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Oskarshamn site investigation

Precipitation at Simpevarp 2006

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October 2008

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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Abstract

Sampling and analysis of precipitation was performed throughout 2006 at an open field site at Äspö. The purpose of this activity was to measure chemical compounds in the precipitation within the site investigation area at Oskarshamn.

The precipitation was collected in samplers placed two to ten meters apart in an area with a diameter of approximately 25 meter. The samplers were emptied weekly and the water volume was measured. Water from six of the weekly periods was sent for full analysis (anions and main components, alkalinity, pH, conductivity and isotopes) to different laboratories. Water from the rest of the periods were analysed for anions, alkalinity, pH and conductivity if precipitation had occurred.

The concentrations of different ions varied between the different measuring periods. Calculations of ion balances showed rather great imbalances in many of the samples (more than 10% relative error). This imbalance was so large that there might be an error either in the analysis or in the handling of the samples. Another explanation might be that the concentration of many of the ions was close to or below the detection limits.

The weighted average concentration of some of the ions and of pH was compared with results from two national monitoring stations for depositions in south east Sweden. The comparison shows that the concentration of ions was generally higher at Äspö. The average of pH was similar though. The main reason for higher concentration of ions is probably that the Äspö station is situated very close to the sea with a greater influx of sea salt. A corrected average of SO₄-S (which excludes the part of sulphur that originates from sea salt) at Äspö was more similar to the other stations in south east Sweden.

The hydrogen isotope ratio of $\delta^2\text{H}$ (deuterium) varied with a small tendency of lowest ratio in winter. As expected these ratios correlated well with the ratios of $\delta^{18}\text{O}$ (oxygen-18) and the linear relation corresponds well with the "Global Meteoric Water Line". The ratios of ^3H (tritium) varied with a small tendency for lower values in the late autumn and early winter period.

Four types of nonconformities have occurred. The first is that notes were not taken on when the samplers was changed from buckets to cans in spring. The second type of nonconformity was that the number of samplers was lower than stipulated in AP PS 400-06-034. The third type was that analysis of HCO₃ was not performed on every occasion, due to low pH values. The last type was that the general sample from the period 2006-01-01 to 2006-06-30 was lost and therefore analyses were not performed.

Sammanfattning

Provtagning och analys av regnvatten från Äspö har utförts under 2006. Syftet med undersökningarna var att mäta regnvattnets kemiska sammansättning inom området för platsundersökningen i Oskarshamn.

Regnvatten samlades in i behållare som slumpmässigt placerats inom ett område med en diameter på ca 25 m. Behållarna tömdes och volymen mättes regelbundet varje vecka. Vatten från sex av veckoperioderna analyserades på samtliga parametrar (anjoner och huvudkomponenter, alkalinitet, pH, konduktivitet samt isotoper). Vatten från övriga veckor analyserades endast på anjoner, alkalinitet, pH och konduktivitet om det fanns vatten tillräckligt för analys.

Koncentrationen av olika joner varierade mycket mellan olika provtagningsperioder. Beräkningar av jonbalanserna visade på relativt stora avvikelser (mer än 10 % relativt fel) i många av proverna. Skillnaderna var så stora att ett fel kan föreligga, antingen vid analyserna eller vid hanteringen av proverna. En annan förklaring kan vara att koncentrationen av många av jonerna var under eller nära detektionsgränsen.

Viktade medelvärden av några av de undersökta jonerna samt av pH jämfördes med resultat från stationer i sydöstra Sverige som ingår i det nationella nederbördskemiska nätet. Jämförelsen visar att halten av joner generellt var högre vid Äspö. Medelvärdet av pH var dock relativt lika. Den huvudsakliga orsaken till skillnaden i jonkoncentration är sannolikt närheten till havet. Ett beräknat korrigerat värde för $\text{SO}_4\text{-S}$ (som utesluter svavel som härrör från havet) var också mer likt resultaten från de andra stationerna i sydöstra Sverige.

Väteisotopen $\delta^2\text{H}$ (deuterium) varierade mellan provtagningsstillfällena med den lägsta kvoten under vintern. Som förväntat var kvoterna av $\delta^2\text{H}$ väl korrelerade med kvoterna av $\delta^{18}\text{O}$ (syre-18). Även kvoterna av ^3H (tritium) varierade mellan provtillfällena med en svag tendens till lägre värden under senhösten och den tidiga vintern.

Fyra typer av avvikelser från vad som planerats har förekommit under året. Den första är att anteckningar inte gjordes om när regnvattensbehållarna byttes från hinkar till dunkar under våren. Den andra avvikelser är att antalet regnvattensbehållare var färre än vad som bestämts i AP PS 400-06-034. Den tredje avvikelser var att HCO_3 inte analyserades vid flera tillfällen på grund av ett för lågt pH. Den fjärde avvikelser var att samlingsprovet från perioden 2006-01-01 till 2006-06-30 kom bort och att det därför inte utfördes några analyser.

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1 Introduction

This document reports the results gained by the sampling and analysis of precipitation during 2006, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-06-034. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The aim of the activity was to measure chemical substances in the precipitation (rain and snow). These data will be a part of the data needed to describe the circulation of water and water transported substances in the investigation area. The sampling was performed from January to December of 2006 at the site PSM002170 at Äspö (Figure 1-1). All data generated was stored in the database Sicada. The data is traceable by the activity plan number.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Nederbördsprovtagning och analyser 2006 (monitering)	AP PS 400-06-034	1.0
Method descriptions	Number	Version
Metodbeskrivning för provtagning och analys av nederbörd	SKB MD 423.003	2.0

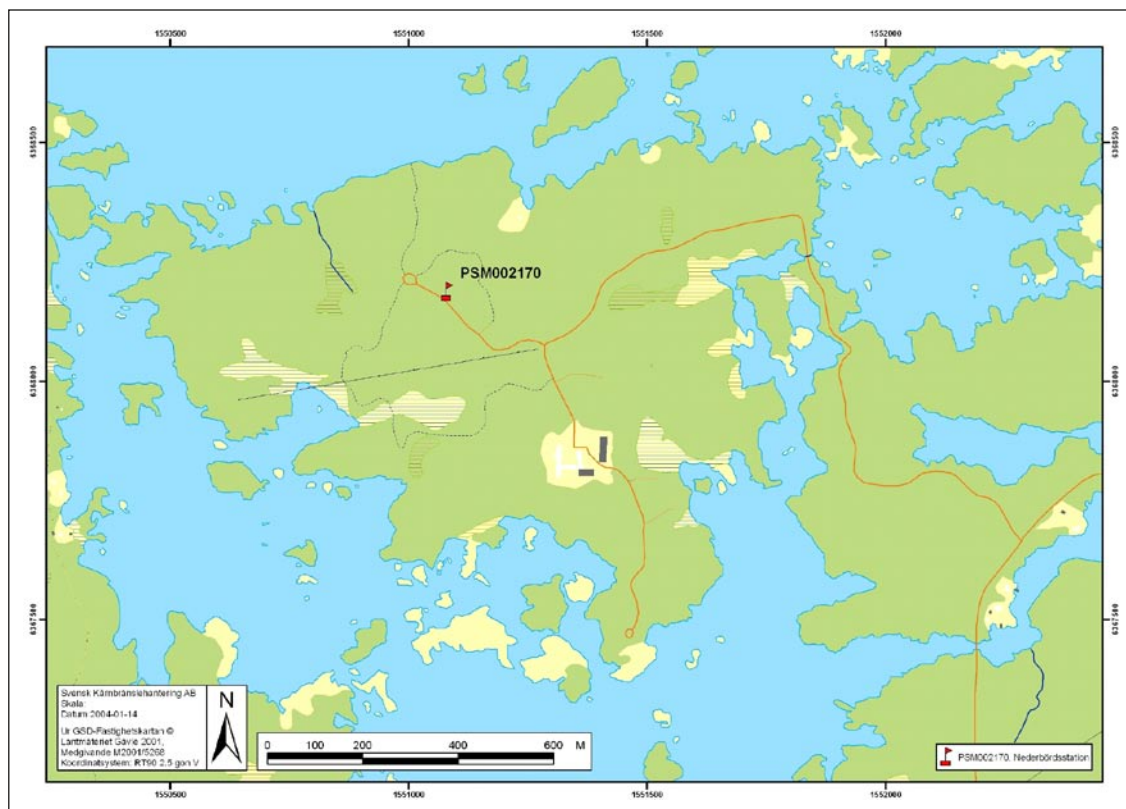


Figure 1-1. Site for sampling of precipitation (PSM002170) at the island of Äspö. Coordinates for the site is N 6368188.887; E 1551081.634 (RT90/RHB70). The elevation is 6.165 m.

2 Objective and scope

The purpose of this activity was to measure the bulk deposition, i.e. chemical compounds in the precipitation, within the site investigation area. The method used was designed to measure precipitation in an open field and in undisturbed conditions. Samples for analysis were to be taken once every week provided enough water was present. After the sampling of water the samplers was completely emptied.

The measurements and analysis performed aimed to give results of high quality from an undisturbed site. To ensure high quality the samples were transported by post to the external laboratories as fast as possible. The samples for the laboratory at Äspö were delivered immediately. According to the method description (SKB MD 423.003, internal document) the relative error in the ion balance should be less than 10%.

The parameters measured in the samples are presented in Table 4-1.

3 Equipment

Ten to twelve samplers were placed in an open field site approximately half a meter above the ground (Figure 3-1). Exact locations with coordinates are given in Table 3-1. The samplers were placed two to ten meters apart in an area with a diameter of approximately 25 meter. The total volume caught in the samplers in each sampling period was treated as one sample to ensure that enough water was caught for all analysis planned. The number of functional samplers at the site varied during the year (se Table 5-1).

In the summer season the samplers were cans with funnels with a diameter of 15.5 cm. In winter buckets with a diameter of 21 cm were used. The cans and the buckets could hold a maximum volume of five litres. Plastic bags made of polyethene were used inside the cans or buckets to prevent contamination. A new plastic bag was used for every measuring period. When emptying the samplers a graduated glass was used to measure the volumes in the samplers. One or two five litres plastic container was then used to transport the sample to the laboratory where the sample was divided into smaller bottles before they were delivered to the different analysing laboratories. When the sample was divided into smaller bottles the water for some analysis were filtrated with a membrane filter.



Figure 3 1. The samplers used in summer at the site for sampling of precipitation at the island of Äspö.

Table 3-1. Locations with coordinates for the individual samplers (RT90/RHB70).

ID-code	Northing (m)	Easting (m)
PSM002164	6368190.379	1551095.219
PSM002165	6368190.772	1551092.651
PSM002166	6368191.406	1551089.403
PSM002167	6368189.112	1551087.298
PSM002168	6368186.288	1551085.978
PSM002169	6368186.333	1551083.621
PSM002170	6368188.887	1551081.634
PSM002171	6368191.387	1551082.044
PSM002172	6368192.608	1551081.786
PSM002173	6368194.691	1551080.047
PSM002174	6368197.498	1551078.972
PSM002175	6368198.224	1551081.681
PSM002176	6368198.204	1551086.452
PSM002177	Not measured	Not measured

4 Execution

4.1 General

The precipitation was collected in samplers placed two to ten meters apart in an area with a diameter of approximately 25 meter. The samplers were emptied weekly and the water volume was measured. Water from six of the weekly periods was sent for full analysis (anions and main components, alkalinity, pH, conductivity and isotopes) to different laboratories. Water from the rest of the periods were analysed for anions, alkalinity, pH and conductivity if precipitation had occurred. The work was performed in accordance to the method description “Metodbeskrivning för provtagning och analys av nederbörd, SKB MD 423 003”.

4.2 Preparations

To prevent contamination and avoid extensive algal growth plastic bags made of polyethene were used inside the samplers. New plastic bags were used for each measuring period.

4.3 Execution of field work

The precipitation was collected in samplers placed in an open field at Äspö (Figure 1-1, 3-1). The samplers were emptied regularly each week and if the precipitation had been large enough water was stored and later sent for analysis at different laboratories (Table 4-1). The total volume gathered from the samplers was measured with a graduated glass. If the samplers contained snow or ice the volume was measured on a scale.

Approximately 20% of the sample from each week was assembled to a so called “general sample”. The general sample was stored in a refrigerator and samples from each week were added for six months before the sample was sent for analysis.

In each week the rest of the sample was saved as a so called “point sample”. If the volume of the “point sample” was larger than one litre, but smaller than 2.7 litres the sample was marked with a SKB number. Half of the sample was delivered to the Äspö laboratory for “quick analysis” (conductivity, pH, Cl, SO₄, Br, and F). The rest of the sample was stored in a refrigerator marked with date, week and volume until a decision was taken on which analysis to perform or if analysis should be performed at all.

If the “point sample” was larger than 2.7 litres then 500 ml of the sample was marked with an SKB-number and delivered to the Äspö laboratory for “quick analysis”. The rest of the sample was marked with the same SKB-number and stored in a refrigerator until a decision was taken on which analysis to perform or if analysis should be performed at all.

If the volume of the “point sample” was smaller than one litre the sample was stored in the same manner as other “point samples” but no sample was delivered to the Äspö laboratory for “quick analysis”.

When decisions were taken on which “point samples” to analyse the bottles were marked with SKB-numbers and sent to the laboratories for analysis of main components, $\delta^2\text{H}$, ^3H and $\delta^{18}\text{O}$. During the year six “point samples”, denominated as complete samples, were analysed. All of these contained more than 2.7 litres. Analysis was also performed on one of the two general samples. This sample was only to be analysed for $\delta^2\text{H}$, ^3H and $\delta^{18}\text{O}$ but main components was also analysed. Volumes from different weeks in the general sample are presented in Table 4-2.

Notes on the handling of the samples were kept in a diary.

See Tables 4-1 and 4-2 for the different kind of samples and SKB-numbers.

Table 4-1. Explanations of the different kind of samples and SKB-numbers. (The complete samples and the general sample are highlighted).

Sample period	Sample number	Type of sample and analyses
2005-12-21–2006-01-02	10704	Anions, pH, conductivity and HCO ₃ ⁻
2006-01-18–2006-01-25	10790	Anions, pH, conductivity and HCO ₃ ⁻
2006-02-01–2006-02-08	10804	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2006-02-08–2006-02-16	10816	Anions, pH, conductivity and HCO ₃ ⁻
2006-02-26–2006-02-23	10849	Anions, pH, conductivity and HCO ₃ ⁻
2006-02-23–2006-03-02	10858	Anions, pH, conductivity and HCO ₃ ⁻
2006-03-02–2006-03-08	10869	Anions, pH, conductivity and HCO ₃ ⁻
2006-03-08–2006-03-16	10902	Anions, pH, conductivity and HCO ₃ ⁻
2006-03-23–2006-03-29	10945	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2006-03-29–2006-04-06	10965	Anions, pH, conductivity and HCO ₃ ⁻
2006-04-12–2006-04-19	10984	Anions, pH, conductivity and HCO ₃ ⁻
2006-04-19–2006-04-27	10999	Anions, pH, conductivity and HCO ₃ ⁻
2006-04-27–2006-05-03	11029	Anions, pH, conductivity and HCO ₃ ⁻
2006-05-16–2006-05-22	11073	Anions, pH, conductivity and HCO ₃ ⁻
2006-05-22–2006-05-31	11113	Anions, pH, conductivity and HCO ₃ ⁻
2006-06-14–2006-06-22	11184	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2006-07-11–2006-07-18	11225	Anions, pH, conductivity and HCO ₃ ⁻
2006-01-01–2006-06-30	11258	General sample (sample and results missing)
2006-08-10–2006-08-17	11276	Anions, pH, conductivity and HCO ₃ ⁻
2006-08-17–2006-08-24	11293	Anions, pH, conductivity and HCO ₃ ⁻
2006-08-24–2006-08-30	11299	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2006-08-30–2006-09-06	11309	Anions, pH, conductivity and HCO ₃ ⁻
2006-09-27–2006-10-04	11375	Anions, pH, conductivity and HCO ₃ ⁻
2006-10-19–2006-10-25	11481	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2006-10-25–2006-11-01	11492	Anions, pH, conductivity and HCO ₃ ⁻
2006-11-01–2006-11-09	11507	Anions, pH, conductivity and HCO ₃ ⁻
2006-11-09–2006-11-16	11528	Anions, pH, conductivity and HCO ₃ ⁻
2006-11-16–2006-11-22	11553	Anions, pH, conductivity and HCO ₃ ⁻
2006-11-22–2006-11-29	11562	Anions, pH, conductivity and HCO ₃ ⁻
2006-12-14–2006-12-20	11599	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2006-07-01–2006-12-31	11803	General sample. Only main components, δ²H, ³H and δ¹⁸O

Table 4-2. Volumes from different sampling weeks in the general sample (July–December 2006).

Sample date	Sample number	Volume (ml)	Volume (%)	Comments
2006-07-18	11225	254	2.0	
2006-07-27	–	202	1.6	no point sample for analysis
2006-08-02	–	196	1.5	no point sample for analysis
2006-08-10	–	158	1.2	no point sample for analysis
2006-08-17	11276	487	3.8	
2006-08-24	11293	882	6.9	
2006-08-30	11299	1,310	10.2	
2006-09-06	11309	266	2.1	
2006-09-14	–	128	1.0	no point sample for analysis
2006-10-04	11375	437	3.4	
2006-10-12	–	208	1.6	no point sample for analysis
2006-10-25	11481	1,061	8.3	
2006-11-01	11492	1,740	13.6	
2006-11-09	11507	1,973	15.4	
2006-11-16	11528	1,176	9.2	
2006-11-22	11553	790	6.2	
2006-11-29	11562	697	5.5	
2006-12-14	–	247	1.9	no point sample for analysis
2006-12-20	11599	574	4.5	

The analysis performed follow chemistry class 3 (MD 450.001 SKB internal controlling document). The method used is described in detail in MD 423.003, SKB internal document.

The handling of the samples prior to analysis with type of bottles, filtration, acidification, filling instructions and the laboratories used are shown in Table 4-3. In addition two archive samples of 250 ml was taken out and stored by SKB. The 250 ml archive samples where filtrated in a Pall filter (0.45 µm) prior to storage.

Three different ways of delivery to the laboratories were used. The samples for Äspö laboratory were delivered directly. To Analytica, IFE in Norway and EIL in Canada the samples were sent by postal service.

Table 4-3. Analysed components, treatments of samples and analysing laboratory.

Components	Bottle/volume	Preparation of sample	Laboratory
pH, Conductivity, HCO ₃	250 ml	–	Äspö laboratory
Cl, Br, SO ₄ , F	250 ml	Filtration-Pallfilter (in connection with analysis)	Äspö laboratory
Density	250 ml	–	Äspö laboratory
Ca, Fe, K, Mg, Na, S, Si, Li, Mn, Sr	100 ml, acid rinsed	Filtration membrane filter/ acidification 1% HNO ₃	Analytica
³ H	500 ml	Dried bottle, flow over at least once	Environmental Isotope Lab at the University of Waterloo, Canada
² H, ¹⁸ O	100 ml		Institutute for Energy Technology, Norway

4.4 Data handling and calculations

After analysis data has continuously been reported from the laboratories. As a routine a first preliminary control of the data quality was performed before storing them in the database Sicada. Data for this evaluation was delivered from Sicada 2008-04-25.

The precipitation (P) during the sampling periods was calculated from the collected average volume (V) and the area of the samplers (A). $P \text{ (mm)} = 10 \cdot V \text{ (ml)} / A \text{ (cm}^2\text{)}$.

The concentration of SO₄-S in the precipitation was calculated as the atomic proportion of SO₄ ($[\text{SO}_4\text{-S}] = [\text{SO}_4] / 96 \cdot 32$).

A part of the SO₄-S originates from sea salt which makes it difficult to compare the concentrations of SO₄-S from different sites at different distances from the sea. A corrected value which excludes the part that originate from sea salt was calculated from the concentration of Na ($[\text{SO}_4\text{-Scorr}] = [\text{SO}_4\text{-S}] - 0.0837 \cdot [\text{Na}]$) (concentrations in mg/l).

To compare with results from other sites in south east Sweden weighted averages were calculated on some of the ions and pH. The weighted averages were calculated as $X_m = \sum(c_i \cdot m_i) / \sum(m_i)$ where c_i is the concentration during a period and m_i is the precipitation during the same period.

4.5 Nonconformities

Notes were not taken on when the samplers was changed from buckets to cans in spring. It is therefore uncertain which week the change was made. From the diary it can be concluded that the switch was made during the period of 2006-04-12 to 2006-04-27. In the calculations of the precipitation from this period (see Table 5-1) it was assumed that the switch was made 2006-04-27.

According to AP PS 400-06-034 the number of samplers used in the investigation area should be fourteen. In fact the number of samplers varied, from ten to twelve during the year (Table 5-1).

The third type of nonconformity was that analysis of HCO₃ was not performed on every occasion, due to very low pH.

The general sample from the period 2006-01-01 to 2006-06-30 was lost and analyses therefore were not performed.

5 Results

All data gained were stored in the primary data base Sicada. The data is traceable in Sicada and GIS by the Activity Plan number (AP PS 400-05-027). Only data in databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major revisions entail a revision of the P-report. Minor revisions are normally presented as supplements, available at www.skb.se.

Precipitation was measured in 50 sampling periods during 2006. The average volume collected per sampler during this period was 248.5 ml (Table 5-1). The mean calculated precipitation per sampling period was 9.4 mm. The total measured precipitation of the year was 442.6 mm. This is probably an underestimation of the true total precipitation due to evaporation from the samplers.

The complete results from the analysis are presented in the Appendix at the end of this report. The results from the six occasions when full analysis were performed are also presented in Tables 5-2, 5-4, 5-5 and 5-7. The concentrations of different ions varied much between the different measuring periods (Table 5-2 and Appendix). On most occasions the concentrations of main components exceeded the concentrations of the anions. This imbalance was large in most of the samples and there might be an error either in the analysis or in the handling of the samples. To test the quality of the samples the relative error in the ion balance was calculated for this report (Table 5-3). These calculations show rather great imbalances (more than 10% relative error) in five of the six samples. The reason for this is difficult to interpret. It cannot be explained by the lack of analysis of two major ions, NO_3 and NH_4 . In a nearby station for measurement of precipitation (Norra Kvill in the municipality of Vimmerby) the average concentrations of $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ was 0.36 mg/l and 0.35 mg/l in 2006 (www.ivl.se). If the relation between NO_3 and NH_4 is similar at the Äspö site the imbalance would be similar. There might be another explanation though, the concentration of many of the ions was close to or below the detection limits which could have caused calculation errors. In one of the samples (sample number 11599) there was an unusually large error in the ion balance (Table 5-2). The error is caused mainly by unusually high values on Na and Mg. These values are not likely to be correct since the conductivity of the sample were low to normal (Table 5-5).

Water from the general sample was also sent for analysis of main components and sulphur. Although these samples were not acidified during storage the results were similar to the results in the point samples (Table 5-4 and Appendix).

Also pH and conductivity varied between the different measuring periods (Table 5-5 and Appendix). Some periods differ with higher conductivity, probably due to influx of sea water spray (Table 5-5 and Appendix).

Table 5-1. Sampling periods and measured volumes of water in the samplers and calculated precipitation during the periods when measurements were performed.

Sample period	Number of samplers in order	Total volume (ml)	Average volume per sampler (ml)	Sampler diameter (cm)	Sampler area (cm ²)	Precipitation (mm)
2005-12-21–2006-01-02	11	12,340	1,121.8	21	346.4	32.4
2006-01-02–2006-01-11	11	0	0	21	346.4	0.0
2006-01-11–2006-01-18	11	0	0	21	346.4	0.0
2006-01-18–2006-01-25	11	2,530	230.0	21	346.4	6.6
2006-01-25–2006-02-01	11	0	0	21	346.4	0.0
2006-02-01–2006-02-08	11	8,140	740.0	21	346.4	21.4
2006-02-08–2006-02-16	11	2,750	250.0	21	346.4	7.2
2006-02-26–2006-02-23	11	5,150	468.2	21	346.4	13.5
2006-02-23–2006-03-02	11	1,345	122.3	21	346.4	3.5
2006-03-02–2006-03-08	11	1,750	159.1	21	346.4	4.6
2006-03-08–2006-03-16	11	5,750	522.7	21	346.4	15.1
2006-03-16–2006-03-23	11	1,150	104.5	21	346.4	3.0
2006-03-23–2006-03-29	11	5,500	500.0	21	346.4	14.4
2006-03-29–2006-04-06	11	8,800	800.0	21	346.4	23.1
2006-04-06–2006-04-12	11	0	0	21	346.4	0.0
2006-04-12–2006-04-19	11	3,600	327.3	21	346.4	9.4
2006-04-19–2006-04-27	11	4,000	363.6	21	346.4	10.5
2006-04-27–2006-05-03	12	2,500	208.3	15.5	188.7	11.0
2006-05-03–2006-05-16	12	0	0	15.5	188.7	0.0
2006-05-16–2006-05-22	12	4,855	404.6	15.5	188.7	21.4
2006-05-22–2006-05-31	12	3,815	317.9	15.5	188.7	16.8
2006-05-31–2006-06-08	12	0	0	15.5	188.7	0.0
2006-06-08–2006-06-14	12	0	0	15.5	188.7	0.0
2006-06-14–2006-06-22	12	3,005	250.4	15.5	188.7	13.3
2006-06-22–2006-06-30	12	0	0	15.5	188.7	0.0
2006-06-30–2006-07-06	12	0	0	15.5	188.7	0.0
2006-07-06–2006-07-11	12	0	0	15.5	188.7	0.0
2006-07-11–2006-07-18	12	1,270	105.8	15.5	188.7	5.6
2006-07-18–2006-07-27	12	1,010	84.2	15.5	188.7	4.5
2006-07-27–2006-08-02	12	980	81.7	15.5	188.7	4.3
2006-08-02–2006-08-10	12	790	65.8	15.5	188.7	3.5
2006-08-10–2006-08-17	12	2,435	202.9	15.5	188.7	10.8
2006-08-17–2006-08-24	12	4,410	367.5	15.5	188.7	19.5
2006-08-24–2006-08-30	12	6,550	545.8	15.5	188.7	28.9
2006-08-30–2006-09-06	12	1,330	110.8	15.5	188.7	5.9
2006-09-06–2006-09-14	12	640	53.3	15.5	188.7	2.8
2006-09-14–2006-09-20	11	0	0	15.5	188.7	0.0
2006-09-20–2006-09-27	11	0	0	15.5	188.7	0.0
2006-09-27–2006-10-04	11	2,185	198.6	15.5	188.7	10.5
2006-10-04–2006-10-12	11	1,040	94.5	15.5	188.7	5.0
2006-10-12–2006-10-19	11	0	0	15.5	188.7	0.0
2006-10-19–2006-10-25	11	5,305	482.3	15.5	188.7	25.6
2006-10-25–2006-11-01	11	8,700	790.9	15.5	188.7	41.9
2006-11-01–2006-11-09	10	9,865	986.5	21	346.4	28.5
2006-11-09–2006-11-16	10	5,880	588.0	21	346.4	17.0
2006-11-16–2006-11-22	10	3,950	395.0	21	346.4	11.4
2006-11-22–2006-11-29	10	3,485	348.5	21	346.4	10.1
2006-11-29–2006-12-06	10	0	0	21	346.4	0.0
2006-12-06–2006-12-14	10	1,235	123.5	21	346.4	3.6
2006-12-14–2006-12-20	10	2,870	287.0	21	346.4	8.3
Average			248.5			9.4
Standard deviation			252.1			9.6

Table 5-2. Measured concentrations of ions and some other components during the measuring periods when full analyses were performed. (There is one measured and one calculated SO₄-S value for the samples, the calculated SO₄-S was calculated from SO₄, see chapter 4.4.)

Sample period	Sample number	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)	Mn (mg/l)	Li (mg/l)	Si (mg/l)	Sr (mg/l)
2006-02-01–2006-02-08	10804	0.3	<0.4	<0.1	<0.1	<0.02	<0.003	<0.004	<0.03	<0.002
2006-03-23–2006-03-29	10945	0.5	<0.4	0.2	<0.1	0.0203	0.00466	<0.004	<0.03	<0.002
2006-06-14–2006-06-22	11184	0.4	3.17	0.7	0.3	0.0766	0.13900	<0.004	0.13	0.004
2006-08-24–2006-08-30	11299	0.6	<0.4	0.4	<0.1	0.0318	0.00785	<0.004	0.09	0.004
2006-10-19–2006-10-25	11481	0.6	0.88	0.5	0.2	0.1000	0.02380	<0.004	0.14	0.004
2006-12-14–2006-12-20	11599	11.7	0.91	0.4	1.8	<0.02	<0.003	<0.004	0.11	0.012

Sample period	Sample number	SO ₄ -S meas. (mg/l)	Cl (mg/l)	SO ₄ (mg/l)	SO ₄ -S calc. (mg/l)	SO ₄ -S _{korrr} calc. (mg/l)	Br (mg/l)	F (mg/l)	HCO ₃ (mg/l)
2006-02-01–2006-02-08	10804	0.32	0.4	1.02	0.340	0.315	<0.2	<0.2	
2006-03-23–2006-03-29	10945	0.42	0.6	1.22	0.407	0.365	<0.2	<0.2	
2006-06-14–2006-06-22	11184	0.81	1.2	1.84	0.613	0.580	<0.2	<0.2	3.80
2006-08-24–2006-08-30	11299	0.21	0.6	0.66	0.220	0.170	<0.2	<0.2	
2006-10-19–2006-10-25	11481	0.66	0.7	1.88	0.627	0.576	<0.2	<0.2	
2006-12-14–2006-12-20	11599	0.17	0.6	<0.2	<0.067	<0.067	<0.2	<0.2	

Table 5-3. Calculated relative errors of the ion balance in the samples from the different measuring periods.

Sample period	Sample number	Ion balance relative error (%)
2006-02-01–2006-02-08	10804	12.76
2006-03-23–2006-03-29	10945	15.63
2006-06-14–2006-06-22	11184	3.67
2006-08-24–2006-08-30	11299	27.48
2006-10-19–2006-10-25	11481	22.39
2006-12-14–2006-12-20	11599	90.73

Table 5-4. Measured concentrations of positive ions and some other components in the general sample from July to December 2006.

Sample period	Sample number	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)
2006-07-01–2006-12-31	11803	0.6	0.58	0.4	0.1	0.02

Sample period	Sample number	Mn (mg/l)	Li (mg/l)	Si (mg/l)	Sr (mg/l)	SO ₄ -S meas. (mg/l)
2006-07-01–2006-12-31	11803	0.0157	0.004	0.03	0.002	0.30

Table 5-5. Measured values of pH. Conductivity and density during periods when analysis were performed.

Sample period	Sample number	pH	Conductivity (mS/m)
2005-12-21–2006-01-02	10704	4.40	2.9
2006-01-18–2006-01-25	10790	4.31	4.1
2006-02-01–2006-02-08	10804	4.65	1.7
2006-02-08–2006-02-16	10816	4.01	5.7
2006-02-26–2006-02-23	10849	3.96	5.8
2006-02-23–2006-03-02	10858	4.08	6.0
2006-03-02–2006-03-08	10869	4.16	3.6
2006-03-08–2006-03-16	10902	3.82	4.6
2006-03-23–2006-03-29	10945	4.59	2.4
2006-03-29–2006-04-06	10965	4.58	1.7
2006-04-12–2006-04-19	10984	4.98	1.6
2006-04-19–2006-04-27	10999	4.95	4.9
2006-04-27–2006-05-03	11029	4.92	4.0
2006-05-16–2006-05-22	11073	4.96	2.4
2006-05-22–2006-05-31	11113	5.76	1.9
2006-06-14–2006-06-22	11184	6.19	3.5
2006-07-11–2006-07-18	11225	5.20	4.7
2006-08-10–2006-08-17	11276	5.40	2.7
2006-08-17–2006-08-24	11293	4.73	1.5
2006-08-24–2006-08-30	11299	4.91	1.1
2006-08-30–2006-09-06	11309	4.69	2.4
2006-09-27–2006-10-04	11375	5.04	3.1
2006-10-19–2006-10-25	11481	4.63	2.6
2006-10-25–2006-11-01	11492	5.10	1.3
2006-11-01–2006-11-09	11507	5.03	1.1
2006-11-09–2006-11-16	11528	4.76	2.0
2006-11-16–2006-11-22	11553	4.58	1.9
2006-11-22–2006-11-29	11562	4.53	2.6
2006-12-14–2006-12-20	11599	5.73	1.1
Average		4.78	2.9
Standard deviation		0.55	1.5

To compare some of the results with those from national stations for monitoring deposition in south east Sweden, weighted averages was calculated on some of the ions and on pH (see Section 4.3). Two stations situated in the counties of Kalmar and Kronoberg were chosen and the results as weighted averages from 2004, 2005 and 2006 were taken from the Swedish environmental program for air and precipitation financed by SEPA (Swedish Environmental Protection Board) (data can be obtained from www.ivl.se). The results from 2006 was also compared to the data obtained at the Äspö site during 2002 to 2005 /Ericsson 2004, 2005, Ericsson and Engdahl 2007/. The comparison shows that the concentration of ions is generally higher at Äspö (Table 5-6). The average of pH has varied at the Äspö site with slightly higher values than the other sites in south east Sweden. The main reason for higher concentration of ions at the Äspö site is probably because the site is situated very close to the sea with a greater influx of sea salt. The corrected average of $\text{SO}_4\text{-S}_{\text{kor}}$ (which excludes the part of sulphate that originates from sea salt) at Äspö has also been more similar to the other stations in south east Sweden (Table 5-6).

Table 5-6. Volume weighted averages of some major ions and pH in Äspö and in some other stations in south east Sweden 2004, 2005 and 2006.

Station	Cl (mg/l)	SO ₄ -S _{korrr} (mg/l)	Na (mg/l)	Ca (mg/l)	K (mg/l)	Mg (mg/l)	pH (mg/l)
Äspö 2006	0.66	0.36	1.33	0.38	0.88	0.27	4.97
Äspö 2005	0.99	0.41	0.74	0.37	0.59	0.15	4.66
Äspö 2004	1.50	0.25	2.13	0.78	0.51	0.12	4.75
Äspö 2002 to 2003	1.64	0.50	2.05	0.74	0.78	0.16	5.09
N Kvill 2006	0.42	0.32	0.27	0.19	0.21	0.07	4.88
N Kvill 2005	0.50	0.26	0.33	0.15	0.09	0.05	4.77
N Kvill 2004	0.36	0.26	0.28	0.11	0.10	0.05	4.89
Aneboda 2006	1.00	0.37	0.65	0.13	0.16	0.09	4.71
Aneboda 2005	0.69	0.38	0.44	0.14	0.11	0.06	4.69
Aneboda 2004	1.27	0.35	0.87	0.14	0.09	0.12	4.69

The hydrogen isotope ratio of $\delta^2\text{H}$ varied with a weak indication of lowest ratios in winter (Table 5-7 and Appendix). These ratios correlated well with the ratios of $\delta^{18}\text{O}$ (Figure 5-1). The linear relation corresponds reasonable well with the “Global Meteoric Water Line” ($\delta^2\text{H} = 8 \cdot \delta^{18}\text{O} + 10$) which is based on precipitation data from locations around the globe /Craig 1961/. The ratios of ^3H varied with a small tendency for lower values in late autumn and early winter.

Table 5-7. Isotope data obtained during the measuring periods. The last samples are the general samples gathered during the period 2006-01-01 to 2006-06-30 and 2006-07-01 to 2006-12-31.

Sample period	Sample number	$\delta^2\text{H}$ (‰ VSMOW)	^3H (TU)	$\delta^{18}\text{O}$ (‰ VSMOW)
2006-02-01–2006-02-08	10804	-119.4	6.0	-16.2
2006-03-23–2006-03-29	10945	-59.8	11.1	-7.9
2006-06-14–2006-06-22	11184	-42.3	14.5	-5.9
2006-08-24–2006-08-30	11299	-93.0	14.0	-12.7
2006-10-19–2006-10-25	11481	-56.6	7.7	-8.0
2006-12-14–2006-12-20	11599	-54.7	4.9	-7.9
Average		-71.0	9.7	-9.8
Standard deviation		29.2	4.1	3.9

Sample period	Sample number	$\delta^2\text{H}$ (‰ V-SMOW)	^3H (TU)	$\delta^{18}\text{O}$ (‰ V-SMOW)
2005-01-01–2005-06-30	11258			
2005-07-01–2005-12-31	11803	-76.7	8.8	-10.6

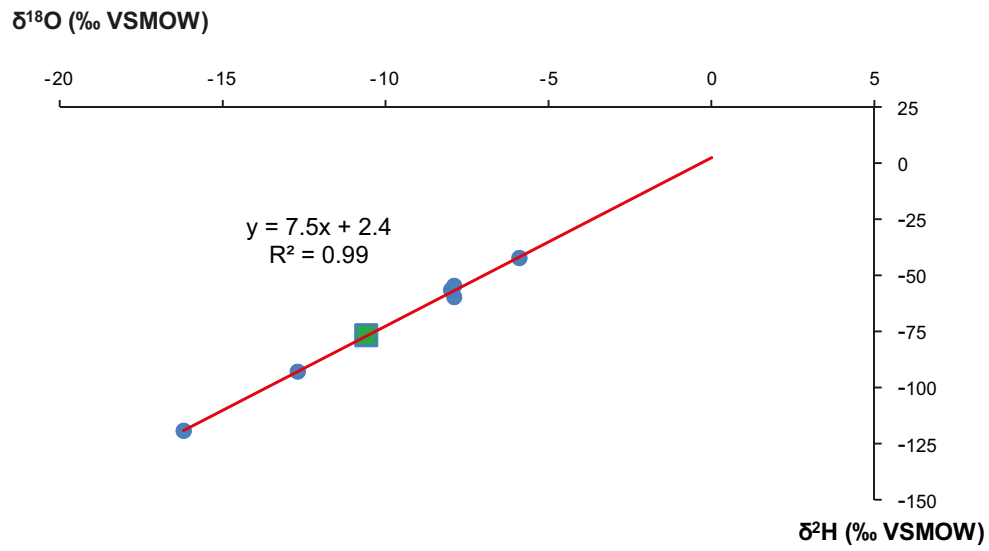


Figure 5-1. The relationship between the ratios of $\delta^2\text{H}$ and $\delta^{18}\text{O}$ at the Äspö site in 2006. The green square is the data from the general sample gathered during the period 2006-07-01 to 2006-12-31.

6 References

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Primary results

Sample period	Sample number	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)	Mn (mg/l)	Li (mg/l)	Si (mg/l)	Sr (mg/l)
2005-12-21–2006-01-02	10704									
2006-01-18–2006-01-25	10790									
2006-02-01–2006-02-08	10804	0.3	<0.4	<0.1	<0.1	<0.02	<0.003	<0.004	<0.03	<0.002
2006-02-08–2006-02-16	10816									
2006-02-26–2006-02-23	10849									
2006-02-23–2006-03-02	10858									
2006-03-02–2006-03-08	10869									
2006-03-08–2006-03-16	10902									
2006-03-23–2006-03-29	10945	0.5	<0.4	0.2	<0.1	0.0203	0.00466	<0.004	<0.03	<0.002
2006-03-29–2006-04-06	10965									
2006-04-12–2006-04-19	10984									
2006-04-19–2006-04-27	10999									
2006-04-27–2006-05-03	11029									
2006-05-16–2006-05-22	11073									
2006-05-22–2006-05-31	11113									
2006-06-14–2006-06-22	11184	0.4	3.17	0.7	0.3	0.0766	0.13900	<0.004	0.13	0.004
2006-07-11–2006-07-18	11225									
2006-08-10–2006-08-17	11276									
2006-08-17–2006-08-24	11293									
2006-08-24–2006-08-30	11299	0.6	<0.4	0.4	<0.1	0.0318	0.00785	<0.004	0.09	0.004
2006-08-30–2006-09-06	11309									
2006-09-27–2006-10-04	11375									
2006-10-19–2006-10-25	11481	0.6	0.88	0.5	0.2	0.1000	0.02380	<0.004	0.14	0.004
2006-10-25–2006-11-01	11492									
2006-11-01–2006-11-09	11507									
2006-11-09–2006-11-16	11528									
2006-11-16–2006-11-22	11553									
2006-11-22–2006-11-29	11562									
2006-12-14–2006-12-20	11599	11.7	0.91	0.4	1.8	<0.02	<0.003	<0.004	0.11	0.012
Sample period	Sample number	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)	Mn (mg/l)	Li (mg/l)	Si (mg/l)	Sr (mg/l)
2005-01-01–2005-06-30										
2005-07-01–2005-12-31	11803	0.6	0.58	0.4	0.1	<0.02	0.01570	<0.004	<0.03	<0.002

Sample period	Sample number	SO ₄ -S meas. (mg/l)	Cl (mg/l)	SO ₄ (mg/l)	Br (mg/l)	F (mg/l)	HCO ₃ (mg/l)	pH	Conductivity (mS/m)
2005-12-21–2006-01-02	10704		1.3	1.53	<0.2	<0.2		4.40	2.9
2006-01-18–2006-01-25	10790		2.3	2.65	<0.2	<0.2		4.31	4.1
2006-02-01–2006-02-08	10804	0.32	0.4	1.02	<0.2	<0.2		4.65	1.7
2006-02-08–2006-02-16	10816		1.1	3.84	<0.2	<0.2		4.01	5.7
2006-02-26–2006-02-23	10849		0.8	4.84	<0.2	<0.2		3.96	5.8
2006-02-23–2006-03-02	10858		1.5	2.93	<0.2	<0.2		4.08	6.0
2006-03-02–2006-03-08	10869		0.6	1.00	<0.2	<0.2		4.16	3.6
2006-03-08–2006-03-16	10902		1.3	2.11	<0.2	<0.2		3.82	4.6
2006-03-23–2006-03-29	10945	0.42	0.6	1.22	<0.2	<0.2		4.59	2.4
2006-03-29–2006-04-06	10965		0.5	0.83	<0.2	<0.2		4.58	1.7
2006-04-12–2006-04-19	10984		0.8	1.04	<0.2	<0.2		4.98	1.6
2006-04-19–2006-04-27	10999		0.7	3.12	<0.2	<0.2		4.95	4.9
2006-04-27–2006-05-03	11029		0.5	4.48	<0.2	<0.2		4.92	4.0
2006-05-16–2006-05-22	11073		0.7	1.20	<0.2	<0.2		4.96	2.4
2006-05-22–2006-05-31	11113		0.7	0.65	<0.2	<0.2	1.21	5.76	1.9
2006-06-14–2006-06-22	11184	0.81	1.2	1.84	<0.2	<0.2	3.80	6.19	3.5
2006-07-11–2006-07-18	11225		1.5	5.62	<0.2	<0.2	1.72	5.20	4.7
2006-08-10–2006-08-17	11276		1.0	1.57	<0.2	<0.2	2.32	5.40	2.7
2006-08-17–2006-08-24	11293		0.4	1.04	<0.2	<0.2		4.73	1.5
2006-08-24–2006-08-30	11299	0.21	0.6	0.66	<0.2	<0.2		4.91	1.1
2006-08-30–2006-09-06	11309		1.1	1.21	<0.2	<0.2		4.69	2.4
2006-09-27–2006-10-04	11375		1.1	1.68	<0.2	<0.2	2.01	5.04	3.1
2006-10-19–2006-10-25	11481	0.66	0.7	1.88	<0.2	<0.2		4.63	2.6
2006-10-25–2006-11-01	11492		1.1	0.33	<0.2	<0.2	1.19	5.10	1.3
2006-11-01–2006-11-09	11507		0.6	<0.2	<0.2	<0.2	0.30	5.03	1.1
2006-11-09–2006-11-16	11528		1.4	0.46	<0.2	<0.2		4.76	2.0
2006-11-16–2006-11-22	11553		1.1	1.17	<0.2	<0.2		4.58	1.9
2006-11-22–2006-11-29	11562		1.2	1.34	<0.2	<0.2		4.53	2.6
2006-12-14–2006-12-20	11599	0.17	0.6	<0.2	<0.2	<0.2		5.73	1.1
Sample period	Sample number	SO ₄ -S meas. (mg/l)							
2005-01-01–2005-06-30									
2005-07-01–2005-12-31	11803	0.30							

Sample period	Sample number	$\delta^2\text{H}$ (‰ V-SMOW)	^3H (TU)	$\delta^{18}\text{O}$ (‰ V-SMOW)
2005-12-21–2006-01-02	10704			
2006-01-18–2006-01-25	10790			
2006-02-01–2006-02-08	10804	-119.4	6.00	-16.20
2006-02-08–2006-02-16	10816			
2006-02-26–2006-02-23	10849			
2006-02-23–2006-03-02	10858			
2006-03-02–2006-03-08	10869			
2006-03-08–2006-03-16	10902			
2006-03-23–2006-03-29	10945	-59.8	11.10	-7.90
2006-03-29–2006-04-06	10965			
2006-04-12–2006-04-19	10984			
2006-04-19–2006-04-27	10999			
2006-04-27–2006-05-03	11029			
2006-05-16–2006-05-22	11073			
2006-05-22–2006-05-31	11113			
2006-06-14–2006-06-22	11184	-42.3	14.50	-5.90
2006-07-11–2006-07-18	11225			
2006-08-10–2006-08-17	11276			
2006-08-17–2006-08-24	11293			
2006-08-24–2006-08-30	11299	-93.0	14.00	-12.70
2006-08-30–2006-09-06	11309			
2006-09-27–2006-10-04	11375			
2006-10-19–2006-10-25	11481	-56.6	7.70	-8.00
2006-10-25–2006-11-01	11492			
2006-11-01–2006-11-09	11507			
2006-11-09–2006-11-16	11528			
2006-11-16–2006-11-22	11553			
2006-11-22–2006-11-29	11562			
2006-12-14–2006-12-20	11599	-54.7	4.90	-7.90
Sample period	Sample number	$\delta^2\text{H}$ (‰ V-SMOW)	^3H (TU)	$\delta^{18}\text{O}$ (‰ V-SMOW)
2005-01-01–2005-06-30				
2005-07-01–2005-12-31	11803	-76.7	8.80	-10.60