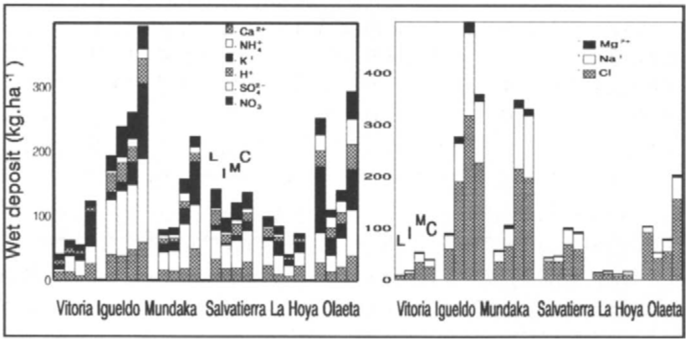

Figure 3. Average wet deposition collected at each site for the different trajectories types.

Anthropogenic ions, NO_3^-, SO_4^{2-} and NH_4^+ show maximum deposition values in Local and/or Continental trajectories depending on the site. This is probably due to the accumulation of contaminants in the case of Local trajectories and to a long-range transport phenomenon in the case of Continental ones.

H^+ shows maximum deposition values in Continental trajectories at all study sites. It also shows an high deposition value in Local trajectories at Olaeta. This can be easily explainable if we take into account that the acid anion (NO_3^- and SO_4^{2-} at all sites and Cl^- at Olaeta) have the maximum deposition level in this trajectories type.

Ca^{2+} has higher wet deposition levels in Local and/or Iberian trajectories, to which would indicate the peninsular origin of this species. This would also be the reason for the lower acidity levels of these trajectories type.

3.4. Scavenging process: Evolution of wet deposition during a continuous precipitation event

Table 3 gives the wet deposition percentage of each ion in each precipitation fraction.

All ionic species experience an important washing process, as is proved in the reduction of wet deposition percentage along the precipitation event. This process is more important at Igueldo and Olaeta.

The anthropogenic-crustal ions experience a greater washing process than the marine ones.

The wet H^+ deposition percentage increases along the rainy event at Vitoria and Salvatierra. This is probably due to the decrease of Ca^{2+} and consecuently the neutralizing power of precipitation. However, H^+ behaviour at Igueldo and Olaeta is similar to the remaining ions, probably due to these sites having a continuous source near sampling points.

Table 3
Wet deposition percentage in the 12 first mm of precipitation. Units: %kg.ha^{-1}.

	Cl^-	NO_3^-	SO_4^{2-}	H^+	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}
Vitoria 2	23.9	27.8	27.9	9.6	27.2	31.3	24.7	34.1	28.1
4	15.8	22.7	21.2	16.0	18.2	22.3	20.5	17.7	19.2
6	15.8	13.2	13.3	15.9	11.4	11.8	12.0	13.0	14.7
8	15.5	13.8	13.3	17.3	12.9	13.6	16.9	11.9	13.5
10	14.7	13.7	13.0	21.4	15.9	14.1	13.1	11.9	12.6
12	9.9	8.9	10.2	20.6	7.3	7.8	11.2	9.9	9.6
Igueldo 2	28.4	37.2	32.4	23.2	28.6	39.3	30.8	29.6	26.0
4	12.5	13.7	14.0	14.5	12.5	11.4	9.5	15.1	13.2
6	11.3	10.5	12.5	14.3	12.4	9.6	13.7	11.7	12.1
8	15.8	12.5	14.4	15.9	15.8	12.3	14.4	13.4	16.5
10	9.5	8.3	9.6	10.7	8.5	9.2	8.0	9.8	9.7
12	8.2	9.0	7.0	9.1	8.6	8.2	10.2	9.3	8.9
Salvatierra 2	24.1	23.1	23.5	7.9	15.8	29.8	17.1	26.9	32.8
4	16.1	15.1	14.3	11.8	14.4	16.0	15.8	16.7	14.0
6	12.0	12.4	13.2	11.1	12.3	12.1	13.6	12.3	12.2
8	11.3	12.4	11.0	13.9	13.5	9.7	13.2	11.1	8.0
10	12.3	12.6	12.4	15.3	13.4	12.5	13.6	11.4	11.3
12	12.0	13.6	14.0	21.8	13.6	12.2	13.8	11.7	8.4
Olaeta 4	42.4	36.6	31.6	31.0	34.1	37.3	36.4	42.1	37.3
6	13.8	19.7	20.2	14.1	18.8	17.4	18.9	17.0	18.5
8	14.6	14.5	15.9	17.7	14.1	16.0	18.5	15.3	13.0
10	16.5	15.5	16.8	16.1	18.5	15.7	15.4	14.1	17.3
12	11.3	12.6	14.2	19.9	12.6	12.0	10.2	10.4	13.8

3.5. Bulk deposition

Bulk deposition has been collected at one-monthly intervals at Olaeta, between Jun 88 and May 91. Average chemical characteristics of the 36 samples can be seen in Table 4. Dry deposition, calculated as the difference between bulk and wet deposition, are also shown in Table 4.

Table 4
Average characteristics of bulk and dry deposition collected at Olaeta. Units: kg.ha^{-1}.y^{-1}.

Ion	Cl^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}
Bulk	31.4	24.6	51.3	21.7	34.7	11.1	36.3	2.9
Dry	negative	10.9	25.2	11.0	21.6	8.4	22.5	1.6

Cl^- undergoes reactions in bulk deposition and later evaporations, probably in the form of HCl or NH_4Cl, or both at the same time.

4. REFERENCES

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