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Oskarshamn site investigation

Sampling and analysis of precipitation at Simpevarp 2005

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Abstract

Sampling and analysis of precipitation was performed throughout 2005 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 metres apart in an area with a diameter of approximately 25 metres. 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 δ²H (deuterium) varied with the lowest ratio in winter. As expected these ratios correlated well with the ratios of δ¹⁸O (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.

Two types of nonconformities have occurred. The first is that sampling was not performed during one period in 2005 (2005-07-13 to 2005-08-08). The second type of nonconformity was that analysis of HCO₃ was not performed on every occasion, due to low pH values.

Sammanfattning

Provtagning och analys av regnvatten från Äspö har utförts under 2005. 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.

Två typer av avvikelser från vad som planerats har förekommit under året. Den första är att provtagning inte genomfördes under en period (2005-07-13 to 2005-08-08). Den andra är att inte alla planerade parametrar har analyserats vid varje provtillfälle. Vid flera tillfällen analyserades inte HCO_3 på grund av för lågt pH.

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1 Introduction

This document reports the results gained by the sampling and analysis of precipitation during 2005, 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 400-05-027. 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 2005 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
Platsundersökning Oskarshamn. Nederbördsprovtagning och analyser (2005)	AP PS 400-05-027	1.0
Method descriptions	Number	Version
Metodbeskrivning för provtagning och analys av nederbörd	SKB MD 423.003	1.0

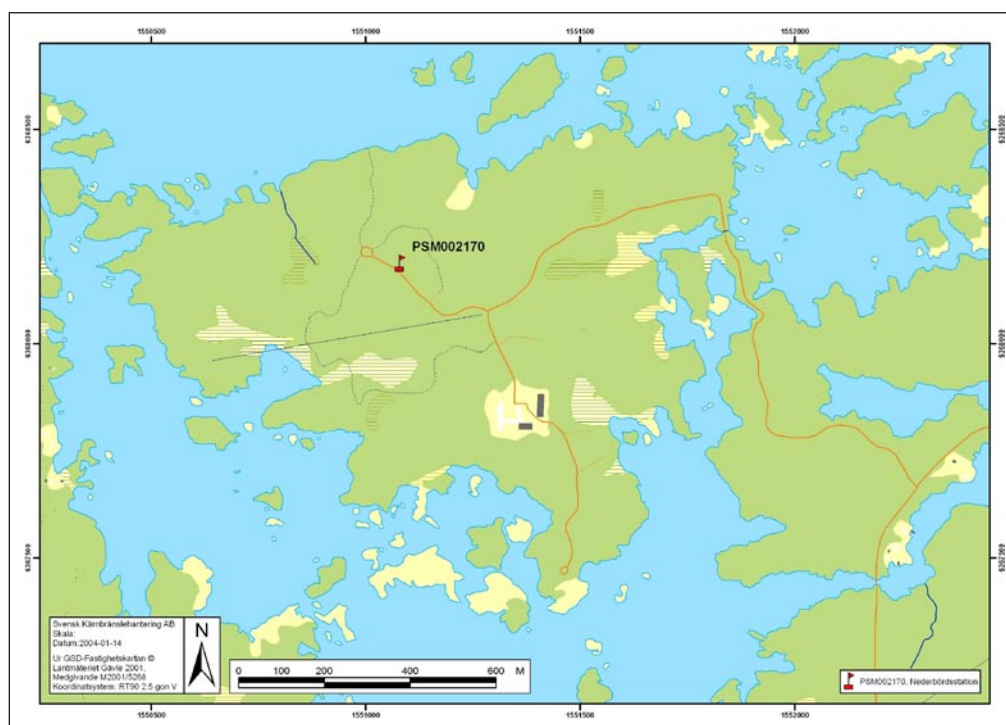


Figure 1-1. Site for sampling of precipitation (PSM002170) at the island of Äspö. Coordinates for the site is N 6368188.887; E 1551081.634 (RT90/RHB70). The elevation is 6.165 m.

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

Fourteen samplers were placed in an open field site approximately half a metre above the ground (Figure 3-1). Exact locations with coordinates are given in Table 3-1. The samplers were placed two to ten metres apart in an area with a diameter of approximately 25 metres. 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.

In summer 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 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.

4.2 Execution of field work

The precipitation was collected in samplers placed in an open field at Äspö (Figure 1-1 and 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, half of the sample was delivered to the Äspö laboratory for “quick analysis” (conductivity, pH, Cl, SO₄, Br, and F). If there were at least 250 ml of this water left a sample for measurements of density were taken. 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”. If there were at least 250 ml of this water left a sample for measurements of density were taken. 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”.

From week 18 the routine was changed slightly. No more samples for measurements of density were taken.

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 the two general samples. These samples was only analysed for $\delta^2\text{H}$, ^3H and $\delta^{18}\text{O}$.

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

See Table 4-1 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
2005-01-17 – 2005-01-24	10039	Density, anions, pH, conductivity and HCO ₃ ⁻
2005-01-24 – 2005-02-01	10073	Complete sample. Density, anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2005-02-07 – 2005-02-15	10079	Density, anions, pH, conductivity and HCO ₃ ⁻
2005-02-15 – 2005-02-23	10092	Density, anions, pH, conductivity and HCO ₃ ⁻
2005-02-23 – 2005-02-28	10116	Density, anions, pH, conductivity and HCO ₃ ⁻
2005-03-07 – 2005-03-14	10137	Density, anions, pH, conductivity and HCO ₃ ⁻
2005-03-14 – 2005-03-21	10182	Complete sample. Density anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2005-04-25 – 2005-05-03	10265	Density, anions, pH, conductivity and HCO ₃ ⁻
2005-05-03 – 2005-05-10	10284	Anions, pH, conductivity and HCO ₃ ⁻
2005-05-23 – 2005-06-01	10317	Density, anions, pH, conductivity and HCO ₃ ⁻
2005-06-01 – 2005-06-08	10329	Anions, pH, conductivity and HCO ₃ ⁻
2005-06-15 – 2005-06-21	10372	Anions, pH, conductivity and HCO ₃ ⁻
2005-06-21 – 2005-06-29	10395	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2005-08-08 – 2005-08-17	10453	Anions, pH, conductivity and HCO ₃ ⁻
2005-08-24 – 2005-09-01	10480	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2005-09-22 – 2005-09-29	10535	Anions, pH, conductivity and HCO ₃ ⁻
2005-10-18 – 2005-10-27	10578	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2005-10-18 – 2005-10-27	10759	Control sample to 10578. Bottles stored for main components, δ ² H, ³ H and δ ¹⁸ O
2005-11-01 – 2005-11-09	10604	Anions, pH, conductivity and HCO ₃ ⁻
2005-11-15 – 2005-12-01	10658	Anions, pH, conductivity and HCO ₃ ⁻
2005-12-01 – 2005-12-08	10663	Complete sample. Anions, pH, conductivity, HCO₃⁻, main components, δ²H, ³H and δ¹⁸O
2005-12-01 – 2005-12-08	11256	Control sample to 10663. Bottles stored for main components, δ ² H, ³ H and δ ¹⁸ O
2005-12-08 – 2005-12-15	10694	Anions, pH, conductivity and HCO ₃ ⁻
2005-12-15 – 2005-12-21	10703	Anions, pH, conductivity and HCO ₃ ⁻
2005-01-01 – 2005-06-30	10805	General sample. Only main components δ²H, ³H and δ¹⁸O
2005-01-01 – 2005-06-30	10806	Control sample to 10805. Bottles stored for main components, δ ² H, ³ H and δ ¹⁸ O
2005-07-01 – 2005-12-31	10859	General sample. Only main components δ²H, ³H and δ¹⁸O
2005-07-01 – 2005-12-31	10860	Control sample to 10859. Bottles stored for main components, δ ² H, ³ H and δ ¹⁸ O

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 4-2. 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 4-2. 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		Institute for Energy Technology, Norway

4.3 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 2006-12-01.

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

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

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 ($[\text{SO}_4\text{-S}_{\text{corr}}] = [\text{SO}_4\text{-S}] - 0.0837 \times [\text{Na}]$) (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.

4.4 Nonconformities

Two types of nonconformities have occurred. The first is that sampling was not performed during the holiday season (2005-07-13 to 2005-08-08).

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

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). These data will later be used for further interpretation and modelling. Here the results are presented in a more general way.

Precipitation was measured in 46 sampling periods during 2005. The average volume collected per sampler during this period was 177 ml (Table 5-1). The mean calculated precipitation per sampling period was 6.6 mm. The total measured precipitation of the year was 302 mm. This is probably an underestimation of the true total precipitation since measurements weren't performed during one period of the year.

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	Total volume (ml)	Average volume per sampler (ml)	Sampler diameter (cm)	Sampler area (cm ²)	Precipitation (mm)
2004-12-20 – 2005-01-03	0	0	21.0	346.4	0.0
2005-01-03 – 2005-01-10	1,080	77	21.0	346.4	2.2
2005-01-10 – 2005-01-17	0	0	21.0	346.4	0.0
2005-01-17 – 2005-01-24	4,000	286	21.0	346.4	8.2
2005-01-24 – 2005-02-01	9,000	643	21.0	346.4	18.6
2005-02-01 – 2005-02-07	0	0	21.0	346.4	0.0
2005-02-07 – 2005-02-15	8,300	593	21.0	346.4	17.1
2005-02-15 – 2005-02-23	5,600	400	21.0	346.4	11.5
2005-02-23 – 2005-02-28	2,400	171	21.0	346.4	4.9
2005-02-28 – 2005-03-07	100	7	21.0	346.4	0.2
2005-03-07 – 2005-03-14	6,700	479	21.0	346.4	13.8
2005-03-14 – 2005-03-21	5,100	364	21.0	346.4	10.5
2005-03-21 – 2005-03-28	0	0	21.0	346.4	0.0
2005-03-28 – 2005-04-05	0	0	21.0	346.4	0.0
2005-04-05 – 2005-04-12	250	18	21.0	346.4	0.5
2005-04-12 – 2005-04-18	0	0	21.0	346.4	0.0
2005-04-18 – 2005-04-25	0	0	21.0	346.4	0.0
2005-04-25 – 2005-05-03	2,215	158	21.0	346.4	4.6
2005-05-03 – 2005-05-10	3,795	271	21.0	346.4	7.8
2005-05-10 – 2005-05-18	0	0	15.5	188.7	0.0
2005-05-18 – 2005-05-23	465	33	15.5	188.7	1.8
2005-05-23 – 2005-06-01	3,910	279	15.5	188.7	14.8
2005-06-01 – 2005-06-08	7,660	547	15.5	188.7	29.0
2005-06-08 – 2005-06-15	0	0	15.5	188.7	0.0
2005-06-15 – 2005-06-21	3,240	231	15.5	188.7	12.3
2005-06-21 – 2005-06-29	4,890	349	15.5	188.7	18.5
2005-06-29 – 2005-07-07	0	0	15.5	188.7	0.0
2005-07-07 – 2005-07-13	0	0	15.5	188.7	0.0
2005-07-13 – 2005-08-08	no measurements	–	–	–	–
2005-08-08 – 2005-08-17	8,700	621	15.5	188.7	32.9
2005-08-17 – 2005-08-24	0	0	15.5	188.7	0.0

Sample period	Total volume (ml)	Average volume per sampler (ml)	Sampler diameter (cm)	Sampler area (cm ²)	Precipitation (mm)
2005-08-24 – 2005-09-01	3,205	229	15.5	188.7	12.1
2005-09-01 – 2005-09-07	0	0	15.5	188.7	0.0
2005-09-07 – 2005-09-14	0	0	15.5	188.7	0.0
2005-09-14 – 2005-09-22	620	44	15.5	188.7	2.3
2005-09-22 – 2005-09-29	1,395	100	15.5	188.7	5.3
2005-09-29 – 2005-10-05	0	0	15.5	188.7	0.0
2005-10-05 – 2005-10-13	0	0	15.5	188.7	0.0
2005-10-13 – 2005-10-18	0	0	15.5	188.7	0.0
2005-10-18 – 2005-10-27	4,675	334	15.5	188.7	17.7
2005-10-27 – 2005-11-01	0	0	21.0	346.4	0.0
2005-11-01 – 2005-11-09	3,205	229	21.0	346.4	6.6
2005-11-09 – 2005-11-15	390	28	21.0	346.4	0.8
2005-11-15 – 2005-12-01	4,650	332	21.0	346.4	9.6
2005-12-01 – 2005-12-08	9,580	684	21.0	346.4	19.8
2005-12-08 – 2005-12-15	3,940	281	21.0	346.4	8.1
2005-12-15 – 2005-12-21	5,000	357	21.0	346.4	10.3
Average		177			6.6
Standard deviation		212			8.3

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 many of the samples. The reason for this is difficult to interpret. It cannot be explained by the lack of analysis of two major ions, NO₃ and NH₄. In a nearby station for measurement of precipitation (Norra Kvill in the municipality of Vimmerby) the average concentrations of NO₃ and NH₄ was 0.22 mg/l and 0.17 mg/l in 2005 (www.ivl.se). If the relation between NO₃ and NH₄ is similar at the Äspö site the imbalance would be similar. Therefore the lack of results on NO₃ and NH₄ is not a probable explanation for the imbalance. 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.

Water from the general samples 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. The measurements of the density was, as can be expected, quite stable (Table 5-5 and Appendix).

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, se 4.3).

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)
2005-01-24 – 2005-02-01	10073	0.8	<0.40	0.2	<0.1			<0.004	0.05	<0.002
2005-03-14 – 2005-03-21	10182	0.7	<0.40	0.3	0.1	0.0919	0.00719	<0.004	0.14	<0.002
2005-06-21 – 2005-06-29	10395	0.1	<0.40	0.2	<0.1	0.0314	0.01010	<0.004	0.04	<0.002
2005-08-24 – 2005-09-01	10480	0.6	0.52	0.6	0.2	0.0272	0.01870	<0.004	0.03	0.004
2005-10-18 – 2005-10-27	10578	1.2	1.36	0.7	0.3	0.0461	0.08810	<0.004	0.07	0.003
2005-12-01 – 2005-12-08	10663	1.0	<0.40	0.3	<0.1	0.2510	0.00765	<0.004	0.05	0.003

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)
2005-01-24 – 2005-02-01	10073	0.48	0.5	1.30	0.433	0.366	<0.200	<0.20	
2005-03-14 – 2005-03-21	10182	0.31	1.0	0.99	0.330	0.271	<0.200	0.46	
2005-06-21 – 2005-06-29	10395	0.73	<0.2	1.43	0.477	0.468	<0.200	<0.20	
2005-08-24 – 2005-09-01	10480	0.59	0.9	1.04	0.347	0.296	<0.200	<0.20	
2005-10-18 – 2005-10-27	10578	0.65	1.8	1.24	0.413	0.313	<0.200	<0.20	
2005-12-01 – 2005-12-08	10663	0.88	1.5	2.20	0.733	0.650	<0.200	<0.20	

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 (%)
2005-01-24 – 2005-02-01	10073	24.9
2005-03-14 – 2005-03-21	10182	11.3
2005-06-21 – 2005-06-29	10395	-4.2
2005-08-24 – 2005-09-01	10480	25.1
2005-10-18 – 2005-10-27	10578	28.1
2005-12-01 – 2005-12-08	10663	12.7

Table 5-4. Measured concentrations of positive ions and some other components in the general samples.

Sample period	Sample number	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)
2005-01-01 – 2005-06-30	10805	1.0	0.55	0.3	0.1	<0.0200
2005-07-01 – 2005-12-31	10859	0.6	0.61	0.3	0.1	<0.0200

Sample period	Sample number	Mn (mg/l)	Li (mg/l)	Si (mg/l)	Sr (mg/l)	SO ₄ -S meas. (mg/l)
2005-01-01 – 2005-06-30	10805	0.00695	<0.004	<0.03	<0.002	0.69
2005-07-01 – 2005-12-31	10859	0.03030	<0.004	<0.03	0.002	0.47

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

Sample period	Sample number	pH	Conductivity (mS/m)	Density (g/ml)
2005-01-17 – 2005-01-24	10039	4.60	5.1	0.9961
2005-01-24 – 2005-02-01	10073	4.57	3.9	0.9962
2005-02-07 – 2005-02-15	10079	4.42	3.4	0.9961
2005-02-15 – 2005-02-23	10092	4.14	3.7	0.9962
2005-02-23 – 2005-02-28	10116	4.13	5.5	0.9961
2005-03-07 – 2005-03-14	10137	4.48	2.7	0.9963
2005-03-14 – 2005-03-21	10182	4.51	1.5	0.9961
2005-04-25 – 2005-05-03	10265	4.68	7.4	0.9961
2005-05-03 – 2005-05-10	10284	4.80	2.3	
2005-05-23 – 2005-06-01	10317	4.47	8.2	
2005-06-01 – 2005-06-08	10329	5.14	4.0	
2005-06-15 – 2005-06-21	10372	5.56	1.1	
2005-06-21 – 2005-06-29	10395	4.93	7.0	
2005-08-08 – 2005-08-17	10453	5.07	3.2	
2005-08-24 – 2005-09-01	10480	4.84	16.8	
2005-09-22 – 2005-09-29	10535	4.73	3.2	
2005-10-18 – 2005-10-27	10578	4.88	3.3	
2005-11-01 – 2005-11-09	10604	4.69	3.2	
2005-11-15 – 2005-12-01	10658	3.95	2.7	
2005-12-01 – 2005-12-08	10663	4.27	4.3	
2005-12-08 – 2005-12-15	10694	5.08	2.8	
2005-12-15 – 2005-12-21	10703	4.69	1.6	
Average:		4.66	4.4	0.9962
Standard deviation:		0.37	3.3	0.0001

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 and 2005 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 2005 was also compared to the data obtained at the Äspö site during 2002–2004 /Ericsson 2004, 2005/. 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 but the last two years average value has been similar to 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).

The hydrogen isotope ratio of $\delta^2\text{H}$ varied with the lowest ratio 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 5-6. Volume weighted averages of some major ions and pH in Äspö and in some other stations in south east Sweden 2004 and 2005.

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 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 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 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

Table 5-7. Isotope data obtained during the measuring periods. The last samples are the general samples gathered during the period 2005-01-01 to 2005-06-30 and 2005-07-01 to 2005-12-31.

Sample period	Sample number	δ ² H (‰ VSMOW)	³ H (TU)	δ ¹⁸ O (‰ VSMOW)
2005-01-24 – 2005-02-01	10073	-109.8	10.30	-16.30
2005-03-14 – 2005-03-21	10182	-79.2	11.20	-10.90
2005-06-21 – 2005-06-29	10395	-52.3	13.80	-7.40
2005-08-24 – 2005-09-01	10480	-58.2	13.30	-7.90
2005-10-18 – 2005-10-27	10578	-80.2	9.20	-11.10
2005-12-01 – 2005-12-08	10663	-97.3	9.40	-13.80
Average		-79.5	11.20	-11.23
Standard deviation		22.04	1.96	3.41

Sample period	Sample number	δ ² H (‰ VSMOW)	³ H (TU)	δ ¹⁸ O (‰ VSMOW)
2005-01-01 – 2005-06-30	10805	-85.3	8.30	-11.60
2005-07-01 – 2005-12-31	10859	-81.3	8.80	-11.20

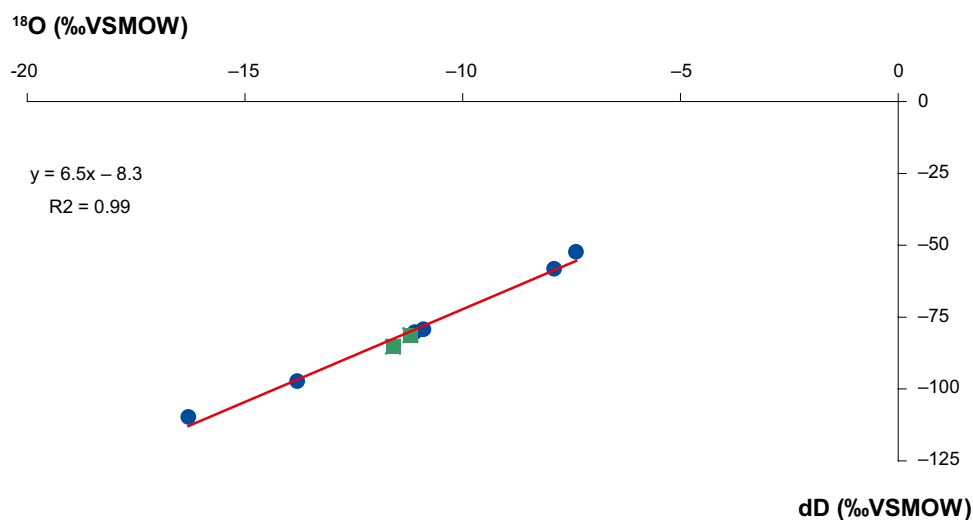


Figure 5-1. The relationship between the ratios of δ²H and δ¹⁸O at the Äspö site in 2005. The green squares are the data from the general samples gathered during the period 2005-01-1 to 2005-06-30 and 2005-07-01 to 2005-12-31.

6 References

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Appendix

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)
2005-01-17 – 2005-01-24	10039									
2005-01-24 – 2005-02-01	10073	0.8	<0.4	0.2	<0.1			<0.004	0.05	<0.002
2005-02-07 – 2005-02-15	10079									
2005-02-15 – 2005-02-23	10092									
2005-02-23 – 2005-02-28	10116									
2005-03-07 – 2005-03-14	10137									
2005-03-14 – 2005-03-21	10182	0.7	<0.4	0.3	0.1	0.092	0.007	<0.004	0.14	<0.002
2005-04-25 – 2005-05-03	10265									
2005-05-03 – 2005-05-10	10284									
2005-05-23 – 2005-06-01	10317									
2005-06-01 – 2005-06-08	10329									
2005-06-15 – 2005-06-21	10372									
2005-06-21 – 2005-06-29	10395	0.1	<0.4	0.2	<0.1	0.031	0.010	<0.004	0.04	<0.002
2005-08-08 – 2005-08-17	10453									
2005-08-24 – 2005-09-01	10480	0.6	0.52	0.6	0.2	0.027	0.019	<0.004	0.03	0.004
2005-09-22 – 2005-09-29	10535									
2005-10-18 – 2005-10-27	10578	1.2	1.36	0.7	0.3	0.046	0.088	<0.004	0.07	0.003
2005-11-01 – 2005-11-09	10604									
2005-11-15 – 2005-12-01	10658									
2005-12-01 – 2005-12-08	10663	1.0	<0.4	0.3	<0.1	0.251	0.008	<0.004	0.05	0.003
2005-12-08 – 2005-12-15	10694									
2005-12-15 – 2005-12-21	10703									
n		6	6	6	6	5	5	6	6	6
Average		0.7	<0.58	0.4	<0.15	0.090	0.026	<0.004	0.06	<0.003
Standard deviation		0.4	0.39	0.2	0.1	0.094	0.035	0.000	0.04	0.001
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	10805	1.0	0.55	0.3	0.1	<0.02	0.007	<0.004	<0.03	<0.002
2005-07-01 - 2005-12-31	10859	0.6	0.61	0.3	0.1	<0.02	0.030	<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)	Density (g/ml)
2005-01-17 – 2005-01-24	10039		5.5	1.54	<0.2	0.46		4.60	5.1	0.9961
2005-01-24 – 2005-02-01	10073	0.48	0.5	1.30	<0.2	<0.2		4.57	3.9	0.9962
2005-02-07 – 2005-02-15	10079		2.2	1.84	<0.2	<0.2		4.42	3.4	0.9961
2005-02-15 – 2005-02-23	10092		1.6	3.80	<0.2	<0.2		4.14	3.7	0.9962
2005-02-23 – 2005-02-28	10116		3.1	4.80	<0.2	<0.2		4.13	5.5	0.9961
2005-03-07 – 2005-03-14	10137		1.6	1.35	<0.2	<0.2		4.48	2.7	0.9963
2005-03-14 – 2005-03-21	10182	0.31	1.0	0.99	<0.2	0.46		4.51	1.5	0.9961
2005-04-25 – 2005-05-03	10265		2.0	4.06	<0.2	<0.2		4.68	7.4	0.9961
2005-05-03 – 2005-05-10	10284		0.9	0.92	<0.2	<0.2		4.80	2.3	
2005-05-23 – 2005-06-01	10317		0.6	2.72	<0.2	<0.2		4.47	8.2	
2005-06-01 – 2005-06-08	10329		0.8	1.20	<0.2	<0.2	1.23	5.14	4.0	
2005-06-15 – 2005-06-21	10372		0.5	0.52	<0.2	<0.2	0.39	5.56	1.1	
2005-06-21 – 2005-06-29	10395	0.73	0.2	1.43	<0.2	<0.2		4.93	7.0	
2005-08-08 – 2005-08-17	10453		0.2	0.59	<0.2	<0.2		5.07	3.2	
2005-08-24 – 2005-09-01	10480	0.59	0.9	1.04	<0.2	<0.2		4.84	16.8	
2005-09-22 – 2005-09-29	10535		1.6	1.33	<0.2	<0.2		4.73	3.2	
2005-10-18 – 2005-10-27	10578	0.65	1.8	1.24	<0.2	<0.2		4.88	3.3	
2005-11-01 – 2005-11-09	10604		1.7	2.09	<0.2	<0.2		4.69	3.2	
2005-11-15 – 2005-12-01	10658		1.1	1.14	<0.2	<0.2		3.95	2.7	
2005-12-01 – 2005-12-08	10663	0.88	1.5	2.20	<0.2	<0.2		4.27	4.3	
2005-12-08 – 2005-12-15	10694		0.8	0.38	<0.2	<0.2	1.29	5.08	2.8	
2005-12-15 – 2005-12-21	10703		0.5	0.42	<0.2	<0.2		4.69	1.6	
n		6	22	22	22	22	3	22	22	8
Average		0.61	1.4	1.68	<0.2	<0.22	0.97	4.67	4.40	0.9962
Standard deviation		0.20	1.2	1.19	0.0	0.08	0.50	0.37	3.33	0.0001
Sample period	Sample number	SO ₄ -S meas. (mg/l)								
2005-01-01 – 2005-06-30	10805	0.69								
2005-07-01 – 2005-12-31	10859	0.47								

Sample period	Sample number	$\delta^2\text{H}$ (‰ VSMOW)	^3H (TU)	$\delta^{18}\text{O}$ (‰ VSMOW)
2005-01-17 – 2005-01-24	10039			
2005-01-24 – 2005-02-01	10073	-109.8	10.30	-16.30
2005-02-07 – 2005-02-15	10079			
2005-02-15 – 2005-02-23	10092			
2005-02-23 – 2005-02-28	10116			
2005-03-07 – 2005-03-14	10137			
2005-03-14 – 2005-03-21	10182	-79.2	11.20	-10.90
2005-04-25 – 2005-05-03	10265			
2005-05-03 – 2005-05-10	10284			
2005-05-23 – 2005-06-01	10317			
2005-06-01 – 2005-06-08	10329			
2005-06-15 – 2005-06-21	10372			
2005-06-21 – 2005-06-29	10395	-52.3	13.80	-7.40
2005-08-08 – 2005-08-17	10453			
2005-08-24 – 2005-09-01	10480	-58.2	13.30	-7.90
2005-09-22 – 2005-09-29	10535			
2005-10-18 – 2005-10-27	10578	-80.2	9.20	-11.10
2005-11-01 – 2005-11-09	10604			
2005-11-15 – 2005-12-01	10658			
2005-12-01 – 2005-12-08	10663	-97.3	9.40	-13.80
2005-12-08 – 2005-12-15	10694			
2005-12-15 – 2005-12-21	10703			
n		6	6	6
Average		-79.50	11.20	-11.23
Standard deviation		22.04	1.96	3.41
Sample period	Sample number	$\delta^2\text{H}$ (‰ VSMOW)	^3H (TU)	$\delta^{18}\text{O}$ (‰ VSMOW)
2005-01-01 – 2005-06-30	10805	-85.3	8.30	-11.60
2005-07-01 – 2005-12-31	10859	-81.3	8.80	-11.20