

# Results from the Swedish National Screening Programme 2004

## Subreport 2: Octachlorostyrene, Monochlorostyrenes and $\beta$ -Bromostyrene

Lennart Kaj, Anna Palm Cousins, Ylva Ekheden, Brita  
Dusan, Katarina Strömberg, Eva Brorström-Lundén, IVL,  
Ingemar Cato, SGU  
B1646  
January 2006

<b>Organization</b> IVL Swedish Environmental Research Institute Ltd.	<b>Report Summary</b>
<b>Address</b> P.O. Box 21060 SE-100 31 Stockholm	<b>Project title</b> Uppdrag inom den nationella miljöövervakningen, screening 2004
<b>Telephone</b> +46 (0)8-598 563 00	<b>Project sponsor</b> Environmental Monitoring, Swedish Environmental Protection Agency
<b>Author</b> Lennart Kaj, Anna Palm Cousins, Jeanette Andersson, Mikael Remberger, Ylva Ekheden, Brita Dusan, Katarina Strömberg, Eva Brorström-Lundén, IVL, Ingemar Cato, SGU	
<b>Title and subtitle of the report</b> Results from the Swedish National Screening Programme 2004 Subreport 2: Octachlorostyrene, Monochlorostyrene and $\beta$ -Bromostyrene	
<b>Summary</b> Measurements were performed of octachlorostyrene, monochlorostyrenes and $\beta$ -bromostyrene in 134 air, deposition, water, sludge, sediment and fish samples near source areas and at background locations. Only octachlorostyrene was detected and only in air from background locations and fish. The results indicate that long-range transport occurs, and that OCS is a generally occurring pollutant in the Baltic Sea. Elevated levels were found in fish from two potential point sources, indicating current emissions of the substance to the water compartment. Diffuse emissions of octachlorostyrene seem to be limited. Biota is suggested as a more suitable matrix for detecting OCS pollution than other matrices. Further measurements in biota and air are recommended in order to provide information on OCS levels in fish and trends related to long-range transport. However, these measurements in air require use of high-volume samplers.	
<b>Keyword</b> Chlorostyrene, screening, environment, analysis, emissions	
<b>Bibliographic data</b> IVL Report B1646	
<b>The report can be ordered via</b> Homepage: <a href="http://www.ivl.se">www.ivl.se</a> , e-mail: <a href="mailto:publicationservice@ivl.se">publicationservice@ivl.se</a> , fax+46 (0)8-598 563 90, or via IVL, P.O. Box 21060, SE-100 31 Stockholm Sweden	

## Sammanfattning

IVL Svenska Miljöinstitutet har på uppdrag av Naturvårdsverket utfört en s k screeningstudie av oktaklorstyren, monoklorstyren samt  $\beta$ -bromstyren. Det huvudsakliga syftet med studien var att bestämma koncentrationen i ett stort antal matriser i den svenska miljön, att undersöka viktiga transportvägar samt utröna om pågående emissioner kan tänkas förekomma i Sverige. Ett ytterligare syfte var att undersöka betydelsen av atmosfärisk transport samt upptag i biota.

Oktaklorstyren emitteras och sprids huvudsakligen som oavsiktligt bildade biprodukt vid ett flertal olika industriella processer. Internationellt har klorstyren även använts inom plastindustrin. Betabromstyren används internationellt som additiv i mat, tvål, tvättmedel samt kosmetika. Oktaklorstyren finns inte med på några internationella prioriteringslistor men har föreslagits som en ny kandidat till Stockholmskonventionen. Den klassas dessutom som ett s k utfasningsämne i Sverige.

En nationell provtagningsstrategi utarbetades med syfte att bestämma förekomsten av oktaklorstyren och de närliggande ämnena i olika matriser i den svenska miljön. Provtagningsprogrammet baserades på identifierade möjliga utsläppskällor samt på ämnets egenskaper. Programmet inkluderade mätningar både i bakgrundsområden och nära potentiella punktkällor. Även mätningar av diffusa spridningsvägar i form av avloppssystem inkluderades. Utöver det nationella programmet deltog även tio länsstyrelser med prover från regionala program, som skickades till IVL för analys. Det totala antalet prover som analyserats i studien framgår av tabellen nedan.

		Luft	Deposition	Vatten	Sediment	Slam	Fisk	Totalt
	Bakgrund	8	8		4		6	<b>26</b>
Nationellt	Punktkällor	6		5	9		6	<b>26</b>
	Diffusa källor	3	3		6	3		<b>15</b>
	Regionalt			10	19	22	10	<b>67</b>
	<b>Totalt</b>	<b>17</b>	<b>11</b>	<b>15</b>	<b>38</b>	<b>25</b>	<b>16</b>	<b>134</b>

Resultaten av mätningarna indikerar att oktaklorstyren finns i den svenska miljön, men i låga koncentrationer. Ämnet kunde endast detekteras i två matriser, luft från bakgrundsstationer samt fisk. Att den återfanns i luft från bakgrundsstationer tyder på att långväga transport förekommer, och förekomsten i strömming från bakgrundslokaler visar att oktaklorstyren är vitt spridd i Östersjön.

De högsta halterna hittades i fisk från två potentiella punktkällor, vilket indikerar möjliga pågående utsläpp av oktaklorstyren till vatten. Koncentrationerna i luft låg vid dessa provplatser under detektionsgränsen, men en generell förekomst i luft kan inte uteslutas, då detektionsgränserna vid dessa platser var högre än de koncentrationer som uppmättes vid bakgrundsstationerna. Diffusa emissioner av oktaklorstyren via reningsverk tycks vara begränsade i Sverige, då oktaklorstyren ej kunde hittas i vare sig slam eller in- och utgående avloppsvatten.

Monoklorstyren eller  $\beta$ -bromstyren har inte kunnat hittas i något av de prover som analyserats.

Eftersom oktaklorstyren är bioackumulerande, med en BCF på 100 000, kan biota anses vara en mer lämplig matris för att detektera pågående miljöbelastning av substansen än övriga matriser.

Med hänsyn taget till ämnets svårnedbrytbarhet samt dess giftighet, liksom indikationerna om giftighet hos dess nedbrytningsprodukter, kan ytterligare mätningar i biota i Östersjön samt i närheten av stora industriområden ge värdefull information om huruvida oktaklorstyren i fisk är ett generellt förekommande problem. Mätningar i luft skulle även kunna ge information om trender relaterade till långväga transport, och möjligen om pågående utsläpp till luft. Sådana mätningar kräver dock låga detektionsgränser, varför det vore nödvändigt att använda s k högvolymsprovtagare.

## Summary

As an assignment from the Swedish Environmental Protection Agency, IVL has performed a "screening study" of octachlorostyrene, monochlorostyrenes and  $\beta$ -bromostyrene. The overall objectives of the screening were to determine concentrations in a variety of media in the Swedish environment, to highlight important transport pathways and to assess the possibility of current emissions in Sweden. A further aim was to investigate the likelihood of atmospheric transport and uptake in biota.

Octachlorostyrene is mainly formed and emitted to the environment as unintentional by-products from several industrial processes. Internationally, chlorostyrenes have also been used in the plastics industry.  $\beta$ -Bromostyrene is also used internationally as an additive in food, soap, washing powder, lotions or perfumes. Octachlorostyrene is not listed on any international priority list but is documented as a chemical of concern in other contexts, and has been proposed as a new candidate for inclusion in the Stockholm Convention. It is qualified as a phase-out substance in Sweden.

A national sampling strategy was developed in order to determine the environmental occurrence of octachlorostyrene and the related substances in different environmental matrices in Sweden. The sampling programme was based on identified possible emission sources as well as on the behaviour of the substances in the environment. The programme included both measurements in background areas and close to potential point sources. Measurements of diffuse pathways from the society including sewage systems were also included. In addition to the national programme, ten different county administrative boards participated in the study and sent samples to IVL for analysis. The total number of samples analysed is shown in the table below.

	<b>Air</b>	<b>Deposition</b>	<b>Water</b>	<b>Sediment</b>	<b>Sludge</b>	<b>Fish</b>	<b>Total</b>
Background	8	8		4		6	<b>26</b>
National							
Point source	6		5	9		6	<b>26</b>
Diffuse source	3	3		6	3		<b>15</b>
Regional			10	19	22	10	<b>67</b>
<b>Total</b>	<b>17</b>	<b>11</b>	<b>15</b>	<b>38</b>	<b>25</b>	<b>16</b>	<b>134</b>

The results indicate that octachlorostyrene is present in the Swedish environment, but in low concentrations. The substance was only detected in two environmental matrices, air from background locations and fish. The presence in air from background stations indicates that long-range transport occurs, and the occurrence in Baltic herring from remote sites shows that octachlorostyrene is a generally occurring pollutant in the Baltic Sea.

The highest levels were found in fish from two potential point sources, indicating possible current emissions of the substance to the water compartment. Air concentrations at these sites were below the detection limits, but general presence in air cannot be entirely ruled out, as detection limits were higher than observed levels at the background sites. Diffuse emissions of octachlorostyrene via sewage treatment plants seem to be limited in Sweden, as octachlorostyrene was not found in sludge or in in- and outgoing wastewater.

Monochlorostyrenes or  $\beta$ -bromostyrene was not detected in any of the samples analysed.

As octachlorostyrene is bioaccumulative, with a BCF of 100 000, biota is considered to be a better matrix for detecting on-going pollution of octachlorostyrene than other matrices.

Considering the persistence and toxicity of the compound as well as the indications of toxicity for its metabolites, further measurements in biota in the Baltic and near industrial sites would provide useful information of whether octachlorostyrene in fish is a generally occurring problem. Monitoring in air could also provide information about the trends related to long-range transport, and possibly about on-going emissions to air. However, these measurements require low detection limits, and use of high-volume air samplers are necessary.

## Table of contents

1	Introduction .....	8
2	Chemical properties, toxicity and fate.....	10
3	Production, use, emission sources and regulation .....	14
4	Previous measurements in the environment.....	15
5	Sampling strategy and study sites.....	17
5.1	National.....	17
5.2	Regional.....	19
6	Methods .....	20
6.1	Sampling.....	20
6.1.1	Air and deposition.....	20
6.1.2	Water and sediment.....	21
6.1.3	Sludge .....	21
6.1.4	Fish .....	21
6.2	Analysis.....	21
6.2.1	Analysis of air samples for octachlorostyrene.....	21
6.2.2	Analysis of water samples for octachlorostyrene .....	22
6.2.3	Analysis of sediment and sludge for octachlorostyrene .....	22
6.2.4	Analysis of air samples for monochlorostyrenes and $\beta$ -bromostyrene .....	22
6.2.5	Analysis of sediment, sludge, water and fish for monochlorostyrenes and $\beta$ - bromostyrene .....	22
7	Results and discussion .....	24
7.1	National.....	24
7.1.1	Air and deposition.....	24
7.1.2	Biota.....	26
7.2	Regional.....	27
7.3	Relationship between abiotic and biotic concentrations .....	28
8	Conclusions .....	29
9	Acknowledgements .....	29
10	References .....	30
	Appendix 1. Sample information .....	32
	Appendix 2. Results.....	38

## 1 Introduction

As an assignment from the Swedish Environmental Protection Agency, IVL has performed a "Screening Study". This screening, which was carried out during 2004/2005, includes the following substances: adipates, octachlorostyrene, limonene, siloxanes, mirex, endosulfan and isocyanates. The different substances or groups of substances are emitted to and spread in the environment via a variety of sources, e.g. point sources and use in products. Some of the chemicals are commonly used internationally and/or in Sweden.

The seven chemicals or chemical groups studied have been identified as potentially toxic, bioaccumulative and/or persistent. Some are also included on different international or national priority lists. Table 1 shows an overview of the chemicals included and the major reasons for their concern.

Table 1. Overview of chemicals included in the screening 2004 and the reason for their concern (Loh et al., 2003; Andersson, 2004; OSPAR, 2005; UNEP, 2005). The chemicals considered in the current report are written in bold/italic letters.

Chemical	Chemical type	Banned/ Restricted	HPV <sup>a</sup>	Indications of toxicity	Evidence for B/P <sup>b</sup>	International Priority List
Adipates	Additive	No	x	x		
Octachlorostyrene	Unintentional by-product	PRIO- substance <sup>c</sup>		x	x	Candidate for the Stockholm convention
Limonene	Cleaning agent (also naturally occurring)			x		
Siloxanes	Lubricant, industrial raw material, chemical additive	PRIO- substance <sup>c</sup>	x	x	x	OSPAR (HMDS)
Mirex	Pesticide	Banned		x	x	Stockholm convention
Endosulfan	Pesticide	Banned		x	x	WFD, OSPAR, Candidate for the Stockholm convention
Isocyanates	Industrial raw material	Regulated	x	x		OSPAR <sup>d</sup>

<sup>a</sup>) High Production Volume

<sup>b</sup>) Bioaccumulation/Persistence

<sup>c</sup>) The chemical is included on Swedish Chemicals Inspectorate's PRIO-list, and is identified as a "phase-out-chemical"

<sup>d</sup>) Concerns 3,3'-(ureylenedimethylene)-bis-(3,5,5-trimethylcyclohexyl) diisocyanate

The overall objectives of the screening were to determine concentrations in a variety of media in the Swedish environment, to highlight important transport pathways, and to assess the possibility

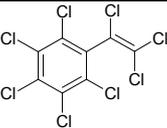
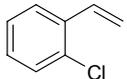
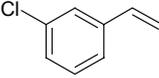
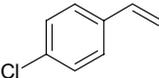
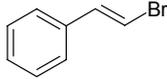
of current emissions in Sweden. A further aim was to investigate the likelihood of atmospheric transport and uptake in biota. The outcome of the study is aimed to serve as a basis for decision-making regarding monitoring activities of these chemicals.

Due to the variety in emission sources and use as well as differences in chemical properties, the screening has been carried out in seven sub-projects. This report considers the screening of octachlorostyrene, monochlorostyrenes and  $\beta$ -bromostyrene. Results for the other chemicals are presented in subreports 1 and 3-6.

## 2 Chemical properties, toxicity and fate

Chloro- and bromostyrenes according to Table 2 were selected for this screening study.

Table 2. Chemicals selected for screening

Name	CAS no	Chemical structure
Octachlorostyrene	29082-74-4	
o-Chlorostyrene	2039-87-4	
m-Chlorostyrene	2039-85-2	
p-Chlorostyrene	1073-67-2	
$\beta$ -Bromostyrene	103-64-0	

Octachlorostyrene (OCS) is known to be a persistent chemical, and degradation processes are generally slow. The most important degradation pathway is via reaction with OH-radicals in the atmosphere. The atmospheric half-life of octachlorostyrene has been estimated to 15 days (HSDB, 2005). Octachlorostyrene can be degraded in organisms but this is a very slow process. The half-life of octachlorostyrene in eels was estimated to 790 days in a study of contaminated eels that were put in clean water (US EPA, 1998). A possible metabolite following biological degradation is 4-hydroxy-heptachlorostyrene, which is water-soluble and thus may be transported out of the organism. Studies indicate a possibility of accumulation of the metabolite blood plasma due to hindered excretion (Sandau *et al.*, 2000).

Monochloro- and bromostyrenes are not as persistent as octachlorostyrene. In the atmosphere, they are degraded by hydroxyl radicals and ozone. Monochlorostyrenes have a relatively short atmospheric half-life of 13-14 hours and are not expected to be transported long distances by atmospheric processes while  $\beta$ -bromostyrene has a half-life of 22 hours to 6 days in the atmosphere, depending on the reaction pathway (HSDB, 2005). A compilation of physical-chemical properties is shown in Table 3.

Table 3. Physical-chemical properties of chloro- and bromostyrenes (Source: <sup>a</sup>HSDB, 2005; <sup>b</sup>SRC, 2005).

Styrene	MW (g/mol)	$W_{sol}$ (mg/L, 24°)	$V_p$ (mm Hg, 25°) <sup>a</sup>	H (Atm m <sup>3</sup> /mol) <sup>a</sup>	Log $K_{ow}$ <sup>a</sup>	BCF <sup>a</sup>	BAF <sup>a</sup>	$K_{oc}$ (L/kg) <sup>a</sup>
Octachloro-	379.71	Insol. <sup>a</sup> 0.00174 <sup>b</sup>	$1.3 \times 10^{-5}$	$2.3 \times 10^{-4}$	7.46 <sup>b</sup>	$1 \times 10^5$	$1.2 \times 10^8$	$2 \times 10^5 - 1 \times 10^7$
o-Chloro-	138.60	Insol. <sup>a</sup> , 80.5 <sup>b</sup>	0.96	$2.1 \times 10^{-3}$	3.54	100		860
m-Chloro-	138.60	Insol. <sup>a</sup> , 80.5 <sup>b</sup>	0.98	$2.1 \times 10^{-3}$	3.54	100		840
p-Chloro-	138.60	Insol. <sup>a</sup> , 80.5 <sup>b</sup>	0.82	$2.1 \times 10^{-3}$	3.54	100		840
$\beta$ -Bromo-	183.05	Insol. <sup>a</sup> , 108 <sup>b</sup>	0.12	$5.5 \times 10^{-4}$	3.15	3		960

A modelling exercise was performed using the Equilibrium Criterion (EQC) model (Mackay et al., 1996) in order to highlight the likely fate and partitioning behaviour of chloro- and bromostyrenes. Three substances were selected for this purpose: octachlorostyrene, o-chlorostyrene and  $\beta$ -bromostyrene. In a modelling perspective, it is important to use input data (physical-chemical properties and degradation half-lives) that are as internally consistent as possible. In particular, this is crucial when the aim is to compare partitioning properties between different chemicals. As the half-lives given above only concern the atmosphere, and as they in some cases cover a wide range (e.g.  $\beta$ -bromostyrene, see above), it was decided to use a different approach in order to obtain half-lives for modelling purposes. First, environmental half-lives for octachlorostyrene, monochlorostyrene,  $\beta$ -bromostyrene were estimated with the EPIWIN software (Meylan, 1999) and compared to those given above, which showed a good agreement. They were then classified according to Mackay (2001), who suggested 7 groups, ranging from 5 to 55000 hours, depending on the range of reported half-lives. Thus, an atmospheric half-life estimated to 19 hours and reported to be 13-14 hours was assigned a half-life of 17 hours. For a more detailed description of the classification method, the reader is referred to Mackay (2001). The estimated environmental half-lives used in the modelling exercise are shown in Table 4 while physical-chemical properties were taken from Table 3.

Table 4. Estimated environmental half-lives in hours.<sup>a</sup>

Chemical	Air	Water	Soil	Sediment
Octachlorostyrene	170	5500	5500	55000
(o,m,p)-chlorostyrene	5	550	1700	5500
$\beta$ -Bromostyrene	17	550	550	5500

<sup>a</sup>Calculated with EPIWIN (Meylan, 1999) and classified according to Mackay (2001).

Emission rates were set to 1000 kg/h, for illustrative purposes. The outcome of the modeling exercise is shown in Figure 1. The results should be interpreted as indicative, as the partitioning behavior is dependent on model structure as well as chemical property data and may be different in a different environment. The exercise does, however, fruitfully illustrate the difference in partitioning behavior and environmental persistence (residence time) between these three chemicals.

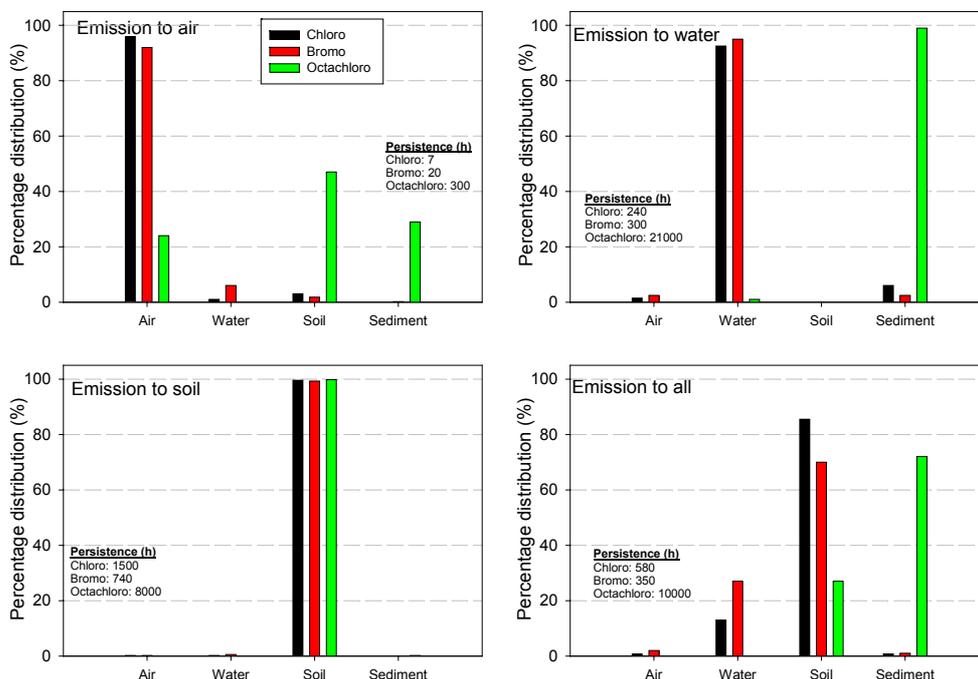


Figure 1. Results from EQC modelling of chloro- and bromostyrenes, using emission rates of 1000 kg/h

The overall residence time (“persistence”) in the system of octachlorostyrene is predicted to be significantly higher (>1 year when emitted to all media) than for monochloro- and bromostyrene (<30 days). The model definition of persistence includes both reaction/degradation and chemical transport out of the model system with air and water currents (advection). In this case, the latter processes are the dominant removal mechanisms, thus low persistence in the model system does not mean that the chemical is ultimately removed from the environment.

The primary receiving medium for all the substances investigated is likely to be air. The model results emphasize that octachlorostyrene tends to partition to soils and sediment regardless of medium of release, whereas monochloro- and bromostyrenes tend to partition to the matrices where they are released.

Octachlorostyrene has high bioconcentration and bioaccumulation factors (BCF = 100 000, BAF =  $1.2 \times 10^8$ ; Table 3) and will bioconcentrate when released to water. In a study performed in 1988 the biomagnification pattern for octachlorostyrene was very similar to that of the well-known environmental pollutant hexachlorobenzene (Figure 2).

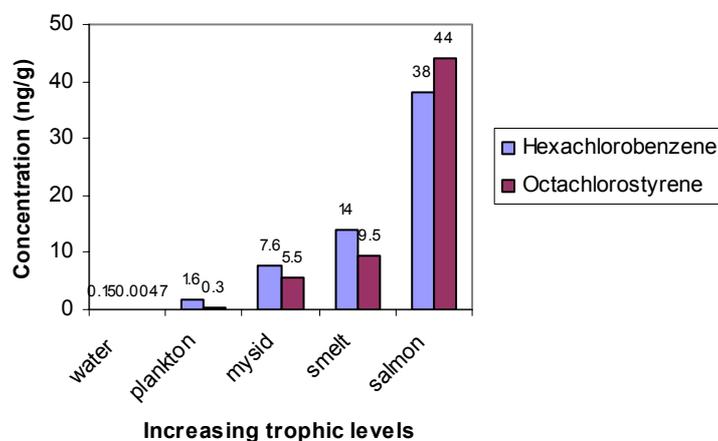


Figure 2. Comparison of concentrations of octachlorostyrene and hexachlorobenzene between trophic levels in Lake Ontario (Oliver and Nimii, 1988).

US EPA considers octachlorostyrene as a potential mutagenic and carcinogenic chemical as it has structural similarities with hexachlorobutadiene and hexachlorobenzene, which both have these properties (US EPA, 1998). The "No observable adverse effect level" (NOAEL) for octachlorostyrene is 0.03 mg/kg day. The state of New York has adopted an acceptable daily intake of 0.03  $\mu$ g/kg. Octachlorostyrene has a high toxicity towards aquatic animals which is shown in Table 5, where it is compared with two well-known organic contaminants, DDT and pentachlorophenol (US EPA, 1998). Judging from their  $K_{OW}$ -values, chloro- and bromostyrenes have a potential for partitioning to organic media (e.g. biological organisms). However, their BCF-values are generally low (Table 3), indicating low potential for bioconcentration (HSDB, 2005). Chlorostyrenes are irritating to eye and skin (HSDB, 2005).

Table 5.  $LC_{50}$  (*Nitocra spinipies*, subphylum crustacea) (US EPA, 1998) for some organic chemicals

	$LC_{50}$ , <i>Nitocra spinipies</i> (mg/L)
Octachlorostyrene	0.068
DDT	0.03
Pentachlorophenol	0.27

### **3 Production, use, emission sources and regulation**

Octachlorostyrene is an unintentional by-product from several industrial processes. It is not listed on any international priority list but it is documented as a chemical of concern in other contexts (Bremle, 2002). It is also considered as a candidate for inclusion on the Stockholm convention priority list for POPs (IPEN, 2005). Although there are no official restrictions on the usage of octachlorostyrene in Sweden, its chemical properties qualify it as a phase-out substance according to criteria in the priority database (PRIO, 2005).

Octachlorostyrene is formed in different industrial processes e.g. through chlorination of alkane/alkenes and chlorination of elementary carbon. Just like chlorinated dioxins, chlorinated dibenzofurans and hexachlorobenzene, octachlorostyrene is also formed during incomplete combustion in the presence of chlorine. Thus, co-emissions of octachlorostyrene and dioxins are likely to occur and detection of one substance often implies existing levels of the other (US EPA, 2000). Emission to air may be an important source.

US EPA (1998) has done a large study on octachlorostyrene, where probable and definite emission sources were identified. A number of industrial activities were pointed out as probable OCS emitters, including various metal industries such as e.g. primary and secondary aluminium producers, magnesium industries and copper melting plants. Different chlorine-related industries were also identified as probable emission sources.

There is no registered use of monochlorostyrenes in Sweden and no official restrictions. However, they have been used internationally in the plastics industry when producing polychlorostyrene and polyester. Betabromostyrene is also used internationally as an additive in food, soap, washing powder, lotions or perfumes. In addition to this, monochloro- and bromostyrenes can also form as unintentional by-products (Loh et al, 2003).

## 4 Previous measurements in the environment

The environmental occurrence of octachlorostyrene was first reported in 1969 in the river Rhine in the Netherlands. In 1986, octachlorostyrene was detected in the breast milk of women in Ontario, Canada and was thereby considered to be an environmental pollutant of international interest. During 1997, contamination of octachlorostyrene in Norwegian fjords was traced to a magnesium plant. In the same year, the occurrence of octachlorostyrene in blood from the workers in that plant was reported (US EPA, 1998).

High levels of octachlorostyrene have been detected in the river Elbe in Germany, the river Rhine in the Netherlands, the North Sea between Great Britain and Norway, the Frier fjord in Norway, the Great Lakes Basin on the border between Canada and USA and Bayou d'Inde, Louisiana, USA. In the USA, there has recently been a new discovery of contaminated areas, indicating on-going emissions (US EPA, 1998).

Shaogang et al. (2003), showed that levels of octachlorostyrene were primarily related to locations for incineration and in strong correlation with levels of hexachlorobenzene (Table 6).

Table 6. Measurements of octachlorostyrene in different matrices in Europe

Matrix	Conc.	Unit	Location	References
Sediment from polluted areas	5.41	ng/g ww	Belgium, Romania and Great Britain	Shaogang et al., (2003)
Fresh water clams (and fresh water fish)	< 0.01 -0.18	ng/g ww	Belgium and Romania	d.o.
Fresh water fish	10-45	ng/g ww	Elbe, Germany	Bester at al. (1998)
Shrimps	0.08	ng/g ww	Belgium, Romania and Great Britain	Shaogang et al., (2003)
Marine fish	0.02-0.01	ng/g ww	Belgium, Romania and Great Britain	d.o.
Marine fish	0.4-40	ng/g lw	Atlantic ocean (North Cape and North Sea)	Coelhan et al. (2000)
Harbour porpoise (Phocoena Phocoena) liver	1.90	ng/g ww	Belgium, Romania and Great Britain	Shaogang et al., (2003)
Blue tits (Parus caeruleus) egg	1.24	ng/g ww	Belgium, Romania and Great Britain	d.o.
Great tits (Parus major) lipid	3.24	ng/g ww	Belgium, Romania and Great Britain	d.o.
Hedgehog (Erinaceus europeus) lipid	0.34	ng/g ww	Belgium, Romania and Great Britain	d.o.
Human lipid	0.38	ng/g ww	Belgium, Romania and Great Britain	d.o.

Sandau *et al.* (2000) found high levels of 4-hydroxy-heptachlorostyrene, a probable metabolite of octachlorostyrene, in blood plasma of polar bears and seals (Table 7). The differences in concentration between bears and seals may depend on different possibilities of metabolising the substance. A high level of this substance is possibly due to its affinity to specific plasma proteins, transthyretin, which occurs, in high quantities in the blood of polar bears. 4-hydroxy-

heptachlorostyrene has also been detected in benthic and pelagic fresh water fish in the Huron river, Canada, a well-known contamination spot for octachlorostyrene (Hongxia *et al.*, 2003).

Table 7. Concentrations of chlorostyrenes and other environmental pollutants in bloodplasma (ng/g wet weight) at Resolute Bay Area, Nunawut Territory, Canada (Sandau *et al.*, 2000).

Substance	Polar bear			Seal
	Average	Min	Max	Average
Octachlorostyrene	0.35	0.106	0.940	0.27
4-Hydroxy-heptachlorostyrene	9.1	2.89	22.9	0.062
Pentachlorophenol	0.21	0.093	0.531	0.24
$\Sigma$ PCBs	47	16.1	161	27
$\Sigma$ OH-PCBs	93	26.4	576	0.081

In Sweden, 4-hydroxy-heptachlorostyrene was qualitatively detected in blood samples from ten randomly selected men (Hovander *et al.*, 2002). The implications of the presence of this substance in human bodies are still not entirely known. Exposure to phenolic substances has been discussed as a possible contributing factor in the disturbance of endocrine related processes in both humans and animals. Phenolic substances and in particular halogenated ones have also been shown to interfere with transport of thyroid hormones (Hovander *et al.* 2002). The substances can therefore either act as hormones or stop other hormones from functioning.

## 5 Sampling strategy and study sites

### 5.1 National

A national sampling strategy was developed in order to determine the environmental concentrations of octachlorostyrene and related substances in different environmental matrices in Sweden. An additional aim of the sampling programme was to identify major emission sources as well as important transport pathways. The sampling programme was therefore based on identified possible emission sources and use of the chemicals as well as on the behaviour of the substances in the environment. The programme included both measurements in background areas and close to potential point sources. Measurements of diffuse pathways from the society including sewage systems were also included. The programme is summarised in Table 8.

Two aluminium manufactories (one with primary and one with secondary production) were chosen as potential point sources for chlorostyrenes, as aluminium industries were one of the many metal industries pointed out as potential emission sources by US EPA (1998). One of the sites is situated in a large industrial area, with many other industries in the vicinity, whereas the other site is purely an aluminium melting plant. As diffuse sources, three wastewater treatment plants were selected, which are included in the Swedish Environmental Protection Agency's monitoring programme for environmental pollutants in sludge (Naturvårdsverkets miljöövervakningsprogram av miljögifter i slam). Diffuse pathways were also studied in an urban area, Stockholm, where air, deposition, and sediment samples were collected (Figure 3).

In order to determine background levels, sediment, biota, air and deposition samples were collected. The locations of the sampling sites are shown in Figure 3. The sampling stations Råö and Pallas are also a part of the national monitoring programme for air pollutants and included in the EMEP and AMAP networks. The sediment samples were collected at off shore stations in the Baltic Sea (SGU, Ingemar Cato). The biota samples were collected at background sites used within the national monitoring programme of contaminants in biota (NRM, Anders Bignert).

Table 8. National sampling programme for chlorostyrenes

	Air	Deposition	Water	Sediment	Fish	Sludge	Total
<b>Background</b>							
Råö	4	4					<b>8</b>
Pallas	4	4					<b>8</b>
Various				4	6		<b>10</b>
<b>Point sources</b>							
Primary Aluminium production plant	3		2	3	3		<b>11</b>
Secondary Aluminium production plant	3		2	6	3		<b>15</b>
<b>Diffuse sources</b>							
STP Henriksdal						1	<b>1</b>
STP Eslöv						1	<b>1</b>
STP Floda						1	<b>1</b>
Stockholm	3	3		6			<b>12</b>
<b>Total</b>	<b>17</b>	<b>11</b>	<b>6</b>	<b>15</b>	<b>12</b>	<b>3</b>	<b>67</b>

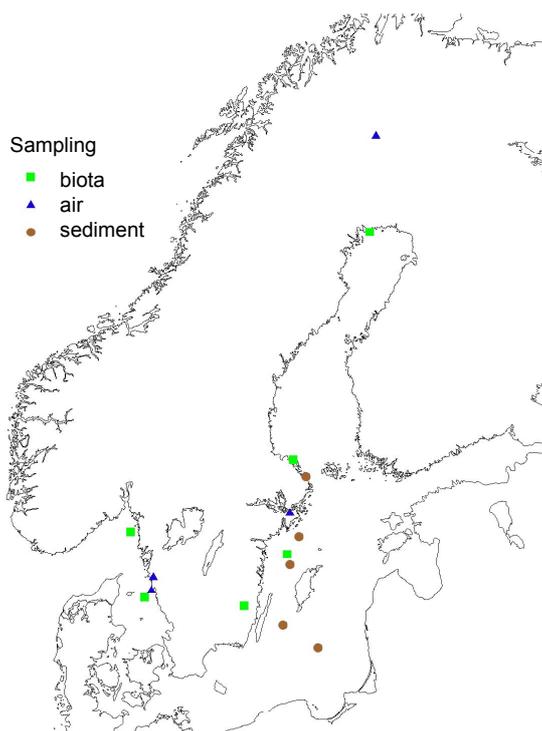


Figure 3. Geographic distribution of background and urban sampling stations.

## 5.2 Regional

A regional screening programme was carried out by different Swedish county administrative boards that had the possibility to collect samples to send to IVL for analysis. Different counties have chosen different strategies for their regional sampling scheme. The selection of the "regional" samples was meant to increase the number of samples for substances connected to their environmental programmes i.e. substances that have been regulated or included in the national priority database. Another strategy was to choose substances where environmental levels are expected to differ from national levels because of intensive use within the county i.e. local industrial areas or because of geographic proximity to European industrial areas.

The aim of the regional sampling was further to identify major emission sources as well as important transport pathways. Ten different county administrative boards participated in the regional sampling programme with a total of 62 samples consisting of ten fish samples, 19 sediment samples, 22 sludge samples and ten water samples (see Table A 2 for detailed sample description).

## 6 Methods

### 6.1 Sampling

A manual was developed as a guideline for adequate and consistent sampling. This manual was used both in the national and in the regional screening programme. Detailed instructions for sampling, storing and transport were given. Sampling protocols for all sample types were included in the sampling manual. The overall aim of the sampling protocols was to:

1. Guide the personnel responsible for sampling on how to avoid contamination of the samples.
2. Ensure documentation of the sampling procedure, quality of the sample and environmental and physical circumstances during the sampling.

All samples from the regional county administrative boards were sent to IVL, Swedish Environmental Research Institute, for analysis.

#### 6.1.1 Air and deposition

Air samples for analysis of octachlorostyrene at Råö and Pallas were collected using a high volume air sampler (HVS) with a flow of approximately 25 m<sup>3</sup>/h. The substances in particle phase were collected on a glass fibre filter and in the gas phase on PUF-plugs. The sampling was carried out for one week and four weekly samples were pooled to represent a monthly average.

Air samples for analysis of octachlorostyrene from Stockholm, Sundsvall and Älmhult were collected using a low volume air sampler (LVS) with a flow of approximately 1 m<sup>3</sup>/h. The particles were collected on a glass fibre filter (MG160, Munktell) and octachlorostyrene in the gas phase in two glass columns in series each packed with the adsorbents XAD-2 (Amberlite) and polyurethane foam (PUF). Sampling duration was two weeks. Filter and adsorbents were changed after one week.

Air samples for analysis of monochlorostyrenes and  $\beta$ -bromostyrene were collected by pumping air through adsorbent tubes containing Tenax TA. A filter impregnated with sodium thiosulphate was used as an ozone trap to prevent break down of the analytes on the adsorbent. The flow was 60-100 ml/min and the sampling time was usually 6h.

Wet and dry deposition was jointly collected using an open sampler (bulk sampler). This sampler consists of a 1 m<sup>2</sup> Teflon coated surface with 10 cm high edges. The bottom declines slightly to a central opening where a cassette with an adsorbent (PUF) is attached. The deposition sample includes both compounds in the precipitation and compounds deposited to the collection surface of the sampler. Both the precipitation and the deposited particles are included in the analysis. This type of sampler is used for deposition measurements of organic contaminants within the Swedish national monitoring of air pollutants (Brorström-Lundén, 1996).

Prior to sampling, glass fibre filters were heated to 400°C, and the adsorbent columns were cleaned by Soxhlet extraction with acetone. After sampling, the filter and columns were wrapped in aluminium foil and sent to the laboratory, where they were stored in a freezer (-18°C) until analysis. An additional filter and column used as a field blank was sent back to the laboratory unexposed.

## 6.1.2 Water and sediment

Surface water was collected in glass bottles by direct immersion of the bottle mounted on a metal rod. Sediment samples from lakes or sites close to the coast were collected by means of a Kajak sampler. The sediment core was sliced and transferred into pre-heated (400°C) glass jars fitted with aluminium foil lined screw caps and stored in a freezer (-18°C) until analysed.

The four marine sampling sites (Ö Gotlandsdjupet, Ö Öland, Norrköpingsdjupet, Ö Landsortsdjupet) were chosen from areas with continuous deposition of fine-grained sediment. These sites were identified with hydroacoustic methods (shallow seismic, sub-bottom profiler and chirp side-scan sonar). Prior to sampling, the bottom at the sampling site was inspected with a submarine video camera. Furthermore, a sediment-core from the site was X-rayed with a sediment-scanner (Cato et al. 2000) in order to detect unwanted physical disturbances as strong bioturbation, anchoring, trawling, etc. Sites, which fulfilled the sedimentological demands set up, were then sampled with a Gemini corer and the cores were sliced in vertical position with a core-cutter onboard. Surface sediments (0-1 cm) from four cores taken at each site were mixed in order to neutralise sediment inhomogenities. The samples collected were stored dark and frozen in pre-cleaned and burned glass bottles.

## 6.1.3 Sludge

The staff at the different treatment plants collected the sludge samples from the anaerobic chambers. The sludge was transferred into pre-heated (400°C) glass jars fitted with aluminium foil lined screw caps and stored at 4°C or -18°C until analysed.

## 6.1.4 Fish

Fish samples were collected by means of fishing net, hoop net or fishing rod. Samples of herring from background areas were supplied from The Environmental Specimen Bank and the Museum of Natural History (A. Bignert and Colleagues). Fish samples were individually wrapped in aluminium foil and stored in a freezer (-20°C).

## 6.2 Analysis

The solvents, HPLC-quality, acetone, hexane, pentane, and methyl-*tert*-butylether (MTBE) were delivered from Rathburn (Chemical Ltd., Peeblesshire, Scotland). Sodium sulphate, sodium chloride and silica gel were pre-heated (400°C) prior to use. Ultra-pure water was produced by a Milli-Qplus (Millipore Corporation, Bedford, MA, USA)

### 6.2.1 Analysis of air samples for octachlorostyrene

The filter and adsorbents were Soxhlet extracted with acetone for 24 h. The acetone was spiked with surrogate standards ( $^{13}\text{C}_6$  chlorobenzenes) and diluted with ultra pure water to a final concentration of 25 % acetone in water. The mixture was extracted twice with pentane. The combined extracts were concentrated to 2 ml and dried over sodium sulphate. Concentrated sulphuric acid was added. After gentle shaking for 30 min the organic phase was applied to a column containing silica gel (5%  $\text{H}_2\text{O}$ ). The analytes were eluted with hexane. The extract was

analyzed on GC-MS (6890N-5973MSD, Agilent) in SIR mode. Injection was splitless at 250 °C, column VF-5MS 30m  $\times$  0.25 mm i.d., film thickness 0.25  $\mu$ m (Varian), carrier gas helium 1 ml/min constant flow, column temperature program 50°C for 5 min, 12°/min to 280°C, hold for 10 min. The massspectrometric detector was used in single ion recording mode, ionisation energy 70 eV, quantification ion m/e 380. The ions 378 and 382 were used as supporting ions. Hexachlorobenzene  $^{13}\text{C}_6$ , m/e 290, was used as internal standard.

### **6.2.2 Analysis of water samples for octachlorostyrene**

The water sample (750 ml) was spiked with surrogate standards ( $^{13}\text{C}_6$ -chlorobenzenes) and extracted twice with pentane: MTBE (1:1; 100 + 50 ml). The extracts were combined, dried over sodium sulphate and concentrated with a gentle steam of nitrogen. The extract was treated with concentrated sulphuric acid (gentle shaking for 30 min) and chromatographed on a silica gel column with hexane as mobile phase. The extract was analysed with GC-MS as described for air samples.

### **6.2.3 Analysis of sediment and sludge for octachlorostyrene**

The water in the sediment and sludge samples was separated by centrifugation before the extraction. Surrogate standards ( $^{13}\text{C}_6$ -chlorobenzenes) were added and mixed carefully. The sample was extracted with (a) acetone, (b) acetone and MTBE and finally acetone plus pentane: MTBE (3+1). The pooled extract was diluted with the water separated from the sample and ultra pure water and mixed carefully. After phase separation the organic extract was safeguarded. The water phase was extracted once more with a mixture of pentane and MTBE (1+1), the combined extract was concentrated, the solvent changed to hexane, treated with concentrated sulphuric acid (gentle shaking for 30 min) and chromatographed on a silica gel column with hexane as mobile phase. The extract was analysed with GC-MS as described for air samples.

### **6.2.4 Analysis of air samples for monochlorostyrenes and $\beta$ -bromostyrene**

The adsorbent tube was transferred to a thermal desorber (Unity, Markes) connected to a GC-MS instrument (6890N, 5973N, Agilent). Pre-purge time was 2 min, tube desorption time 5 min at 225°C, the trap was held at 3°C and heated at 32°C/s to 250°C. The desorb flow was 30 ml/min and the split flow 10 ml/min. The flow path temperature was 150 °C and it connected directly to the GC-column which was a CP-Sil 8CB 30m  $\times$  0.25 mm id, film thickness 0.5 $\mu$ m (Varian). The column temperature was 40°C for 3 min, programmed to 200°C at 12°C/min and to 260°C at 30°C/min. The carrier gas was helium held at constant pressure 10 psi measured at 40°C. The massspectrometric detector was used in single ion recording mode.

### **6.2.5 Analysis of sediment, sludge, water and fish for monochlorostyrenes and $\beta$ -bromostyrene**

Approximately 2 g of wet sludge were diluted to 20 ml with MilliQ water and homogenised with a high frequency mixer (Polytron). Approximately 1 ml of the slurry was weighed in to a purge & trap vessel and diluted to 10 ml. Sediment was diluted in a similar way, but homogenised by shaking only. Water samples were homogenised by shaking. In all cases 0.5 ml buffer solution (2 M

$K_2HPO_4$ , 0.4M HCl, 80g  $Na_2EDTA \cdot 2H_2O$  per litre) was added to the purge & trap vessel. The purge & trap apparatus for sludge and sediment samples consisted of a 25 ml graduated glass test tube with an adapter with one inlet for a Pasteur pipette extending to the bottom of the tube and one side arm to which an empty adsorbent tube was connected using flexible tubing (Viton). This tube acted as a short cooler and water trap. An adsorbent tube containing 0.25 g Tenax TA was connected to the empty tube, the Pasteur pipette was connected to the purge gas (nitrogen, 50 ml/min) and the tube was immersed in a thermostated water bath held at 70°C. An electric fan facilitated air cooling of the upper part of the apparatus. Samples were purged for 2h. For water samples gas washing bottles with glass frit gas inlet was used as purge vessels. Water volume was 60 - 150 ml, the other conditions were the same as above. The adsorbent tube was transferred to a thermal desorber and analyzed as described for air samples

Fish muscle and was homogenized in water with the high frequency mixer while being cooled in an ice bath. Purging was done in a vessel as described above for sludge and sediment. To reduce foaming the nitrogen flow was reduced to 25 ml/min. The sampling time was increased to 4h.

## 7 Results and discussion

### 7.1 National

All results are presented in detail in Table A 3 in Appendix 2.

Octachlorostyrene was detected in air from background stations and in biota but not in any of the other samples. Monochlorostyrenes or  $\beta$ -bromostyrene was not detected in any of the samples analysed.

Detection limits are summarised in Table 9.

Table 9. Limits of detection (LOD) in different matrices, national samples

Matrix	Octachlorostyrene	Monochlorostyrenes, $\beta$ -bromostyrene
Air	0,0001-0,0003 ng/m <sup>3</sup> backgr. stn 0.01 ng/m <sup>3</sup> , point sources	7- 20 ng /m <sup>3</sup>
Deposition	0.03 - 0.15 ng/m <sup>2</sup> day	
Sediment	1 - 3 ng/g dw	3 - 32 ng/g dw
Sludge	1 ng/g dw	10 - 20 ng/g dw
Water	1.1 - 2.5 ng/l	10 ng/l
Fish	0.3- 2 ng/g lipid	16 - 100 ng/g lipid

#### 7.1.1 Air and deposition

The atmospheric concentrations of octachlorostyrene at the background stations were 0.3 - 0.5 pg/m<sup>3</sup> at Råö and 0.4 - 0.8 pg/m<sup>3</sup> at Pallas. The samples represent monthly averages. There was a seasonal variation with the highest concentrations during spring and summer at both sites, which is shown in Figure 4.

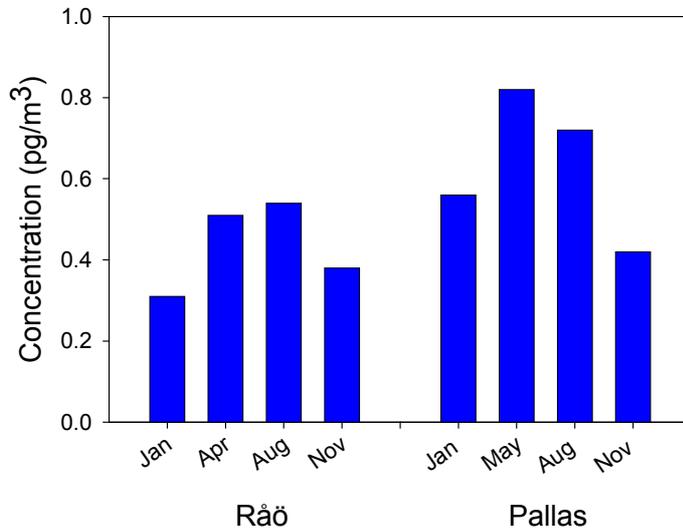


Figure 4 Concentrations of octachlorostyrene in air at Råö and Pallas (pg/m³)

The concentrations were slightly higher at Pallas (northern Finland) compared to Råö (Swedish West Coast), which is similar to the findings for PBDEs (Figure 5, upper part). The concentrations of octachlorostyrene were in the same range as for PBDE-47 at both stations measured during the same time period. Octachlorostyrene concentrations compared to PCB-153 were somewhat higher at Pallas and lower at Råö (Figure 5, lower part) (data from national monitoring of air pollutants, 2004).

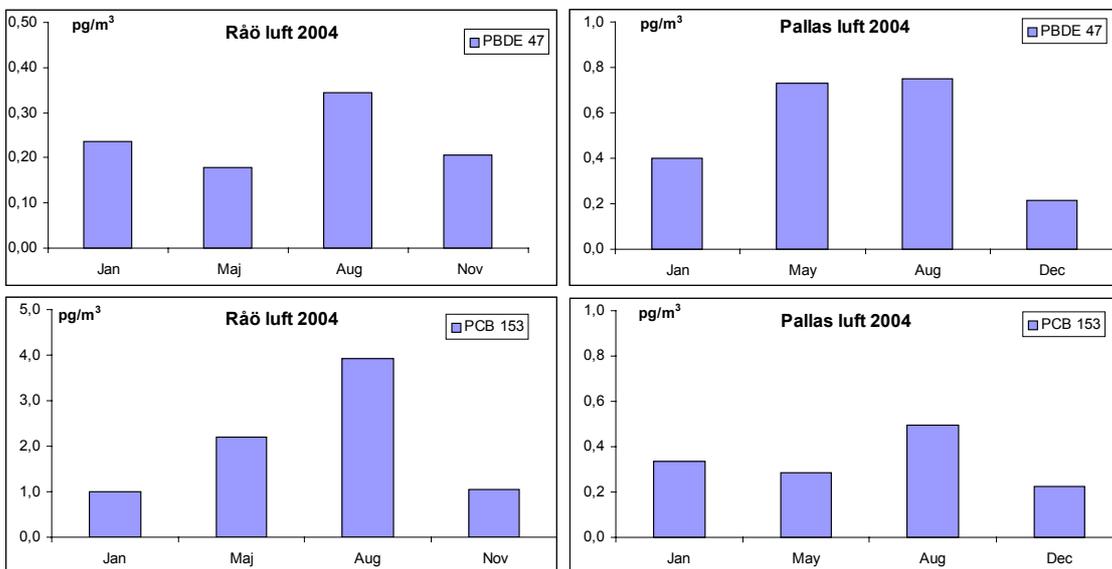


Figure 5. Concentrations of PBDE 47 and PCB 153 at in air Råö and Pallas during the same sampling period as for chlorostyrenes.

Octachlorostyrene was not detected in atmospheric deposition neither at Råö nor Pallas. The detection limit was 0.03 - 0.15 ng/m² day. The monthly fluxes of PCB 153 during 2004 varied

between 0.03 and 0.07 ng/m<sup>2</sup> day at Pallas and between 0.2 and 0.5 ng/m<sup>2</sup> day at Råö. Thus, the atmospheric deposition of octachlorostyrene seems to be lower than or in the same level as for individual PCBs. The measured concentrations at background stations indicate that long-range transport of octachlorostyrenes occurs, and may originate from international sources as well as national activities and current emissions.

Octachlorostyrene was not found in air at the potential point sources Älmhult and Sundsvall or in the urban area Stockholm. Due to differences in sampling equipment the detection limits at these stations were higher than at the background stations. Octachlorostyrene was not detected in atmospheric deposition in Stockholm.

### 7.1.2 Biota

Octachlorostyrene was detected in Baltic herring from 4 background locations in the Baltic Sea (0.45-1.3 ng/g lw), and in Baltic herring from the potential point source in Sundsvall (1.6-3.2 ng/g lw). It was not found in herring from the West Coast or in fish from the potential point source in Älmhult. As hexachlorobenzene has similar potential for bioconcentration as octachlorostyrene, and can be determined in the same analysis, this substance was also analysed in the biota samples and is co-presented with them (Figure 6).

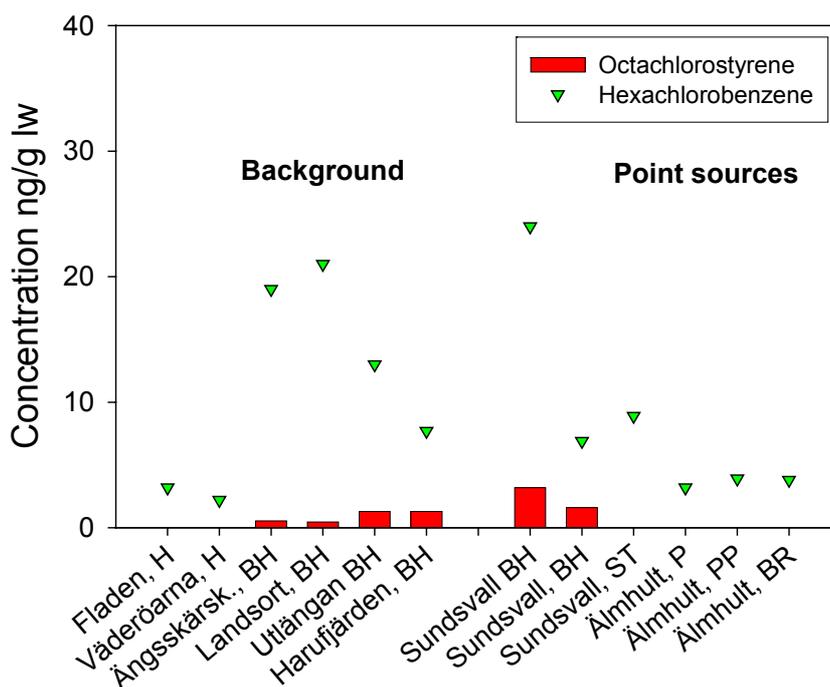


Figure 6. Concentration of octachlorostyrene and hexachlorobenzene in biota. H = herring, BH = Baltic herring, ST = Sea trout, P = perch, PP = pike-perch, BR = bream.

Concentrations of hexachlorobenzene (HCB) were higher in fish where OCS was detected. Regarding the background stations, this pattern has been observed also for other organic contaminants such as PCB-153, sumDDT,  $\alpha$ -HCH and dioxins, with slightly higher levels in fish

from the Baltic Sea than from the west coast (Bignert et al., 2004). Concentrations in herring from Sundsvall were 2-3 times higher than detected levels in background samples, indicating there might be a potential point source for octachlorostyrene in the industrialised areas in Sundsvall. It was not detected in sea trout from Sundsvall. It is probably not appropriate to draw conclusions from the lack of detection of OCS in sea trout as this sample represents one single individual. There is more confidence in the herring data as they represent pooled samples. OCS was not found in fish from Lake Möckeln in Älmhult, which is near an aluminium melting plant, but no other major industries.

The concentrations in fish were in the lower range of the detected levels in marine fish from the Atlantic Ocean (Coelhan et al, 2000), and in the same range or slightly higher than reported concentrations in marine fish from Belgium, Romania and Great Britain (Shaougang et al., 2003; see Table 6, note the different units).

The occurrence of OCS in fish from background locations in the Baltic Sea indicates that the substance is widely distributed in this aquatic system. As OCS was not detected in deposition, it seems likely that levels observed in biota mainly originate from direct emissions to the water compartment.

## 7.2 Regional

Analytical results are given in Table A 4 in Appendix 2.

Octachlorostyrene was detected in one sample of fish from Lake Skutbosjön in the county of Östergötland but not in any other samples. Monochlorostyrenes or  $\beta$ -bromostyrene was not detected in any of the samples analysed. Due to differences in water and lipid contents the detection limits of regional samples (Table 10) differ somewhat from those for the national samples.

Table 10. Limits of detection (LOD) in different matrices, regional samples.

Matrix	Octachlorostyrene	Monochlorostyrenes, $\beta$ -bromostyrene
Sediment	0.2 - 2.4 ng/g dw	1 - 22 ng/g dw
Sludge		1 - 26 ng/g dw
Water	0.5 - 1.3 ng/g dw	8 - 10 ng/l
Fish	1 - 2.1 ng/l	83 - 140 ng/g lipid
	2 ng/g lipid	

The observed concentrations of OCS in perch from Lake Skutbosjön in Östergötland were 2-3 times higher than the observed concentrations in the national samples (5.9 ng/g lipid). The lake is situated in the same area as a large industrial complex, and is known to be heavily polluted by e.g. heavy metals. The surrounding industries include mechanical workshops producing gas- and steam turbines, secondary aluminium production, varnishing industries and secondary copper production (S Olsson, pers.comm.). It is possible that the industrial activities in the area contribute to emissions causing the elevated concentrations in biota.

The observed concentration of OCS in perch from Lake Skutbosjön corresponds to a wet weight concentration of 0.06 ng/g. In order to reach the tolerable daily intake level set up by the state of New York (see chapter 2), an adult person of 65 kg would have to consume over 200 such fishes per day (given a perch of 155 g). The observed levels are more than 10 times higher than EU's recommended upper limit for *dioxins* in fish (4 pg TEQ/g ww), but significantly lower than the limit value for PCB-153 (0.1  $\mu$ g/g ww), set up by the National Food Administration (LIVSFS 1993:36).

Consequently, the observed levels should not have any severe impact on human health, but may be of importance in the marine food chain.

### **7.3 Relationship between abiotic and biotic concentrations**

Octachlorostyrene was not detected in sediments or water. However, the BCF is high enough (100 000) to allow for significant bioconcentration. Neglecting food-web transfer (which is basically negligible for herring, but more important for perch), the concentrations in water corresponding to the highest biota concentration observed would be 0.6 pg/L (calculated from the wet weight fish concentration and a BCF of 100 000), which is far below the detection limits. Thus, water and sediment concentrations below the detection limit may still result in high concentrations in biota.

## 8 Conclusions

The results show that octachlorostyrene is present in the Swedish environment, but that the concentrations are generally low. Its presence in air at background stations, indicates that long-range transport occurs.

Two potential point sources representing large industrial complexes including e.g. primary and secondary aluminium production, showed elevated concentrations in Baltic herring and perch, but not in other environmental matrices. It should be emphasised, however, that the detection limits of OCS in air at point sources were higher than detected concentrations at the background sites.

Diffuse emissions of octachlorostyrene via households and/or sewage treatment plants seem to be limited in Sweden, as OCS was not found in sludge (<1.3 ng/g dw) or in in- and outgoing wastewater.

Due to the high bioaccumulation of octachlorostyrene in fish, species such as herring or perch are more suitable indicators of aquatic pollution of octachlorostyrene than abiotic matrices (water, sediment).

Considering the persistence and toxicity of the compound as well as the indications of toxicity for its metabolite, further measurements in biota in the Baltic and near industrial sites would provide useful information of whether octachlorostyrene in fish is a generally occurring problem. Monitoring in air could also provide information about the trends related to long-range transport. However, these measurements require low detection limits, and use of high-volume air samplers are necessary.

Monochlorostyrenes or  $\beta$ -bromostyrene was not detected in any of the samples analysed.

## 9 Acknowledgements

Thanks to all staff at the county administrative boards and different municipalities that have contributed to the sampling. Especially thanks to Anders Bignert, NRM, and staff at potential point source industry for contributing with samples for the national programme. Thanks to Thomas Östergren, Environment and Public Health Office, Sundsvall for carrying out air sampling for the national programme. The study has been financed by Environmental Monitoring at Swedish EPA.

## 10 References

- Andersson, J. 2004. Teoretisk förstudie till screening av miljögifter i Skåne 2004. M Sc. Thesis. Department of Ecology, University of Lund. *In Swedish*
- Bester, K., Biselli, S., Ellerichman, T., Hunerfuss, H., Möller, K., Rimkus, G., Wolf, M. 1998. Chlorostyrenes in Fish and Sediment- Samples from the River Elbe. *Chemosphere* 37: 9-12
- Bremle, G. 2002. Genomgång och prioritering av kemiska ämnen för nationell screening inom miljöövervakningen. County administrative board, County of Jönköping. *In Swedish*
- Brorström-Lundén, E. 1996. Atmospheric Deposition of Persistent Organic Compounds to the Sea Surface. *Journal of Sea Research* 35: 81-90
- Bignert, A., Asplund, L., Wilander, A. 2004. Comments Concerning the National Swedish Contaminant Monitoring Programme in Marine Biota. Available at: [http://www.naturvardsverket.se/dokument/mo/modok/export/biota\\_hav.pdf](http://www.naturvardsverket.se/dokument/mo/modok/export/biota_hav.pdf)
- Cato, I., Rindby, A., Rudolfsson, J., 2000: Unik sedimentscanner utvecklad. *Geologiskt forum* 25, 13-15. *In Swedish*
- Coelhan, M., Reil, I., Rimkus, G., Parlar, H.. 2000. Peak Patterns of Chlorostyrenes in Fish and Fish Oils from the North Atlantic. *Environ. Sci. Technol.* 34: 4695-4700.
- HSDB 2005. Hazardous Substance Data Base. U.S. National Library of Medicine <http://www.toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>. 2004-02-10 till 2005-05-30
- Hongxia, L., Drouillard, K.G., Bennett, E., Haffner, C.D., Letcher, R.J. 2003. Plasma-associated Halogenated Phenolic Contaminants in Benthic and Pelagic Fish Species from the Detroit River. *Environ. Sci. Technol.* 37:832-839.
- Hovander, L., Malmberg, T., Athanasiadou, I., Athanassiadis, I., Rahm, S., Bergman, Å., Klasson Wehler, E.. 2002. Identification of Hydroxyrelated PCB Metabolites and Other Phenolic Halogenated Pollutants in Human Blood Plasma. *Environmental Contamination Toxicology* 42:105-117
- Loh, C., Johansson, V., Ivarsson, P. 2003. Utredning av ämnen inför screening 2004. *EnviroPlanning Rapport* 1003-01/10/01/rap001. *In Swedish*
- Mackay, D., Di Guardo, A., Paterson, S., Cowan, C.E. 1996. Evaluating the environmental fate of a variety of types of chemicals using the EQC model. *Environ. Toxicol. Chem.* Vol. 15 pp 1627-1637
- Mackay, D. 2001. *Multimedia Environmental Models: The Fugacity Approach*, CRC Boca Raton, FL, USA
- Meylan, W. 1999. EPIWIN x3.04 [computer program: US EPA Version for Windows], Syracuse Research Corporation, Syracuse, NY, US. <http://www.epa.gov/oppt/exposure/docs/episuitedl.htm> (June 13, 2005)
- Oliver, B. G., Niimi, A. J. 1988. Trophodynamic Analysis of Polychlorinated Biphenyl Congeners and Other Chlorinated Hydrocarbons in the Lake Ontario Ecosystem. *Environ. Sci. Technol.* 1988. 22:388-397
- PRIO 2005. <http://www.kemi.se/templates/PRIOframes.aspx?id=1067>. 20050130-20050530

- Sandau, C., Meerts, I., Letcher, R., McAlees, A., Chittim, B., Brouwer, A., Norstrom, R. 2000. Identification of 4-hydroxyheptachlorostyrene in Polar Bear Plasma and its Binding Affinity to Transthyretin: A Metabolite of Octachlorostyrene? *Environ. Sci. Technol.* 34:3871-3877
- Chu, S, Covaci, A., Voorspoels, S., Schepens, P. 2003. The Distribution Of Octachlorostyrene in Environmental Samples from Europe. *The Journal of Environmental Monitoring* 2003:5 s 619-625
- SRC, 2005. Syracuse Research Corporation's Interactive PhysProp Database Demo. Available at <http://www.syrres.com/esc/physdemo.htm>, 30 June, 2005
- UNEP. 2005. Stockholm Convention on Persistent Organic Pollutants (POPs)  
<http://www.pops.int/>
- US EPA. 1998. Great Lakes Binational Toxics Strategy Octachlorostyrene (OCS) Report: A Review of Potential Sources. Draft. Available at: [www.epa.gov/glnpo/bnsdocs/98summ/ocs.pdf](http://www.epa.gov/glnpo/bnsdocs/98summ/ocs.pdf)
- US EPA. 2000. PBT National Action Plan for Octachlorostyrene(OCS) DRAFT. Available at: [www.epa.gov/pbt/pubs/ocstyrene.pdf](http://www.epa.gov/pbt/pubs/ocstyrene.pdf)
- OSPAR, 2005. OSPAR List of Chemicals for Priority Action - Replaced OSPAR Annex 2 from June 2002, [www.ospar.org](http://www.ospar.org), March, 2005.
- IPEN, 2005. International POPs Elimination Network  
<http://www.oztoxics.org/cmwg/chemicals/new%20pop.html>

## Appendix 1. Sample information

Table A 1. Sample information for national screening of chlorostyrenes. **DW = dry weight (sediment, sludge), LW = lipid weight (fish)**

	Sample ID	City	Site	Notes	Matrix	Sampling date	X co-ord.	Y co-ord.	DW/LW (%)
<b>Back-ground</b>	RA-01A	Råö			Air	2003-12-29-2004-01-2 (MS 04-11-16)*	6369857	1266139	-
	RA-05A	Råö			Air	2004-05-03-2004-06-01 (MS 04-11-23)*	6369857	1266139	-
	RA-08A	Råö			Air	2004-08-09-2004-09-06 (MS 04-11-30)*	6369857	1266139	-
	RA-11A	Råö			Air	2004-11-01-2004-11-29	6369857	1266139	-
	Pallas-01A	Pallas			Air	2004-01-19-2004-01-26 (MCIS 05-03-09)*	67° 58'N	24° 07'E	-
	Pallas-05A	Pallas			Air	2004-05-24-2004-05-30 (MCIS 05-03-23)*	67° 58'N	24° 07'E	-
	Pallas-08A	Pallas			Air	2004-08-16-2004-08-23 (MCIS 05-03-29)*	67° 58'N	24° 07'E	-
	Pallas-11A	Pallas			Air	2004-11-22-2004-11-29	67° 58'N	24° 07'E	-
	RA-01D	Råö			Deposition	2003-12-29-2004-02-02	6369857	1266139	-
	RA-05D	Råö			Deposition	2004-04-26-2004-06-01	6369857	1266139	-
	RA-08D	Råö			Deposition	2004-07-26-2004-08-30	6369857	1266139	-
	RA-11D	Råö			Deposition	2004-11-03-2004-11-29	6369857	1266139	-
	Pallas-01D	Pallas			Deposition	2004-01-19-2004-01-26	67° 58'N	24° 07'E	-
	Pallas-05D	Pallas			Deposition	2004-05-24-2004-05-30	67° 58'N	24° 07'E	-
	Pallas-08D	Pallas			Deposition	2004-08-16-2004-08-23	67° 58'N	24° 07'E	-
	Pallas-11D	Pallas			Deposition	2004-11-22-2004-11-29	67° 58'N	24° 07'E	-
	Mr-3641		Landsort	Baltic herring	Biota	2003-11-12	57° 12' 27"	11°39' 53"	4.5
	Mr-3644		Harufjärden	Baltic herring	Biota	2003-09-29	60° 30'	18°15'	4.6
	Mr-3642		Utlängan	Herring	Biota	2003-10-10	58°17'	17°50'	4.4
	Mr-3639		V.Fladen	Herring	Biota	2003-09-16	57° 04' 47"	15 °55' 18"	1.7
Mr-3643		Väderöarna	Herring	Biota	2003-09-04	58°43'	10°51'	6.4	
Mr-3640		Ängsskärsklubb	Baltic herring	Biota	2003-10-01	65°43'	23°*03'	2.3	
Mr-3752		Norrköpingsdjupet	0-2 cm , 179m depth SGU 07i-001	Sediment	Autumn 2004	6435399	1625504	6.6	
Mr-3750		Ö Gotlandsdjupet	0-2 cm, 121 m depth, SGU 04-0058	Sediment	Autumn 2004	6216805	1697299	9.5	
Mr-3751		Ö Öland	0-2 cm, 77m depth SGU 04-0368	Sediment	Autumn 2004	6277308	1607374	8.3	
MR-3753		Ö Landsortsdjupet	0-2cm 403m SGU 09i-0841	Sediment	Autumn 2004	6508995	1648002	3.8	

	Sample ID	City	Site	Notes	Matrix	Sampling date	X co-ord.	Y co-ord.	DW/LW (%)
Potential point source	Sundsv-1	Sundsvall	Kubikenborgsskolan		Air	2004-10-22 – 2004-11-04 (MCIS 04-10-25)*			-
	Sundsv-2	Sundsvall	Kubikenborgsskolan		Air	2004-11-04 – 2004-11-18 (MCIS 04-11-11)*			-
	Sundsv-3	Sundsvall	Kubikenborgsskolan		Air	2004-11-24 – 2004-12-02 (MCIS 04-11-24)*			-
	Mr-4050	Sundsvall	Sundsvallsbukten	Baltic herring	Biota	2004-10-21			1.7
	Mr-4051	Sundsvall	Sundsvallsbukten	Baltic herring	Biota	2004-10-21			2.4
	Mr-4052	Sundsvall	Sundsvallsbukten	Sea trout, 1 individual	Biota	2004-10-21			2.3
	Mr-3608	Sundsvall	Kubal		Water	2004-10-21	6918905	1581179	-
	Mr-3606	Sundsvall	Sundsvallsfjärden outside Kubal	Recipient	Water	2004-10-21	6918231	1581492	-
	Mr-3593	Sundsvall	Sundsvallsfjärden outside Kubal 1	0-2 cm	Sediment	2004-10-21	6918274	1581483	20
	Mr-3594	Sundsvall	Sundsvallsfjärden outside Kubal 1	2-7 cm	Sediment	2004-10-21	6918274	1581483	30
	Mr-3595	Sundsvall	Sundsvallsfjärden outside Kubal 1	7-12 cm	Sediment	2004-10-21	6918274	1581483	35
	Mr-3596	Sundsvall	Sundsvallsfjärden outside Kubal 2	0-2 cm	Sediment	2004-10-21	6918973	1581344	27
	Mr-3597	Sundsvall	Sundsvallsfjärden outside Kubal 2	2-7 cm	Sediment	2004-10-21	6918973	1581344	33
	Mr-3598	Sundsvall	Sundsvallsfjärden outside Kubal 2	7-12 cm	Sediment	2004-10-21	6918973	1581344	36
	Älmhult-1	Älmhult,	Stena Aluminium, Factory area		Air	2004-11-17 - 2004-12-01 (MS 04-11-22)*	6271800	1397445	-
	Älmhult-2	Älmhult,	Stena Aluminium, Factory area		Air	2004-12-01 - 2004-12-15 (MS 04-12-10)*	6271800	1397445	-
	Älmhult-3	Älmhult,	Stena Aluminium, Factory area		Air	2004-12-15 - 2004-12-29 (MS 04-12-22)*	6271800	1397445	-
	Mr-3834	Älmhult	Möckeln	Perch	Biota	October 2004	6272529	1397455	1.2
	Mr-3835	Älmhult	Möckeln	Pike-perch	Biota	October 2004	6272529	1397455	0.98
	Mr-3836	Älmhult	Möckeln	Bream	Biota	October 2004	6272529	1397455	1.1
Mr-3784	Älmhult	Äskya landfill	Leachate	Water	2004-11-18	6271645	1398968	-	
Mr-3780	Älmhult	Äskya landfill	Leachate	Sediment	2004-11-18	6271645	1398968	20	
Mr-3787	Älmhult	Möckeln	Surface water	Water	2004-11-18	6272529	1397455	-	
Mr-3782	Älmhult	Möckeln	Lake	Sediment	2004-11-18	6272529	1397455	8	

	Sample ID	City	Site	Notes	Matrix	Sampling date	X co-ord.	Y co-ord.	DW/LW (%)
	RA-01A	Råö			Air	2003-12-29-2004-01-2 (MS 04-11-16)*	6369857	1266139	-
	Mr-3778	Älmhult		storm water effluent	Sediment	2004-11-18	6271800	1397445	18
<b>Diffuse sources</b>	Mr-3760	Stockholm	Henriksdal STP	700.000 pe, mech, chem,bio cleaning. No major industrial impact	Sludge	2004-11-16			26.7
	Mr-3848	Eslöv	Eslöv STP	100 000 pe, mech., chem., bio., cleaning. Food industry(75%),	Inc. sludge	2004-12-07			18.4
	Mr-3701	Floda	Floda STP		Sludge	2004-11-08			27.7
	Sthlm-1	Stockholm	Hudiksvallsgatan 2		Air	2004-11-08 - 2004-11-22 (MS 04-11-18)*			-
	Sthlm-2	Stockholm	Hudiksvallsgatan 2		Air	2004-11-22 - 2004-12-06 (MS 04-12-03)*			-
	Sthlm-3	Stockholm	Hudiksvallsgatan 2		Air	2004-12-06 - 2004-12-20 (04-12-06)*			-
	MR-4012	Stockholm	Hudiksvallsgatan 2		Deposition	2004-11-08 - 2004-12-06			-
	MR-4013	Stockholm	Hudiksvallsgatan 2		Deposition	2004-12-04 - 2005-01-03			-
	MR-4014	Stockholm	Hudiksvallsgatan 2		Deposition	2005-01-03 - 2005-02-01			-
	Mr-2535	Stockholm	Sicklasjön	0-2 cm mixed samples 4.5 m depth	Sediment	spring 2002	6577886	1632207	4.8
	Mr-2539	Stockholm	Laduviken	0-2 cm mixed samples 3 m depth	Sediment	spring 2002	6584432	1629075	3.2
	Mr-2541	Stockholm	Drevviken	0-2 cm mixed samples 12m depth	Sediment	spring 2002	6570599	1635190	5.8
	Mr-2530	Stockholm	Strömmen	0-2 cm mixed samples 27 m depth	Sediment	spring 2002	6581049	1634496	5.5
	Mr-2547	Stockholm	Riddarfjärden	0-2 cm mixed samples 19 m depth	Sediment	spring 2002	6580116	1627280	27.8
	Mr-2549	Stockholm	Fjäderholmarna	0-2 cm mixed samples 28 m depth	Sediment	spring 2002	6580073	1629454	6.4

\*Sampling date within brackets is for monochloro- and monobromostyrenes

Table A 2. Sample information for regional screening of chlorostyrenes. **DW = dry weight (sediment, sludge), LW = lipid weight (fish)**

County	Sample ID	City	Site	information	matrix	Notes	pe (STP)	cleaning mechanism	Sampling date	DW/LW (%)
Dalarna	MR-3478	Avesta	Krylbo STP		sludge	Incinerated	17000	suspension, active sludge	2004-09-29	24
	MR-3540	Borlänge	Fagersta STP		sludge	Incinerated	44000	suspension, active sludge	2004-10-12	29
	MR-3535	Mora	Venjan STP		sludge	Incinerated	500	mech, chem	2004-10-06	0.7
	MR-3496	Mora	Venjansjön		sediment	Lake			2004-10-03	5.19
	MR-3498	Avesta	Bäsingen		sediment	Lake			2004-10-04	21.4
	MR-3501	Avesta	Bäsingen		fish				2004-09-29	1.2
	MR-3500	Mora	Venjansjön		fish				2004-10-01	1.2
Gävleborg	MR-3584	Bollnäs	Bollnäs STP		sludge				2004-10-20	14.6
	MR-3549	Gävle	Duvbacken STP		sludge				2004-10-12	19.9
	MR-3846	Hudiksvall	Resselvans STP		sludge				2004-12-07	26.6
	MR-3555	Sandviken	Sandviken STP		sludge				2004-10-13	22.0
Jönköping	MR- 3855	Eksjö	Waste incineration		water	Leachate			2004-12-13	-
	MR- 3803	Vetlanda	Gröpplebacken		sediment				2004-11-24	22.8
Kalmar	MR-3800	Hultsfred	Hulingen		sediment				2004-11-24	34.4
	MR-3798	Hultsfred	Virserum		sediment	Recipient			2004-11-24	58.5
	MR-3627	Oskarshamn	Mouth of river Emån		sediment	Recipient			2004-10-27	22.7
Skåne	MR-3466	Bromölla	Bromölla STP		sludge				2004-09-28	25.7
	MR-3459 MR-3460	Helsingborg	Helsingborgs STP		sludge				2004-09-22	25.0
	MR-3514	Kristianstad	Kristianstad STP	Possible siloxane conta-mination from STP	sludge				2004-10-05	18.2
	MR-3489	Landskrona	Lundåkraverket STP	Possible siloxane conta-mination from STP	sludge				2004-09-29	22.0
	MR-3464	Lund	Källby STP		sludge	Thermophilic incineration			2004-09-27	26.1
	MR-3456 MR-3457	Malmö	Sjölunda STP		sludge				2004-09-22	23.8
	MR-3623	Perstorp	Perstorp STP		sludge				2004-10-26	18.7

County	Sample ID	City	Site	information	matrix	Notes	pe (STP)	cleaning mechanism	Sampling date	DW/L W (%)
	MR-3453 MR3454	Ystad	Ystad STP		sludge				2004-09-22	15.8
	MR-3677	Kristianstad	Lake Hammarsjön		sediment				2004-10-19	14.2
	MR-3679	Bromölla	Lake Ivösjön		sediment				2004-10-19	6.68
	MR-3706	Helsingborg	Coast	55 59 110-12 44 265	sediment				2004-11-03	43.4
	MR-3670	Perstorp	Storarydsdammen		sediment				2004-10-22	9.66
	MR-3682	Bromölla	Ivösjön		fish	Perch			2004-10-19	1.1
	MR-3681	Kristianstad	Hammarsjön		fish	Flounder			2004-10-19	1.0
	MR-3672	Perstorp	Storarydsdammen		fish	Perch			2004-10-22	1.1
	MR-3708	Helsingborg	Coast	55 58 915-12 44 313	fish	Flounder			2004-10-15	1.1
Stockholm	MR-3482,84,86	Botkyrka	Himmerfjärdsverket STP	Mixed sample (3 days)	sludge				2004-09-28-30	23.3
	MR-3480	Botkyrka	Himmerfjärdsverket STP		water	Effluent				-
	MR-3449	Hölö, Botkyrka or Nynäshamn	Himmerfjärden	x654978 y:161021	sediment				2004-09-01	24.4
	MR-3448	Södertälje	St Envättern	x:655613 y:158793	sediment				2004-09-01	3.75
	MR-3450	Hölö, Botkyrka or Nynäshamn	Himmerfjärden		fish	Perch			2004-09-01	0.73
Södermanland	MR-3451	Södertälje	St Envättern		fish	Perch			2004-07-22	0.96
	MR-3693	Eskilstuna	Torshällaån		sediment				2004-11-02	16.0
	MR-3695	Eskilstuna	Sörfjorden	depth 3 m	sediment				2004-11-02	11.7
	MR-3699	Oxelösund	Ålöfjärden	depth 9-12 m	sediment				2004-11-04	25.9
	MR-3697	Strängnäs	Östra magsjön	depth 19 m	sediment				2004-11-04	6.17
Värmland	MR-3709	Arvika	Vik STP	municipal, industrial	sludge	Incinerated	19500	mech, chem, bio	2004-11-02	14.5
	MR-3582	Karlstad	Skåre STP	municipal, industrial	sludge	Primary	4005	mech, chem, bio	2004-10-19	13.7
	MR-3629	Kristinehamn	Fiskartorpet STP	municipal	sludge	Incinerated	16109	mech, chem, bio	2004-10-26/28	29.9
	MR-3711	Arvika	Vik STP	municipal, industrial	water	Effluent	19500	mech, chem, bio	2004-11-02	-
	MR-3580	Karlstad	Skåre STP	municipal, industrial	water	Effluent	4005	mech, chem, bio	2004-10-19	-
	MR-3631	Kristinehamn	Fiskartorpet STP	municipal	water	Effluent	16109	mech, chem, bio		-

County	Sample ID	City	Site	information	matrix	Notes	pe (STP)	cleaning mechanism	Sampling date	DW/L W (%)
Västernorrland	MR-3590	Örnsköldsvik	Husum	pulp industry bleaching 4, leaf trees	water				2004-10-22	-
	MR-3591	Örnsköldsvik	Husum	pulp industry bleaching 5, pine wood	water				2004-10-22	-
	MR-3588	Örnsköldsvik	Husum		sediment				2004-10-22	34.7
Östergötland	MR-3633	Finspång	Finspångs STP		sludge				2004-10-26	4.1
	MR-3673	Finspång	SAPA	industrial	sludge				2004-10-28	45
	MR-3729	Linköping	Linköping STP		sludge				2004-11-09	27.6
	MR-3635	Finspång	Finspångs STP		water				2004-10-27	-
	MR-3675	Finspång	SAPA	industrial	water				2004-10-28	-
	MR-3728	Linköping	Linköping STP		water				2004-11-09	-
	MR-3683	Finspång	Skutbosjön		sediment				2004-10-29	7.65
	MR-3685	Linköping	Roxen		sediment				2004-10-21	12.7
	MR-3854	Linköping	Roxen		fish	Perch, no individuals			dec-04	1.0
	MR-3857	Finspång	Skutbosjön		fish	Perch, no individuals			04-dec	0.98

## Appendix 2. Results

Table A 3. Results from national screening of chlorostyrenes

	Sample ID	City	Matrix	Sampling date	Unit	Octachloro-styrene	2-Chloro-styrene	3-Chloro-styrene	4-Chloro-styrene	Bromo-styrene
Back-ground	RA-01A	Råö	Air	2003-12-29-2004-01-26 (MS 04-11-16)*	ng/m3	0.00031	<13	<13	<13	<13
	RA-05A	Råö	Air	2004-05-03-2004-06-01 (MS 04-11-23)*	ng/m3	0.00051	<13	<13	<13	<13
	RA-08A	Råö	Air	2004-08-09-2004-09-06 (MS 04-11-30)*	ng/m3	0.00054	<17	<17	<17	<17
	RA-11A	Råö	Air	2004-11-01-2004-11-29	ng/m3	0.00038				
	Pallas-01A	Pallas	Air	2004-01-19-2004-01-26 (MCIS 05-03-09)*	ng/m3	0.00056	<20	<20	<20	<20
	Pallas-05A	Pallas	Air	2004-05-24-2004-05-30 (MCIS 05-03-23)*	ng/m3	0.00082	<20	<20	<20	<20
	Pallas-08A	Pallas	Air	2004-08-16-2004-08-23 (MCIS 05-03-29)*	ng/m3	0.00072	<20	<20	<20	<20
	Pallas-11A	Pallas	Air	2004-11-22-2004-11-29	ng/m3	0.00042				
	RA-01D	Råö	Deposition	2003-12-29-2004-02-02	ng / m2 day	<0.03				
	RA-05D	Råö	Deposition	2004-04-26-2004-06-01	ng / m2 day	<0.03				
	RA-08D	Råö	Deposition	2004-07-26-2004-08-30	ng / m2 day	<0.03				
	RA-11D	Råö	Deposition	2004-11-03-2004-11-29	ng / m2 day	<0.04				
	Pallas-01D	Pallas	Deposition	2004-01-19-2004-01-26	ng / m2 day	<0.15				
	Pallas-05D	Pallas	Deposition	2004-05-24-2004-05-30	ng / m2 day	<0.15				
	Pallas-08D	Pallas	Deposition	2004-08-16-2004-08-23	ng / m2 day	<0.15				
	Pallas-11D	Pallas	Deposition	2004-11-22-2004-11-29	ng / m2 day	<0.15				
	MR-3750	Ö Gotlandsdjupet	Sediment	2004	ng/g DW	<1	<4	<4	<4	<4
	MR-3751	Ö Öland	Sediment	2004	ng/g DW	<1	<7	<7	<7	<7
	MR-3752	Norrköpingsdjupet	Sediment	2004	ng/g DW	<1	<3	<3	<3	<3
	MR-3753	Ö Landsortsdjupet	Sediment	2004	ng/g DW	<1	<22	<22	<22	<22
	MR-3639	W.Fladen	Biota	2004-11-01	ng/g lipid	<0.4	<22	<22	<22	<22
	MR-3640	Ängsskärsklubb	Biota	2004-11-01	ng/g lipid	0.54	<22	<22	<22	<22
	MR-3641	Landsort	Biota	2004-11-01	ng/g lipid	0.45	<23	<23	<23	<23
	MR-3642	Utlången	Biota	2004-11-01	ng/g lipid	1.3	<60	<60	<60	<60
	MR-3643	Väderöarna	Biota	2004-11-01	ng/g lipid	<0.3	<16	<16	<16	<16
	MR-3644	Storöfjärden	Biota	2004-11-01	ng/g lipid	1.3	<44	<44	<44	<44

	Sample ID	City	Matrix	Sampling date	Unit	Octachloro- styrene	2-Chloro- styrene	3-Chloro- styrene	4-Chloro- styrene	Bromo- styrene
<b>Potential point source</b>	Älmhult-1	Älmhult	Air	2004-11-17 - 2004-12-01 (MS 04-11-22)*	ng/m3	<0.01	<13	<13	<13	<13
	Älmhult-2	Älmhult	Air	2004-12-01 - 2004-12-15 (MS 04-12-10)*	ng/m3	<0.01	<13	<13	<13	<13
	Älmhult-3	Älmhult	Air	2004-12-15 - 2004-12-29 (MS 04-12-22)*	ng/m3	<0.01	<13	<13	<13	<13
	MR-3785	Älmhult	Water	2004-11-18	ng/l	<1.1	<10	<10	<10	<10
	MR-3784	Älmhult	Water	2004-11-18	ng/l	<1.4	<10	<10	<10	<10
	MR-3787	Älmhult	Water	2004-11-18	ng/l	<1.1	<10	<10	<10	<10
	MR-3778	Älmhult	Sediment	2004-11-18	ng/g DW	<1	<10	<10	<10	<10
	MR-3780	Älmhult	Sediment	2004-11-18	ng/g DW	<1	<10	<10	<10	<10
	MR-3782	Älmhult	Sediment	2004-11-18	ng/g DW	<1	<20	<20	<20	<20
	MR-3834	Älmhult	Biota	Autumn 2004	ng/g lipid	<2	<80	<80	<80	<80
	MR-3835	Älmhult	Biota	Autumn 2004	ng/g lipid	<2	<100	<100	<100	<100
	MR-3836	Älmhult	Biota	Autumn 2004	ng/g lipid	<2	<90	<90	<90	<90
	Sundsv-1	Sundsvall	Air	2004-10-22 - 2004-11-04 (MCIS 04-10-25)*	ng/m3	<0.01	<11	<11	<11	<11
	Sundsv-2	Sundsvall	Air	2004-11-04 - 2004-11-18 (MCIS 04-11-11)*	ng/m3	<0.01	<7	<7	<7	<7
	Sundsv-3	Sundsvall	Air	2004-11-24 - 2004-12-02 (MCIS 04-11-24)*	ng/m3	<0.01	<9	<9	<9	<9
	MR-3593	Sundsvall	Sediment	2004-10-21	ng/g DW	<1	<23	<23	<23	<23
	MR-3594	Sundsvall	Sediment	2004-10-21	ng/g DW	<1	<16	<16	<16	<16
	MR-3595	Sundsvall	Sediment	2004-10-21	ng/g DW	<1	<14	<14	<14	<14
	MR-3596	Sundsvall	Sediment	2004-10-21	ng/g DW	<1	<18	<18	<18	<18
	MR-3597	Sundsvall	Sediment	2004-10-21	ng/g DW	<1	<14	<14	<14	<14
	MR-3598	Sundsvall	Sediment	2004-10-21	ng/g DW	<1	<12	<12	<12	<12
	MR-3608	Sundsvall	Water	2004-10-21	ng/l	<1.3	<10	<10	<10	<10
	MR-3606	Sundsvall	Water	2004-10-21	ng/l	<2.5	<10	<10	<10	<10
	MR-4050	Sundsvallsbukten	Biota	2004-10-21	ng/g lipid	3.2	<60	<60	<60	<60
	MR-4051	Sundsvallsbukten	Biota	2004-10-21	ng/g lipid	1.6	<40	<40	<40	<40
	MR-4052	Sundsvallsbukten	Biota	2004-10-21	ng/g lipid	<1	<40	<40	<40	<40

	Sample ID	City	Matrix	Sampling date	Unit	Octachloro-styrene	2-Chloro-styrene	3-Chloro-styrene	4-Chloro-styrene	Bromo-styrene
<b>Diffuse sources</b>	MR-3760	Henriksdal	Sludge	2004-11-16	ng/g DW	<1	<20	<20	<20	<20
	MR-3848	Eslöv	Sludge	2004-12-07	ng/g DW	<1	<10	<10	<10	<25
	MR-3701	Floda	Sludge	2004-11-08	ng/g DW	<1	<10	<10	<10	<10
	Sthlm-1	Stockholm	Air	2004-11-08 - 2004-11-22 (MS 04-11-18)*	ng/m3	<0.01	<10	<10	<10	<10
	Sthlm-2	Stockholm	Air	2004-11-22 - 2004-12-06 (MS 04-12-03)*	ng/m3	<0.01	<10	<10	<10	<10
	Sthlm-3	Stockholm	Air	2004-12-06 - 2004-12-20 (04-12-06)*	ng/m3	<0.01	<10	<10	<10	<10
	MR-4012	Stockholm	Deposition	2004-11-08 - 2004-12-06	ng / m2 day	<0.04				
	MR-4013	Stockholm	Deposition	2004-12-04 - 2005-01-03	ng / m2 day	<0.04				
	MR-4014	Stockholm	Deposition	2005-01-03 - 2005-02-01	ng / m2 day	<0.04				
	MR-2535	Stockholm	Sediment		ng/g DW	<2	<14	<14	<14	<14
	MR-2539	Stockholm	Sediment		ng/g DW	<3	<32	<32	<32	<32
	MR-2541	Stockholm	Sediment		ng/g DW	<2	<19	<19	<19	<19
	MR-2530	Stockholm	Sediment		ng/g DW	<2	<20	<20	<20	<20
	MR-2547	Stockholm	Sediment		ng/g DW	<1	<14	<14	<14	<14
	MR-2549	Stockholm	Sediment		ng/g DW	<2	<12	<12	<12	<12

**Table A 4. Results from regional screening of chlorostyrenes**

County	Sample ID	Sampling date	City	Matrix	Unit	Octachloro- styrene	2-Chloro- styrene	3-Chloro- styrene	4-Chloro- styrene	Bromo-styrene
Dalarna	MR-3478	2004-09-29	Avesta	Sludge	ng/g DW	<0.7	<24	<24	<24	<24
	MR-3535	2004-10-06	Mora	Sludge	ng/g DW	<5	<10	<10	<10	<10
	MR-3540	2004-10-12	Borlänge	Sludge	ng/g DW	<0.6	<3	<3	<3	<3
	MR-3501	2004-09-29	Avesta	Fish	ng/g lipid	<2	<83	<83	<83	<83
	MR-3500	2004-10-01	Mora	Fish	ng/g lipid	<2	<83	<83	<83	<83
	MR-3498	2004-10-04	Avesta	Sediment	ng/g DW	<0.5	<3	<3	<3	<3
	MR-3496	2004-10-03	Mora	Sediment	ng/g DW	<2	<7	<7	<7	<7
Gävleborg	MR-3846	2004-12-07	Hudiksvall	Sludge	ng/g DW	<0.7	<3	<3	<3	<3
	MR-3549	2004-10-12	Gävle	Sludge	ng/g DW	<1	<4	<4	<4	<4
	MR-3555	2004-10-13	Sandviken	Sludge	ng/g DW	<0.9	<4	<4	<4	<4
	MR-3584	2004-10-20	Bollnäs	Sludge	ng/g DW	<1.2	<7	<7	<7	<7
Jönköping	MR 3855	2004-12-13	Eksjö	Water	ng/l	<1	<10	<10	<10	<10
	MR 3803	2004-11-24	Vetlanda	Sediment	ng/g DW	<0.3	<3	<	<	<
Kalmar	MR-3800	2004-11-24	Hultsfred	Sediment	ng/g DW	<0.3	<3	<3	<3	<3
	MR-3798	2004-11-24	Hultsfred	Sediment	ng/g DW	<0.2	<1	<1	<1	<1
	MR-3627	2004-10-27	Oskarshamn	Sediment	ng/g DW	<0.3	<2	<2	<2	<2
	MR-3453,-54	2004-09-22	Ystad	Sludge	ng/g DW	<1.1	<19	<19	<19	<19
	MR-3456,-57	2004-09-22	Malmö	Sludge	ng/g DW	<0.8	<21	<21	<21	<21
	MR-3459,-60	2004-09-22	Helsingborg	Sludge	ng/g DW	<0.8	<24	<24	<24	<24
	MR-3464	2004-09-27	Lund	Sludge	ng/g DW	<0.7	<26	<26	<26	<26
Skåne	MR-3466	2004-09-28	Bromölla	Sludge	ng/g DW	<0.7	<18	<18	<18	<18
	MR-3489	2004-09-29	Landskrona	Sludge	ng/g DW	<0.9	<20	<20	<20	<20
	MR-3514	2004-10-05	Kristianstad	Sludge	ng/g DW	<1.1	<6	<6	<6	<6
	MR-3623	2004-10-26	Perstorp	Sludge	ng/g DW	<1	<5	<6	<7	<8
	MR-3682	2004-10-19	Bromölla	fish	ng/g lipid	<2	<91	<91	<91	<91
	MR-3681	2004-10-19	Kristianstad	fish	ng/g lipid	<2	<100	<100	<100	<100
	MR-3672	2004-10-22	Perstorp	fish	ng/g lipid	<2	<91	<91	<91	<91
	MR-3708	2004-10-15	Helsingborg	fish	ng/g lipid	<2	<91	<91	<91	<91
	MR-3679	2004-10-19	Bromölla	Sediment	ng/g DW	<0.8	<9	<9	<9	<9
	MR-3706	2004-11-03	Helsingborg	Sediment	ng/g DW	<0.2	<2	<2	<2	<2
MR-3677	2004-10-19	Kristianstad	Sediment	ng/g DW	<0.4	<3	<3	<3	<3	
MR-3670	2004-10-22	Perstorp	Sediment	ng/g DW	<0.6	<4	<4	<4	<4	

County	Sample ID	Sampling date	City	Matrix	Unit	Octachloro- styrene	2-Chloro- styrene	3-Chloro- styrene	4-Chloro- styrene	Bromo- styrene
Stockholm	MR-3450	2004-09-01	Hölö, Botkyrka or Nynäshamn	Fish	ng/g lipid	<2	<140	<140	<140	<140
	MR-3451	2004-07-22	Södertälje	Fish	ng/g lipid	<2	<100	<100	<100	<100
	MR-3449	2004-09-01	Hölö, Botkyrka or Nynäshamn	Sediment	ng/g DW	<0.5	<4	<4	<4	<4
	MR-3448	2004-09-01	Södertälje	Sediment	ng/g DW	<2.4	<18	<18	<18	<18
	MR-3480		Botkyrka	Water	ng/l	<1.3	<8	<8	<8	<8
	MR-3482,84,86	2004-09-28/30	Botkyrka	Sludge	ng/g DW	<0.8	<24	<24	<24	<24
Söder- manland	MR-3693	2004-11-02	Eskilstuna	Sediment	ng/g DW	<0.4	<6	<6	<6	<6
	MR-3695	2004-11-02	Eskilstuna	Sediment	ng/g DW	<0.5	<10	<10	<10	<10
	MR-3699	2004-11-04	Oxelösund	Sediment	ng/g DW	<0.3	<5	<5	<5	<5
	MR-3697	2004-11-04	Strängnäs	Sediment	ng/g DW	<0.9	<22	<22	<22	<22
Värmland	MR-3582	2004-10-19	Karlstad	Sludge	ng/g DW	<1.3	<7	<7	<7	<7
	MR-3629	2004-10-26/28	Kristinehamn	Sludge	ng/g DW	<0.7	<12	<12	<12	<23
	MR-3709	2004-11-02	Arvika	Sludge	ng/g DW	<1.3	<6	<6	<6	<6
	MR-3631		Kristinehamn	Water	ng/l	<1.3	<8	<8	<8	<8
	MR-3711	2004-11-02	Arvika	Water	ng/l	<1.3	<8	<8	<8	<8
	MR-3580	2004-10-19	Karlstad	Water	ng/l	<1.3	<8	<8	<8	<8
Väster- norrland	MR-3588	2004-10-20	Örnsköldsvik	Sediment	ng/g DW	<0.2	<3	<3	<3	<3
	MR-3590	2004-10-20	Örnsköldsvik	Water	ng/l	<2.1	<10	<10	<10	<10
	MR-3591	2004-10-20	Örnsköldsvik	Water	ng/l	<2.0	<10	<10	<10	<10
Östergötland	MR-3633	2004-10-26	Finspång	Sludge	ng/g DW	<3.3	<18	<19	<20	<21
	MR-3673	2004-10-28	Finspång	Sludge	ng/g DW	<0.5	<1	<1	<1	<1
	MR-3729	2004-11-09	Linköping	Sludge	ng/g DW	<0.7	<4	<4	<4	<4
	MR-3854	Dec-04	Linköping	Fish	ng/g lipid	<2	<100	<100	<100	<100
	MR-3857	Dec-04	Finspång	Fish	ng/g lipid	5.9	<100	<100	<100	<100
	MR-3683	2004-10-29	Finspång	Sediment	ng/g DW	<1.3	<4	<4	<4	<4
	MR-3685	2004-10-21	Linköping	Sediment	ng/g DW	<0.7	<7	<7	<7	<7
	MR-3635	2004-10-27	Finspång	Water	ng/l	<1.3	<8	<8	<8	<8
	MR-3675	2004-10-28	Finspång	Water	ng/l	<1	<8	<8	<8	<8
	MR-3728	2004-11-09	Linköping	Water	ng/l	<1.3	<8	<8	<8	<8