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Oskarshamn site investigation

Monitoring of surface water chemistry 2008

Ulf Ericsson
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November 2009

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Abstract

Within the site investigation area at Oskarshamn surface water has been sampled from November 2002. After a period of two years with basic sampling the program for sampling was changed in 2005 to a program for monitoring in some of the sites. In 2008 sampling has been conducted at totally 11 sites. Seven of these were sites in streams, one was a site in a lake and three were sites at sea in the inner coastal area. Sampling was performed on twelve occasions in 2008 and the water was analysed for a large number of parameters. In the lake and at sea vertical measurements were also taken by a multi parameter sonde. All data collected has after an initial control been sent to SKB for storage in their database SICADA.

In this report the results from 2008 was evaluated. The results were similar to the results obtained previous years /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, b, Ericsson and Engdahl 2009/.

The data gathered are generally considered to be of high quality but the measurements of chlorophyll with the sonde in Lake Frisksjön (PSM002065) are disturbed by the high concentration of humus in the water. Since both humic substances and chlorophyll have similar fluorescence in the wavelength used by the sonde the concentration of chlorophyll is highly overestimated by these measurements. The light sensor on the YSI-sonde is also unable to give zero values even in a complete darkness. This results in readings (which are around 5 µmoles/second/m^2 to high) which are not compensated for in the data set.

Sammanfattning

Provtagning av ytvatten har skett inom platsundersökningsområdet vid Oskarshamn från november 2002. Efter två års basprovtagning övergick provtagningen under 2005 till ett program för monitering vid något färre provplatser. Under 2008 har provtagning skett vid 11 stationer. Sju av dessa var i vattendrag, en var i en sjö och tre var platser i havet. Provtagning genomfördes vid tolv tillfällen under 2008 och ett stort antal parametrar analyserades. I sjön och i havet genomfördes även vertikala mätningar med en sond. Alla data som samlades in skickades efter en första kvalitetsgranskning till SKB för lagring i databasen SICADA.

I denna rapport har 2008 års resultat utvärderats. Resultaten liknade de som erhållits vid tidigare års undersökningar /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005 och Ericsson and Engdahl 2007a, Ericsson and Engdahl 2007b och Ericsson and Engdahl 2009/.

De data som samlats in är generellt av hög kvalitet. Två typer av data bedöms dock vara av en lägre kvalitet. De mätningar av klorofyll som utförts med sonden i Frisksjön (PSM002065) har blivit störda av den höga halten av humus som förekommer i vattnet. Orsaken är att både humusämnen och klorofyll fluorescerar vid den våglängd som används av sonden för att mäta klorofyllhalten. Detta har resulterat i en kraftig övervärdering av klorofyllhalten i sjön. YSI-sondens ljussensor ger inte nollvärden i totalt mörker. Detta har resulterat i värden som är ungefär 5 µmol/sekund/m^2 för höga och kompensation för detta har inte gjorts i SICADA.

Contents

1 Introduction

This document reports the data gained by hydrogeochemical and surface ecological monitoring of surface water 2008, 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 400-07-068. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Within the site investigation area surface water has been sampled from November 2002. After a period of two years with basic sampling in the area the program for sampling was changed in 2005 to a program for monitoring in some of the sites. According to the monitoring program sampling has been conducted at 11 sites in 2008 (Figure 1.1). Seven of these were sites in streams, three were sites at sea in the inner coastal area, and one was a site in a lake. An additional site was sampled once in the sea during the year and these results are also presented here. Sampling was performed on twelve occasions in 2008 and the water was analysed for a large number of parameters. In the lake and at two of the sites at sea vertical measurements were also taken by a multi parameter sonde. All original results have, after an initial control, been sent to SKB for storage in their primary database SICADA. The results are traceable by the activity plan number.

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

Activity plan	Number	Version
Hydrogeokemisk och ytekologisk monitering av ytvatten 2008	AP PS 400-07-068	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för ytvattenprovtagningar vid platsundersökningar	SKB MD 900.004	1.0

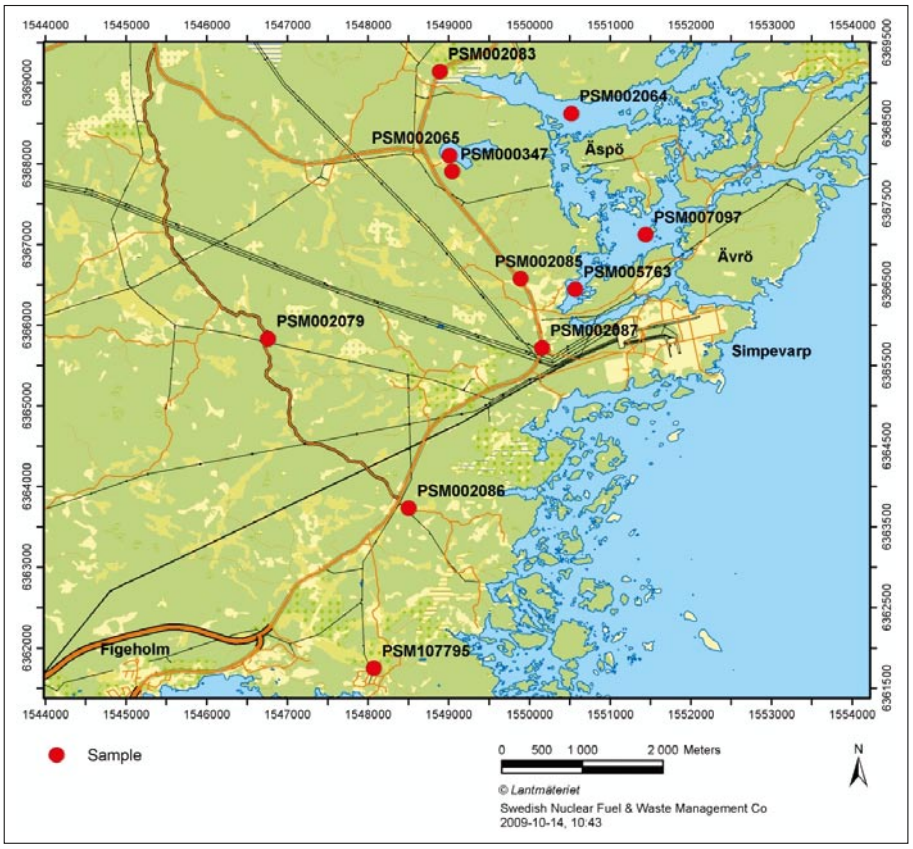

Figure 1-1. *The site investigation area and the sites sampled during 2008.*

2 Objective and scope

The purpose of monitoring is to continue to characterise the surface water at some chosen sites in the site investigation area. A number of streams, sites in the coastal area and a lake were sampled during 2008 (Figure 1.1 and Appendix 1). The sampling was performed once a month and on each sampling occasion all sites planned were sampled during a two-day period (Appendix 2). In week 42 one additional site was sampled outside the monitoring programme. The results from this site are also presented in this report.

The surface water monitoring program consisted mainly of two different programmes, the chemical programme and the ecological programme. The chemical programme included fewer working seasons in comparison with the ecological programme (Appendix 2 and Appendix 3). For the working seasons that coincided between the two programmes sampling was co-ordinated. The ecological programme as well as the chemical basically included the same parameters regardless of the type of water that was sampled (stream, lake or coastal area).

A special control programme comprising limited sites and parameters has been performed at four occasions (Appendix 2 and 3), where the accuracy of the analysing laboratories was evaluated.

A number of physical and chemical parameters were measured directly at the sampling site using a multi-parameter sonde (Table 2-1). Water samples were also taken for analysis of further parameters and the samples were later sent to different laboratories.

In this report the evaluation aims to describe the quality of the data sampled in 2008.

The data gained in this activity will be used for continued advanced analysis and modelling.

Table 2-1. Parameters measured with the multi-parameter sonde 2008.

Parameter	Unit	Parameter	Unit
Date/time	(Y/M/D:hh/mm)	Turbidity	(NTU)
Depth	(m)	Light	(PAR)
Water temperature	(C)	Oxygen	(mg/l)
pH		Chlorophyll	(µg/l)
Conductivity	(mS/cm)	Redox potential	(mV)
Salinity	(ppt)	Atmospheric pressure	(psi)

3 Methods

3.1 Sites and sampling frequency

Sampling was performed on twelve occasions in 2008 (Appendix 2). The total number of sampled sites was eleven (seven streams, one lake and three sites in the inner coastal area).

3.2 Execution of sampling and treatment of samples

Methods used when sampling in the field, calibration procedures, treatments of samples before analysis and how samples was stored and transported to the analysing laboratories, is described in earlier P-reports /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a/.

3.3 Analysed parameters and Laboratories used

The analysed parameters and the laboratories used are shown in Table 3-1.

3.4 Documentation

All activities were continuously documented. Notes were taken on field conditions, time of sampling, marking of samples, calibration protocols and so forth. Any deviations from the normal routines were also noted and commented in a report, which was sent to SKB after each sampling occasion. Delivery notes with instructions on which components to analyse were always sent with the samples to the different laboratories. In Table 3-2 a number of documents and files delivered to SKB after a sampling occasion are presented.

After analysis the data has continuously been reported from the laboratories. As a routine a first preliminary control of the data quality was performed before sending them for storage in the primary database SICADA. These data will later be used for further interpretation (modelling). The data is traceable in SICADA by the Activity Plan number (AP PS 400-07-068).

Table 3-1. Analysed parameters and Laboratories used January–December 2008.

Components	Analysing Laboratory
Alkalinity, pH, Conductivity, Anions (F, Cl, Br, SO_4), Absorbance, HS, Fe II, Fe (tot)	Äspö Laboratory
Standard elements (Na, K, Ca, Mg, Si, Fe, Mn, Li, Sr, TOT-S)	Eurofins, Lidköping (control)
Standard elements (Na, K, Ca, Mg, Si, Fe, Mn, Li, Sr, TOT-S), Iodine, Lantanoides, trace elements, environmental metals, La, In, As, Br	ALS, Luleå
TOC, DOC, DIC, TOT-N/P, POP, PON, POC, $N0_3$-N, NO_2-N, NH_4-N, PO_4-P, Silicate, Chlorophyll, Oxygen	Department of Systems Ecology Stockholm University
Ra- and Rn-isotopes	SUERC, Scotland

Table 3-2. Delivery of documents and files to SKB after a sampling occasion.

Document/file	Media
WC107 – Surface water measurements	File
Activity diary	Paper
Delivery notes to the laboratories	Paper
Calibration notes for the YSI sonde	File
Calibration data and additional parameters for the YSI sonde	Files
Quality checked data and signed document of field measurements with the YSI sonde	File and paper
All raw data from field measurements with the YSI sonde	Files
PAR profile data (Photosynthetic Active Radiation) from the YSI sonde	File
Sample comments – Observations in the field	File
Deviation reports	Paper
Document of stored samples in refrigerator and freezer	File
Photos from the sites	Files
Delivery control documents	Paper

4 Nonconformities

It was not possible to sample all sites at all occasions (Appendix 4). During summer and early autumn three stream sites were dried up at two or more occasions.

In the period from January to September the measurements of pH with the YSI sonde failed due to malfunction.

In the period from May to September the measurements of light (PAR), Chlorophyll and redox with the YSI sonde failed due to malfunction.

In September the measurements of turbidity with the YSI sonde failed due to malfunction.

5 Results and discussion

5.1 Biochemical characterisation

5.1.1 Nutrients

Many of the streams had relatively high concentrations of nutrients (Table 5-1). Highest concentrations were generally measured downstream from farmland areas and in the larger tributaries. These results were similar to those measured in previous years /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, b, Ericsson and Engdahl 2009/. At many sites there was a clear tendency for the concentration of nutrient to be higher in the summer than in the winter (Figure 5-1).

The results from Lake Frisksjön (PSM002065) were similar to previous years (Figure 5-2 and Table 5-2). A large part of the nutrients were bound to particles (mostly plankton) in the summer month compared to the winter conditions (Figure 5-3).

Table 5-1. Average concentration of nutrients and chlorophyll a from the stream water sites, 2008.

Site number	Depth zone	NH_4-N (mg/l)	NO_3-N/NO_2-N (mg/l)	N-tot (mg/l)	P-tot (mg/l)	PO_4-P (mg/l)	POP (mg/l)	PON (mg/l)	Clorophyll a (µg/l)
PSM002079	Surface	0.058	0.224	0.940	0.058	0.005	0.014	0.084	
PSM002083	Surface	0.141	0.410	1.784	0.064	0.012	0.033	0.227	12.0
PSM002085	Surface	0.039	0.547	1.634	0.039	0.007	0.010	0.058	
PSM002086	Surface	0.102	1.486	2.686	0.055	0.018	0.014	0.071	
PSM002087	Surface	0.070	0.351	1.052	0.034	0.005	0.016	0.094	1.8
PSM000347	Surface	0.017	0.201	0.863	0.026	0.005	0.011	0.060	
PSM107795	Surface	0.092	0.405	2.112	0.086	0.026	0.034	0.181	

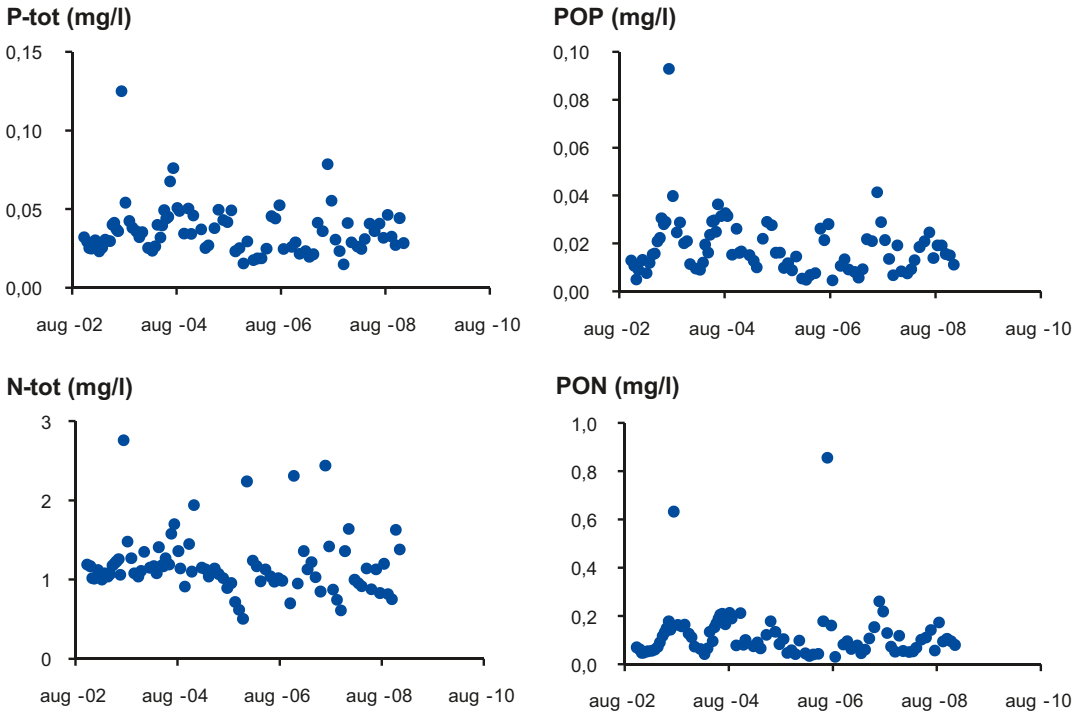

Figure 5-1. *Nutrients measured as total phosphorus, particulate phosphorus, total nitrogen and particulate nitrogen in Laxemarsån (PSM002087).*

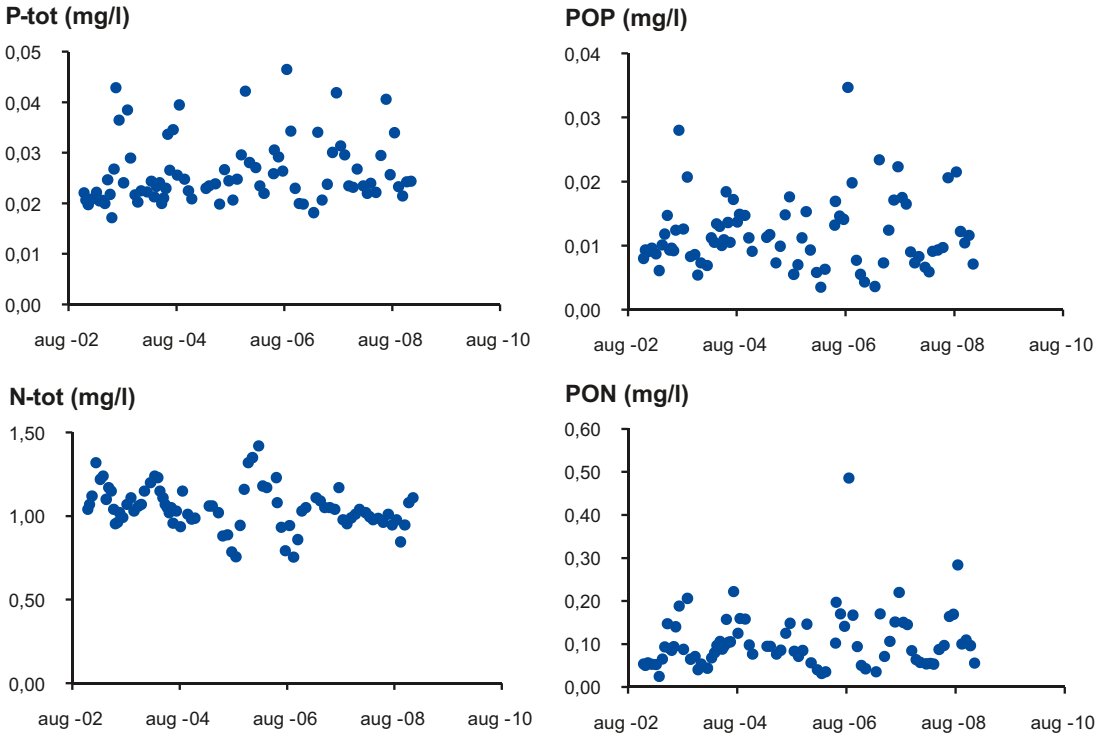

Figure 5-2. *Nutrients measured as total phosphorus, particulate phosphorus, total nitrogen and particulate nitrogen in the surface water of Lake Frisksjön (PSM002065).*

Table 5-2. Average concentration of nutrients and chlorophyll in Lake Frisksjön, 2008.

Site number	Depth zone	NH_4-N (mg/l)	NO_3-N/NO_2-N (mg/l)	N-tot (mg/l)	P-tot (mg/l)	PO_4-P (mg/l)	POP (mg/l)	PON (mg/l)	Clorophyll a (µg/l)
PSM002065	Surface	0.115	0.200	0.988	0.026	0.001	0.011	0.110	4.6
PSM002065	Bottom	0.115	0.172	0.978	0.026	0.001	0.012	0.101	4.1

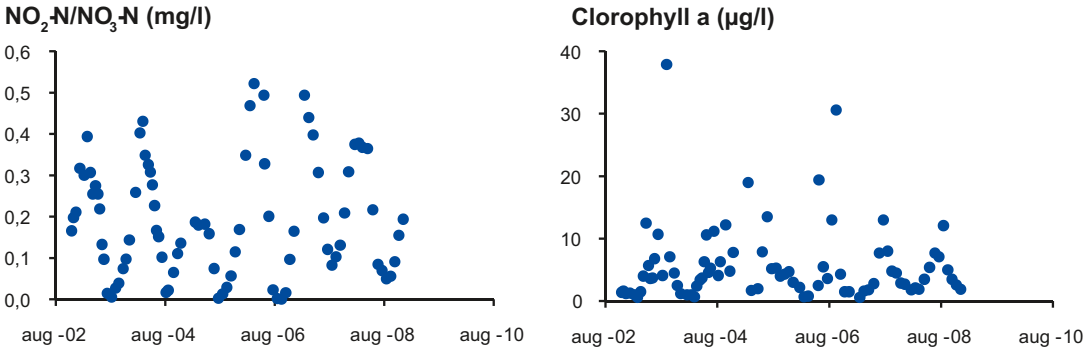

Figure 5-3. *Concentrations of chlorophyll and NO_2-N/NO_3-N in the surface water of Lake Frisksjön (PSM002065).*

The results from the sea sites were similar (Table 5-3). At both sites there was a tendency for the concentration of ammonium and nitrite/nitrate to be lower in the summer than in the winter (an example of the variation is shown in Figure 5-4). The probable reason is higher concentration of plankton in the summer but the concentration of chlorophyll a did not vary accordingly (Figure 5-4).

Table 5-3. Average concentration of nutrients and chlorophyll a at the investigated sites in the sea, 2008.

Site number	Depth zone	NH_4-N (mg/l)	NO_2-N/NO_3-N (mg/l)	N-tot (mg/l)	P-tot (mg/l)	PO_4-P (mg/l)	POP (mg/l)	PON (mg/l)	Clorophyll a (µg/l)
PSM005763	Surface	0.005	0.001	0.577	0.029	0.002	0.020	0.158	11.8
PSM007097	Surface	0.023	0.071	0.584	0.026	0.002	0.014	0.104	4.7
PSM007097	Bottom	0.026	0.035	0.512	0.030	0.005	0.017	0.101	5.7
PSM002064	Surface	0.018	0.043	0.524	0.029	0.003	0.013	0.095	6.1
PSM002064	Bottom	0.112	0.036	0.517	0.075	0.041	0.060	0.072	2.8

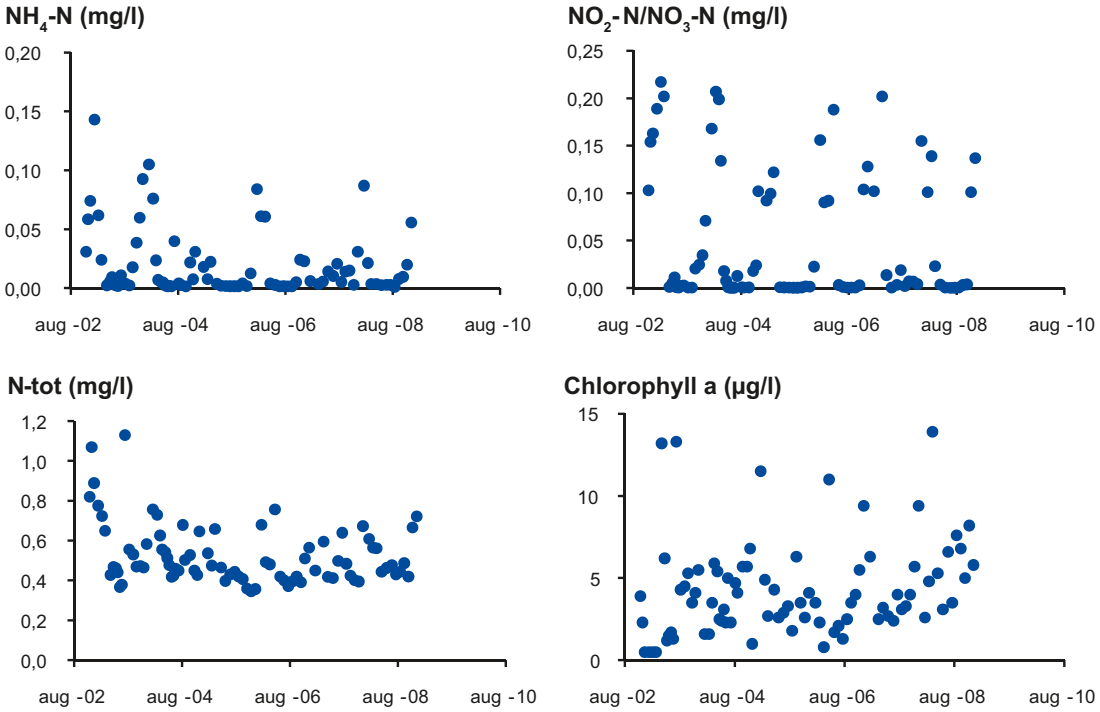

Figure 5-4. *Chlorophyll a and nutrients measured as ammonium, nitrite/nitrate and total nitrogen in the surface water of Granholmsfjärden (PSM002064).*

5.1.2 Carbon fractions

The streams in the area were humic with high concentrations of organic carbons and high absorbance (Table 5-4). At most stream sites there was a tendency of higher concentrations of organic carbon during the summer months (an example is shown in Figure 5-5). There was not any obvious seasonal pattern in the concentrations of DIC (dissolved inorganic carbon) which instead strongly varies with the run-off /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, b/.

As in the streams the water in Lake Frisksjön were strongly coloured with humus. The concentration of TOC (total organic carbon) and DOC (dissolved organic carbon) were high which led to low transparency of the water (Table 5-5). These results were similar to those measured in previous years (Figure 5-6). There was no obvious seasonal variation, neither in the concentration of DOC or TOC (dissolved organic carbon and total organic carbon) or in the transparency (Figure 5-6). A tendency of higher values of POC (particulate organic carbon) in the spring and summer month can probably be explained by higher concentrations of plankton during these months.

Similar to the results from previous years the concentrations of organic carbon fractions were rather high at the two sites in the sea (PSM007097 and PSM002064) (Table 5-6). As a consequence the transparency was reduced compared to what is normal for sea water in the area. As in the lake there was no obvious seasonal pattern of the carbon fractions (an example is shown in Figure 5-7).

Table 5-4. Average concentration of carbon fractions and absorbance at the investigated stream water sites, 2008.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)
PSM002079	Surface	0.1	1.21	17.1	17.5	4.58	0.178
PSM002083	Surface	0.1	2.97	28.7	30.4	4.13	0.388
PSM002085	Surface	0.1	0.785	20.2	20.5	13.6	0.199
PSM002086	Surface	0.1	0.974	24.5	24.8	6.62	0.189
PSM002087	Surface	0.1	1.26	16.9	17.4	5.12	0.189
PSM000347	Surface	0.1	0.794	17.6	17.9	3.99	0.142
PSM107795	Surface	0.1	1.90	29.7	30.4	10.3	0.285

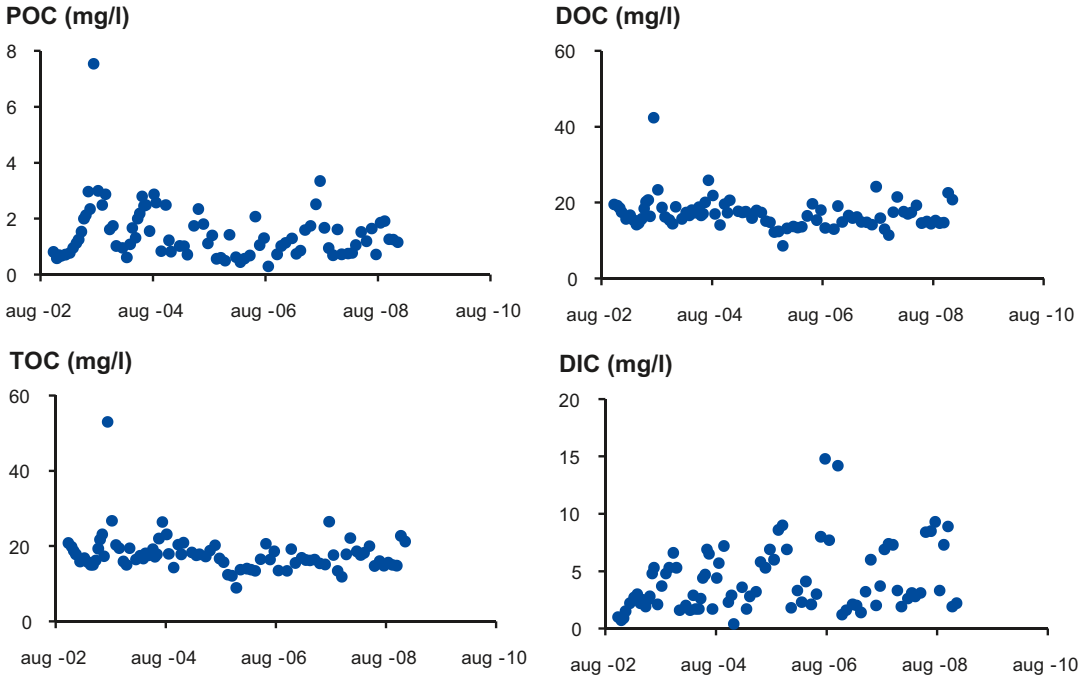

Figure 5-5. *Carbon fractions measured as particulate organic carbon (POC), dissolved organic carbon (DOC), total organic carbon (TOC) and dissolved inorganic carbon (DIC) in Laxemarsån (PSM002087).*

Table 5-5. Average concentration of carbon fractions, absorbance and transparency in Lake Frisksjön, 2008.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)	Transparency (m)
PSM002065	Surface	0.5	0.94	14.1	14.3	2.56	0.102	2.14
PSM002065	Bottom	2.0	0.98	13.9	14.2	2.53	0.100	

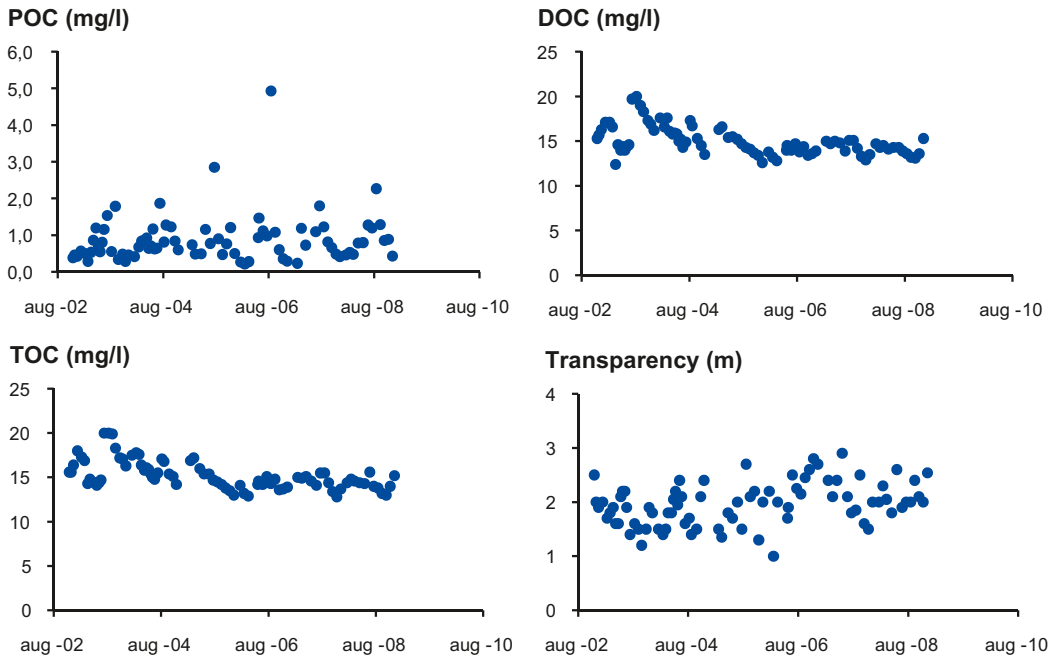

Figure 5-6. *Carbon fractions measured as particulate organic carbon (POC), dissolved organic carbon (DOC), total organic carbon (TOC) and transparency of the surface water in Lake Frisksjön (PSM002065).*

Table 5-6. Average concentration of carbon fractions, absorbance and transparency at the investigated sea sites, 2008.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)	Transparency (m)
PSM005763	Surface	0.5	0.990	6.60	6.90	15.5	0.049	2.05
PSM007097	Surface	0.5	0.832	7.62	7.86	14.6	0.044	2.59
PSM007097	Bottom	6.5	0.846	6.13	6.53	16.7	0.029	
PSM002064	Surface	0.5	0.700	7.09	7.43	15.9	0.045	3.02
PSM002064	Bottom	16.0	0.638	5.76	5.82	18.7	0.062	

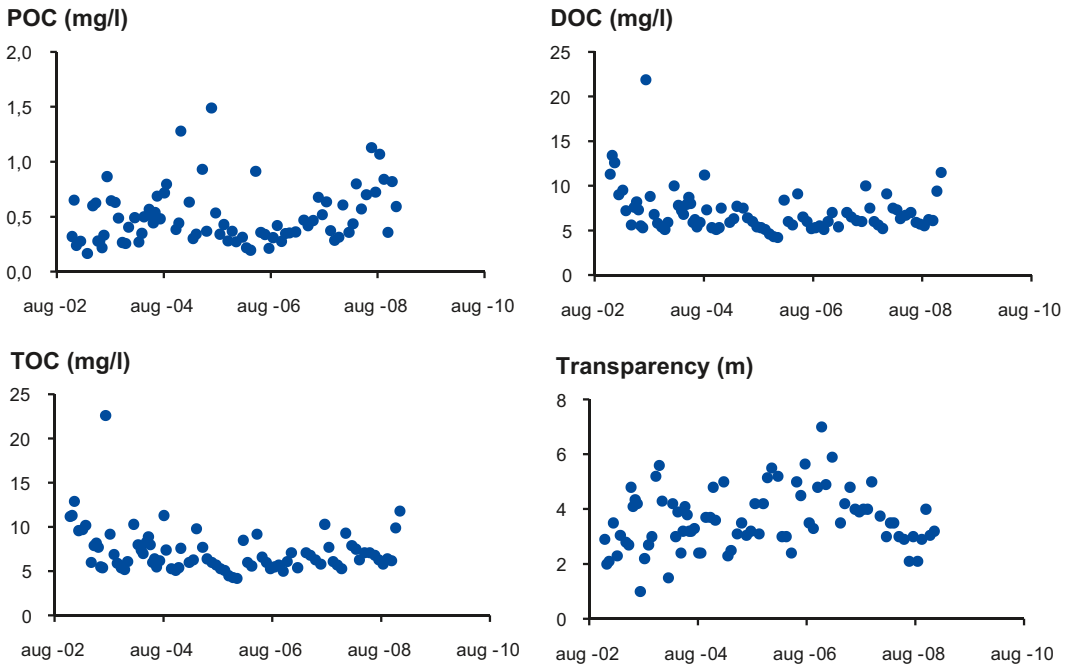

Figure 5-7. *Carbon fractions and transparency of the surface water sea site of Granholmsfjärden (PSM002064).*

5.1.3 Acidification

In the streams HCO_3 and pH strongly correlates with the run-off /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, b/. The minimum concentration of HCO_3 and the minimum pH varied between the streams with a markedly higher value at the site PSM002085 in Ekerumsbäcken, and there is an indication of problems with acidification in some of the other sampled sites (Table 5-7).

Similar to the results from previous years Lake Frisksjön had relatively high concentrations of HCO_3 and relatively high pH values during 2008 (Table 5-8) /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, b, Ericsson and Engdahl 2009/.

The results from the two sea sites showed lower minimum values of HCO_3 in the surface water compared to the bottom water (Table 5-9). This is probably due to the outflow of fresh water and poor turn over at the sites which are secluded from the open sea.

5.1.4 Oxygen

The minimum concentration of oxygen was quite low at one of the stream water sites (Table 5-10). Low concentration of oxygen mostly appears in the summer, partly as a consequence of high water temperature (an example is shown in Figure 5-8).

The oxygen concentration in the bottom water of Lake Frisksjön has previous years occasionally been very low (Figure 5-9). In 2007 and 2008 the concentration of oxygen was unusually high during the summer month (Table 5-11 and Figure 5-9). More or less pronounced thermoclines usually evolve in both winter and summer. The thermocline regularly breaks in April and in late autumn but also at other times (probably as a consequence of strong winds). When the thermocline is broken a rapid raise of the oxygen concentration in the bottom water usually occurs (Figure 5-9).

At the sea sites the concentration of oxygen in the bottom water was occasionally very low (Table 5-12). Especially the site in Granholmsfjärden showed a similar pattern of thermocline build up and breakage as Lake Frisksjön (Figure 5-10).

Table 5-7. Minimum, average and maximum concentration of HCO_3 and minimum, average and maximum pH at the stream water sites, 2008.

Site number	Depth zone	Depth (m)	HCO_3 (min) (mg/l)	HCO_3 (aver.) (mg/l)	HCO_3 (max) (mg/l)	pH (min)	pH (aver.)	pH (max)
PSM002079	Surface	0.1	4.2	20.0	39.2	5.85	6.50	7.00
PSM002083	Surface	0.1	8.2	19.0	29.7	6.02	6.37	6.67
PSM002085	Surface	0.1	35.6	73.5	86.7	7.12	7.48	7.83
PSM002086	Surface	0.1	4.9	27.8	81.1	5.62	6.30	7.00
PSM002087	Surface	0.1	5.2	23.9	45.1	5.99	6.63	7.05
PSM000347	Surface	0.1	10.4	16.2	31.2	6.04	6.26	6.52
PSM107795	Surface	0.1	11.3	46.9	141.0	6.05	6.45	6.99

Table 5-8. Minimum, average and maximum concentration of HCO_3 and minimum, average and maximum pH in Lake Frisksjön, 2008.

Site number	Depth zone	Depth (m)	HCO_3 (min) (mg/l)	HCO_3 (aver.) (mg/l)	HCO_3 (max) (mg/l)	pH (min)	pH (aver.)	pH (max)
PSM002065	Surface	0.5	9.59	12.8	15.7	6.52	6.82	7.10
PSM002065	Bottom	2.0	9.75	12.9	15.7	6.53	6.83	7.11

Table 5-9. Minimum, average and maximum concentration of HCO_3 and minimum, average and maximum pH at the investigated sea sites, 2008.

Site number	Depth zone	Depth (m)	HCO_3 (min) (mg/l)	HCO_3 (aver.) (mg/l)	HCO_3 (max) (mg/l)	pH (min)	pH (aver.)	pH (max)
PSM005763	Surface	0.5	80.0	80.0	80.0	7.65	7.65	7.65
PSM007097	Surface	0.5	55.6	77.8	88.3	7.32	7.79	8.18
PSM007097	Bottom	6.5	80.3	86.0	98.1	7.13	7.58	8.12
PSM002064	Surface	0.5	73.4	84.4	92.2	7.43	7.80	8.13
PSM002064	Bottom	16.0	87.1	94.5	113	7.01	7.47	8.00

Table 5-10. Minimum, average and maximum concentration of oxygen measured at the stream water sites, 2008.

Site number	Depth zone	Depth (m)	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM002079	Surface	0.1	6.4	9.8	14.1
PSM002083	Surface	0.1	6.5	8.8	10.7
PSM002085	Surface	0.1	9.4	11.3	14.5
PSM002086	Surface	0.1	6.6	9.7	13.5
PSM002087	Surface	0.1	6.1	9.7	14.4
PSM000347	Surface	0.1	6.3	9.8	12.1
PSM107795	Surface	0.1	2.0	7.0	11.6

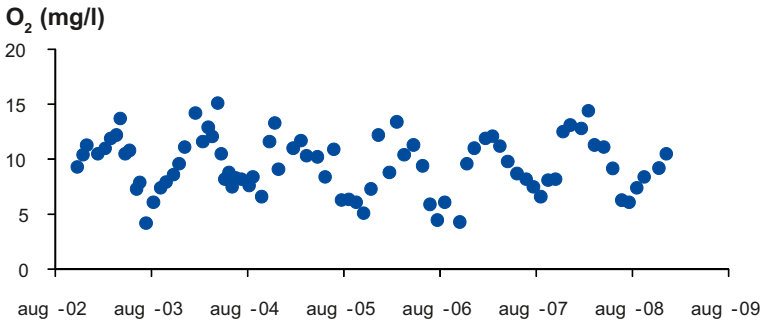

Figure 5-8. *Concentration of oxygen at the stream water site Laxemarsån (PSM002087).*

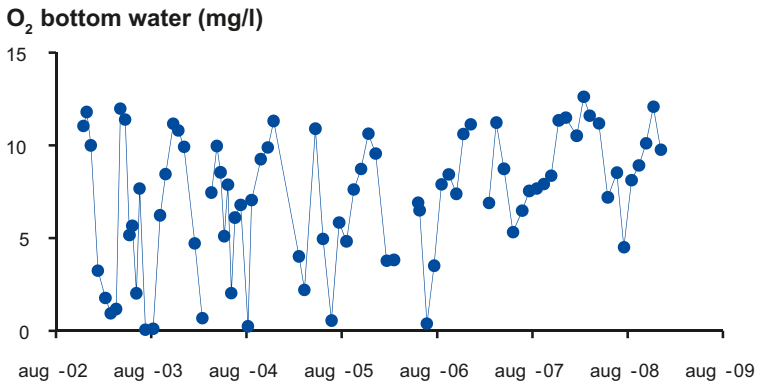

Figure 5-9. *Concentration of oxygen in the bottom water of Lake Frisksjön (PSM002065).*

Table 5-11. Minimum, average and maximum concentration of oxygen in the surface and bottom water in Lake Frisksjön, 2008.

Site number	Depth zone	Depth (m)	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM002065	Surface	0.5	8.2	10.3	12.7
PSM002065	Bottom	2	4.5	9.6	12.6

Table 5-12. Minimum, average and maximum concentration of oxygen in the surface and bottom water at the sea water sites, 2008.

Site number	Depth zone	Depth (m)	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM005763	Surface	0.5	–	–	–
PSM007097	Surface	0.5	9.4	11.1	13.5
PSM007097	Bottom	6.5	0.2	7.2	12.1
PSM002064	Surface	0.5	8.7	11.3	13.6
PSM002064	Bottom	16	0.0	4.9	11.9

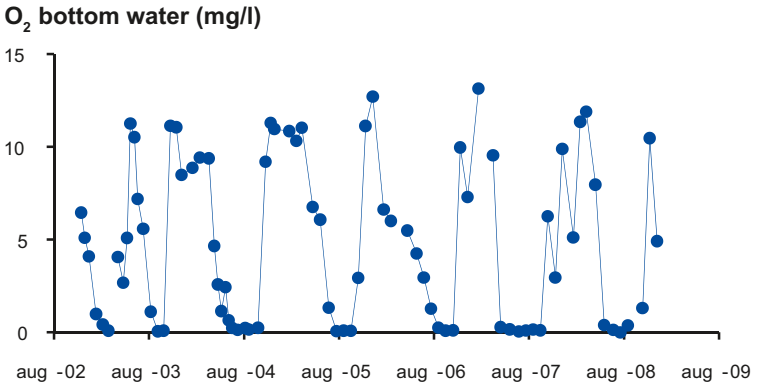

Figure 5-10. *Concentration of oxygen in the bottom water at the sea site (PSM002064).*

5.2 Chemical characterisation

5.2.1 Major ions and conductivity

The concentration of major ions and the conductivity is presented in Tables 5-13, 5-14 and 5-15. The site PSM002085 differed with markedly higher concentration of Calcium and HCO_3 than the other streams suggesting different composition of the bedrock in the tributary. The concentration of most ions correlates well with the run off /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, b/.

In Lake Frisksjön the concentrations of ions and the conductivity was slightly lower than in the streams (Table 5-14).

At the sea sites the surface water differed from the bottom water with lower average concentrations of ions and lower average conductivity (Table 5-15). This was probably a consequence of the outflow of fresh water and poor turn over at the sites which are secluded from the open sea. The periodic variation in the outflow of fresh water has caused a marked variation of the ion concentration in the surface waters at the sea sites (an example is shown in Figure 5-11).

Table 5-13. Average concentration of major ions and conductivity at the stream water sites, 2008. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Br (mg/l)	Conductivity (mS/m)
PSM002079	Surface	0.1	13.1	1.75	13.7	3.56	20.0	23.1	23.3	*0.300*	18.2
PSM002083	Surface	0.1	8.79	1.58	12.7	2.73	19.0	11.3	17.5	*0.300*	14.2
PSM002085	Surface	0.1	13.5	1.61	39.8	5.17	73.5	21.6	45.2	*0.274*	30.7
PSM002086	Surface	0.1	17.9	3.89	24.1	5.29	27.8	25.1	53.8	*0.674*	31.6
PSM002087	Surface	0.1	17.1	2.21	16.8	4.30	23.9	32.9	26.4	*0.304*	23.3
PSM000347	Surface	0.1	14.9	1.86	11.7	3.03	16.2	27.3	14.5	*0.200*	17.8
PSM107795	Surface	0.1	12.1	2.83	21.4	5.30	46.9	13.6	29.8	*0.707*	27.2

Table 5-14. Average concentration of major ions and conductivity in Lake Frisksjön 2008. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Br (mg/l)	Conductivity (mS/m)
PSM002065	Surface	0.5	12.2	1.70	8.93	3.02	12.8	21.2	17.1	*0.279*	14.9
PSM002065	Bottom	2.0	12.3	1.69	8.93	3.03	12.9	20.8	16.5	*0.307*	17.1

Table 5-15. Average concentration of major ions and conductivity at the sea water sites, 2008.

Site number	Depth zone	Depth (m)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Br (mg/l)	Conductivity (mS/m)
PSM005763	Surface	0.5	1,840	69.5	89.2	220	80.0	3,340	502	11.4	1,050
PSM007097	Surface	0.5	1,691	64.7	82.5	201	77.8	3,144	470	10.6	999
PSM007097	Bottom	6.5	1,913	73.4	91.5	228	86.0	3,513	504	11.7	1,106
PSM002064	Surface	0.5	1,833	71.2	88.8	219	84.4	3,367	489	11.0	1,061
PSM002064	Bottom	16	1,970	76.6	94.7	235	94.5	3,651	530	12.5	1,136

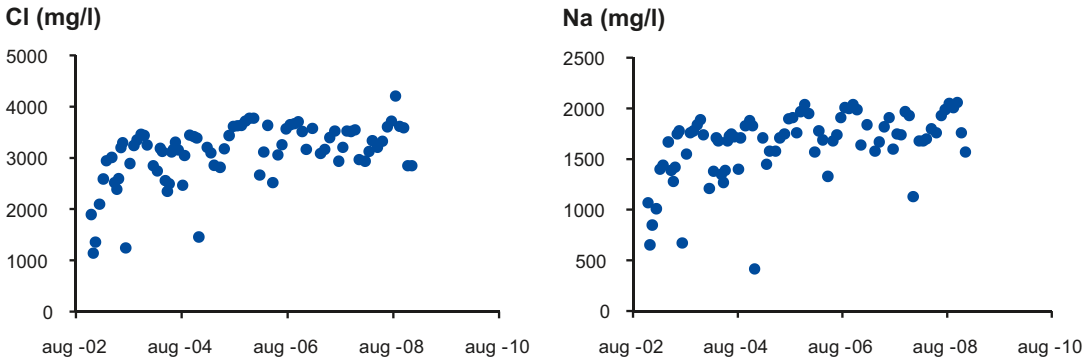

Figure 5-11. *Concentration of Na and Cl in the surface water at the secluded sea site Granholmsfjärden (PSM002064).*

5.2.2 Heavy metals and trace elements

The concentrations of metals are presented in Table 5-16, 5-17 and 5-18. Most metals differ between the sites at sea and the sites in the lake and streams with lower concentrations in the sea water. At sea most metal concentrations are similar between the two sites were measurements were performed. Likewise most inland sites had similar concentrations of metals.

Table 5-16. Average concentration of heavy metals and trace elements at the stream water sites, 2008. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Al (ug/l)	As (ug/l)	Ba (ug/l)	Cd (ug/l)	Ce (ug/l)	Co (ug/l)	Cr (ug/l)	Cs (ug/l)	Cu (ug/l)	Dy (ug/l)
PSM002079	Surface	474	0.342	23.8	0.050	7.31	0.779	0.768	*0.030*	2.30	0.513
PSM002083	Surface	899	0.716	18.9	0.044	11.7	1.13	1.33	*0.035*	2.73	0.711
PSM002085	Surface	224	0.513	22.9	0.044	4.06	0.663	1.27	*0.030*	4.42	0.342
PSM002086	Surface	831	0.636	30.2	0.265	9.32	1.44	1.39	*0.030*	5.70	0.638
PSM002087	Surface	414	0.345	26.2	0.054	6.72	0.78	0.772	*0.032*	2.59	0.473
PSM000347	Surface	756	0.432	21.2	0.067	10.6	1.29	1.21	*0.030*	3.19	0.567
PSM107795	Surface	686	0.583	21.4	0.159	9.67	1.30	1.56	*0.030*	4.72	0.610

Site number	Depth zone	Er (ug/l)	Eu (ug/l)	Gd (ug/l)	Hf (ug/l)	Hg (ug/l)	Ho (ug/l)	I (ug/l)	La (ug/l)	Lu (ug/l)	Mo (ug/l)
PSM002079	Surface	0.328	0.116	0.639	0.034	*0.002*	0.107	*0.050*	4.15	0.050	0.284
PSM002083	Surface	0.480	0.165	0.849	0.085	0.004	0.149	*0.050*	5.93	0.088	0.738
PSM002085	Surface	0.2305	0.082	0.409	0.050	0.003	0.072	*0.050*	2.30	0.040	1.77
PSM002086	Surface	0.435	0.158	0.785	0.062	0.004	0.136	*0.050*	4.75	0.074	2.91
PSM002087	Surface	0.303	0.105	0.566	0.033	*0.002*	0.099	*0.050*	3.74	0.046	0.418
PSM000347	Surface	0.359	0.157	0.708	0.045	0.003	0.116	*0.050*	5.04	0.057	0.830
PSM107795	Surface	0.4068	0.140	0.726	0.100	*0.004*	0.126	*0.050*	4.84	0.067	2.23

Site number	Depth zone	Nd (ug/l)	Ni (ug/l)	Pb (ug/l)	Pr (ug/l)	Rb (ug/l)	Sb (ug/l)	Sc (ug/l)	Se (ug/l)	Sm (ug/l)	Tb (ug/l)
PSM002079	Surface	4.305	2.94	0.162	1.08	3.22	0.071	0.165		0.752	0.081
PSM002083	Surface	5.933	3.91	0.496	1.52	4.28	0.102	0.280		1.04	0.107
PSM002085	Surface	2.755	5.37	0.101	0.647	2.74	0.086	0.151	0.286	0.494	0.052
PSM002086	Surface	5.528	9.81	0.198	1.37	5.06	0.135	0.240		0.975	0.098
PSM002087	Surface	3.908	3.29	0.161	0.976	3.71	0.074	0.148	0.140	0.680	0.088
PSM000347	Surface	5.485	3.63	0.126	1.40	3.18	0.103	0.221		0.947	0.092
PSM107795	Surface	5.123	7.27	0.221	1.30	4.63	0.114	0.253		0.911	0.094

Site number	Depth zone	Th (ug/l)	Tl (ug/l)	Tm (ug/l)	U (ug/l)	V (ug/l)	Y (ug/l)	Yb (ug/l)	Zn (ug/l)	Zr (ug/l)
PSM002079	Surface	0.139	*0.014*	0.046	0.316	0.899	3.73	0.317	8.18	1.11
PSM002083	Surface	0.385	0.016	0.072	1.10	1.64	4.89	0.533	10.7	2.73
PSM002085	Surface	0.158	*0.012*	0.034	1.32	1.24	2.39	0.251	5.21	2.14
PSM002086	Surface	0.227	0.038	0.066	0.900	1.95	4.60	0.469	15.0	2.52
PSM002087	Surface	0.136	0.015	0.043	0.354	0.908	3.31	0.293	8.30	1.17
PSM000347	Surface	0.229	0.018	0.051	0.618	0.995	3.72	0.369	9.94	1.39
PSM107795	Surface	0.294	0.020	0.058	0.844	1.65	4.16	0.414	8.96	3.10

Table 5-17. Average concentration of heavy metals and trace elements in Lake Frisksjön, 2008. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Al (ug/l)	As (ug/l)	Ba (ug/l)	Cd (ug/l)	Ce (ug/l)	Co (ug/l)	Cr (ug/l)	Cs (ug/l)	Cu (ug/l)	Dy (ug/l)
PSM002065	Surface	217	0.550	14.8	*0.009*	3.08	0.270	0.534	*0.030*	1.82	0.169
PSM002065	Bottom	231	0.560	14.8	0.011	3.03	0.259	0.505	*0.030*	1.81	0.171

Site number	Depth zone	Er (ug/l)	Eu (ug/l)	Gd (ug/l)	Hf (ug/l)	Hg (ug/l)	Ho (ug/l)	I (ug/l)	La (ug/l)	Lu (ug/l)	Mo (ug/l)
PSM002065	Surface	0.110	0.046	0.217	0.024	*0.002*	0.034	*0.050*	1.56	0.018	0.955
PSM002065	Bottom	0.1094	0.045	0.208	0.086	*0.002*	0.034	*0.050*	1.54	0.018	0.991

Site number	Depth zone	Nd (ug/l)	Ni (ug/l)	Pb (ug/l)	Pr (ug/l)	Rb (ug/l)	Sb (ug/l)	Sc (ug/l)	Se (ug/l)	Sm (ug/l)	Tb (ug/l)
PSM002065	Surface	1.672	1.51	0.626	0.432	3.67	0.102	*0.073*	0.148	0.288	0.027
PSM002065	Bottom	1.660	1.49	0.629	0.431	3.68	0.136	*0.069*		0.291	0.027

Site number	Depth zone	Th (ug/l)	Tl (ug/l)	Tm (ug/l)	U (ug/l)	V (ug/l)	Y (ug/l)	Yb (ug/l)	Zn (ug/l)	Zr (ug/l)
PSM002065	Surface	0.093	*0.010*	0.016	0.307	1.16	1.07	0.113	3.39	0.777
PSM002065	Bottom	0.088	*0.010*	0.016	0.316	1.13	1.08	0.115	3.14	0.966

Table 5-18. Average concentration of heavy metals and trace elements at the sea water sites, 2008. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Al (ug/l)	As (ug/l)	Ba (ug/l)	Cd (ug/l)	Ce (ug/l)	Co (ug/l)	Cr (ug/l)	Cs (ug/l)	Cu (ug/l)	Dy (ug/l)
PSM005763	Surface	–	–	–	–	–	–	–	–	–	–
PSM007097	Surface	81.6	*0.590*	19.9	*0.029*	1.10	0.237	*0.308*	*0.113*	0.988	*0.084*
PSM007097	Bottom	27.4	0.600	19.7	*0.027*	0.325	0.177	*0.236*	*0.181*	0.646	*0.032*
PSM002064	Surface	71.6	0.653	19.1	*0.022*	*0.695*	0.160	*0.396*	*0.100*	0.838	*0.057*
PSM002064	Bottom	12.0	0.740	18.8	*0.022*	0.137	0.180	*0.203*	*0.106*	0.524	*0.020*

Site number	Depth zone	Er (ug/l)	Eu (ug/l)	Gd (ug/l)	Hf (ug/l)	Hg (ug/l)	Ho (ug/l)	I (ug/l)	La (ug/l)	Lu (ug/l)	Mo (ug/l)
PSM005763	Surface	–	–	–	–	–	–	–	–	–	–
PSM007097	Surface	*0.061*	*0.030*	*0.107*	*0.026*	*0.002*	*0.029*	*0.200*	0.608	*0.022*	1.79
PSM007097	Bottom	*0.0268*	*0.020*	*0.034*	*0.033*	*0.002*	*0.020*	*0.200*	0.202	*0.020*	1.88
PSM002064	Surface	*0.042*	*0.024*	*0.069*	*0.021*	*0.002*	*0.023*	*0.200*	*0.358*	*0.020*	1.80
PSM002064	Bottom	*0.020*	*0.020*	*0.022*	*0.022*	*0.002*	*0.020*	*0.200*	*0.084*	*0.020*	1.76

Site number	Depth zone	Nd (ug/l)	Ni (ug/l)	Pb (ug/l)	Pr (ug/l)	Rb (ug/l)	Sb (ug/l)	Sc (ug/l)	Se (ug/l)	Sm (ug/l)	Tb (ug/l)
PSM005763	Surface	–	–	–	–	–	–	–	–	–	–
PSM007097	Surface	0.645	*1.40*	*0.127*	*0.168*	18.9	*0.105*	*0.400*	0.108	*0.123*	*0.025*
PSM007097	Bottom	0.206	*0.854*	*0.127*	*0.055*	21.7	0.112	*0.400*		*0.041*	*0.020*
PSM002064	Surface	*0.380*	*1.06*	*0.126*	*0.102*	20.9	*0.122*	*0.400*		*0.076*	*0.021*
PSM002064	Bottom	*0.086*	*0.697*	*0.115*	*0.024*	21.7	*0.101*	*0.400*		*0.021*	*0.020*

Site number	Depth zone	Th (ug/l)	Tl (ug/l)	Tm (ug/l)	U (ug/l)	V (ug/l)	Y (ug/l)	Yb (ug/l)	Zn (ug/l)	Zr (ug/l)
PSM005763	Surface	–	–	–	–	–	–	–	–	–
PSM007097	Surface	*0.200*	*0.050*	*0.021*	0.791	0.300	0.586	*0.061*	3.42	*0.265*
PSM007097	Bottom	*0.200*	*0.050*	*0.020*	0.776	0.266	0.216	*0.026*	2.96	*0.186*
PSM002064	Surface	*0.200*	*0.050*	*0.020*	0.827	0.286	0.343	*0.045*	2.81	*0.250*
PSM002064	Bottom	*0.200*	*0.050*	*0.020*	0.745	0.203	0.109	*0.020*	2.77	*0.135*

5.2.3 Isotopes

The results of the measurements of isotopes are presented in Tables 5-19, 5-20 and 5-21. For radium all sites had values below the detection limit.

The measurements of radon varied between the streams were measurements were performed with a markedly higher value at the stream site PSM002083. This result was similar to previous years /Ericsson and Engdahl 2004a, b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, b, Ericsson and Engdahl 2009/.

5.3 Effect on the results of methodological changes

No major change of methods that could have an effect on the results occurred in 2008.

Table 5-19. Isotope data from the investigated sites in the streams 2008. Figures in italic indicate that some individual values were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	^{226}Ra (Bq/l)	^{222}Rn $_{(corr)}$ (Bq/l)
PSM002079	Surface	0.1	*0.015*	1.26
PSM002083	Surface	0.1	*0.015*	3.54
PSM002085	Surface	0.1	*0.015*	0.19
PSM002086	Surface	0.1	*0.015*	2.69
PSM002087	Surface	0.1	*0.015*	0.92
PSM000347	Surface	0.1	–	–
PSM107795	Surface	0.1	*0.015*	1.54

Table 5-20. Isotope data from Lake Frisksjön 2008. Figures in italic indicate that some individual values were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	^{226}Ra (Bq/l)	^{222}Rn $_{(corr)}$ (Bq/l)
PSM002065	Surface	0.5	*0.015*	0.081
PSM002065	Bottom	2	*0.015*	0.057

Table 5-21. Isotope data from the investigated sea sites 2008. Figures in italic indicate that some individual values were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	^{226}Ra (Bq/l)	^{222}Rn $_{(corr)}$ (Bq/l)
PSM005763	Surface	0.5	–	–
PSM007097	Surface	0.5	*0.015*	0.024
PSM007097	Bottom	6.5	*0.015*	*0.015*
PSM002064	Surface	0.5	*0.015*	*0.015*
PSM002064	Bottom	16	*0.015*	*0.015*

5.4 Accuracy of data

Data has continuously been assessed after analysis and before storage into SICADA. Generally very few analysing errors or indications of contaminations have been detected and it is our opinion that the data is of high quality.

One set of data are of lower quality. The measurements of chlorophyll performed in Lake Frisksjön by the multi parameter sonde are of low quality. This problem is known from previous years and the problem seems to be that both humic substances and chlorophyll have similar fluorescence in the wavelength used by the chlorophyll probe. Since the inland waters contains high concentrations of humic substances the sonde to a large proportion measure humic substances as chlorophyll.

Another problem with the sonde data is that the sensor measuring photosynthetically active radiation (PAR) is unable to give a zero value, when it is completely dark. The lowest PAR value that the sensor can show seems to be around 5 µmoles/second/m^2. The manufacturer says that this error is due to an electronic mismatch between the sonde port and the light sensor and suggests that the offset could be subtracted. The error has not been compensated for in the dataset.

6 References

Ericsson U, Engdahl A, 2004a. Oskarshamn site investigation. Surface water sampling in Simpevarp 2002–2003. SKB P-04-13, Svensk Kärnbränslehantering AB.

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Ericsson U, Engdahl A, 2007b. Oskarshamn site investigation. Monitoring of surface water 2006. SKB P-08-10, Svensk Kärnbränslehantering AB.

Ericsson U, Engdahl A, 2009. Oskarshamn site investigation. Monitoring of surface water chemistry 2007. SKB P-09-40, Svensk Kärnbränslehantering AB.

Appendix 1

Sites, co-ordinates and sampling depths

Sites, depths and co-ordinates 2008.

ID-code	Name	Type of water	Co-ordinate X	Co-ordinate Y	Sampling depth (m)
PSM005763*	Ekerumsviken	Sea	636644	155057	0.5
PSM007097	Borholmsfjärden	Sea	636714	155156	0.5–7.0
PSM002064	Granholmsfjärden	Sea	636862	155052	0.5–17
PSM002065	Frisksjön	Lake	636810	154901	0.5–3.0
PSM002079	Kvarnstugan	Stream	636583	154674	0.1
PSM002083	Smedtorpet	Stream	636912	154888	0.1
PSM002085	Ekerum	Stream	636656	154986	0.1
PSM002086	Basteböla	Stream	636373	154851	0.1
PSM002087	Ekhyddan	Stream	636570	155012	0.1
PSM000347	Frisksjöns inlopp	Stream	636791	154904	0.1
PSM107795	Uthammar	Stream	636175	154807	0.1

* Note: PSM005763 was only sampled once (week 42) during 2008.

Appendix 2

Schedule – Surface water sampling, weekly working seasons

Sampling occasions and programme 2008.

Month	Jan	Feb	Mar	Apr	May	June
Programme	**Week nr**					
Ecological	4	8	11	16	21	26
Chemical class 5 (reduced)			11		21	
Chemical class 5 (full)						
Control programme (Br and standard elements)			11		21	

Month	July	Aug	Sept	Oct	Nov	Dec
Programme	**Week nr**					
Ecological	30	34	38	42	46	50
Chemical class 5 (reduced)						50
Chemical class 5 (full)		34				
Control programme (Br and standard elements)		34				50

Appendix 3

Programmes performed at the different sites

Sites and programmes 2008.

ID-code	Name	Type of water	Ecological programme	Chemical programme	Control programme
PSM005763*	Ekerumsviken	Sea	X		
PSM007097	Borholmsfjärden	Sea	X	X	X
PSM002064	Granholmsfjärden	Sea	X	X	X
PSM002065	Frisksjön	Lake	X	X	X
PSM002079	Kvarnstugan	Stream	X	X	
PSM002083	Smedtorpet	Stream	X	X	
PSM002085	Ekerum	Stream	X	X	
PSM002086	Basteböla	Stream	X	X	
PSM002087	Ekhyddan	Stream	X	X	X
PSM000347	Frisksjöns inlopp	Stream	X	X	
PSM107795	Uthammar	Stream	X	X	

* Note: PSM005763 was only sampled once (week 42) during 2008.

Appendix 4

Sampling sites and weeks when not sampled

Sampling sites and weeks when not sampled 2008.

ID-code	Name	Type of water	Weeks when not sampled	Comment
PSM005763	Ekerumsviken	Sea	*	
PSM007097	Borholmsfjärden	Sea		
PSM002064	Granholmsfjärden	Sea		
PSM002065	Frisksjön	Lake		
PSM002079	Kvarnstugan	Stream		
PSM002083	Smedtorpet	Stream		
PSM002085	Ekerum	Stream	26, 30	Dried up
PSM002086	Basteböla	Stream	26, 30, 42	Dried up
PSM002087	Ekhyddan	Stream		
PSM000347	Frisksjöns inlopp	Stream	21, 26, 30, 34, 38	Dried up
PSM107795	Uthammar	Stream		

* Note: PSM005763 was only sampled once (week 42) during 2008.