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Oskarshamn site investigation

Monitoring of surface water chemistry 2009

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May 2010

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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 2009 sampling has been conducted at totally 10 sites. Seven of these were sites in streams, one was a site in a lake and two were sites at sea in the inner coastal area. Sampling was performed on twelve occasions in 2009 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 probe. All data collected has after an initial control been sent to SKB for storage in their database SICADA.

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

The data gathered are generally considered to be of high quality but the measurements of chlorophyll with the probe in Lake Frisksjön (PSM002065) are disturbed by the high concentration of humus in the water. Since both humic substances and chlorophyll a have similar fluorescence in the wavelength used by the probe the concentration of chlorophyll a is highly overestimated by these measurements. The light sensor on the YSI-probe 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 2009 har provtagning skett vid 10 stationer. Sju av dessa var i vattendrag, en var i en sjö och två var platser i havet. Provtagning genomfördes vid tolv tillfällen under 2009 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 2009 års resultat utvärderats. Resultaten liknade de som erhållits vid tidigare års undersökningar /Ericsson and Engdahl 2004a, Ericsson and Engdahl 2004b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, Ericsson and Engdahl 2007b, Ericsson and Engdahl 2009, Ericsson 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 a 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 a 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 2009, 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 400-08-025. 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 10 sites in 2009 (Figure 1-1). Seven of these were sites in streams, two were sites at sea in the inner coastal area, and one was a site in a lake. Sampling was performed on twelve occasions in 2009 and the water was analysed for a large number of parameters. In the lake and at the two sites at sea vertical measurements were also taken by a multi parameter probe. 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 2009.	AP PS 400-08-025	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för ytvattenprovtagningar vid platsundersökningar.	SKB MD 900.004	1.0

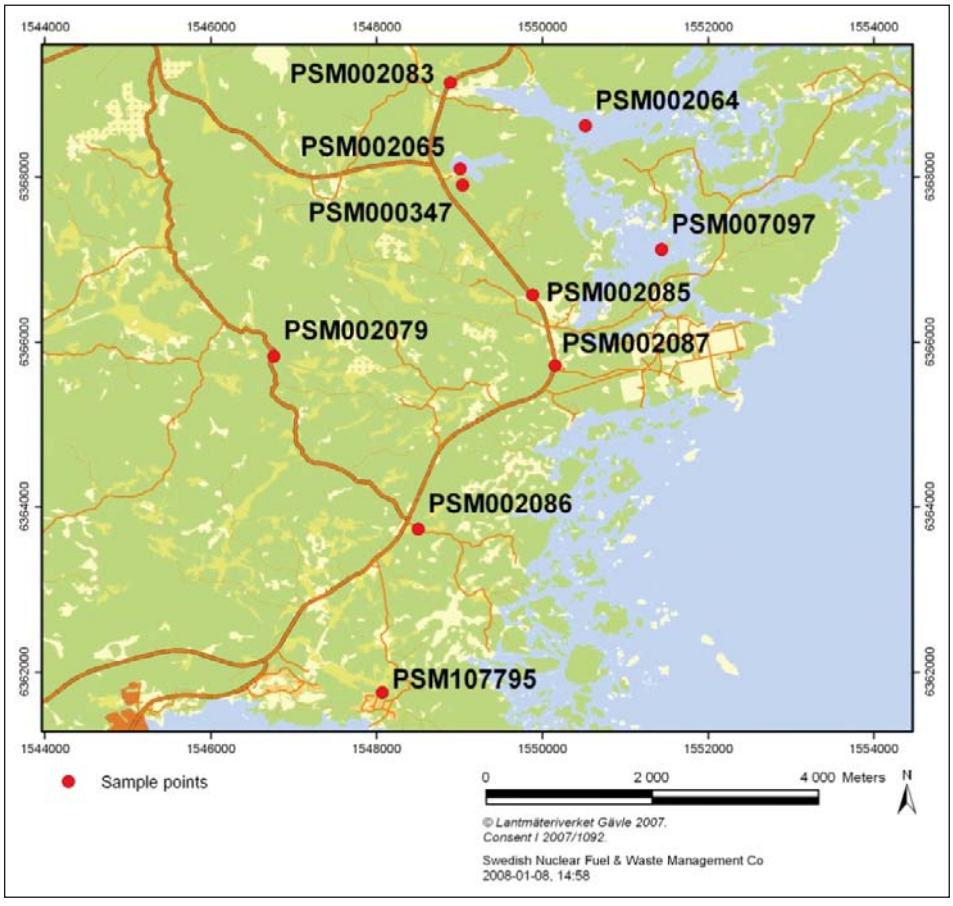

Figure 1-1. The site investigation area and the sites sampled during 2009.

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 2009 (Figure 1-1 and Appendix 1). The sampling was performed once a month and on most sampling occasion all sites planned were sampled during a two-day period (Appendix 2).

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). 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 probe (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 2009.

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

Table 2-1. Parameters measured with the multi-parameter probe 2009.

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 2009 (Appendix 2). The total number of sampled sites was ten (seven streams, one lake and two 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, Ericsson and Engdahl 2004b, 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 400-08-025).

Table 3-1. Analysed parameters and Laboratories used January – December 2009.

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, NO_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
Copys of delivery notes to the laboratories.	Paper
Calibration notes for the YSI probe.	File
Calibration data and additional parameters for the YSI probe.	Files
Quality checked data and signed document of field measurements with the YSI probe.	File and paper
All raw data from field measurements with the YSI probe.	Files
PAR profile data (Photosynthetic Active Radiation) from the YSI probe.	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 four stream sites were dried up at two or more occasions. Unsafe ice made it impossible to sample the lake and the sites at sea at one or more occasions during the winter months.

In the period from July to October the measurements of light (PAR) with the YSI probe 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, Ericsson and Engdahl 2004b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, Ericsson and Engdahl 2007b, Ericsson and Engdahl 2009, Ericsson 2009/. At many sites there was a clear tendency for the concentration of nutrient to be higher in the summer than in the winter, an example of this is shown in Figure 5-1.

Table 5-1. Average concentration of nutrients and chlorophyll a from the stream water sites, 2009. Figures in italic indicate that some individual values in the calculation were below the report limit of the analysis.

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	0.047	0.214	0.984	0.036	0.006	0.018	0.105	–
PSM002083	Surface	0.237	0.232	1.60	0.059	0.015	0.025	0.164	5.3
PSM002085	Surface	0.063	0.319	1.58	0.057	0.013	0.018	0.101	–
PSM002086	Surface	0.083	1.36	2.73	0.066	0.023	0.019	0.096	–
PSM002087	Surface	0.048	0.241	1.057	0.038	0.008	0.024	0.110	*2.1*
PSM000347	Surface	0.028	0.118	0.914	0.031	0.005	0.012	0.085	–
PSM107795	Surface	0.097	0.419	2.12	0.084	0.025	0.029	0.170	–

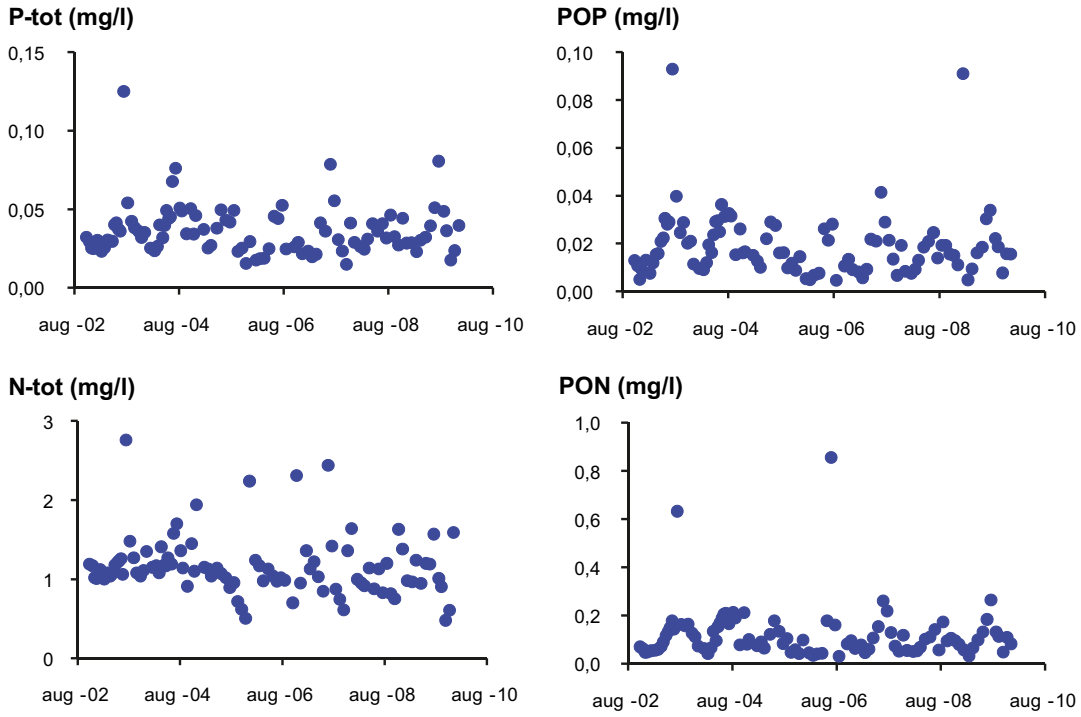

Figure 5-1. *Nutrients measured as total phosphorus, particulate phosphorus, total nitrogen and particulate nitrogen in Laxemarsån (PSM002087).*

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 months compared to the winter conditions (Figure 5-3).

The results from the sea sites were similar to the results from Lake Frisksjön (Table 5-3). At both sea 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 5-2. Average concentration of nutrients and chlorophyll a in Lake Frisksjön, 2009.

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	0.061	0.138	0.975	0.029	0.002	0.014	0.129	11.0
PSM002065	Bottom	0.081	0.138	0.975	0.028	0.002	0.013	0.127	11.5

Table 5-3. Average concentration of nutrients and chlorophyll a at the investigated sites in the sea, 2009.

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)
PSM007097	Surface	0.020	0.030	0.557	0.021	0.004	0.011	0.096	4.8
PSM007097	Bottom	0.071	0.030	0.552	0.048	0.012	0.036	0.137	4.9
PSM002064	Surface	0.007	0.007	0.459	0.020	0.001	0.010	0.073	4.4
PSM002064	Bottom	0.163	0.049	0.558	0.042	0.007	0.029	0.073	3.1

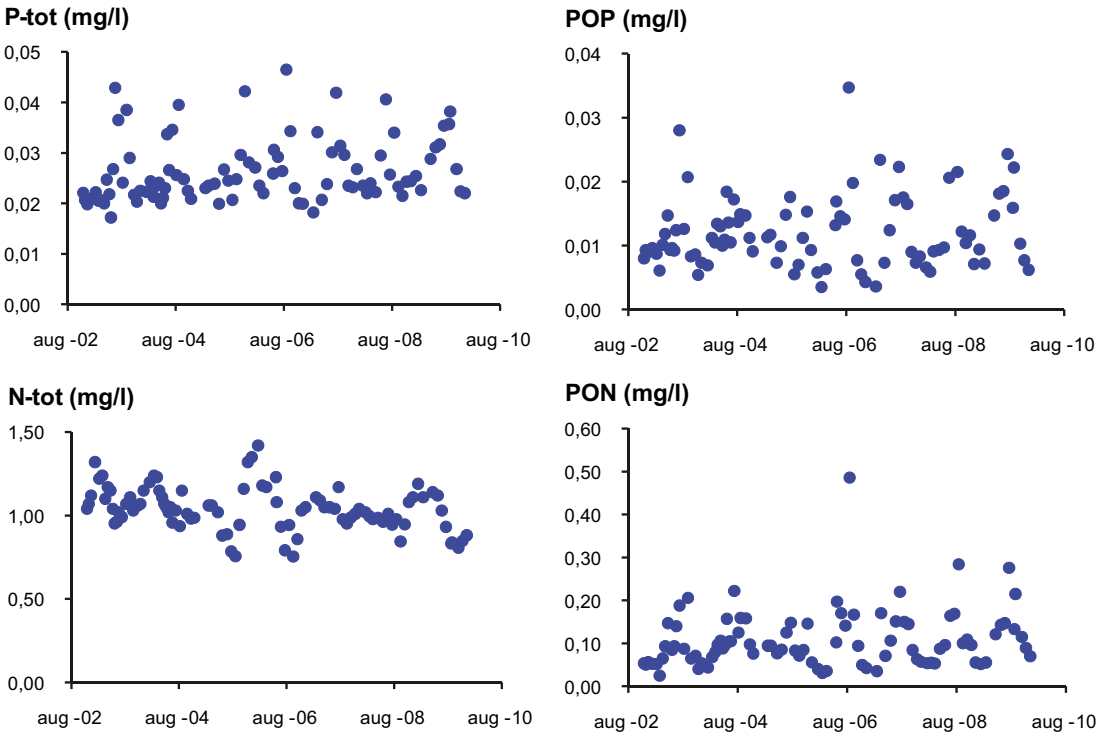

Figure 5-2. *Nutrients measured as total phosphorus, particulate phosphorus, total nitrogen and particulate nitrogen in the surface water of Lake Frisksjön (PSM002065).*

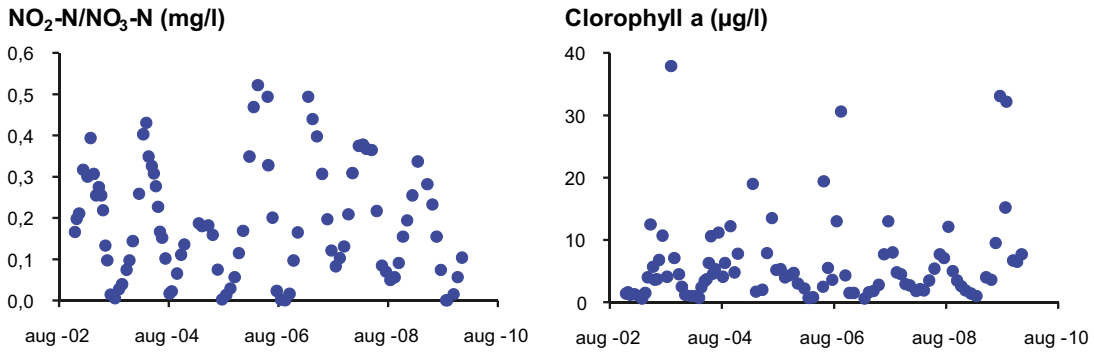

Figure 5-3. *Concentrations of chlorophyll a and NO_2-N/NO_3-N in the surface water of Lake Frisksjön (PSM002065).*

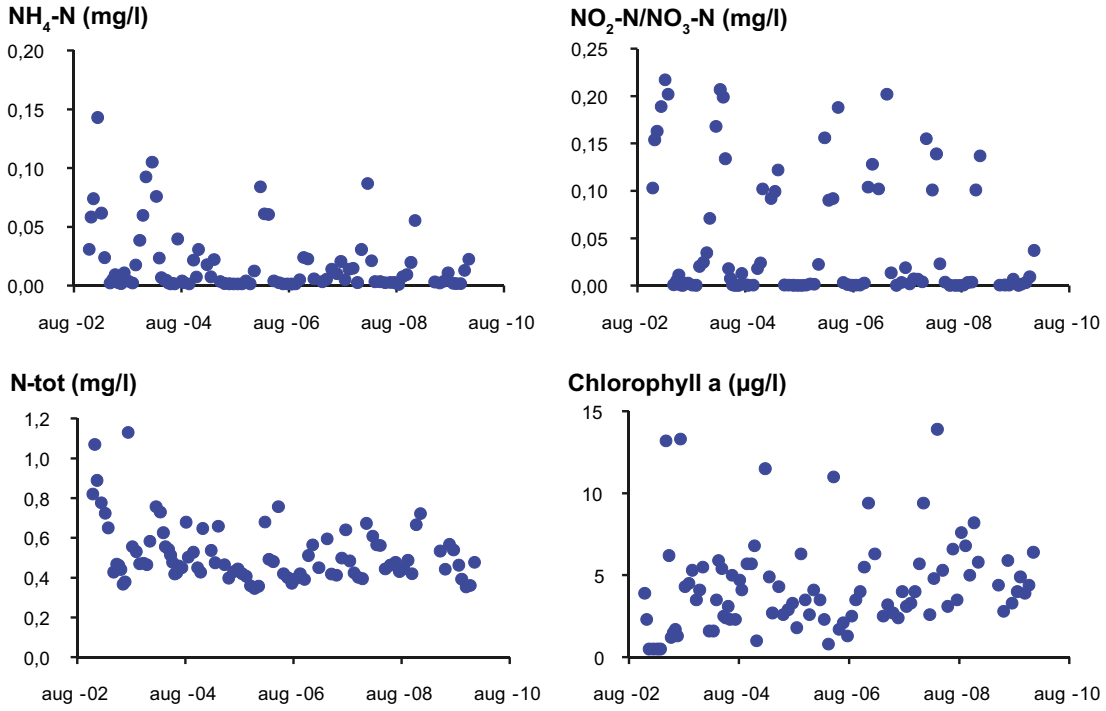

Figure 5-4. *Chlorophyll a and nutrients measured as ammonium, nitrite/nitrate and total nitrogen in the surface water of Granholmsfjärden (PSM002064).*

5.1.2 Carbon fractions and transparensy

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 varied with the run-off /Ericsson and Engdahl 2004a, Ericsson and Engdahl 2004b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, Ericsson and Engdahl 2007b/.

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 or in the transparency (Figure 5-6). A tendency of higher values of POC (particulate organic carbon) in the spring and summer months 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 (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, 2009. Figures in italic indicate that some individual values in the calculation were below the report limit of the analysis.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)	Susp. matrl. (mg/l)
PSM002079	Surface	0.1	1.46	19.2	19.5	4.29	0.224	*6.63*
PSM002083	Surface	0.1	2.30	28.1	29.1	5.74	0.354	5.36
PSM002085	Surface	0.1	1.16	22.1	22.1	16.5	0.218	*8.71*
PSM002086	Surface	0.1	1.24	28.4	28.4	5.53	0.260	*2.78*
PSM002087	Surface	0.1	1.43	19.0	19.2	4.84	0.216	*4.63*
PSM000347	Surface	0.1	1.22	19.7	20.0	4.68	0.197	2.46
PSM107795	Surface	0.1	2.22	31.1	32.5	7.12	0.366	*3.99*

Table 5-5. Average concentration of carbon fractions, absorbance and transparency in Lake Frisksjön, 2009. Figures in italic indicate that some individual values in the calculation were below the report limit of the analysis.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)	Susp. matrl. (mg/l)	Transparency (m)
PSM002065	Surface	0.5	0.954	16.6	17.0	3.35	0.143	*2.67*	1.85
PSM002065	Bottom	2.0	0.967	16.4	16.7	3.36	0.143	*2.73*	

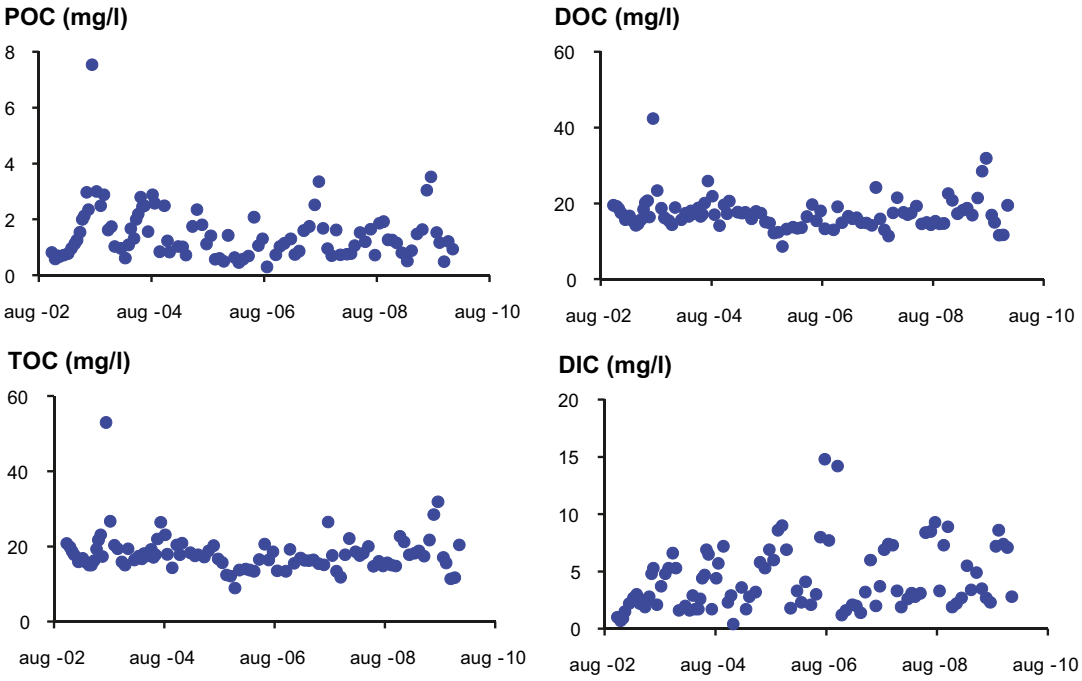

Figure 5-5. *Carbon fractions measured as particulate organic carbon (POC), dissolved organic carbon (DOC), total organic carbon (TOC) and dissolved inorganic carbon (DIC) in Laxemarsån (PSM002087).*

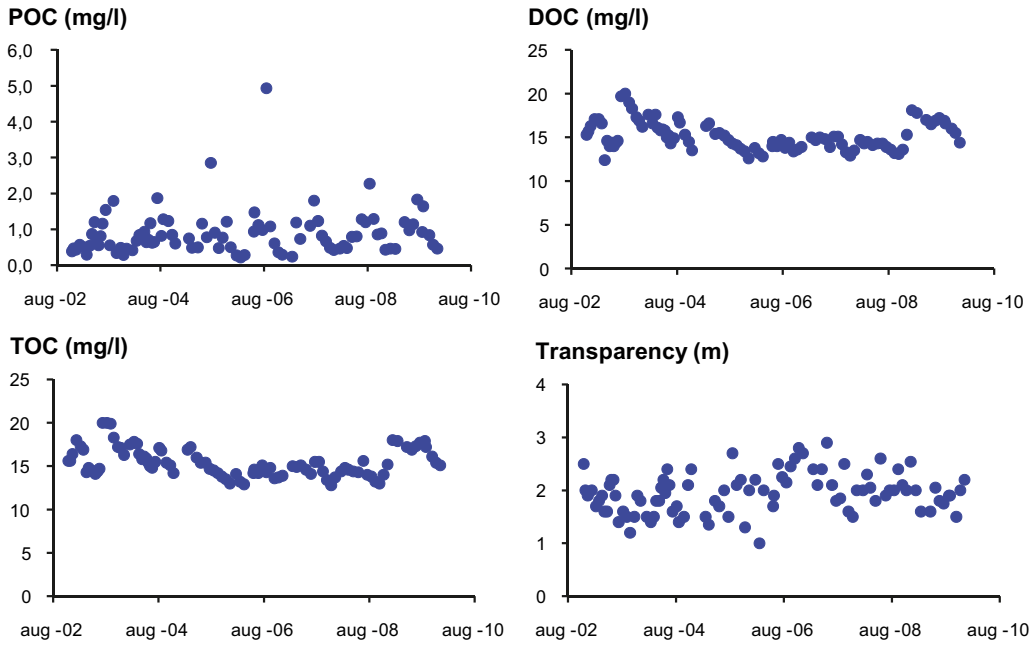

Figure 5-6. *Carbon fractions measured as particulate organic carbon (POC), dissolved organic carbon (DOC), total organic carbon (TOC) and transparency of the surface water in Lake Frisksjön (PSM002065).*

Table 5-6. Average concentration of carbon fractions, absorbance and transparency at the investigated sea sites, 2009. Figures in italic indicate that some individual values in the calculation were below the report limit of the analysis.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)	Susp. matrl. (mg/l)	Transparency (m)
PSM007097	Surface	0.5	0.710	8.35	8.53	14.4	0.052	*2.45*	3.18
PSM007097	Bottom	6.5	1.05	6.20	6.40	17.1	0.032	*4.71*	
PSM002064	Surface	0.5	0.476	6.92	7.07	15.8	0.036	*1.90*	4.28
PSM002064	Bottom	16.0	0.656	5.46	5.68	18.8	0.033	*2.99*	

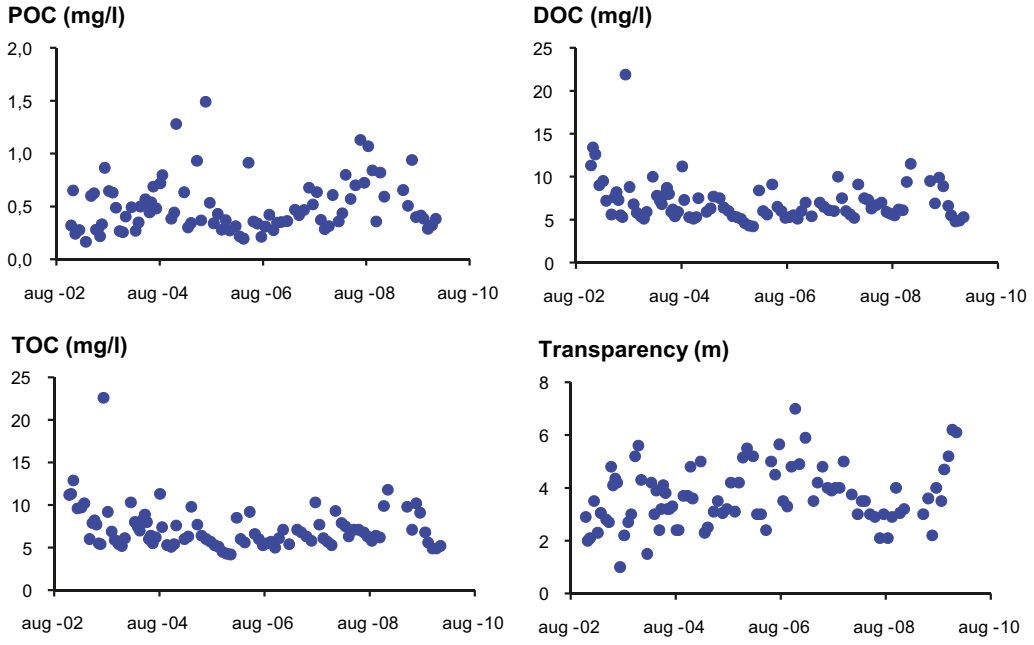

Figure 5-7. *Carbon fractions and transparency of the surface water sea site of Granholmsfjärden (PSM002064).*

5.1.3 Acidification

In the streams HCO_3 and pH strongly correlates with the run-off /Ericsson and Engdahl 2004a, Ericsson and Engdahl 2004b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, Ericsson and Engdahl 2007b/. 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 at the site Basteböla (PS002086) (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 2009 (Table 5-8) /Ericsson and Engdahl 2004a, Ericsson and Engdahl 2004b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, Ericsson and Engdahl 2007b, Ericsson and Engdahl 2009, Ericsson 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.

Table 5-7. Minimum, average and maximum concentration of HCO_3 and minimum, average and maximum pH at the stream water sites, 2009.

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	8.05	17.3	37.2	6.13	6.50	6.94
PSM002083	Surface	0.1	9.36	25.0	45.0	6.07	6.44	6.86
PSM002085	Surface	0.1	64.9	88.9	117	7.02	7.56	7.78
PSM002086	Surface	0.1	5.59	21.3	63.5	5.69	6.24	6.79
PSM002087	Surface	0.1	10.1	22.2	42.9	6.31	6.66	7.03
PSM000347	Surface	0.1	13.5	18.7	27.6	6.09	6.37	6.60
PSM107795	Surface	0.1	14.7	31.0	103	6.09	6.41	6.86

Table 5-8. Minimum, average and maximum concentration of HCO_3 and minimum, average and maximum pH in Lake Frisksjön, 2009.

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	13.3	16.9	21.1	6.34	7.01	7.52
PSM002065	Bottom	2.0	13.7	17.2	21.4	6.40	6.96	7.50

Table 5-9. Minimum, average and maximum concentration of HCO_3 and minimum, average and maximum pH at the investigated sea sites, 2009.

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)
PSM007097	Surface	0.5	57.2	78.0	93.8	7.25	7.95	8.39
PSM007097	Bottom	6.5	82.8	92.0	108	7.05	7.43	7.82
PSM002064	Surface	0.5	71.8	85.6	96.0	7.70	7.87	8.05
PSM002064	Bottom	16.0	92.5	98.6	111	6.96	7.29	7.85

5.1.4 Oxygen

The minimum concentration of oxygen was quite low at one of the stream water sites Uthammar (PSM107795) (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). Since 2007 the concentration of oxygen has been markedly higher during the summer month (Table 5-11 and Figure 5-9). More or less pronounced thermoclines usually evolve in the lake 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 (PSM002064) showed a similar pattern of regular thermocline build up and breakage as Lake Frisksjön (PSM002065) (compare Figure 5-9 to Figure 5-10).

Table 5-10. Minimum, average and maximum concentration of oxygen measured at the stream water sites, 2009.

Site number	Depth zone	Depth (m)	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM002079	Surface	0.1	7.20	9.40	11.7
PSM002083	Surface	0.1	6.30	8.39	10.7
PSM002085	Surface	0.1	8.76	11.3	13.5
PSM002086	Surface	0.1	6.00	9.26	11.3
PSM002087	Surface	0.1	7.40	9.65	12.4
PSM000347	Surface	0.1	8.50	10.0	11.8
PSM107795	Surface	0.1	2.70	7.33	11.3

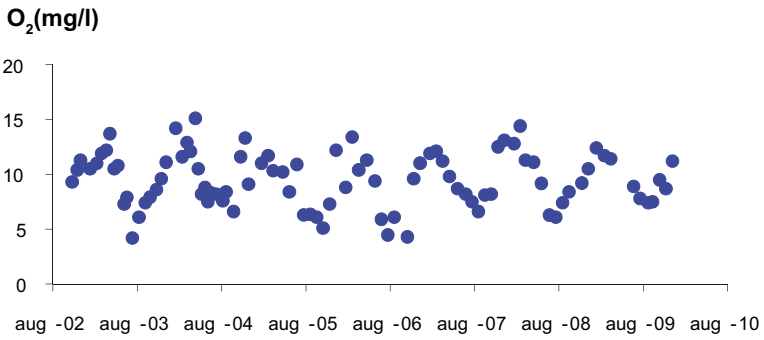

Figure 5-8. *Concentration of oxygen at the stream water site Laxemarsån (PSM002087).*

Table 5-11. Minimum, average and maximum concentration of oxygen in the surface and bottom water in Lake Frisksjön, 2009.

Site number	Depth zone	Depth (m)	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM002065	Surface	0.5	8.67	10.1	12.3
PSM002065	Bottom	2	3.18	8.74	11.2

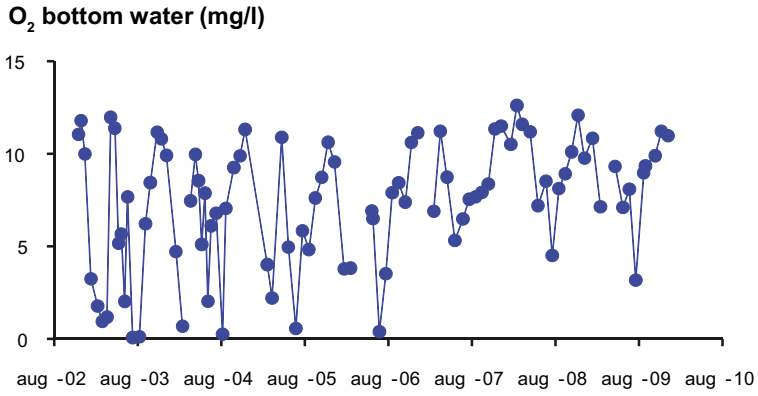

Figure 5-9. *Concentration of oxygen in the bottom water of Lake Frisksjön (PSM002065).*

Table 5-12. Minimum, average and maximum concentration of oxygen in the surface and bottom water at the sea water sites, 2009.

Site number	Depth zone	Depth (m)	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM007097	Surface	0.5	9.88	11.0	12.9
PSM007097	Bottom	6.5	1.23	5.92	11.4
PSM002064	Surface	0.5	9.42	10.7	12.3
PSM002064	Bottom	16	0.49	5.27	11.2

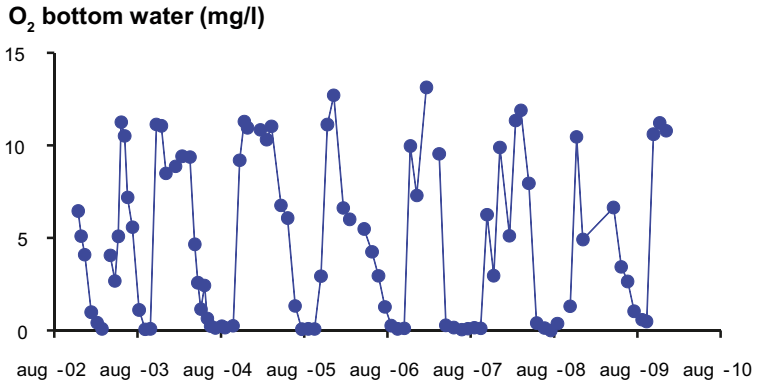

Figure 5-10. *Concentration of oxygen in the bottom water at the sea site Granholmsfjärden (PSM002064).*

5.2 Chemical characterisation

5.2.1 Major ions and conductivity

The average concentration of major ions and the conductivity is presented in Tables 5-13, 5-14 and 5-15. The site Ekerumsbäcken (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, Ericsson and Engdahl 2004b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, Ericsson and Engdahl 2007b/.

In Lake Frisksjön the concentrations of ions and the conductivity was slightly lower than in most of the streams (compare Table 5-13 and 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, 2009. Figures in italic indicate that some individual values in the calculation were below the report 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	12.7	2.00	11.9	3.13	17.3	20.4	18.2	0.202	17.3
PSM002083	Surface	0.1	13.6	1.74	13.1	3.13	25.0	16.7	16.9	0.259	16.4
PSM002085	Surface	0.1	13.8	2.06	38.5	5.11	88.9	19.8	30.3	0.244	29.1
PSM002086	Surface	0.1	15.9	3.40	21.3	4.86	21.3	18.4	46.1	0.684	24.0
PSM002087	Surface	0.1	15.3	2.42	13.9	3.62	22.2	24.8	20.5	0.211	18.3
PSM000347	Surface	0.1	15.8	1.85	11.5	2.96	18.7	27.0	11.4	0.207	17.5
PSM107795	Surface	0.1	11.0	3.99	18.0	4.12	31.0	14.6	24.7	0.763	18.9

Table 5-14. Average concentration of major ions and conductivity in Lake Frisksjön 2009.

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	12.6	1.67	9.17	3.03	16.9	20.9	11.1	0.246	14.9
PSM002065	Bottom	2.0	12.5	1.67	9.15	3.01	17.2	19.9	11.0	0.246	15.4

Table 5-15. Average concentration of major ions and conductivity at the sea water sites, 2009.

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)
PSM007097	Surface	0.5	1,580	62.4	76.2	187	78.0	2,866	394	9.25	916
PSM007097	Bottom	6.5	1,870	73.1	88.7	224	92.0	3,366	467	11.1	1,068
PSM002064	Surface	0.5	1,838	72.7	86.8	218	85.6	3,277	450	10.6	1,037
PSM002064	Bottom	16	2,002	79.4	94.7	240	98.6	3,581	497	11.8	1,129

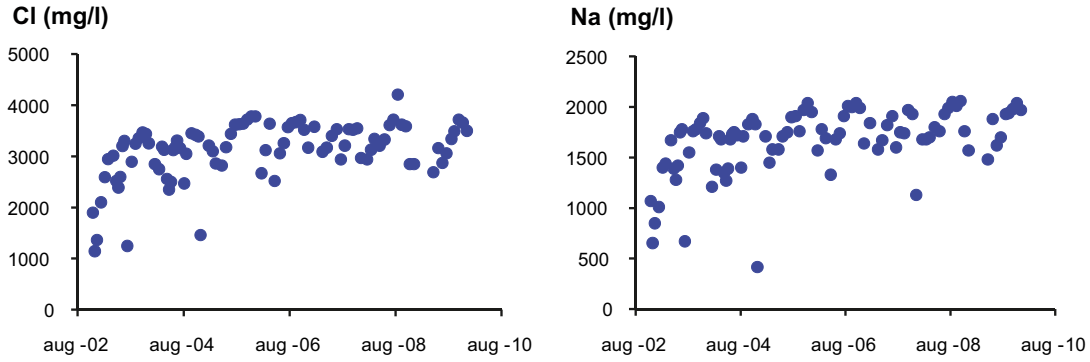

Figure 5-11. *Concentration of Na and Cl in the surface water at the secluded sea site Granholmsfjärden (PSM002064).*

5.2.2 Heavy metals and trace elements

The concentrations of metals and trace elements are presented in Table 5-16, 5-17 and 5-18. Most metals differed 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 were similar between the two sites. 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, 2009. Figures in italic indicate that some individual values in the calculation were below the report 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	545	0.454	23.2	0.129	8.22	0.801	1.06	*0.030*	3.06	0.593
PSM002083	Surface	896	0.621	18.0	0.043	11.2	1.02	1.54	*0.032*	2.97	0.700
PSM002085	Surface	254	0.526	22.2	0.050	4.28	0.538	1.54	*0.030*	5.43	0.365
PSM002086	Surface	1,171	0.587	31.9	0.391	12.5	2.15	1.72	*0.030*	5.96	0.831
PSM002087	Surface	499	0.392	23.4	0.165	7.93	0.710	1.15	*0.030*	3.58	0.607
PSM000347	Surface	655	0.430	20.9	0.064	10.6	0.959	1.54	*0.030*	3.80	0.622
PSM107795	Surface	812	0.636	22.4	0.185	11.3	1.34	1.79	*0.030*	6.15	0.728

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	0.389	0.141	0.773	0.034	0.004	0.126	*0.050*	4.83	0.062	0.389
PSM002083	Surface	0.488	0.164	0.870	0.069	0.005	0.148	*0.050*	5.68	0.095	0.843
PSM002085	Surface	0.255	0.094	0.468	0.042	0.004	0.080	*0.050*	2.54	0.045	2.40
PSM002086	Surface	0.577	0.209	1.06	0.057	0.006	0.181	*0.050*	6.03	0.104	2.47
PSM002087	Surface	0.384	0.139	0.737	0.035	*0.004*	0.123	*0.050*	4.78	0.061	0.507
PSM000347	Surface	0.403	0.175	0.800	0.047	0.005	0.132	*0.050*	5.56	0.066	1.09
PSM107795	Surface	0.488	0.175	0.935	0.061	0.006	0.157	*0.050*	5.68	0.083	2.28

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	4.96	3.46	0.190	1.25	3.06	0.087	0.218	–	0.889	0.098
PSM002083	Surface	5.76	3.32	0.464	1.44	4.02	0.106	0.297	–	1.02	0.114
PSM002085	Surface	2.99	5.88	0.121	0.70	2.53	0.102	0.188	0.280	0.527	0.061
PSM002086	Surface	7.25	11.1	0.161	1.75	4.06	0.153	0.336	–	1.27	0.135
PSM002087	Surface	4.97	3.76	0.178	1.19	3.44	0.087	0.218	0.214	0.850	0.097
PSM000347	Surface	5.94	3.95	0.112	1.48	3.80	0.100	0.263	–	1.00	0.101
PSM107795	Surface	6.27	6.77	0.224	1.60	3.39	0.125	0.331	–	1.13	0.118

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	0.212	*0.016*	0.053	0.434	1.09	4.36	0.376	16.8	1.00
PSM002083	Surface	0.445	*0.016*	0.071	1.20	1.71	5.01	0.555	7.45	1.88
PSM002085	Surface	0.198	*0.013*	0.038	1.62	1.41	2.58	0.272	3.58	1.61
PSM002086	Surface	0.311	0.047	0.086	0.904	1.99	6.10	0.638	21.5	2.07
PSM002087	Surface	0.215	*0.016*	0.052	0.461	1.08	4.17	0.381	20.5	1.11
PSM000347	Surface	0.317	0.018	0.057	0.742	1.21	4.17	0.410	7.71	1.32
PSM107795	Surface	0.375	0.025	0.069	0.937	1.77	5.19	0.507	11.7	2.00

Table 5-17. Average concentration of heavy metals and trace elements in Lake Frisksjön, 2009. Figures in italic indicate that some individual values in the calculation were below the report 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	190	0.775	14.7	*0.008*	3.25	0.193	0.757	*0.030*	1.95	0.180
PSM002065	Bottom	193	0.758	15.0	*0.007*	3.25	0.192	0.795	*0.030*	1.77	0.178

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	0.120	0.053	0.243	0.023	*0.002*	0.039	*0.050*	1.77	0.021	1.02
PSM002065	Bottom	0.122	0.054	0.245	0.022	*0.002*	0.038	*0.050*	1.77	0.021	1.01

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	1.80	1.92	0.785	0.466	3.63	0.141	0.103	–	0.308	0.032
PSM002065	Bottom	1.85	1.85	0.747	0.456	3.53	0.145	0.096	–	0.300	0.031

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	0.1471	*0.01*	0.017	0.383	1.307	1.199	0.125	2.407	0.673
PSM002065	Bottom	0.1433	*0.01*	0.016	0.376	1.35	1.173	0.125	2.387	0.689

Table 5-18. Average concentration of heavy metals and trace elements at the sea water sites, 2009. Figures in italic indicate that some individual values in the calculation were below the report 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)
PSM007097	Surface	47.4	0.633	20.6	*0.020*	0.349	0.148	0.254	*0.100*	1.01	*0.048*
PSM007097	Bottom	10.2	0.760	19.9	*0.020*	0.147	0.186	*0.162*	*0.100*	0.582	*0.024*
PSM002064	Surface	23.9	0.723	19.2	*0.023*	0.118	0.136	0.259	*0.100*	0.681	*0.020*
PSM002064	Bottom	8.85	0.740	18.9	*0.022*	0.169	0.201	0.279	*0.100*	0.474	*0.025*

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)
PSM007097	Surface	*0.031*	*0.020*	*0.046*	*0.020*	*0.002*	*0.020*	*0.200*	0.241	*0.020*	1.62
PSM007097	Bottom	*0.020*	*0.020*	*0.022*	*0.020*	*0.002*	*0.020*	*0.200*	0.108	*0.020*	1.75
PSM002064	Surface	*0.020*	*0.020*	*0.021*	*0.020*	*0.002*	*0.020*	*0.200*	0.081	*0.020*	1.73
PSM002064	Bottom	*0.021*	*0.020*	*0.027*	*0.020*	*0.002*	*0.020*	*0.200*	0.098	*0.020*	1.66

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)
PSM007097	Surface	0.277	1.30	*0.100*	*0.070*	19.2	*0.107*	*0.400*	–	*0.053*	*0.020*
PSM007097	Bottom	0.099	1.10	*0.100*	*0.027*	22.9	*0.107*	*0.400*	–	*0.021*	*0.020*
PSM002064	Surface	0.083	1.17	*0.100*	*0.023*	22.2	*0.118*	*0.400*	–	*0.022*	*0.020*
PSM002064	Bottom	0.112	1.13	*0.100*	*0.030*	23.3	*0.100*	*0.400*	–	*0.026*	*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)
PSM007097	Surface	*0.200*	*0.050*	*0.020*	0.774	0.348	0.310	0.035	2.35	0.174
PSM007097	Bottom	*0.200*	*0.050*	*0.020*	0.704	0.325	0.138	*0.020*	3.36	*0.123*
PSM002064	Surface	*0.200*	*0.050*	*0.020*	0.775	0.361	0.117	*0.026*	5.76	*0.115*
PSM002064	Bottom	*0.200*	*0.050*	*0.020*	0.780	0.345	0.140	*0.031*	3.53	*0.124*

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 report limit.

The measurements of radon were below the report limit in Lake Frisksjön and in most streams. The measurements at the stream site Smedtorpet (PSM002083) differed with a markedly higher value. This result was similar to previous years /Ericsson and Engdahl 2004a, Ericsson and Engdahl 2004b, Ericsson and Engdahl 2005, Ericsson and Engdahl 2007a, Ericsson and Engdahl 2007b, Ericsson and Engdahl 2009, Ericsson 2009/.

Table 5-19. Isotope data from the investigated sites in the streams 2009. Figures in italic indicate that some individual values were below the report 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*	1.129
PSM002083	Surface	0.1	*0.015*	15.34
PSM002085	Surface	0.1	*0.015*	0.907
PSM002086	Surface	0.1	–	–
PSM002087	Surface	0.1	*0.015*	0.695
PSM000347	Surface	0.1	–	–
PSM107795	Surface	0.1	–	–

Table 5-20. Isotope data from Lake Frisksjön 2009. Figures in italic indicate that some individual values were below the report 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*	*0.015*
PSM002065	Bottom	2	*0.015*	*0.015*

Table 5-21. Isotope data from the investigated sea sites 2009. Figures in italic indicate that some individual values were below the report limit of the analysis.

Site number	Depth zone	Depth (m)	^{226}Ra (Bq/l)	^{222}Rn $_{(corr)}$ (Bq/l)
PSM007097	Surface	0.5	*0.015*	*0.015*
PSM007097	Bottom	6.5	*0.015*	0.055
PSM002064	Surface	0.5	*0.015*	*0.015*
PSM002064	Bottom	16	*0.015*	*0.015*

5.3 Effect on the results of methodological changes

No major change of methods that could have an effect on the results occurred in 2009.

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

Another problem with the probedata 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 probe 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, 2009. Oskarshamn site investigation. Monitoring of surface water chemistry 2008. SKB P-09-64, 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 2009.

ID-code	Name	Type of water	Co-ordinate X	Co-ordinate Y	Sampling depth (m)
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

Appendix 2

Schedule – Surface water sampling, weekly working seasons

Sampling occasions and programme 2009.

Month Programme	Jan Week nr	Feb	Mar	Apr	May	June
Ecological	3	8	12	17	22	26
Chemical class 5 (reduced)			12		22	
Chemical class 5 (full)						
Control programme (Br and standard elements)			12		22	

Month Programme	July Week nr	Aug	Sept	Oct	Nov	Dec
Ecological	30	35	38	42	46	50
Chemical class 5 (reduced)						50
Chemical class 5 (full)		35				
Control programme (Br and standard elements)		35				50

Appendix 3

Programmes performed at the different sites

Sampling occasions and programme 2009.

ID-code	Name	Type of water	Ecological programme	Chemical programme	Control programme
PSM007097	Borholmsfjärden	Sea	X	X	X
PSM002064	Granholmsfjärden	Sea	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	

Appendix 4

Sampling sites and weeks when not sampled

Sampling sites and weeks when not sampled 2009.

ID-code	Name	Type of water	Weeks when not sampled	Comment
PSM007097	Borholmsfjärden	Sea	8, 12	Unsafe ice
PSM002064	Granholmsfjärden	Sea	3, 8, 12	Unsafe ice
PSM002065	Frisksjön	Lake	12	Unsafe ice
PSM002079	Kvarnstugan	Stream		
PSM002083	Smedtorpet	Stream		
PSM002085	Ekerum	Stream	38, 42	Dried up
PSM002086	Basteböla	Stream	35, 38, 42, 46	Dried up
PSM002087	Ekhyddan	Stream		
PSM000347	Frisksjöns inlopp	Stream	35, 38, 42, 46	Dried up
PSM107795	Uthammar	Stream	35, 38, 42	Dried up