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Oskarshamn site investigation

Sampling and analysis of shallow ground water at Simpevarp 2005

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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

In 2005 sampling of shallow ground water in water wells in soil has been performed at 26 sites within the site investigation area at Oskarshamn. The purpose of the activity is to characterise the shallow ground water in the site investigation area.

Some physical and chemical parameters were measured directly in the field but most parameters were analysed at different laboratories. The ground water sampling activity consisted of three different programmes, chemical programme class 3, chemical programme class 5 (full) and class 5 (reduced). The class 5 programme included more components to be analysed.

The large number of sites and parameters analysed have generated a large amount of data, which will later be used for advanced analysis and modelling. In this report the evaluation aims to give a simple overview of the results and to describe the quality of the data sampled from January 2005 to December 2005.

Some nonconformities from the Activity Plan occurred. The most important one is that it was not possible to sample the sites at all occasions. Three ground water wells in the Laxemar area were not possible to sample at all and these wells were omitted after the summer. Some other wells sometimes lacked enough water, which limited the number of components that could be analysed. Another type of nonconformity was that measurements of water temperature and pH in the field were not performed at all sites during 2005.

The results showed a quite large variation between the different wells. The ion concentrations and conductivity ranged from what can be termed as low to high values. Likewise the concentration of HCO_3 varied extensively throughout the investigation area with high concentrations in most wells. In two wells the concentration of HCO_3 was lower with an indication of a problem with acidification in the ground water.

As with the ions measurements on environmental metals and trace elements varied quite much between the wells. High concentration of lead in some of the wells indicated pollution but since the concentration of lead in the wells had a similar relation to aluminium as most other elements it was argued that the high concentration of lead probably can be explained by the natural composition of minerals in the Simpevarp area.

The average ratios of isotopes of boron, chlorine, strontium and oxygen ($^{10}\text{B}/^{11}\text{B}$, $\delta^{37}\text{Cl}$, $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{18}\text{O}$) were similar in most wells and there seems to be low variation in the investigated areas. The isotopes of carbon ($\delta^{13}\text{C}$ and ^{14}C) and sulphur ($\delta^{34}\text{S}$) varied more between the different wells with the greatest variation in $\delta^{34}\text{S}$.

The average hydrogen isotope ratios of deuterium ($\delta^2\text{H}$) and tritium (^3H) had similar values in most wells. However, one well differed, with a markedly lower ratio for ^3H . The ratios of $\delta^2\text{H}$ correlated well with the ratios of $\delta^{18}\text{O}$ but the linear relation differed markedly from the "Global Meteoric Line" which is based on precipitation data.

The concentration of uranium (^{234}U and ^{238}U) and thorium (^{230}Th) isotopes varied in the area with considerably higher concentration in some of the wells.

The concentration of radium (^{226}Ra) was close to the reporting limit in the wells and there seems to be little variation in the investigation areas. The activity of radon (^{222}Rn) varied to some extent but all values measured can be considered as normal background values for shallow ground water.

The concentration of nitrate varied with considerable higher concentration in some of the wells. The concentration in these wells can be termed as moderately high according to Swedish environmental quality criteria. Likewise the concentration of $\text{NH}_4\text{-N}$, phosphorus, silica and sulphide varied with considerably higher values in some of the wells. The concentration of dissolved organic carbon (DOC) varied with values up to 21.7 mg/l. This is only slightly lower than most surface waters in the area.

Sammanfattning

Provtagning av ytligt grundvatten i jordrör har under 2005 skett vid 26 platser inom platsundersökningsområdet vid Simpevarp.

Några fysiska och kemiska parametrar har mätts direkt i fält men merparten av de insamlade parametrarna är resultatet av laboratorieanalyser. Aktiviteten bestod av tre olika program, klass 3 och 5 (fullt) samt klass 5 (reducerat), med fler analyserade parametrar under de veckor då klass 5 programmen följdes.

Det stora antalet platser och analyserade parametrar har genererat en stor mängd data som senare kommer att användas för avancerad analys och modellering. I denna rapport har utvärderingen syftat till att ge en enkel översikt över resultaten och att beskriva kvaliteten av de data som samlats in mellan januari och december 2005.

En del avvikelser från aktivitetsplanen har skett. Viktigast är att det inte alltid varit möjligt att ta prover vid alla stationer. Tre av grundvattenrören inom Laxemarsområdet har inte kunnat provtas alls och utgick ur programmet efter sommaren. Vid andra stationer har det ibland funnits för lite vatten för att kunna utföra alla planerade analyser. En annan typ av avvikelse mot planen var att vattentemperatur och pH inte mätts i fält vid alla provtagningstillfällen under året.

Resultaten av undersökningarna visade på en ganska stor variation mellan de olika grundvattenrören i området. Koncentrationen av joner och konduktiviteten varierade mellan vad som kan betecknas som låga till höga värden. Likadant varierade koncentrationen av HCO_3 mycket med höga koncentrationer vid de flesta provplatserna. I två av grundvattenrören var koncentrationen så låg att resultatet indikerade problem med försurning av grundvattnet.

Liksom för jonerna varierade värdena för miljömetaller och spårelement ganska mycket mellan de olika provplatserna. En hög koncentration av bly vid några av platserna indikerade någon sorts förorening. Men eftersom relationen mellan koncentrationen av bly och aluminium liknade den som flertalet andra metaller och spårelement hade med aluminium drogs slutsatsen att resultatet med höga blyhalter kan förklaras med mineralets naturliga sammansättning i området.

Isotopkvoterna av bor, klor, strontium och syre ($^{10}\text{B}/^{11}\text{B}$, $\delta^{37}\text{Cl}$, $^{87}\text{Sr}/^{86}\text{Sr}$ och $\delta^{18}\text{O}$) var liknande vid de flesta provplatserna och det verkar vara en liten variation inom undersökningsområdet. Isotoperna av kol ($\delta^{13}\text{C}$ och ^{14}C) och svavel ($\delta^{34}\text{S}$) varierade mer med en något större variation för $\delta^{34}\text{S}$.

Medelvärdena av väteisotoperna deuterium ($\delta^2\text{H}$) och tritium (^3H) var liknande i de flesta grundvattenrören. Resultatet från ett av rören skiljde sig dock med en märkbart lägre kvot för ^3H . Kvoterna av $\delta^2\text{H}$ var väl korrelerade till kvoterna av $\delta^{18}\text{O}$ men den linjära relationen skiljde sig märkbart från "the Global Meteoric Line" vilken baseras på data från nederbörd.

Koncentrationen av uran- och thoriumisotoper (^{234}U , ^{238}U och ^{230}Th) varierade mellan grundvattenrören i området med betydligt högre koncentrationer i några av grundvattenrören. Koncentrationen av radium (^{226}Ra) var nära rapporteringsgränsen vid de olika provplatserna och variationen verkar vara liten inom undersökningsområdet. Aktiviteten av radon (^{222}Rn) varierade i viss utsträckning men alla uppmätta värden kan betraktas som normala bakgrundsvärden för grundvatten.

Koncentrationen av nitrat varierade med betydligt högre värden i några av grundvattenrören. Dessa värden kan klassas som måttligt höga enligt Naturvårdsverkets kriterier. Även koncentrationen av $\text{NH}_4\text{-N}$, fosfor, kisel och sulfid varierade med betydligt högre värden vid vissa av provplatserna. Koncentrationen av löst organiskt kol (DOC) varierade med värden upp till 21.7 mg/l. Detta är endast något lägre än innehållet i de flesta ytvatten i området.

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1 Introduction

This document reports the data gained by the sampling of shallow ground water in the areas of Ävrö, Hålö, Simpevarp peninsula and Laxemar 2005, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with Activity Plans AP PS 400-05-024 and AP PS 400-04-077. In Table 1-1 controlling documents for performing this activity are listed. The activity plans are SKB's internal controlling documents.

Within the site investigation area at Simpevarp and Laxemar, water has been sampled from shallow ground water wells in soil. During 2005 sampling was performed at 26 sites on up to four occasions (Figure 1-1). The water was analysed for a large number of parameters. All original results have been stored in the primary database SICADA. The results are traceable by the activity plan number. The data in the database will later be used for further interpretation (modelling).

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

Activity Plan	Number	Version
Vattenprovtagning i jordrör 2005 (Ävrö, Hålö och Simpevarphalvön)	AP PS 400-05-024	1.0
Vattenprovtagning i jordrör, Laxemar 2004-2006	AP PS 400-04-077	1.0

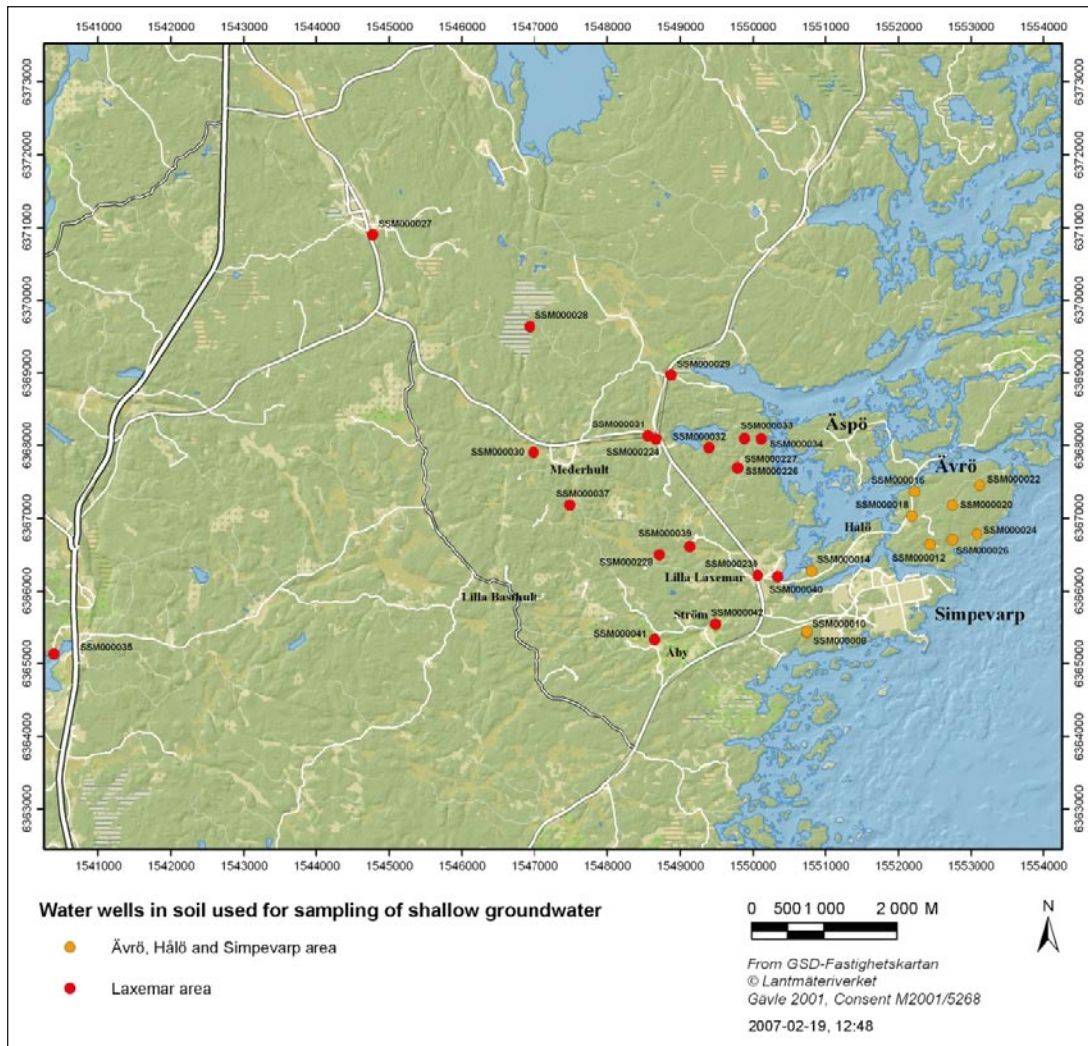


Figure 1-1. The site investigation area and water wells in soil used for sampling of shallow groundwater. Three water wells in the Laxemar area (PSM000028, PSM000032 and PSM000033) were not possible to sample and were omitted at the end of August 2005.

2 Objective and scope

The purpose of the activity was to characterise the shallow ground water in the site investigation area. This document reports the data gained by the sampling of ground water in two areas; the Ävrö, Hålö and Simpevarp peninsula area and in the Laxemar area. Sampling was planned to be performed at 29 different ground water wells, at one, two or four occasions during 2005. 10 of the water wells are situated in the Ävrö, Hålö and Simpevarp peninsula area, and 19 water wells in the Laxemar area.

Some physical and chemical parameters were measured directly on the spot. Water samples were then taken for analysis of further parameters. The samples were later sent to different laboratories for the analysis.

In general the ground water sampling activity consisted of three different programmes; chemical programme class 3 and chemical programmes class 5 (full), and chemical class 5 (reduced). The reduced chemical class 5 programme was performed at two occasions during 2005 and these occasions differed somewhat in which parameters that were analysed (Table 2-1). In general, the class 5 programmes included more components to be analysed than the class 3 (Table 2-1). Sometimes it was not possible to get a sufficient amount of water for analysis of all components, so a priority order for the programmes was set up (Table 2-1). A time schedule for both areas and performed programmes can be viewed in Appendix 2.

The large number of sites and parameters analysed have generated a large amount of data, which will later be used for advanced analysis and modelling. In this report the evaluation aims to give a simple overview of the results and to describe the quality of the data sampled from January 2005 to December 2005.

Table 2-1. Analysed components, priority order, and the different programmes, when sampling ground water wells in the Simpevarp and Laxemar area 2005.

Chemical programme class 3 March 2005		Chemical programme class 5 – reduced May/June 2005	
Components	Priority	Components	Priority
Alkalinity, pH, Conductivity	2	Alkalinity, pH, Conductivity	2
Anions (F ⁻ , Cl ⁻ , Br ⁻ , SO ₄ ²⁻)	3	Anions (F ⁻ , Cl ⁻ , Br ⁻ , SO ₄ ²⁻)	3
Main components	1	NH ₄	7
Density	7	Fe II + Fe (tot)	6
Archive	6	S ₂ ⁻	8
		Main components	1
Optional components:		Archive (acid rinsed)	9
Deuterium, O-18	4	Archive	9
Tritium	5		
		Optional components:	
		Deuterium, O-18	4
		Tritium	5
Chemical programme class 5 – full September 2005¹		Optional components:	
Components	Priority		Priority
Alkalinity, pH, Conductivity	2	B-10	7
Anions (F ⁻ , Cl ⁻ , Br ⁻ , SO ₄ ²⁻)	3	As, In	7
NH ₄	12	Environmental metals	7
Fe II + Fe (tot)	11	Lantanoides	7
S ₂ ⁻	13	Trace elements	7
Main components	1	TOC	17
Archive (acid rinsed)	20	Cl-37	6
Archive	20	Sr-87	9
I ⁻	16	C-13, PMC	8
NO ₃ , NO ₂ , NO ₂ +NO ₃ , PO ₄	19	S-34	10
DOC	18	U-, Th-isotopes	14
Deuterium, O-18	4	Ra-, Rn-isotopes	15
Tritium	5		
Chemical programme class 5 – reduced (new) November/December 2005¹		Optional components:	
Components	Priority		Priority
Alkalinity, pH, Conductivity	2	Deuterium, O-18	4
Anions (F ⁻ , Cl ⁻ , Br ⁻ , SO ₄ ²⁻)	3	Tritium	5
Main components	1	Cl-37	11
B-10	1	S-34	12
Environmental metals	1	NH ₄ , NO ₃ , NO ₂ , NO ₂ +NO ₃ , PO ₄	6
Lantanoides	1	Tot-N and Tot-P	7
Trace elements	1	DOC	8
Archive (acid rinsed)	13	TOC	9
Archive	13	POP, PON and POC	10

¹ The sampling programmes in the Ävrö, Hälö and Simpevarp area was terminated in August 2005, except for SSM000022.

3 Equipment

3.1 Equipment used in the field

Underwater pump (type 12 V Avimex). Used in the field for pumping up water from the ground water wells.

Volume graded five litre containers, used in field as collecting vessels. Acid rinsed vessels were used when sampling for analysis of Fe II + Fe (tot) main components, trace elements, lantanoides and environmental metals.

Sounding apparatus, pH-meter and thermometer were used for field measurements.

Field notes.

3.2 Equipment used at the laboratory

Tube pump. Used in the laboratory to filter sampled water.

0.45 μm filter (PALL). Capsule filter used together with the tube pump.

0.45 μm membrane filter. Used together with the tube pump.

4 Execution

4.1 Sites and sampling frequency

The total number of sampled sites was 26, both areas included. In Appendix 1, location coordinates and sample depths for all ground water wells can be viewed. During 2005, sampling was performed on two occasions in the Ävrö, Hålö, and Simpevarp peninsula area. However one site (SSM000022), was sampled four times. In the Laxemar area sampling was performed on four occasions. A time schedule for both areas and programmes are presented in Appendix 2. Although all sites were meant to be sampled on every occasion, this wasn't always possible due to insufficient amount of water, frozen water and other disturbances (Appendix 3).

4.2 Execution of sampling and treatment of samples

To avoid contamination all sampling was conducted with protective rubber gloves and great care was taken not to contaminate containers or equipment. The day before sampling, each ground water well was visited and water was pumped out, if possible, for at least ten minutes. On the sampling day, the ground water level was sounded and noted. Field measurements of pH were then performed, before the collecting vessels were filled with water.

After sampling in field the samples were taken to a preparation room where most of the samples were prepared before analysis (Table 4-1). The sample in the collecting bottles was divided into smaller bottles. Many of the samples were then prepared with different types of filtrations and/or different type of conservations. This was conducted with protective rubber gloves to minimise the risk of contamination.

Routines for storing and delivery of samples to the different analysing laboratories are presented in Table 4-2. Some of the samples were sent immediately at the end of each day and some were stored in a refrigerator or freezer till the end of the week, when they were sent to the laboratory.

During the year some changes of the methods used have occurred:

From May 2005 it was decided that no more estimations of density would be performed.

From May 2005 it was decided that analysis of Ra/Rn and U/Th would be performed by SUERC (Scottish Universities Environmental Research Centre) instead of Institutt For Energiteknikk (IFE, Norway).

In August 2005 the two-year sampling programme in the Ävrö, Hålö, and Simpevarp peninsula area was interrupted and the two remaining sampling occasions 2005 were omitted, however, in one water well (SSM000022), the sampling were continued in accordance to the original plan.

From August 2005, three water wells in the Laxemar area were omitted (SSM000028, SSM000032 and SSM000033). These water wells have never been sampled due to low water levels and/or low water quality.

Five new water wells in the Laxemar area were added to the sampling programme during autumn 2005. In three of these water wells sampling started in September 2005 (SS000224, SSM000226, SSM000227) and in two wells sampling started in December 2005 (SSM000228, SSM000230).

Table 4-1. Indoor treatments of samples.

Bottle	Number	SKB-label	Components	Filling instructions	Preparation
250 ml	1	green	Alkalinity, pH, Conductivity	Fill up	–
250 ml	1	green	Anions (F ⁻ , Cl ⁻ , Br ⁻ , SO ₄ ²⁻)	Fill up	Filter. in connection with analysis
250 ml	1	green	Density	Fill up	–
500 ml acid rinsed PEH bottle	1	red	Fe II + Fe tot	Fill up	Filter. with membrane filter, add 5 ml concentrated HCl
Graduated flask reagent rinsed	2		Ammonium	25 ml	–
Winkler bottle	2		S ₂ ⁻	Flow over three times	Filter. with "Pallfilter" 0.45 µm, add 0.5 ml 1M ZnAc and 0.5 ml 1M NaOH
125 ml	1	red	Standard elements, B-10, As, In, environment. metals lantanoides, trace elements	Fill up	Filter. with membrane filter, add 1 ml concentrated HNO ₃
100 ml	1	green	Iodine	Fill up	Filter. with membrane filter
100 ml	1	green	NO ₃ ⁻ , NO ₂ ⁻ , (NO ₂ ⁻ +NO ₃ ⁻), PO ₄ ³⁻	Fill 80%	Filter. with "Pallfilter" 0.45 µm
100 ml	1	green	Tot-N and Tot-P	Fill up	–
1,000 ml	1	green	POP, POC and PON	Fill up	–
250 ml	1	green	DOC ¹	Fill 80%	–
250 ml	1	green	TOC ²	Fill 80%	–
100 ml quadrangular	1	green	Deuterium, O-18	Fill up	–
500 ml dried	1	green	Tritium	Flow over	–
1,000 ml	1	green	Cl-37	Fill up	–
100 ml quadrangular	1	green	Sr-87	Fill 80%	–
100 ml brown glass	2	green	C-13, PMC	Fill up	–
1,000 ml	1	green	S-34	Fill up	–
100 ml quadrangular	1	green	U-, Th-isotopes	Fill up	–
500 ml PEH bottle		green	Ra-, Rn-isotopes	Fill up	–
250 ml	2	green	Archive	Fill 80%	Filter. with "Pallfilter" 0.45 µm
100 ml	2	red	Archive	Fill 80%	Filter. with membrane filter, add 1 ml concentrated HNO ₃

¹From week 39 the sample was filtered in field with syringe and 0.45 µm filter and 2 drops of 2 M HCl were added in a 20 ml scintillation vessel. The sample was sent to Systemekologen, Stockholm.

²From week 39 2 drops of 2 M HCl were added in a 20 ml scintillation vessel. The sample was sent to Systemekologen, Stockholm.

From October 2005 some chemical analyses were added to the original programme planned in November/December. The Chemical programme class 3 became a chemical class 5 reduced (new) and that activity was called WC105. The new parameters analysed are listed below:

Nutrient components (NH₄, NO₃, NO₂, PO₄, total-N and total-P).

Dissolved organic carbon (DOC), total organic carbon (TOC).

Particular organic carbon, nitrogen and phosphorus (POC, PON and POP).

Trace elements, environmental metals, lantanoides (package 5, Analytica).

δ³⁷Cl, ¹⁰B/¹¹B and δ³⁴S.

It was also decided that samples for analysis of DOC and TOC would be sent to Systemekologen in Stockholm instead of Paavo Ristola, Finland.

Table 4-2. Treatments of samples when storing and delivering to analysing laboratories.

Bottle	Number	SKB-label	Components	Storing	Analysing laboratory	Way of delivery
250 ml	1	green	Alkalinity, pH, Conductivity	Refrigerator	Äspö laboratory	Directly
250 ml	1	green	Anions (F ⁻ , Cl ⁻ , Br ⁻ , SO ₄ ²⁻)	Refrigerator	Äspö laboratory	Directly
250 ml	1	green	Density	Refrigerator	Äspö laboratory	Directly
500 ml acid rinsed PEH bottle	1	red	Fe II + Fe tot	Refrigerator	Äspö laboratory	Directly
Graduated flask reagent rinsed	2		Ammonium	Refrigerator	Äspö laboratory	Directly
Winkler bottle	2		S ₂ ⁻	Refrigerator	Äspö laboratory	Directly
125 ml	1	red	Standard elements, B-10, As, In, environment metals lanthanoides, trace elements	Refrigerator	Analytica	Parcel post
100 ml	1	green	Iodine	Refrigerator	Analytica	Parcel post
100 ml	1	green	NO ₃ ⁻ , NO ₂ ⁻ , (NO ₂ ⁻ +NO ₃ ⁻), PO ₄ ³⁻	Freezer	Systemekologen	Parcel post
100 ml	1	green	Tot-N and Tot-P	Refrigerator	Systemekologen	Parcel post
1,000 ml	1	green	POP, POC and PON	Refrigerator	Systemekologen	Parcel post
250 ml	1	green	DOC	Freezer	Paavo Ristola/ Systemekologen	Parcel post Parcel post
250 ml	1	green	TOC	Freezer	Paavo Ristola/ Systemekologen	Parcel post Parcel post
100 ml quadrangular	1	green	Deuterium, O-18	Refrigerator	IFE, Norway	Parcel post
500 ml dried	1	green	Tritium	Refrigerator	Waterloo	Parcel post
1,000 ml	1	green	Cl-37	Refrigerator	Waterloo	Parcel post
100 ml quadrangular	1	green	Sr-87	Refrigerator	IFE, Norway	Parcel post
100 ml brown glass	2	green	C-13, PMC	Refrigerator	Waterloo	Parcel post
1,000 ml	1	green	S-34	Refrigerator	IFE, Norway	Parcel post
100 ml quadrangular	1	green	U-, Th-isotopes	Refrigerator	IFE, Norway/ SUERC, Scotland	Parcel post Parcel post
500 ml PEH bottle	1	green	Ra-, Rn-isotopes	Refrigerator	IFE, Norway/ SUERC, Scotland	DHL DHL
250 ml	2	green	Archive	Freezer	–	–
100 ml	2	red	Archive	Freezer	–	–

4.3 Documentation

All activities were continuously documented. Notes were taken on field conditions, time of sampling, marking of samples and so forth. Any deviations from the normal routines were also noted and commented in a special report. Delivery notes with instructions on which components to analyse were always sent with the samples to the different laboratories.

After analysis data has continuously been reported from the laboratories. As a routine a first preliminary quality control of the data was performed before storing them in the database SICADA.

5 Nonconformities

It was not possible to sample the sites at all occasions. Three ground water wells in the Laxemar area (PSM000028, PSM000032 and PSM000033) were not possible to sample at all, and some other wells sometimes lacked water, which limited the number of components that could be analysed. In Table 5-1 and 5-2 explanations are listed on why sampling could not be performed and why some components were not analysed. In Appendix 3 and 4 lists of sampled and analysed components at the different sites and sampling occasions are presented for each area.

Measurements of water temperature and pH in the field were not taken on every sampling occasion during 2005.

Table 5-1. Sites that were not sampled in the Ävrö, Hälö and Simpevarp area 2005.

ID-code	Chemical class 3 week 11–12 (Mars)
SSM000008	Frozen
SSM000018	Frozen

Table 5-2. Sites that were not sampled, or were sampling in other ways deviated from the planned sampling schedule. The Laxemar area 2005.

ID-code	Chemical class 3 week 12–13 (Mars)	Chemical class 5 – reduced week 22 and 24 (June)
SSM000028	No samples, low water levels and/or low water quality	No samples, low water levels and/or low water quality
SSM000029	No samples, too high water level around the pipe	
SSM000032	No samples, low water levels and/or low water quality	No samples, low water levels and/or low water quality
SSM000033	No samples, low water levels and/or low water quality	No samples, low water levels and/or low water quality
SSM000034	No samples, frozen	
SSM000035		Not enough water for all parameters
ID-code	Chemical class 5 – full week 36–38 (September)	Chemical class 5 – reduced (new) week 48–50 (November–December)
SSM000039	Lack of water	Lack of water
SSM000040	Not enough water for all parameters	Lack of water
SSM000227	Lack of water	

6 Results

6.1 Dissolved ions and conductivity

The concentrations of ions and the conductivity varied quite much between the sites in the different areas (Table 6-1 and 6-2). Most of the sites with the highest concentrations are situated close to the coast. The site SSM000042 which is situated quite far from the coast was an exception with comparably high concentrations of ions.

According to the Swedish Environmental Quality Criteria /Naturvårdsverket 1999/ the chloride concentrations range from low to high at different wells, with concentrations above 100 mg/l termed as high.

As a quality control the charge balance has been calculated for the samples. In some of the samples there was a deviation of more than 10 percent (Table 6-3). This could indicate analytical problems or significant concentrations of negative ions which were not included in the calculation of the charge balance. Samples with high deviation in charge balance had all low conductivity (Figure 6-1). This might be an indication of an occurrence of ions not included in the calculation of charge balance instead of analytical errors. One possible example is organic anions which has not been included in the calculations.

Table 6-1. Average concentration of major ions and conductivity in shallow ground water wells at Ävrö, Hålö and Simpevarp peninsula 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Fe ²⁺ (mg/l)	Fe-tot (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Li (mg/l)	HCO ₃ (mg/l)
SSM000008	0.405	0.320	10.3	1.99	35.0	4.00	<i>0.004</i>	120
SSM000010	1.77	1.39	9.25	3.65	41.3	6.55	0.009	142
SSM000012	1.32	0.843	49.7	5.26	49.4	8.00	0.014	204
SSM000014	7.97	5.82	10.4	4.90	21.4	11.4	0.038	34.7
SSM000016	1.68	1.12	5.45	3.28	58.3	7.30	0.009	164
SSM000018	1.16	0.681	35.8	29.5	36.5	12.3	0.017	78.7
SSM000020	2.00	1.50	6.60	3.79	27.9	6.70	0.011	34.5
SSM000022	0.163	0.165	204	6.40	22.4	7.73	0.021	284
SSM000024	–	–	6.60	2.25	12.7	3.80	0.007	29.0
SSM000026	3.38	2.55	6.55	1.83	21.6	3.60	<i>0.005</i>	56.9

Site number	Cl (mg/l)	SO ₄ (mg/l)	SO ₄ -S (mg/l)	I (mg/l)	F (mg/l)	Sr (mg/l)	Conductivity (mS/m)
SSM000008	6.20	6.74	2.62	–	0.360	0.088	24.0
SSM000010	6.00	12.8	4.70	–	0.890	0.116	29.1
SSM000012	17.6	63.1	22.5	–	2.49	0.166	53.6
SSM000014	10.0	63.0	22.8	–	3.13	0.080	26.2
SSM000016	7.40	20.9	7.24	–	2.04	0.072	33.6
SSM000018	71.2	54.1	17.4	–	1.07	0.103	55.2
SSM000020	5.90	55.6	19.0	–	1.84	0.088	22.5
SSM000022	129	122	42.4	0.007	4.20	0.250	116
SSM000024	7.80	7.56	2.52	–	0.830	0.062	10.1
SSM000026	6.90	12.8	4.66	–	0.785	0.049	16.8

Table 6-2. Average concentration of major ions and conductivity in shallow ground water wells in the Laxemar area 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Fe ²⁺ (mg/l)	Fe-tot (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Li (mg/l)	HCO ₃ (mg/l)
SSM000027	2.79	2.84	5.53	1.21	3.80	1.17	0.004	10.2
SSM000029	4.14	4.02	96.7	8.07	19.3	10.0	0.014	201
SSM000030	2.38	2.28	32.9	2.74	73.4	9.30	0.012	258
SSM000031	4.31	4.17	8.43	1.09	13.3	2.90	0.004	43.3
SSM000034	6.92	6.28	74.3	13.1	103	44.8	0.025	530
SSM000035	6.68	6.68	9.87	4.48	18.9	8.13	0.013	66.8
SSM000037	3.61	3.38	48.7	4.32	47.2	8.43	0.017	204
SSM000039	3.05	2.21	6.50	2.44	18.7	4.70	0.009	36.0
SSM000040	14.1	10.6	101	9.73	27.9	19.3	0.016	156
SSM000041	6.68	6.11	11.8	6.31	51.3	10.2	0.018	169
SSM000042	8.34	7.29	67.8	4.71	59.6	13.8	0.011	170
SSM000224	0.241	0.148	26.1	3.54	15.1	3.65	0.004	39.2
SSM000226	0.218	0.178	13.2	2.44	38.9	5.25	0.004	133
SSM000227	–	–	6.50	3.60	13.7	5.30	0.006	
SSM000228	–	–	15.4	2.87	37.0	6.80	0.013	135
SSM000230	–	–	99.6	5.77	32.3	4.70	0.009	38.1
Site number	Cl (mg/l)	SO ₄ (mg/l)	SO ₄ -S (mg/l)	I (mg/l)	F (mg/l)	Sr (mg/l)	Conductivity (mS/m)	
SSM000027	4.53	10.6	3.69	0.005	0.327	0.016	7.93	
SSM000029	83.0	21.5	7.54	0.067	3.09	0.121	67.6	
SSM000030	17.1	46.5	16.4	0.005	2.34	0.279	52.4	
SSM000031	7.93	12.8	4.50	0.005	2.10	10.98	15.3	
SSM000034	105	0.203	0.317	0.042	0.537	0.507	120	
SSM000035	3.97	14.8	5.45	0.005	1.74	0.065	16.9	
SSM000037	29.6	27.5	11.0	0.005	1.93	0.229	48.1	
SSM000039	6.90	14.2	5.21	–	1.32	0.058	14.3	
SSM000040	167	21.6	7.99	–	1.33	0.190	113	
SSM000041	13.2	23.3	8.20	0.005	1.13	0.143	36.2	
SSM000042	80.9	84.5	30.9	0.005	1.00	0.154	77.4	
SSM000224	41.6	15.6	5.65	0.005	2.22	0.060	27.2	
SSM000226	7.85	10.4	3.94	0.005	0.970	0.131	29.7	
SSM000227	9.60	28.1	9.93	–	0.620	0.089	16.3	
SSM000228	7.70	24.6	9.01	–	2.35	0.105	30.8	
SSM000230	180	20.5	8.06	–	0.400	0.143	80.8	

Table 6-3. Samples with a charge balance which deviates more than 10 percent. Sampling in shallow ground water wells at Ävrö, Hålö, the Simpevarp peninsula and the Laxemar area 2005.

Site number	Sampling date	Sample number	Charge balance (%)
SSM000020	2005-05-31	10311	11.11
SSM000024	2005-03-17	10142	18.47
SSM000026	2005-05-31	10314	14.94
SSM000027	2005-06-14	10347	12.24
SSM000031	2005-03-22	10175	26.26
SSM000035	2005-03-30	10206	24.01
SSM000035	2005-09-13	10498	11.51
SSM000035	2005-12-01	10660	10.12
SSM000039	2005-03-22	10177	15.36
SSM000039	2005-06-02	10322	20.30
SSM000226	2005-12-09	10667	12.97

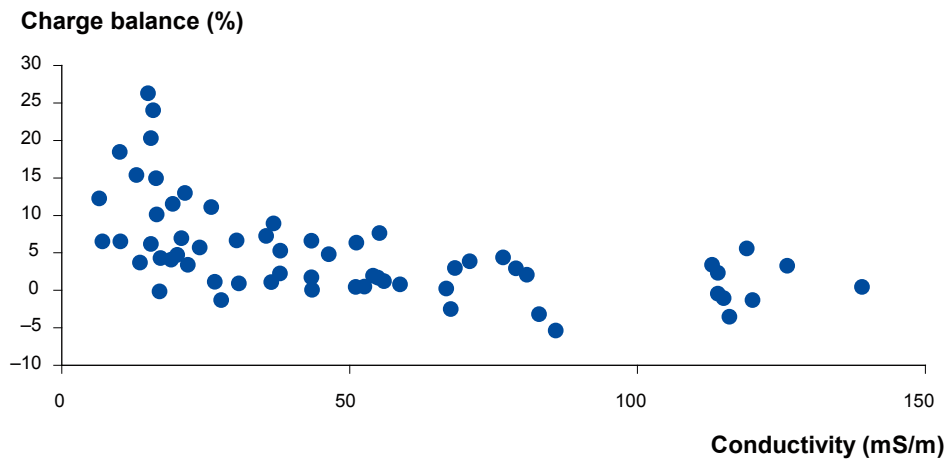


Figure 6-1. Relation of charge balance and conductivity in samples from all ground water wells at Ävrö, Hålö, the Simpevarp peninsula and the Laxemar area in 2005.

6.2 Density

The density of the water in different wells varied throughout the investigation areas (Table 6-3). To a great extent the variation is correlated to the concentration of ions and with the conductivity (Figure 6-2 and Table 6-4). The result from two of the wells (SSM000035 and SSM000041) deviates from the correlation with a density considerably higher than what seems to be motivated by the conductivity.

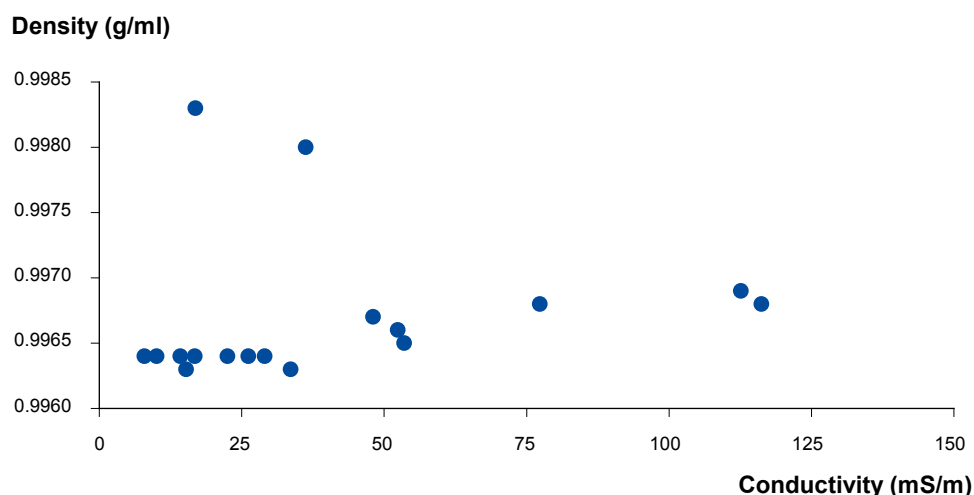


Figure 6-2. Relation of density and conductivity in ground water wells at Ävrö, Hålö, the Simpevarp peninsula and the Laxemar area in March 2005.

Table 6-4. Density of water in shallow ground water wells at Ävrö, Hålö, the Simpevarp peninsula and the Laxemar area. Measurements from March 2005. In some wells measurements were not performed (marked with –).

Site number	Density (g/ml)	Site number	Density (g/ml)
SSM000008	–	SSM000027	0.9964
SSM000010	0.9964	SSM000029	–
SSM000012	0.9965	SSM000030	0.9966
SSM000014	0.9964	SSM000031	0.9963
SSM000016	0.9963	SSM000034	–
SSM000018	–	SSM000035	0.9983
SSM000020	0.9964	SSM000037	0.9967
SSM000022	0.9968	SSM000039	0.9964
SSM000024	0.9964	SSM000040	0.9969
SSM000026	0.9964	SSM000041	0.9980
		SSM000042	0.9968

6.3 Acidification

As with other ions the concentration of HCO_3 varied extensively throughout the investigation areas (Table 5-4). In most wells the average concentration of HCO_3 was higher than 60 mg/l which is termed as a high concentration according to the Swedish Environmental Quality Criteria /Naturvårdsverket 1999/. In two wells (SSM000024 and SSM000027) the concentration of HCO_3 was lower than 30 mg/l which is termed as a low concentration according to the Swedish EQC. In these cases the result is an indication of a problem with acidification in the ground water. The field measurements of pH were in many cases higher than the laboratory measurements (Figure 6-3). In most ground waters the opposite reaction is normal due to a shift in the carbonate system when the gas pressure in the water is equalised prior to the analysis in the laboratory. An explanation to the observed results might be high contents of inorganic manganese and iron which is oxidised when the water is aerated prior to the analysis.

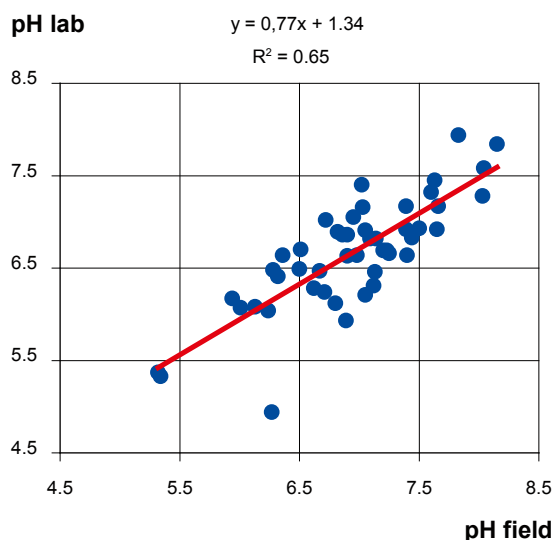


Figure 6-3. Relation of pH measured in the laboratory and in the field in ground water wells at Ävrö, Hålö, the Simpevarp peninsula and the Laxemar area in 2005.

Table 6-5. Average concentration of HCO₃, alkalinity and pH in shallow ground water wells at Ävrö, Hålö, the Simpevarp peninsula and the Laxemar area 2005.

Site number	HCO ₃ (mg/l)	Alkalinity (meq/l)	pH	pH-field	Site number	HCO ₃ (mg/l)	Alkalinity (meq/l)	pH	pH-field
SSM000008	120	1.97	7.0	6.7	SSM000027	10.2	0.17	5.5	5.9
SSM000010	142	2.33	6.7	7.0	SSM000029	201	3.29	6.7	7.0
SSM000012	204	3.34	7.5	7.6	SSM000030	258	4.23	7.1	7.2
SSM000014	34.7	0.57	6.1	6.1	SSM000031	43.3	0.71	6.3	6.8
SSM000016	164	2.69	6.6	6.3	SSM000034	530	8.69	6.9	7.0
SSM000018	78.7	1.29	6.3	–	SSM000035	66.8	1.09	6.5	6.8
SSM000020	34.5	0.56	6.0	6.0	SSM000037	204	3.35	6.9	7.3
SSM000022	284	4.65	7.8	8.0	SSM000039	36.0	0.59	6.1	5.9
SSM000024	29.0	0.48	6.0	6.2	SSM000040	156	2.56	6.7	6.5
SSM000026	56.9	0.93	6.5	6.7	SSM000041	169	2.78	6.9	7.5
					SSM000042	170	2.78	6.9	7.2
					SSM000224	39.2	0.64	6.2	6.9
					SSM000226	133	2.18	7.0	7.5
					SSM000227	–	0.00	4.9	6.3
					SSM000228	135	2.21	6.7	7.2
					SSM000230	38.1	0.62	6.6	6.9

6.4 Environmental metals and trace elements

The results of measurements on environmental metals and trace elements are presented in Tables 6-6 to 6-9. The results varied quite much between the wells but most elements had a strong relation with aluminium, examples are shown in Figure 6-4. This indicates a good quality of the analysis performed. However, in some cases apparent out layers exists indicating pollution, contamination or analytical errors. Two examples are Zn in well SSM000230 (sample number 10673) and U in well SSM000016 (sample number 10309) (Figure 6-5).

Some of the environmental metals can be classified according to the Swedish Environmental Quality Criteria /Naturvårdsverket 1999/. According to these criteria's the concentration of As, Cd and Zn was low to moderately high in the different wells. These results are what to be expected in an unpolluted area. However, the concentration of Pb were high ($> 3\mu\text{g/l}$) or very high ($> 10\mu\text{g/l}$) in some of the wells (Figure 6-6). This could be an indication of some kind of pollution but since the relation to aluminium is similar to most other elements the high concentration of Pb in some of the wells can probably be explained as a natural composition of the mineral in the Simpevarp area.

Table 6-6. Average concentration of environmental metals in shallow ground water wells at Ävrö, Hålö and the Simpevarp peninsula 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Al ($\mu\text{g/l}$)	As ($\mu\text{g/l}$)	Ba ($\mu\text{g/l}$)	Cd ($\mu\text{g/l}$)	Cr ($\mu\text{g/l}$)	Cu ($\mu\text{g/l}$)	Co ($\mu\text{g/l}$)
SSM000008	1,600	–	43.4	0.0698	2.91	9.57	1.01
SSM000010	2,520	–	60.7	0.0275	4.33	8.80	1.98
SSM000012	902	–	46.5	0.0200	1.41	5.41	0.612
SSM000014	3,910	–	63.2	0.0651	5.14	12.0	4.26
SSM000016	4,040	–	92.1	0.0433	12.2	12.9	3.02
SSM000018	4,490	–	88.6	0.0895	9.64	24.7	4.02
SSM000020	4,650	–	77.8	0.102	7.96	12.1	3.84
SSM000022	905	0.50	41.0	0.0161	2.01	2.13	0.675
SSM000024	–	–	–	–	–	–	–
SSM000026	2,360	–	31.3	0.0279	3.73	7.13	1.52
Site number	Hg ($\mu\text{g/l}$)	Ni ($\mu\text{g/l}$)	Mo ($\mu\text{g/l}$)	Pb ($\mu\text{g/l}$)	V ($\mu\text{g/l}$)	Zn ($\mu\text{g/l}$)	
SSM000008	0.0024	2.34	0.263	1.71	3.65	7.23	
SSM000010	<i>0.0020</i>	3.03	0.510	3.02	5.95	14.3	
SSM000012	<i>0.0020</i>	4.80	3.11	2.53	3.47	14.8	
SSM000014	<i>0.0020</i>	10.5	0.681	13.9	10.3	17.9	
SSM000016	<i>0.0020</i>	6.64	1.09	5.45	10.7	20.9	
SSM000018	<i>0.0020</i>	14.7	2.21	5.47	12.6	22.5	
SSM000020	<i>0.0020</i>	11.6	0.418	5.66	10.7	22.0	
SSM000022	<i>0.0020</i>	1.83	9.39	1.10	3.57	6.13	
SSM000024	–	–	–	–	–	–	
SSM000026	<i>0.0020</i>	3.24	0.545	2.65	7.13	12.4	

Table 6-7. Average concentration of environmental metals in shallow ground water wells in the Laxemar area 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Al (µg/l)	As (µg/l)	Ba (µg/l)	Cd (µg/l)	Cr (µg/l)	Cu (µg/l)	Co (µg/l)
SSM000027	1,139	0.60	31.3	0.0148	2.15	4.46	2.23
SSM000029	2,990	0.20	68.9	0.0589	7.91	4.48	2.21
SSM000030	1,070	0.20	47.4	0.0269	2.82	1.94	0.846
SSM000031	781	0.20	21.0	0.0170	2.17	1.02	0.286
SSM000034	350	<i>0.10</i>	101	0.00870	1.10	1.73	0.278
SSM000035	3,715	0.60	65.7	0.0685	4.53	8.32	3.37
SSM000037	1,913	0.70	49.8	0.0286	3.81	4.23	1.55
SSM000039	5,570	–	60.4	0.0354	5.99	15.1	4.04
SSM000040	2,200	0.40	50.2	0.0970	7.20	7.71	1.39
SSM000041	4,790	1.10	70.0	0.0358	9.32	11.0	4.49
SSM000042	3,473	1.00	109	0.0800	11.6	21.4	3.78
SSM000224	534	<i>0.10</i>	30.1	0.0373	1.20	9.63	2.65
SSM000226	944	0.60	30.6	0.0178	1.78	7.49	1.04
SSM000227	3,960	–	81.9	0.244	4.70	8.84	5.68
SSM000228	1,090	–	32.4	0.00990	2.60	1.29	1.11
SSM000230	1,000	–	24.5	0.0543	2.06	28.6	0.688
Site number	Hg (µg/l)	Ni (µg/l)	Mo (µg/l)	Pb (µg/l)	V (µg/l)	Zn (µg/l)	
SSM000027	<i>0.0020</i>	2.83	0.492	1.40	4.93	6.05	
SSM000029	<i>0.0020</i>	4.35	3.27	5.70	18.6	18.2	
SSM000030	0.0020	1.74	0.679	1.69	9.41	8.92	
SSM000031	<i>0.0020</i>	0.749	0.248	0.855	8.73	4.86	
SSM000034	<i>0.0025</i>	1.11	0.123	0.835	1.46	5.88	
SSM000035	<i>0.0020</i>	4.11	1.47	8.67	19.1	23.4	
SSM000037	<i>0.0020</i>	3.06	2.19	2.84	8.25	13.4	
SSM000039	<i>0.0020</i>	6.45	0.204	12.3	15.7	30.5	
SSM000040	<i>0.0020</i>	4.43	1.09	4.44	15.5	21.9	
SSM000041	<i>0.0020</i>	9.74	0.583	7.45	16.0	24.6	
SSM000042	<i>0.0020</i>	7.33	2.00	6.23	14.0	21.3	
SSM000224	<i>0.0023</i>	5.68	0.969	0.613	0.629	7.43	
SSM000226	<i>0.0048</i>	2.91	1.35	0.890	2.37	4.49	
SSM000227	0.0046	6.18	0.104	2.84	3.93	32.1	
SSM000228	<i>0.0020</i>	2.02	4.14	1.96	7.18	8.79	
SSM000230	0.0059	4.70	5.98	2.48	6.83	49.1	

Table 6-8. Average concentration of trace elements in shallow ground water wells at Ävrö, Hälö and the Simpevarp peninsula 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	U (µg/l)	Th (µg/l)	Sc (µg/l)	Rb (µg/l)	Y (µg/l)	Zr (µg/l)	In (µg/l)	Sb (µg/l)	Cs (µg/l)
SSM000008	3.06	0.740	0.805	5.83	7.08	2.33	–	0.159	0.375
SSM000010	7.62	1.68	0.893	8.98	10.0	3.69	–	0.103	0.580
SSM000012	2.30	1.30	0.232	6.60	3.38	3.50	–	0.151	0.173
SSM000014	7.12	2.00	0.861	11.2	8.76	4.30	–	0.0774	0.640
SSM000016	27.6	2.37	1.00	17.9	8.56	3.67	–	0.148	1.12
SSM000018	5.95	2.16	1.34	41.9	12.0	6.60	–	0.286	0.804
SSM000020	1.92	2.25	1.29	17.6	13.8	4.79	–	0.129	0.682
SSM000022	5.28	0.548	0.204	4.58	2.02	2.07	0.050	0.0493	0.224
SSM000024	–	–	–	–	–	–	–	–	–
SSM000026	1.00	1.24	0.727	7.33	9.69	3.88	–	0.128	0.431
Site number	La (µg/l)	Hf (µg/l)	Tl (µg/l)	Ce (µg/l)	Pr (µg/l)	Nd (µg/l)	Sm (µg/l)	Eu (µg/l)	
SSM000008	10.1	0.0743	0.0468	21.4	2.32	9.05	1.57	0.284	
SSM000010	19.9	0.122	0.0627	23.3	4.25	16.6	2.68	0.382	
SSM000012	4.01	0.102	0.0364	8.16	0.921	3.53	0.620	0.100	
SSM000014	15.8	0.126	0.0742	31.3	3.76	14.7	2.48	0.423	
SSM000016	19.3	0.112	0.106	25.2	4.34	15.4	2.60	0.432	
SSM000018	24.8	0.215	0.114	39.9	5.53	21.9	3.64	0.622	
SSM000020	25.3	0.142	0.118	47.4	6.47	24.8	4.36	0.637	
SSM000022	3.60	0.0526	0.0207	5.85	0.843	3.18	0.522	0.0793	
SSM000024	–	–	–	–	–	–	–	–	
SSM000026	18.7	0.124	0.0589	37.4	4.46	17.5	2.87	0.493	
Site number	Gd (µg/l)	Tb (µg/l)	Dy (µg/l)	Ho (µg/l)	Er (µg/l)	Tm (µg/l)	Yb (µg/l)	Lu (µg/l)	
SSM000008	1.41	0.179	1.05	0.207	0.581	0.0756	0.532	0.0696	
SSM000010	2.45	0.287	1.50	0.290	0.775	0.111	0.620	0.117	
SSM000012	0.588	0.0857	0.461	0.105	0.315	0.0491	0.313	0.0599	
SSM000014	2.12	0.262	1.40	0.266	0.787	0.110	0.730	0.124	
SSM000016	2.14	0.276	1.45	0.269	0.698	0.103	0.657	0.106	
SSM000018	3.13	0.396	2.04	0.403	1.05	0.151	0.949	0.161	
SSM000020	3.55	0.460	2.38	0.446	1.19	0.161	1.05	0.162	
SSM000022	0.448	0.0710	0.316	0.0650	0.175	0.0245	0.150	0.0264	
SSM000024	–	–	–	–	–	–	–	–	
SSM000026	2.51	0.313	1.67	0.325	0.900	0.133	0.846	0.146	

Table 6-9. Average concentration of trace elements in shallow ground water wells in the Laxemar area 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	U (µg/l)	Th (µg/l)	Sc (µg/l)	Rb (µg/l)	Y (µg/l)	Zr (µg/l)	In (µg/l)	Sb (µg/l)	Cs (µg/l)
SSM000027	1.03	0.827	0.360	4.40	7.01	1.01	0.050	0.0409	0.181
SSM000029	1.63	2.99	0.934	12.2	9.47	7.98	0.050	0.0292	0.470
SSM000030	0.770	1.07	0.291	7.02	2.32	3.10	0.050	0.0345	0.725
SSM000031	0.885	1.01	0.389	2.95	6.68	1.64	0.050	0.0392	0.133
SSM000034	0.125	0.379	0.113	3.37	0.752	1.01	0.050	0.0307	0.0816
SSM000035	3.53	5.04	1.10	12.3	17.7	4.76	0.050	0.0533	0.658
SSM000037	2.04	1.82	0.454	7.04	6.39	3.00	0.050	0.0493	0.633
SSM000039	4.93	5.33	1.38	13.4	24.0	5.51	–	0.120	1.38
SSM000040	3.24	0.972	0.517	11.5	5.75	3.02	0.050	0.101	0.503
SSM000041	1.57	3.56	1.40	18.1	11.7	5.18	0.050	0.0568	0.881
SSM000042	3.09	3.27	1.36	13.1	14.5	4.12	0.050	0.0448	1.87
SSM000224	3.75	0.516	0.314	7.21	6.55	1.25	0.050	0.111	0.106
SSM000226	4.63	0.418	0.280	5.45	7.45	1.44	0.050	0.202	0.238
SSM000227	1.21	0.303	0.195	13.4	8.15	1.84	–	0.109	0.310
SSM000228	4.74	1.47	0.529	4.72	9.73	4.07	–	0.0798	0.355
SSM000230	1.59	0.357	0.179	12.1	5.05	1.49	–	0.405	0.202
Site number	La (µg/l)	Hf (µg/l)	Tl (µg/l)	Ce (µg/l)	Pr (µg/l)	Nd (µg/l)	Sm (µg/l)	Eu (µg/l)	
SSM000027	14.8	0.0444	0.0342	33.5	3.63	14.6	2.31	0.365	
SSM000029	13.5	0.274	0.0562	29.9	3.51	13.4	2.36	0.356	
SSM000030	4.70	0.0747	0.0253	8.99	1.06	3.85	0.665	0.117	
SSM000031	12.0	0.0684	0.0155	28.2	3.48	14.0	2.42	0.404	
SSM000034	1.15	0.0267	0.00867	2.45	0.284	1.04	0.183	0.0223	
SSM000035	34.3	0.180	0.0804	62.1	7.95	29.2	4.82	0.712	
SSM000037	17.1	0.0946	0.0445	25.2	3.33	12.2	1.88	0.288	
SSM000039	78.1	0.155	0.110	96.4	16.6	59.0	9.24	1.51	
SSM000040	10.7	0.0956	0.0437	20.0	2.35	8.77	1.52	0.236	
SSM000041	25.6	0.163	0.107	50.1	6.42	23.6	3.98	0.608	
SSM000042	36.0	0.145	0.0861	46.9	7.69	29.1	4.62	0.671	
SSM000224	8.18	0.0493	0.00975	16.3	2.22	8.45	1.50	0.253	
SSM000226	14.8	0.0479	0.0336	10.1	3.22	12.2	1.91	0.285	
SSM000227	19.8	0.0790	0.0688	29.6	4.59	16.3	2.68	0.451	
SSM000228	14.7	0.140	0.0218	22.4	3.24	12.9	2.08	0.349	
SSM000230	10.1	0.0554	0.0259	14.0	2.12	7.95	1.28	0.218	
Site number	Gd (µg/l)	Tb (µg/l)	Dy (µg/l)	Ho (µg/l)	Er (µg/l)	Tm (µg/l)	Yb (µg/l)	Lu (µg/l)	
SSM000027	1.94	0.216	1.17	0.221	0.620	0.0870	0.608	0.0883	
SSM000029	2.03	0.269	1.54	0.303	0.875	0.125	0.844	0.129	
SSM000030	0.564	0.0789	0.414	0.0824	0.229	0.0353	0.211	0.0370	
SSM000031	1.91	0.213	1.09	0.209	0.574	0.0765	0.519	0.0822	
SSM000034	0.146	0.0500	0.112	0.0205	0.0646	0.00750	0.0647	0.0368	
SSM000035	3.97	0.514	2.80	0.543	1.45	0.192	1.20	0.187	
SSM000037	1.62	0.190	0.986	0.185	0.489	0.0633	0.401	0.0575	
SSM000039	7.25	0.855	4.28	0.763	1.89	0.232	1.55	0.222	

SSM000040	1.24	0.156	0.883	0.166	0.492	0.0695	0.481	0.0746
SSM000041	3.11	0.391	2.05	0.394	1.09	0.147	0.926	0.147
SSM000042	3.85	0.467	2.36	0.450	1.19	0.151	0.943	0.140
SSM000224	1.27	0.158	0.926	0.185	0.558	0.0826	0.569	0.0891
SSM000226	1.67	0.179	0.941	0.179	0.470	0.0573	0.358	0.0481
SSM000227	2.10	0.255	1.39	0.261	0.686	0.0935	0.592	0.0847
SSM000228	1.97	0.225	1.29	0.272	0.800	0.107	0.719	0.123
SSM000230	1.15	0.133	0.706	0.140	0.387	0.0508	0.306	0.0531

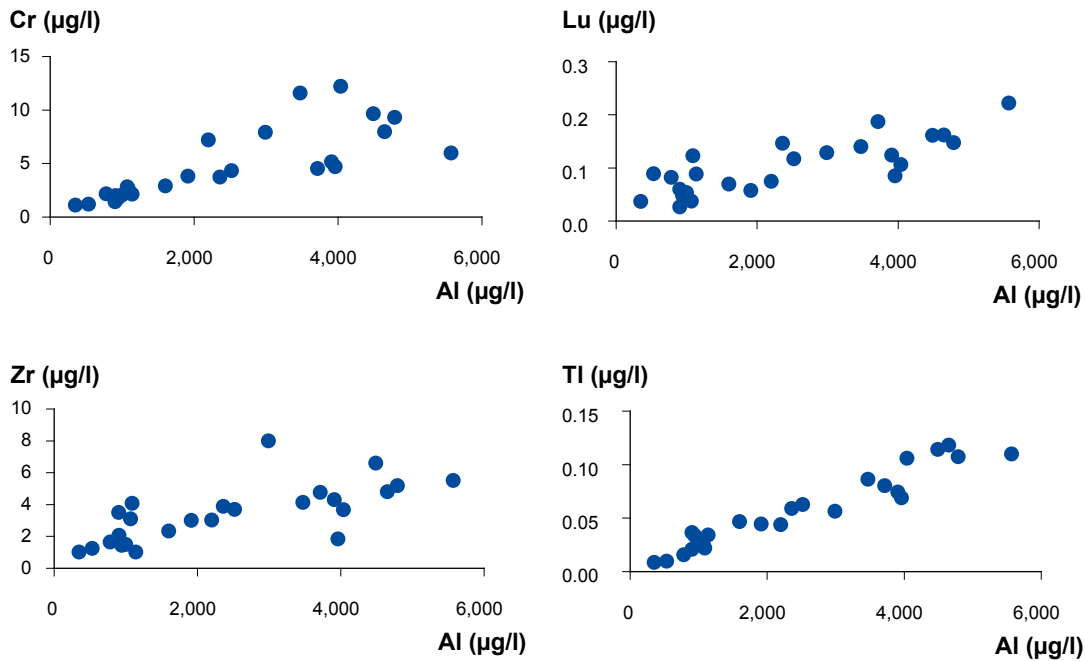


Figure 6-4. Relations between concentrations of Al and some other elements in ground water wells at Ävrö, Hälö, the Simpevarp peninsula and the Laxemar area 2005.

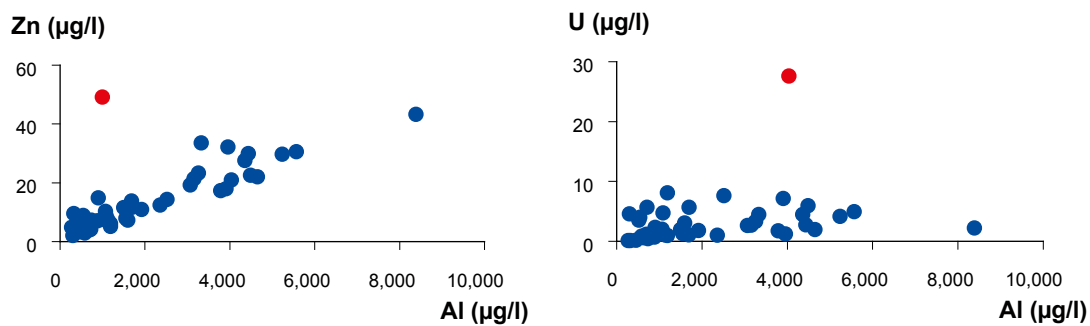


Figure 6-5. Relations between concentrations of Al and Zn and Al and U in ground water wells at Ävrö, Hälö, the Simpevarp peninsula and the Laxemar area 2005. Out layers are marked red.

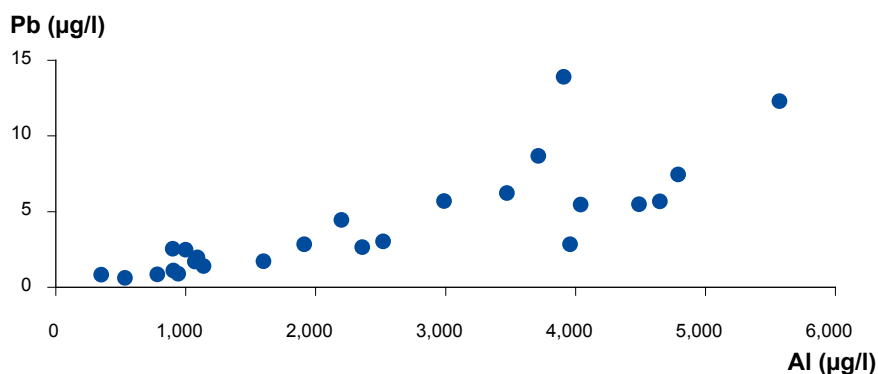


Figure 6-6. Relations between concentrations of Al and Pb in ground water wells at Ävrö, Hålö, the Simpevarp peninsula and the Laxemar area 2005.

6.5 Isotopes

The results of the measurements of isotopes are presented in Table 6-10 to Table 6-13. The average ratios of boron, strontium and oxygen ($^{10}\text{B}/^{11}\text{B}$, $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{18}\text{O}$) were similar in most wells and there seems to be low variation in the two investigated areas. The isotopes of $\delta^{37}\text{Cl}$, $\delta^{13}\text{C}$, ^{14}C and $\delta^{34}\text{S}$ varied more between the different wells with the greatest variation in $\delta^{34}\text{S}$.

The average hydrogen isotope ratios of $\delta^2\text{H}$ and ^3H had similar values in most wells. However the well SSM000022 differed with a markedly lower ratio for ^3H . The ratios of $\delta^2\text{H}$ correlate well with the ratios of $\delta^{18}\text{O}$ (Figure 6-7). The linear relation differ markedly from the “Global Meteoric Line” ($\delta^2\text{H} = 8 \cdot \delta^{18}\text{O} + 10$) which is based on precipitation data.

The concentration of ^{238}U , ^{234}U and ^{230}Th varied quite much between the wells in the investigation areas. The wells SSM000022, SSM000224 and SSM000226 had considerably higher concentrations of both uranium isotopes. The wells SSM000030 and SSM00035 had notably higher concentration of ^{230}Th than most other wells.

The concentration of ^{226}Ra was close to the reporting limit in most wells and there seems to be little variation in the investigation areas. The activity of ^{222}Rn varied to some extent but all values measured can (according to the Swedish Radiation Protection Authority) be considered as normal background values for shallow ground water /Swedish Radiation Protection Authority, 2005/.

Table 6-10. Average ratio of isotopes in shallow ground water wells at Ävrö, Hålö and the Simpevarp peninsula 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis. Measurements not performed is marked with –.

Site number	^{14}C (pMC)	$\delta^{13}\text{C}$ (‰ PDB)	$\delta^{34}\text{S}$ (‰ CDT)	$^{10}\text{B}/^{11}\text{B}$ (atomic)	$\delta^{37}\text{Cl}$ (‰ SMOC)	$^{87}\text{Sr}/^{86}\text{Sr}$ (ratio)	$\delta^2\text{H}$ (‰ VSMOW)	^3H (TU)	$\delta^{18}\text{O}$ (‰ VSMOW)
SSM000008	–	–	–	–	–	–	–83.9	11.7	–11.7
SSM000010	–	–	–	–	–	–	–80.3	13.7	–11.4
SSM000012	–	–	–	–	–	–	–75.9	9.1	–10.6
SSM000014	–	–	–	–	–	–	–76.0	14.4	–10.7
SSM000016	–	–	–	–	–	–	–83.4	12.1	–11.4
SSM000018	–	–	–	–	–	–	–80.3	11.4	–11.3
SSM000020	–	–	–	–	–	–	–78.4	11.8	–10.9
SSM000022	48.6	–12.1	25.4	0.2390	0.16	0.7158	–77.7	1.9	–10.8
SSM000024	–	–	–	–	–	–	–81.7	13.9	–10.8
SSM000026	–	–	–	–	–	–	–78.8	13.8	–10.8

Table 6-11. Average ratio of isotopes in shallow ground water wells in the Laxemar area 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis. Measurements not performed is marked with –.

Site number	¹⁴ C (pmC)	δ ¹³ C (‰ PDB)	δ ³⁴ S (‰ CDT)	¹⁰ B/ ¹¹ B (atomic)	δ ³⁷ Cl (‰ SMOC)	⁸⁷ Sr/ ⁸⁶ Sr (ratio)	δ ² H (‰ VSMOW)	³ H (TU)	δ ¹⁸ O (‰ VSMOW)
SSM000027	–	–	–5.1	0.2411	–0.12	0.7179	–78.6	9.8	–10.9
SSM000029	84.8	–17.9	27.3	0.2422	0.13	0.7175	–78.6	9.7	–11.1
SSM000030	68.0	–15.4	12.3	0.2421	0.15	0.7150	–78.3	9.5	–11.0
SSM000031			1.4	0.2402	–0.03	0.7198	–78.0	10.7	–11.0
SSM000034	106	–15.6		0.2445	–0.79	0.7117	–79.0	15.0	–11.0
SSM000035	84.7	–21.9	6.4	0.2450	–0.14	0.7328	–78.5	11.3	–10.9
SSM000037	69.0	–17.8	14.6	0.2408	0.03	0.7172	–78.2	7.9	–11.1
SSM000039	–	–	–	–	–	–	–81.0	10.8	–11.5
SSM000040	–	–	–	0.2370	–	–	–78.4	12.0	–10.9
SSM000041	69.2	–16.7	8.1	0.2427	–0.23	0.7197	–78.4	11.0	–10.8
SSM000042	77.0	–17.5	0.7	0.2394	–0.03	0.7182	–78.1	8.9	–10.9
SSM000224	–	–	2.8	0.2416	0.17	0.7215	–78.1	10.8	–11.0
SSM000226	62.8	–14.5	3.5	0.2399	–0.04	0.7179	–76.7	11.4	–10.9
SSM000227	–	–	27.1	0.2420	–0.23	–	–74.9	13.5	–10.9
SSM000228	–	–	–5.7	0.2433	–0.03	–	–78.2	12.1	–11.2
SSM000230	–	–	0.7	0.2469	–0.14	–	–75.7	13.0	–10.8

Table 6-12. Average concentration of radioactive isotopes in shallow ground water wells at Ävrö, Hålö and the Simpevarp peninsula 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis. Measurements not performed is marked with –.

Site number	²²⁶ Ra (Bq/l)	²²² Rn (Bq/l)	²³⁸ U (mBq/kg)	²³⁴ U (mBq/kg)	²³⁰ Th (mBq/kg)
SSM000008	–	–	–	–	–
SSM000010	–	–	–	–	–
SSM000012	–	–	–	–	–
SSM000014	–	–	–	–	–
SSM000016	–	–	–	–	–
SSM000018	–	–	–	–	–
SSM000020	–	–	–	–	–
SSM000022	0.0690	7.70	57.6	83.9	1.10
SSM000024	–	–	–	–	–
SSM000026	–	–	–	–	–

Table 6-13. Average concentration of radioactive isotopes in shallow ground water wells in the Laxemar area 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis. Measurements not performed is marked with –.

Site number	²²⁶ Ra (Bq/l)	²²² Rn (Bq/l)	²³⁸ U (mBq/kg)	²³⁴ U (mBq/kg)	²³⁰ Th (mBq/kg)
SSM000027	0.0310	10.1	8.50	9.70	4.20
SSM000029	<i>0.0300</i>	7.26	11.8	11.2	9.90
SSM000030	0.0490	14.1	20.6	25.1	14.0
SSM000031	0.0460	15.3	6.50	7.70	2.30
SSM000034	<i>0.0300</i>	2.75	1.10	1.10	1.50
SSM000035	0.110	12.0	23.9	29.0	12.6
SSM000037	0.0330	11.6	22.0	31.7	7.70
SSM000039	–	–	–	–	–
SSM000040	–	–	–	–	–
SSM000041	0.0750	8.80	12.9	14.1	5.70
SSM000042	0.101	11.7	21.4	25.9	4.10
SSM000224	0.0410	<i>0.894</i>	48.8	54.9	5.00
SSM000226	0.0950	10.8	99.4	124	4.00
SSM000227	–	–	–	–	–
SSM000228	–	–	–	–	–
SSM000230	–	–	–	–	–

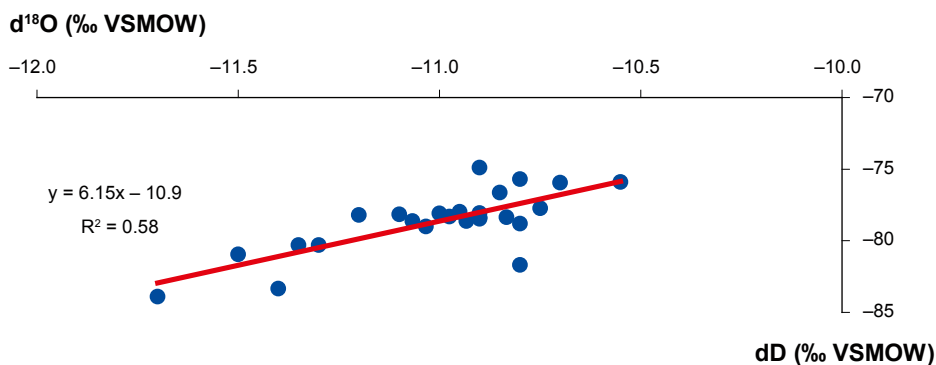


Figure 6-7. The relationship between the ratios of $\delta^2\text{H}$ and $\delta^{18}\text{O}$ in ground water wells at Ävrö, Hålö, the Simpevarp peninsula and the Laxemar area 2005.

6.6 Other substances

The concentration of nitrate varied with considerable higher concentration in some of the wells (Table 6-14 and Table 6-15). According to the Swedish Environmental Quality Criteria /Naturvårdsverket 1999/ the concentration of nitrate was moderately high (1–5 $\mu\text{g/l}$) in these wells. These results might indicate leakage from the surrounding farmland areas. Likewise the concentration of $\text{NH}_4\text{-N}$, phosphorus, silica and sulphur varied with considerably higher values in some of the wells. The concentration of carbon (TOC and DOC) varied with results between 4 and 13 $\mu\text{g/l}$ in most wells (Table 6-14 and 6-15). In one well (SSM000227) a value of 21.7 mg/l was recorded. This must be termed as a high concentration in ground water which is similar to the surface waters in the area /Ericsson and Engdahl 2004/. An analytical error might be evident in that sample though since the concentration of DOC (dissolved organic carbon) was the same as the concentration of TOC (total organic carbon) at the same time as POC (particulate organic carbon) was as high as 8.22 mg/l .

Table 6-14. Average concentration of nitrogen and phosphorus compounds, silica, sulphur and carbon in shallow ground water wells at Ävrö, Hålö and Simpevarp peninsula 2005. The values on $\text{NH}_4\text{-N}$ and sulphide are averages from two measurements. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis. Measurements not performed is marked with –.

Site number	$\text{NO}_2\text{-N}$ (mg/l)	$\text{NO}_3\text{-N}$ (mg/l)	$\text{NO}_2/\text{NO}_3\text{-N}$ (mg/l)	$\text{NH}_4\text{-N}$ (mg/l)	N-tot (mg/l)	$\text{PO}_4\text{-P}$ (mg/l)
SSM000008	–	–	–	0.0062	–	–
SSM000010	–	–	–	0.0399	–	–
SSM000012	–	–	–	0.1870	–	–
SSM000014	–	–	–	0.0854	–	–
SSM000016	–	–	–	<i>0.0030</i>	–	–
SSM000018	–	–	–	0.0067	–	–
SSM000020	–	–	–	0.0198	–	–
SSM000022	0.0028	0.0179	0.0207	0.6877	1.3000	0.0194
SSM000024						
SSM000026				0.0669		
Site number	P-tot (mg/l)	Si (mg/l)	Sulfide (mg/l)	TOC (mg/l)	DOC (mg/l)	POC (mg/l)
SSM000008	0.0396	9.33	0.0030	–	–	–
SSM000010	0.0858	11.7	0.0110	–	–	–
SSM000012	0.0478	10.4	0.0040	–	–	–
SSM000014	0.0978	17.9	0.0060	–	–	–
SSM000016	0.1680	12.3	<i>0.0020</i>	–	–	–
SSM000018	0.2960	18.4	0.0070	–	–	–
SSM000020	0.1230	13.3	0.0040	–	–	–
SSM000022	0.0630	7.68	0.0155	7.20	7.15	1.30
SSM000024	–	10.7	–	–	–	–
SSM000026	0.0803	10.9	0.0070	–	–	–

Table 6-15. Average concentration of nitrogen and phosphorus compounds, silica, sulphur and carbon in shallow ground water wells in the Laxemar area 2005. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis. Measurements not performed is marked with –.

Site number	NO ₂ -N (mg/l)	NO ₃ -N (mg/l)	NO ₂ /NO ₃ -N (mg/l)	NH ₄ -N (mg/l)	N-tot (mg/l)	PO ₄ -P (mg/l)
SSM000027	0.0004	0.0516	0.0520	0.0551		0.0007
SSM000029	0.0039	<i>0.0061</i>	0.0100	0.8633	2.2100	0.0383
SSM000030	0.0010	0.0137	0.0147	1.3487	2.6600	0.0139
SSM000031	<i>0.0004</i>	<i>0.0004</i>	0.0007	0.0371	0.3160	0.0014
SSM000034	<i>0.0002</i>	<i>0.0003</i>	<i>0.0003</i>	0.2873	0.8440	0.0060
SSM000035	0.0010	0.0072	0.0082	0.4306	0.3580	0.0027
SSM000037	0.0004	0.0036	0.0040	0.2370	0.6310	0.0050
SSM000039	–	–	–	<i>0.0030</i>	–	–
SSM000040	–	–	–	0.6840	–	–
SSM000041	<i>0.0005</i>	0.0007	0.0011	0.3445	0.7850	0.0024
SSM000042	<i>0.0014</i>	0.0169	0.0181	0.3100	0.6660	0.0047
SSM000224	0.0064	0.1469	0.1532	0.0012	0.3440	0.0009
SSM000226	0.0047	1.3644	1.3711	0.0539	5.0100	0.0139
SSM000227	0.0027	4.2100	4.2100	0.0175	5.0800	0.0024
SSM000228	<i>0.0002</i>	0.0012	0.0012	0.2190	0.6060	0.0005
SSM000230	0.0002	4.0100	4.0100	0.1100	8.8700	0.1500
Site number	P-tot (mg/l)	Si (mg/l)	Sulfide (mg/l)	TOC (mg/l)	DOC (mg/l)	POC (mg/l)
SSM000027	0.0524	8.75	<i>0.0020</i>	4.2	4.5	
SSM000029	0.1757	17.1	0.0365	11.4	11.7	3.84
SSM000030	0.2340	12.4	0.0055	8.9	8.5	4.86
SSM000031	0.0233	8.54	0.0040	9.4	9.6	0.60
SSM000034	0.1012	15.7	0.0080	7.2	7.2	1.60
SSM000035	0.1870	24.0	0.0040	5.5	4.9	2.41
SSM000037	0.1047	15.4	0.0070	6.7	6.6	1.14
SSM000039	0.2560	17.0	0.0050	–	–	–
SSM000040	0.1955	16.9	–	–	–	–
SSM000041	0.4050	25.4	0.0030	10.5	10.3	3.45
SSM000042	0.1757	16.9	0.0055	7.2	7.0	1.05
SSM000224	0.0058	7.36	0.0060	8.2	7.9	0.03
SSM000226	0.0226	7.74	0.0020	12.8	12.4	0.47
SSM000227	0.0508	13.3	–	21.7	21.7	8.22
SSM000228	0.0455	13.1	–	12.9	11.9	0.27
SSM000230	1.7300	15.6	–	13.3	12.0	0.99

7 References

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Sites, co-ordinates and sampling depths

Sites, sample depths and location co-ordinates at the Ävrö, Hälö and Simpevarp area 2005

ID-code	Co-ordinate X	Co-ordinate Y	Sampling depth (m)
SSM000008	6365431	1550751	3–5
SSM000010	6365447	1550748	2–3
SSM000012	6366645	1552435	5–6
SSM000014	6366286	1550813	2–3
SSM000016	6367372	1552222	2–3
SSM000018	6367038	1552192	2–3
SSM000020	6367186	1552743	2–3
SSM000022 ¹	6367458	1553120	5–7
SSM000024	6366790	1553084	1.8–3.8
SSM000026	6366715	1552749	2–4

¹ The only sampled water well in the Ävrö, Hälö an Simpevarp area from September 2005 and forward.

Sites, sample depths and location co-ordinates at the Laxemar area 2005

ID-code	Co-ordinate X	Co-ordinate Y	Sampling depth (m)
SSM000027	6370909	1544779	3–5
SSM000028 ¹	6369643	1546933	–
SSM000029	6368976	1548879	5–7
SSM000030	6367908	1546986	4–5
SSM000031	6368133	1548563	3–4
SSM000032 ¹	6367971	1549397	–
SSM000033 ¹	6368095	1549884	–
SSM000034	6368090	1550123	3–4
SSM000035	6365138	1540387	3–4
SSM000037	6367186	1547490	3–4
SSM000039	6366620	1549136	3–5
SSM000040	6366207	1550351	2–3
SSM000041	6365332	1548655	2–4
SSM000042	6365541	1549488	3–5
SSM000224 ²	6368092	1548667	16–17
SSM000226 ²	6367696	1549790	4–5
SSM000227 ³	6367693	1549788	1–2
SSM000228 ³	6366504	1548718	6–7
SSM000230 ³	6366220	1550069	4–5

¹ Omitted from september 2005.

² Sampling started in September 2005.

³ Sampling started December 2005.

Schedule – Sampling of shallow ground water 2005

Sampling occasions and programmes at the Ävrö, Hålö and Simpevarp area 2005¹

Month Programme	March Week number	May/June	September	December
Chemical class 3	11–12			
Chemical class 5 reduced		22		
Chemical class 5 reduced new				50
Chemical class 5 full			37	

¹ Only one water well sampled in the Ävrö, Hålö and Simpevarp area from September 2005 and forward (SSM000022).

Sampling occasions and programmes at the Laxemar area 2005

Month Programme	March Week number	May/June	September	November/December
Chemical class 3	11–13			
Chemical class 5 reduced		22–24		
Chemical class 5 reduced new				48–50
Chemical class 5 full			36–38	

Components sampled and analysed at the different sites and sampling occasions at the Ävrö, Hålö and Simpevarp area 2005

ID-code	Chemical class 3 week 11–12 (Mars)	Chemical class 5 reduced week 22 (May/June)
SSM000008	No samples	Complete, and control of Br and cations
SSM000010	Complete	Complete
SSM000012	Complete, and control of Br and cations	Complete
SSM000014	Complete	Complete
SSM000016	Complete	Complete
SSM000018	No samples	Complete
SSM000020	Complete	Complete
SSM000022	Complete	Complete
SSM000024	Complete	Data not quality approved (high ion balance)
SSM000026	Complete	Complete
ID-code	Chemical class 5 full week 37 (September)	Chemical class 5 reduced new week 50 (December)
SSM000022	Complete, and control of Br and cations	Complete, and control of Br and cations

Components sampled and analysed at the different sites and sampling occasions at the Laxemar area 2005

ID-code	Chemical class 3 week 12–13 (Mars)	Chemical class 5 – reduced week 22 and 24 (June)
SSM000027	Complete	Complete
SSM000028	No samples	No samples
SSM000029	No samples	Complete, and control of Br and cations
SSM000030	Complete	Complete
SSM000031	Complete	Complete
SSM000032	No samples	No samples
SSM000033	No samples	No samples
SSM000034	No samples	Complete
SSM000035	Complete	Only pH, alkalinity, conductivity and Fe
SSM000037	Complete	Complete
SSM000039	Complete	Complete
SSM000040	Complete	Complete, except for S ₂ ⁻
SSM000041	Complete	Data not quality approved (high ion balance)
SSM000042	Complete	Complete
ID-code	Chemical class 5 – full week 36–38 (September)	Chemical class 5 – reduced (new) week 48–50 (November–December)
SSM000027	Complete, and control of Br and cations	Complete, except alkalinity
SSM000029	Complete	Complete
SSM000030	Complete	Complete, and control of Br and cations
SSM000031	Complete, except PMC	Complete
SSM000034	Complete, except S-34	Complete
SSM000035	Complete	Complete
SSM000037	Complete	Complete
SSM000039	No samples	No samples
SSM000040	pH, conductivity, alkalinity, anions, cations, lantanoides, environmental metals, trace elements, As, In, I, B-10, O-18, Deuterium	No samples
SSM000041	Complete	Complete
SSM000042	Complete	Complete
SSM000224	Complete	Complete
SSM000226	Complete	Complete
SSM000227	No samples	Complete
SSM000228	–	Complete
SSM000230	–	Complete