

SWECO Environment
Screening Report

Chlorhexidine and
p-chloroaniline

Client

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Sammanfattning

Bakgrund och metoder

Klorhexidin är ett vanligen använt antiseptiskt medel som används för rengöring inom vårdsektorn samt som aktiv substans i receptfria hygienartiklar som t.ex. sårtvättsvätskor, munsköljmedel, tandkräm, hudkräm m.m. Apotekets försäljningsstatistik redovisade att 3,2 ton av ämnet såldes under 2008. De bakteriehämmande och konserverande egenskaperna utnyttjas även genom att ämnet tillsätts till kosmetika och andra hushållsprodukter. Under 2009 registrerades en total användning av 7,9 ton av klorhexidin diglukonat i olika produkter enligt Kemikalieinspektionens databas KemIstat. Av denna mängd användes 5,4 ton som biocid och för desinfektion. Den totala användningen i hela EU under år 2000 uppskattades till mellan 10 000 och 50 000 ton. Samtidigt som detta är ett ämne med utbredd användning vet man mycket lite om eventuella förekomster i miljön av ämnet.

SWECO Environment fick i uppdrag av Naturvårdsverket att genomföra en screeningstudie av klorhexidin. Screeningstudien anpassades till att täcka in många olika typmiljöer och matriser, och innefattar därför endast ett fåtal prover från varje plats. Naturvårdsverket ansvarar för den nationella screeningen av kemikalier men Länsstyrelserna har möjligheten att vara med och komplettera undersökningen med mätpunkter av regionalt intresse. Provtagningen genomfördes nationellt med provpunkter som valdes av Naturvårdsverket och SWECO samt regionalt med provpunkter som valdes av respektive länsstyrelse. Resultaten från den regionala samt den nationella provtagningen samutvärderades.

En provtagningsstrategi togs fram innefattande provtagning av inkommande och utgående vatten samt slam vid avloppsreningsverk liksom provtagning av ytvatten, sediment och fisk i vattendrag som tar emot utgående vatten från avloppsreningsverk. Avloppsreningsverk valdes som provtagningsplatser eftersom hushåll och sjukhus tros vara viktiga utsläppskällor. Då en rad ämnen med ursprung i avloppsslam har återfunnits i åkermark analyserades även jordprov från åker. Vatten, sediment och fiskprover från mindre belastade vattendrag har också provtagits.

Klorhexidin förmodas brytas ned till p-kloranilin som är mer toxisk än modersubstansen. Därför är det relevant att kartlägga eventuell förekomst av även detta ämne. Genom att i studien även kvantifiera alkylfenoler, som är ett väl kartlagt ämne med många möjliga urbana källor, kan man erhålla ett mått på graden av urban belastning vid den aktuella mätpunkten. Sammanlagt provtogs 36 vattenprover, 11 slamprover, 7 sedimentprover, 3 jordprover och 7 fiskprover. För att ge en samlad bedömning analyserades samtliga prover i studien med avseende på klorhexidin, p-kloranilin samt alkylfenoler.

Slutsatser och rekommendationer

De huvudsakliga slutsatserna från denna studie var att:

- Klorhexidin påträffades inte i inkommande avloppsvatten till reningsverk, utgående vatten, recipientvatten eller i vatten från bakgrundsmiljöer. Rapporteringsgränsen var 0,010 µg/l.
- Den mera toxiska nedbrytningsprodukten p-kloranilin påträffades inte i inkommande avloppsvatten till reningsverk, utgående vatten, recipientvatten eller i vatten från bakgrundsmiljöer. Rapporteringsgränsen var 0,0050 µg/l.

- Inget av ämnena detekterades i utgående avloppsvatten från sjukhus.
- Inget av ämnena detekterades i avloppsslam, sediment från recipienter, sediment från ytvatten i bakgrundsområden eller i slambelagd åkermark. Rapporteringsgränsen var 0,010 mg/kg för båda ämnena.
- Inget av ämnena detekterades i muskelprover från fisk fångad i recipienter eller från ytvatten i bakgrundsområden. Rapporteringsgränsen var 0,10 mg/kg (våtvikt) för klorhexidin och 0,050 för p-kloranilin.

Det förekommer inga tidigare studier där klorhexidin har analyserats i den yttre miljön. För avloppsreningsverk finns endast en studie från 1988 där klorhexidin påvisats i ingående och utgående vatten från reningsverk i halter mellan 1 – 10 µg/l. Således kan inte resultaten från denna studie bekräftas med tidigare gjorda mätningar.

Tidigare undersökningar har visat att p-kloranilin är förhållandevis lättnedbrytbart. Data vad gäller klorhexidins (bio)nedbrytbarhet är mer motsägelsefullt, där flera studier pekar på att klorhexidin bryts ned av ett flertal olika bakteriestammar som dessutom isolerats från aktivt slam i reningsverk, medan andra studier klassificerar klorhexidin som svårnedbrytbart.

Eftersom rapporteringsgränsen (LOQ) är ca 100 ggr lägre än den lägsta risknivån i ytvatten ($PNEC_{\text{aqua}}$) tyder resultaten på att det inte finns några ekologiska risker associerade med klorhexidin i den akvatiska miljön. Således är rekommendationen att inga ytterligare screeningstudier av klorhexidin är nödvändiga.

Summary

Background and methods

Chlorhexidine is the active ingredient in many antiseptics and also a common preservative added to e.g. make up. Because of the widespread use but lack of knowledge concerning environmental concentrations the chemical was selected to be included in the screening program of 2010. Within this screening program, SWECO Environment was commissioned by the Swedish EPA to measure and report on the occurrence of chlorhexidine and its major degradation product p-chloroaniline. Chlorhexidine is not labelled as a Persistent, Bioaccumulative, or Toxic chemical, PBT, but some studies show a potential to bioaccumulate and also toxic properties. More so, the degradation product p-chloroaniline has very toxic properties.

There are just a few previous studies world wide on the occurrence of these chemicals in the environment. A Swedish national sampling strategy was devised which included sampling of incoming water, effluents and sludge at sewage treatment plants as well as sampling of surface waters, sediments and fish in streams receiving effluents from sewage treatments plants. Sewage treatment plants (STPs) were chosen as sampling localities because of their general potential to release of household chemicals into the aquatic environment. Further, sewage from hospitals was sampled and also agricultural soils receiving sludge amendment.

Conclusions

The main conclusions from this investigation were:

- Chlorhexidine was not found in incoming sewage water, outgoing treated water, recipient water or background water. The limit of quantification (LOQ) was 0.010 µg/l.
- p-chloroaniline (a more toxic degradation product of chlorhexidine) was not found in incoming sewage water, outgoing treated water, recipient water or background water. The limit of quantification was 0.0050 µg/l.
- Chlorhexidine and p-chloroaniline was not detected in sewage from hospitals.
- Chlorhexidine or p-chloroaniline was not found in sewage sludge, sediments in recipients, background sediments or agricultural soil receiving sludge. The limit of quantification was 0.010 mg/kg.
- Chlorhexidine or p-chloroaniline was not found in the tissue of fish collected in rivers or in lakes. The limit of quantification was 0.10 and 0.050 mg/kg (wet weight, mussle) respectively.

There is no data from other studies on concentrations in the environment, and only very few data on concentrations in STPs. Consequently, there are no supporting studies to confirm the results from this study. p-chloroaniline is known to be readily biodegradable and there is data indicating that chlorhexidine may be inherently biodegradable in STPs although the scant information is contradictory.

Given that LOQ is 100 times lower than $PNEC_{\text{aqua}}$ there is no discernible risk with chlorhexidine in the environment and there is consequently no need for further screening studies of chlorhexidine.

1 Introduction

1.1 Background

At present there is a lack of knowledge regarding the emission, distribution and exposure to many of the chemicals emitted to the environment. The aim of the screening program financed by the Swedish Environmental Protection Agency is to alleviate this lack of knowledge by estimating the occurrence of different chemicals in the environment in relevant matrices (soil, water etc.).

To maximize the information gained from the screening program measurements are made in many matrices at many sites, but with few samples per site. The Swedish EPA is responsible for the screening at the national level and selects the chemicals that are to be included. The regional county administrative boards have the option to complement and extend the sampling program by choosing additional sampling point that are of regional interest.

Chlorhexidine is a common antiseptic used both in household products and in hospitals. The chemical is not classified as a pharmaceutical compound and is therefore widely accessible. Despite the widespread use there is a lack of knowledge concerning environmental concentrations of chlorhexidine. Within the screening program of 2010, SWECO Environment was commissioned by the Swedish EPA to measure the occurrence of chlorhexidine. p-chloroaniline is a major degradation product of chlorhexidine and was therefore also included in the screening program.

1.2 Objectives

Because of the extensive lack of knowledge on environmental concentrations of chlorhexidine, the screening project was designed to cover a wide array of matrices. Suspected major contributing sources of chlorhexidine such as hospitals, households and sewage treatment plants (STPs) were included in the sampling program as well as background surface water, sediment and biota. Both the mother compound and the degradation product p-chloroaniline were monitored.

The objectives of the project were to:

- Elucidate whether chlorhexidine or p-chloroaniline occurs in waste water from hospitals.
- Elucidate the occurrence of chlorhexidine and p-chloroaniline in the sewage water system, including incoming untreated water, outgoing treated sewage water and sewage sludge. Agricultural soil receiving sewage sludge was also included.
- Elucidate the occurrence of chlorhexidine and p-chloroaniline in water, sediments and biota of recipients downstream of STPs.
- Elucidate levels of chlorhexidine or p-chloroaniline in water, sediments and biota in urban lakes and rivers
- Elucidate whether chlorhexidine or p-chloroaniline is occurring in background surface waters and sediments.

1.3 Substance information

1.3.1 Usage

Chlorhexidine is one of the most widely used antimicrobial agents (Ranganathan 1996). It is a cationic antiseptic belonging to biguanidic group and is active against gram-positive bacteria, fungi, species of *Proteus* and also certain types of viruses (Fiorentino 2010). Chlorhexidine has good antiseptic abilities and is possible to incorporate into many different types of products (Fiorentino 2010). This has led to a widespread use in many types of products. It can be found in consumer products such as cosmetics, gels, spray, gum, soaps, mouth wash and toothpaste. Chlorhexidine and its salts (chlorhexidine acetate, chlorhexidine gluconate, chlorhexidine hydrochloride) may be added to cosmetics, as active ingredients or as preservatives, at concentrations of up to 0.3 %, according to current EU legislation (Council Directive 76/768/EEC). In clinical practice chlorhexidine is used for washing of hands, skin, mucous membranes, wounds and burns. It is also used as a disinfectant for veterinary use (Fiorentino 2010). Another use of chlorhexidine is as a preservative to disinfect hydrophilic contact lenses (Akaho 2001).

The annual consumption of chlorhexidine in the EU was 10'000-50'000 tonnes in 2000 (Flygfältsbyrån 2009). A reliable estimate of the annual national consumption of chlorhexidine in Sweden is difficult since the use in cosmetic and hygiene products does not need to be reported to the Swedish chemical agency (KIFS 2008:245). The usage as an additive in these kinds of products is probably a substantial part of the overall use. Estimated use of chlorhexidine digluconate in 2009 was 7.9 tonnes (KemIstat) of which 5.4 tonnes were used for disinfection and biocide use. Data for chlorhexidine digluconate was also found in the SPIN data base and the trend for annual consumption as reported in these two databases are presented in Figure 1.1. No data for Swedish consumption of pure chlorhexidine, chlorhexidine dihydrochloride or chlorhexidine diacetate were available from these databases. According to FASS, the Swedish Medicines Information Engine, there are presently 27 different products registered with chlorhexidine as active component. Typical products are cutaneous disinfectants and mouth wash.

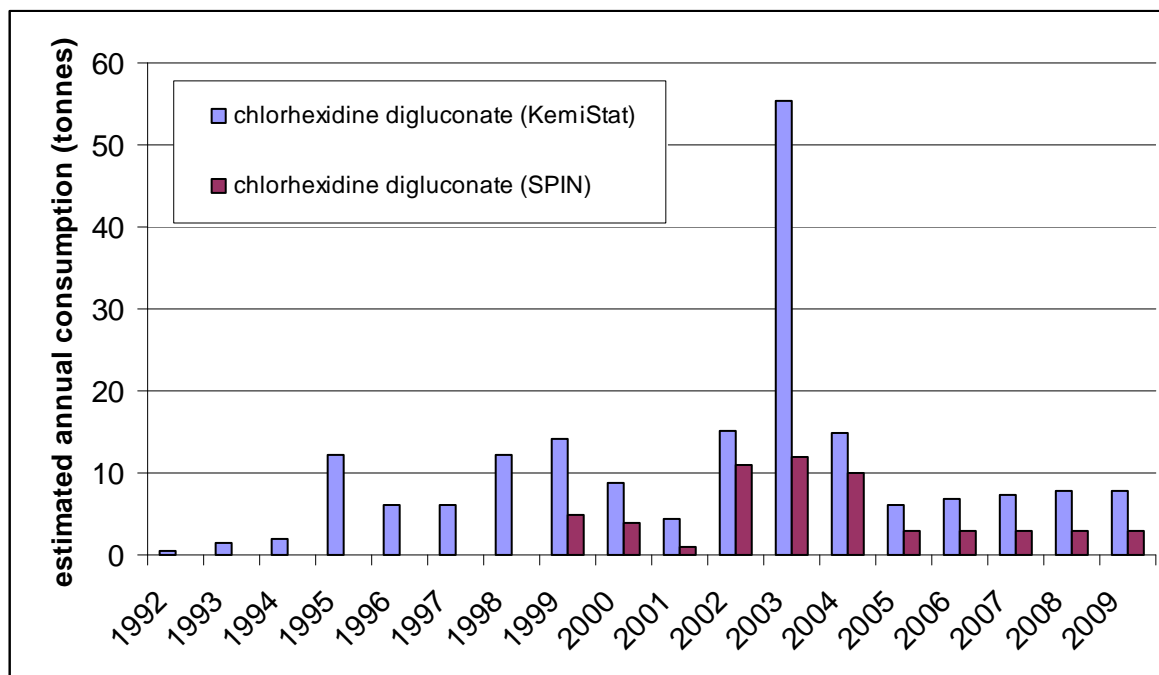


Figure 1.1 Registered sales (tonnes) of chlorhexidine in Sweden (KEMI 2010).

1.3.2 Properties

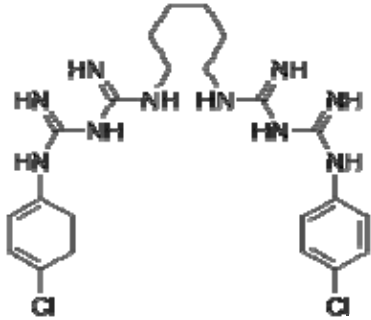
Table 1.1 presents physical and chemical properties as well as toxicological and ecotoxicological information for chlorhexidine.

Based on the physicochemical properties chlorhexidine in its pristine form is not expected to adsorb to suspended solids. The pK_a of 10.78 indicates that the protonated form of chlorhexidine will be the dominating form in the environment and this di-cation can be expected to adsorb to suspended solids in e.g. sewage water. Reports on bioaccumulation and bioconcentration of chlorhexidine are contradictory. The estimated $\log K_{ow}$ of 0.08 and the estimated BCF of 3 suggests that the potential to bioconcentrate in aquatic organisms is low (Toxnet, HSDP). The QSAR modelling performed before the present study suggests a K_{ow} of 4.82 indicating that Chlorhexidine bioconcentrate and bioaccumulate in the aquatic environment (Flygfältsbyrån 2009). If the latter modelling is based on the neutral and not protonated form of chlorhexidin this can be an explanation for the non-coherent results. The estimation for the protonated molecule is the only relevant one, since chlorhexidin has a $pK_a > 10$ and can therefore be expected to be present in water in its protonated hydrophilic form. Experimental data from an exposure study with golden eye (*Leuciscus idus melanotus*) resulted in a bioaccumulation factor of 40 (Freitag 1985). It has also been shown that chlorhexidine can bioaccumulate extensively in lipid-rich regions of diatoms and bacteria in natural river biofilms (Dynes 2006).

Chlorhexidine is a common disinfectant used in many hospitals and health care workers are repeatedly exposed to it. Dilute solutions does not seem to cause allergenic response. A dilute solution of 0.01% chlorhexidine diacetate can however be irritating to eye and mucous membranes and more concentrated solutions are highly acutely toxic when applied to the eye (Toxnet 2010). More

importantly p-chloroaniline, which is the major degradation product of chlorhexidine, has more toxic properties. p-chloroaniline causes the formation of haemoglobin adducts in humans. Further it is proven to be carcinogenic in male rats and there is also some evidence of carcinogenicity in male mice. Possibly, p-chloroaniline is also genotoxic, although results are sometimes conflicting. To aquatic organisms p-chloroaniline can be classified as moderately to highly toxic (Toxnet 2010).

Table 1.1 Physicochemical and (Eco)toxicological properties of Chlorhexidine.

Common name	Chlorhexidine		
			
Name	1,1'-hexamethylenebis {5-(p-chlorophenyl) biguanide}		
CAS #	55-56-1		
Labelling ¹	[Xi - Irritant: R36, R37, R38], [N - Harmful for the environment: R51/R53]		
		Min	Max
Physico-chemical properties	Water solubility	800 at 20°C ²	Unit
	Log K _{ow}	0.08 ²	
	K _{oc}	28 ²	
	pK _a	10.78 ²	
	Henry's law constant	1.1X10 ⁻³⁰	atm-cu m/mole
	Vapour pressure ²	2.0X10 ⁻¹ (Estimated)	mm Hg @ 25 deg C
Ecotoxicology aquatic	LC50 Pteronarcys (stone fly) 48h ²	0.5	
	LC50 <i>Salmo gairdneri</i> 96h ²	1.3	
	LC50 <i>Daphnia magna</i> 48h ²	250	
	LC50 <i>Daphnia magna</i> 25h ²	740	
	LC50 <i>Brachydanio rerio</i> 96h ²	1400	µg/l
	EC50 <i>Daphnia magna</i> ³	60	
	EC50 <i>Daphnia pulex</i> ⁶	50 – 100	
	IC50 Chronic algal toxicity 72h ⁴	11	
PNEC _{aqua} ⁷	1.4		
Toxicology	LD50 Mouse (male/female) oral – iv ²	1 - 3	g/kg
Persistence, Bioaccumulation, Toxicity (PBT)	Chlorhexidine is classified as non-biodegradable and BCF has been estimated to 3 ²		
¹ http://sitem.herts.ac.uk/aeru/vsdb/Reports/1779.htm ² Toxnet, Hazardous Substances Data Bank ³ EPA. Reregistration Eligibility Decision (RED) Chlorhexidine diacetat. 1996. USEPA. www.epa.org . ⁴ MSDS, Fagron GmbH & Co.KG, version: 26.11.2008 ⁶ Product Safety Data Sheet, Vetasept Chlorhexidine Surgical Scrub, Animalcare UK. ⁷ Envision Chemistry/Peter Frisk Associates ,Development and assessment of risk profiles for pharmaceuticals			

1.3.3 Uptake and human metabolism

The most probable route of exposure for humans to Chlorhexidine is by dermal contact with skin disinfectants or ingestion of oral antimicrobial products. Chlorhexidine does not absorb readily through the skin after application and is absorbed poorly from the gastrointestinal tract. If accidentally swallowed, it has been shown that of a 300-mg dose of chlorhexidine gluconate, approximately 90% of the dose is excreted in faeces and less than 1% is eliminated in urine (Toxnet 2009).

2 Methods

2.1 Additional substances

Apart from chlorhexidine and p-chloroaniline, alkyl phenols were also analysed in each sample. Alkyl phenols were chosen as substances that could represent anthropogenic influence in general. This was done to support the evaluation since levels of chlorhexidine may roughly correlate to anthropogenic influence.

2.2 Sampling Strategy

Since household consumption and hospital use is considered to be the main source of chlorhexidine a sampling strategy was devised to elucidate the levels of chlorhexidine within sewage treatment plants (STPs) and in receiving surface water recipients. Locations were selected to give a broad geographical spread and one treatment plant was selected specifically because it receives waste water from a pharmaceutical company that produces a chlorhexidine containing product. Agricultural soil receiving sludge amendments were also sampled.

Apart from the sampling and analysis financed by the Swedish EPA, regional county administration boards financed sampling and analysis of additional samples, mostly in sewage treatment plants.

The different matrices chosen and types of sampling points are presented in Table 2.1.

Table 2.1 Sampling matrices and the types of samples investigated for the occurrence of Chlorhexidine and p-chloroaniline.. The first value denotes samples taken within the national screening program. The second value (after the slash) denotes samples financed by the regional screening program.

	Sample matrices Chlorhexidine and p-chloroaniline						
	Incoming water	Outgoing water	Sludge	Surface water	Sediment	Biota	Soil
Background				1	1	1	
Sewage treatment plant	6 / 4	6 / 10	6 / 5	3 / 2	3	2	
Urban effected areas				3 / 3	3	2 / 2	
Agricultural land							3
Total	6 / 4	6 / 10	6 / 5	7 / 5	7	5 / 2	3
Total				40 / 26			

2.3 Sampling methods

Sampling instructions were given to all sampling personnel. The instructions included sampling procedures and handling of samples.

2.3.1 Sewage water

The staff at the sewage treatment plants collected water samples in glass containers or stainless steel containers. Plastic containers were avoided to exclude cross-contamination of alkyl phenols. A time integrated, or flow-proportional, pooled sample was collected for 4-7 days often in coordination with the ongoing operational monitoring program. Samples were kept cool until analysis. A volume of 1 litre of the sample was analyzed for chlorhexidine and p-chloroaniline and in addition a volume of 0.5 litre was analyzed for alkyl phenols.

2.3.2 Sewage sludge

The staff at the sewage treatment plants collected untreated sludge samples in acid rinsed pre burned dark glass jars. A pooled sludge sample was collected to represent approximately the same time span as the sewage samples but may in some cases, due to the operational procedures, represent a somewhat longer time span.

2.3.3 Surface water

Pooled grab samples of unfiltered water was collected in clean glass bottles. Water samples were stored cold until analysis. A volume of 1 litre of the sample was analyzed for chlorhexidine and p-chloroaniline and in addition a volume of 0.5 litre was analyzed for alkyl phenols.

2.3.4 Biota

All biota samples except from Höje å, Lund, consisted of 50 gram of pooled muscle sample from 5-10 individuals of perch (*Perca fluviatilis*). The sample from Lund consisted of pooled muscle from 2 carp fish (*Cyprinus carpio*).

2.3.5 Sediment

Sediment samples were collected by means of a core sampler or Ekman dredge. All sediment samples were transferred to pre-burned and dark glass jars. They were stored cold until analysis.

2.3.6 Agricultural soil

Agricultural soil was sampled two months after sewage sludge had been spread. Samples from at least 3 sub-samples were pooled.

2.4 Analytical methods

As mentioned above there are very few studies on environmental concentrations of chlorhexidine. Most of the available analytical methods have been developed for the medical industry and subsequently are designated for the analysis of chlorhexidine in saliva, urine or medical products such as creams and washing solutions. In a review of analytical methods no method for measurement in environmental samples was identified (Fiorentino 2010). Consequently, new methods for the analysis

of chlorhexidine was developed and validated for the purpose of this study. The validation process encompassed:

1. A complete calibration test over the whole quantification range to ensure a linear response.
2. A 10 point calibration for the lower quantification range to determine LOQ and LOD (limit of detection).
3. Separate recovery test for all matrices in three concentration levels (low, medium, high). Each concentration level was in turn tested by triplicate spiking and analysis.

2.4.1 Water samples:

After adjustment to basic pH (>10), water samples were extracted with dichloromethane. The extract was treated with 6M HCl which hydrolyses chlorhexidine to two p-chloroaniline molecules. pH was then adjusted to basic once again and the sample was evaporated before a second extraction of p-chloroaniline with cyclohexane. (If only p-chloroaniline is to be measured in the sample the hydrolysis step is omitted). Quantification of p-chloroaniline was made by GCMS.

2.4.2 Solid samples:

Chlorhexidine in sludge, sediment or soil was determined after air-drying of samples. Dry samples were extracted with dichloromethane after alkalinisation of the material (pH >10). Extracts were evaporated to dryness and then hydrolyzed with 6 M HCl over night. pH was then adjusted to basic once again and the sample was evaporated before a second extraction of p-chloroaniline with cyclohexane. Quantification of p-chloroaniline was made by GCMS.

2.4.3 Biota samples:

Chlorhexidine in fish was determined after alkalization of the original fish material (pH >10), followed by centrifugation and decantation. The liquid phase was extracted with dichloromethane and the extract was then treated like described above for water and solid samples.

3 Results

The complete list of sampling points and results are presented in Appendix 1.

Neither chlorhexidine nor p-chloraniline was detected in any of the 38 water samples, 11 sludge samples, 7 sediment samples, 3 soil samples or 7 fish samples. Limit of quantification (LOQ) for the determination of chlorhexidine and p-chloroaniline in the different matrices are presented in Table 3.1. Data on alkyl phenols, as determined for reference, in the same samples are presented in Table 3.2.

Table 3.1 LOQ for the present study of chlorhexidine.

Matrix	unit	LOQ Chlorhexidin, present study	LOQ p-Chloroaniline, present study	number of samples
<u>Incoming sewage water</u>	µg/l	<0.010	<0.005	10
<u>Sludge</u>	mg/kg	< 0.010	<0.010	11
<u>Outgoing sewage water</u>	µg/l	<0.010	<0.005	14
<u>Surface water downstream STP</u>	µg/l	<0.010	<0.005	5
<u>Surface water</u>	µg/l	<0.010	<0.005	7
<u>Sediment</u>	mg/kg	< 0.010	<0.01	7
<u>Fish</u>	mg/kg	<0.10	<0.05	7
<u>Agricultural soil</u>	mg/kg	< 0.010	<0.01	3

Table 3.2 Alkyl phenols in the present study.

Matrix	unit	LOQ Alkyl phenols, present study	Concentration Alkyl phenols*, present study n – n.o. detected m - median among detected 25 th - 25 percentile among detected 95 th - 95 percentile among detected	number of samples
<u>Incoming sewage water</u>	µg/l	<0.3	n = 10; m = 1.60; 25 th = 1.10; 95 th = 2.54	10
<u>Sludge</u>	mg/kg	-	n = 10; m = 6.8; 25 th 3.1; 95 th = 11.6	10
<u>Outgoing sewage water</u>	µg/l	<0.3	n = 11; m = 0.50; 25 th = 0.39; 95 th = 1.18	16
<u>Surface water downstream STP</u>	µg/l	<0.010	n = 2 ("Norrån" = 1.10 ; "Kaplansälven" = 3.88)	5
<u>Surface water</u>	µg/l	<0.3	n = 0	7
<u>Sediment</u>	mg/kg	< 0.010	n = 1 ("Källby" = 3.74)	7

Matrix	unit	LOQ Alkyl phenols, present study	Concentration Alkyl phenols*, present study n – n.o. detected m - median among detected 25 th - 25 percentile among detected 95 th - 95 percentile among detected	number of samples
<u>Fish</u>	mg/kg	<0.011	n = 1 (“Källby” = 0.54)	7
<u>Agricultural soil</u>	mg/kg	< 0.005	n = 0	3

* For water samples data represent the sum of nonyl phenols not including 4-n-nonylphenol, for solid matrices data represent the sum of 4-tert-octyl phenol + 4-nonyl phenol

All samples were also analyzed for Alkyl phenols as substances that could represent anthropogenic influence in general. Alkyl phenols (4-tert-octyl phenol + 4-nonyl phenol) were detected in all analysed samples of incoming sewage water and sludge samples. Analyzed sediment samples were both from background areas and sites located downstream of STPs. The sediment sample “Källby”, where alkyl phenols were detected, was taken from the first treatment dam at the sewage treatment plant. This is the first of three sequential polishing steps handling water after the treatment basins. The fish sampled named “Källby” was from two Carp fish from the same closed dam. These sediment and biota samples do not represent the final recipient stream of Höje å but rather an integral part of the water treatment steps at the plant.

4 Discussion

The reported absence of any detectable concentrations of chlorhexidine or p-chloraniline in the whole screening study motivated a deeper inspection of the analytical methods. The following measures were taken to rule out the possibility of false negatives being reported.

- The laboratory was asked to provide more detailed information regarding the analytical method.
- A comprehensive review of previous methods reported in peer reviewed papers was conducted
- Several merited researchers in analytical chemistry at Lund University were interviewed concerning suitable extraction methods for the present analysis.
- Laboratory chromatograms from the method validation, calibration and from some of the samples were reviewed.

Initially there was a concern for that the extraction procedure for water samples was erroneous. However, after a very detailed description of the steps involved in the extraction procedure had been provided by the laboratory, the initial concern could be precluded.

There is a paucity of information concerning chlorhexidine concentrations in the environment. Kodama et al. (1988) reported that domestic wastewater could contain up to 1.6 to 10.3 µg/l. But apart from this study there is little, if any, data available. For p-chloroaniline there are more data available concerning environmental concentrations estimated in other studies and some of these are presented in Table 4.1 together with the LOQ for determination of p-chloroaniline in different matrices in the present study.

Among the studies presented in Table 4.1 it can be noted that in the most recent studies, from 1995 and 1998, p-chloroaniline was not detected in the river Rhine or in the river Elbe downstream the city of Hamburg.

Table 4.1 Concentrations of p-chloroaniline in studies from other countries.

Matrix	unit	present study	other studies	Year/Country	Reference
<u>Incoming sewage water</u>	µg/l	<0.0050			
<u>Sludge</u>	mg/kg	< 0.010			
<u>Outgoing sewage water</u>	µg/l	<0.0050			
<u>Surface water</u>	µg/l	<0.0050	0,1 – 1	summary 1980-1995 /Germany and the Netherlands, Rhine	a
			0.024 - 0.39 (detected in 9 of 128 samples)	Japan	b
			<0.002	1998/Germany, Elbe	c
			<0.5	1995/Germany, Rhine	d
			0.84	1995/Germany, Emscher	d
<u>Sediment</u>	mg/kg	< 0.010	0,001 - 0,27 (detected in 39 of 121)	1976/Japan	b
<u>Fish</u>	mg/kg	<0.050	<1	1976/Japan	b
<u>Agricultural soil</u>	mg/kg	< 0.010			

^a BUA (1995) p-Chloroaniline. Beratergremium für Umweltrelevante Altstoffe (BUA) der Gesellschaft Deutscher Chemiker. Weinheim, VCH, 171 pp. (BUA Report 153)

^b Office of Health Studies (1985) Chemicals in the environment. Report on environmental survey and wildlife monitoring in F.Y. 1982 and 1983. Tokyo, Environment Agency Japan, 9 pp.

^c Götz R, Bauer OH, Friesel P, Roch K (1998) Organic trace compounds in the water of the river Elbe near Hamburg part-1. Chemosphere, 36(9):2085-2101.

^d LUA (1997) Rheingütebericht NRW 1995. Essen, Landesumweltamt Nordrhein-Westfalen

In the present study neither chlorhexidine nor its major degradation product p-chloroaniline was detected in any of the investigated matrices. The sampling strategy incorporated a wide array of sample types including both general background samples and specially selected locations with possible point source influence. Among the latter was e.g. untreated sewage water that included water from a medical industry known to use chlorhexidine in the production. The methods for quantification of chlorhexidine and p-chloroaniline were developed specifically for the present study and have been thoroughly validated. The limit of quantification for measurement in water was more than 100 times lower than the PNEC_{aqua}. The toxicological data on which the PNEC was based was not accessible. The PNEC is approximately similar for p-chloroaniline (WHO 2003).

The limit of quantification was 100 times lower than the two lowest found LC₅₀ values. These LC₅₀ values, that were lower than the PNEC, were not used for the calculation of a new PNEC since the primary source for the studies were not accessible. It does not seem likely that the lethal concentration for salmon is 1000 times lower than that for zebra fish.

The levels of alkyl phenols found in fish tissue from the Källby STP (taken from a treatment dam) indicates that this biota sample was relevant for pinpointing which chemicals present at the site that are prone to bioaccumulate. If chlorhexidine had been present in relevant concentrations, and been prone to bioaccumulate, it would probably have been detected in this biota sample.

The present screening study of chlorhexidine was motivated mostly by the widespread use of the chemical and the lack of knowledge concerning environmental concentrations. The results indicate that chlorhexidine and p-chloroaniline is either diluted to concentrations below what is quantifiable with present analytical methods or eliminated effectively by biotic and/or abiotic degradation. The quotes on degradation of chlorhexidine are somewhat conflicting. A review on the fate of pharmaceutical substances in the environment states that chlorhexidine is not easily degradable in sewage treatment plants (Halling-Sorensen et al. 1998). On the other hand Japanese studies have showed that bacterial strains have the ability to degrade chlorhexidine via the intermediate degradation product p-chloroaniline (Ogase et al 1992) but also via other previously unknown intermediate degradation products (Tanaka et al 2005). In a study by Kido et al. (1988) two bacterial strains, who were able to use chlorhexidine as sole nitrogen source for growth, were isolated from activated sludge from a STP. Abiotic degradation through hydrolysis is not expected in the environment due to the lack of hydrolyzable functional groups (Lyman 1990) but degradation by light has been reported (Freitag 1985).

The degradation product p-chloroaniline, is less stable in the environment in comparison to the parent compound and numerous studies indicate that p-chloroaniline is inherently biodegradable in water under aerobic conditions. It decomposes in the presence of light and air and at elevated temperature (WHO 2003). Effective degradation of anilines in sludge has also been demonstrated elsewhere (Gledhil 1975).

On the basis of what is known concerning the degradation of both chlorhexidine and p-chloroaniline, it is quite possible that the prevailing conditions in Swedish sewage treatment plants are favourable for elimination of these compounds.

5 Conclusions and recommendations

This study indicates that chlorhexidine and its major degradation product p-chloroaniline does not occur above the limit of quantification in any matrix in the vicinity of the possible sources as identified in this study. There is no data from other studies on concentrations in the environment, and only very few data on concentrations in STPs. Consequently, there are no supporting studies to confirm the results from this study. p-chloroaniline is known to biodegrade easily and there is data indicating that chlorhexidine may be inherently biodegradable in STPs although the scant information is contradictory.

Given that LOQ is 100 times lower than $PNEC_{\text{aqua}}$ there is no discernible risk with chlorhexidine in the environment. There is consequently no need for further screening studies of chlorhexidine.

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4-CHLOROANILINE

Appendix 1, Results Screening 2010 - 2011
Chlorhexidine (including the degradation product p-chloraniline) and Alkyl phenols
Incoming sewage water

compound	county	national/regional	Sample name/location	Concentration	Unit
chlorhexidine	Dalarna	N	Krylbo ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Dalarna	N	Borlänge ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Dalarna	R	Främby ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Gävleborg	N	Hedåsen ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Södermanland	R	Strängnäs ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Södermanland	R	Ekeby ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Värmland	N	Fiskartorpet ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Värmland	N	Sjöstadsverket ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Västernorrland	N	Bällsta ARV, inkommande avloppsvatten	<0,01	µg/L
chlorhexidine	Dalarna	R	Främby ARV, inkommande avloppsvatten (tankbil)	<5	µg/L
p-chloroaniline	Dalarna	N	Krylbo ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Dalarna	N	Borlänge ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Dalarna	R	Främby ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Gävleborg	N	Hedåsen ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Södermanland	R	Strängnäs ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Södermanland	R	Ekeby ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Värmland	N	Fiskartorpet ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Värmland	N	Sjöstadsverket ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Västernorrland	N	Bällsta ARV, inkommande avloppsvatten	<0,005	µg/L
p-chloroaniline	Dalarna	R	Främby ARV, inkommande avloppsvatten (tankbil)	<1	µg/L
nonyl phenols	Gävleborg	N	Hedåsen ARV, inkommande avloppsvatten	2,600	µg/L
nonyl phenols	Värmland	N	Sjöstadsverket ARV, inkommande avloppsvatten	2,300	µg/L
nonyl phenols	Dalarna	N	Borlänge ARV, inkommande avloppsvatten	1,600	µg/L
nonyl phenols	Södermanland	N	Strängnäs ARV, inkommande avloppsvatten	1,600	µg/L
nonyl phenols	Dalarna	N	Främby ARV, inkommande avloppsvatten	1,100	µg/L
nonyl phenols	Västernorrland	N	Bällsta ARV, inkommande avloppsvatten	0,980	µg/L
nonyl phenols	Dalarna	N	Krylbo ARV, inkommande avloppsvatten	0,840	µg/L
nonyl phenols	Värmland	N	Fiskartorpet ARV, inkommande avloppsvatten	0,840	µg/L
nonyl phenols	Gävleborg	N	Österfärnebo ARV, inkommande avloppsvatten	0,810	µg/L
nonyl phenols	Södermanland	N	Ekeby ARV, inkommande avloppsvatten	0,58	µg/L

Outgoing sewage water

compound	county	national/regional	Sample name/location	Concentration	Unit
chlorhexidine	Dalarna	R	Avesta lasarett, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Dalarna	R	Krylbo ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Dalarna	R	Borlänge ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Dalarna	R	Falu lasarett, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Dalarna	R	Frånby ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Gotland	R	Visby ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Gävleborg	N	Österfärnebo ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Gävleborg	N	Gysinge ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Skåne	N	Källby ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Stockholm	N	Henriksdal ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Södermanland	R	Strängnäs ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Södermanland	R	Ekeby ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Uppsala	N	Tärnsjö ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Värmland	R	Fiskartorpet ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Värmland	R	Sjöstadsverket ARV, utgående avloppsvatten	<0,01	µg/L
chlorhexidine	Västernorrland	N	Bällsta ARV, utgående avloppsvatten	<0,01	µg/L
p-chloroaniline	Dalarna	R	Avesta lasarett, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Dalarna	R	Krylbo ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Dalarna	R	Borlänge ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Dalarna	R	Falu lasarett, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Dalarna	R	Frånby ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Gotland	R	Visby ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Gävleborg	N	Österfärnebo ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Gävleborg	N	Gysinge ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Skåne	N	Källby ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Stockholm	N	Henriksdal ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Södermanland	R	Strängnäs ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Södermanland	R	Ekeby ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Uppsala	N	Tärnsjö ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Värmland	R	Fiskartorpet ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Värmland	R	Sjöstadsverket ARV, utgående avloppsvatten	<0,005	µg/L
p-chloroaniline	Västernorrland	N	Bällsta ARV, utgående avloppsvatten	<0,005	µg/L
nonyl phenols	Gävleborg	N	Gysinge ARV, utgående avloppsvatten	1,700	µg/L
nonyl phenols	Gävleborg	N	Österfärnebo ARV, utgående avloppsvatten	0,660	µg/L
nonyl phenols	Dalarna	N	Krylbo ARV, utgående avloppsvatten	0,620	µg/L
nonyl phenols	Västernorrland	N	Bällsta ARV, utgående avloppsvatten	0,590	µg/L
nonyl phenols	Dalarna	N	Borlänge ARV, utgående avloppsvatten	0,500	µg/L
nonyl phenols	Uppsala	N	Tärnsjö ARV, utgående avloppsvatten	0,500	µg/L
nonyl phenols	Värmland	N	Sjöstadsverket ARV, utgående avloppsvatten	0,490	µg/L
nonyl phenols	Dalarna	N	Falu lasarett, utgående avloppsvatten	0,410	µg/L
nonyl phenols	Dalarna	N	Avesta lasarett, utgående avloppsvatten	0,370	µg/L
nonyl phenols	Södermanland	N	Strängnäs ARV, utgående avloppsvatten	0,360	µg/L
nonyl phenols	Skåne	N	Källby ARV, utgående avloppsvatten	0,330	µg/L
nonyl phenols	Dalarna	N	Frånby ARV, utgående avloppsvatten	<0,3	µg/L
nonyl phenols	Gotland	N	Visby ARV, utgående avloppsvatten	<0,3	µg/L
nonyl phenols	Stockholm	N	Henriksdal ARV, utgående avloppsvatten	<0,3	µg/L
nonyl phenols	Södermanland	N	Ekeby ARV, utgående avloppsvatten	<0,3	µg/L
nonyl phenols	Värmland	N	Fiskartorpet ARV, utgående avloppsvatten	<0,3	µg/L

Surface water

compound	county	national/regional	Sample name/location	Concentration	Unit
chlorhexidine	Södermanland	R	Mellanfjärden, ytvatten	<0,01	µg/L
chlorhexidine	Dalarna	N	Runn Främbyviken, ytvatten	<0,01	µg/L
chlorhexidine	Gävleborg	N	Österfärnebo nedströms ARV, Norrån före Fängsjön, yt	<0,01	µg/L
chlorhexidine	Södermanland	R	Djulösjön, ytvatten	<0,01	µg/L
chlorhexidine	Västernorrland	N	Ljungan nedströms Bällsta ARV, ytvatten	<0,01	µg/L
chlorhexidine	Värmland	N	Varnumsviken, ytvatten diffus	<0,01	µg/L
chlorhexidine	Värmland	N	Kaplansälven, ytvatten nedströms	<0,01	µg/L
chlorhexidine	Södermanland	R	Eskilstunaån, ytvatten nedströms Ekeby ARV	<0,01	µg/L
chlorhexidine	Gotland	R	Gothemsån, ytvatten	<0,01	µg/L
chlorhexidine	Södermanland	R	Ekeby ARV, ytvatten utgående efter våtmark	<0,01	µg/L
chlorhexidine	Västra Götalan	N	badsjö 3	<1,0	µg/L
chlorhexidine	Dalarna	N	Ljusacksen	<1,0	µg/L
p-chloroaniline	Södermanland	R	Mellanfjärden, ytvatten	<0,005	µg/L
p-chloroaniline	Dalarna	N	Runn Främbyviken, ytvatten	<0,005	µg/L
p-chloroaniline	Gävleborg	N	Österfärnebo nedströms ARV, Norrån före Fängsjön, yt	<0,005	µg/L
p-chloroaniline	Södermanland	R	Djulösjön, ytvatten	<0,005	µg/L
p-chloroaniline	Västernorrland	N	Ljungan nedströms Bällsta ARV, ytvatten	<0,005	µg/L
p-chloroaniline	Värmland	N	Varnumsviken, ytvatten diffus	<0,005	µg/L
p-chloroaniline	Värmland	N	Kaplansälven, ytvatten nedströms	<0,005	µg/L
p-chloroaniline	Södermanland	R	Eskilstunaån, ytvatten nedströms Ekeby ARV	<0,005	µg/L
p-chloroaniline	Gotland	R	Gothemsån, ytvatten	<0,005	µg/L
p-chloroaniline	Södermanland	R	Ekeby ARV, ytvatten utgående efter våtmark	<0,005	µg/L
p-chloroaniline	Västra Götalan	N	badsjö 3	<0,2	µg/L
p-chloroaniline	Dalarna	N	Ljusacksen	<0,2	µg/L
nonyl phenols	Värmland	N	Kaplansälven, ytvatten nedströms	3,878	µg/L
nonyl phenols	Gävleborg	N	Österfärnebo nedströms ARV, Norrån före Fängsjön, yt	1,100	µg/L
nonyl phenols	Södermanland	N	Mellanfjärden, ytvatten	<0,3	µg/L
nonyl phenols	Dalarna	N	Runn Främbyviken, ytvatten	<0,3	µg/L
nonyl phenols	Södermanland	N	Djulösjön, ytvatten	<0,3	µg/L
nonyl phenols	Västernorrland	N	Ljungan nedströms Bällsta ARV, ytvatten	<0,3	µg/L
nonyl phenols	Värmland	N	Varnumsviken, ytvatten diffus	<0,3	µg/L
nonyl phenols	Södermanland	N	Eskilstunaån, ytvatten nedströms Ekeby ARV	<0,3	µg/L
nonyl phenols	Gotland	N	Gothemsån, ytvatten	<0,3	µg/L
nonyl phenols	Södermanland	N	Ekeby ARV, ytvatten utgående efter våtmark	<0,3	µg/L
nonyl phenols	Västra Götalan	N	badsjö 3	<0,3	µg/L
nonyl phenols	Dalarna	N	Ljusacksen	<0,3	µg/L

Sludge

compound	county	national/regional	Sample name/location	Concentration	Unit
chlorhexidine	Dalarna	N	Krylbo ARV, slam	<0,01	mg/kg TS
chlorhexidine	Dalarna	N	Borlänge ARV, slam	<0,01	mg/kg TS
chlorhexidine	Dalarna	N	Främby ARV, slam	<0,01	mg/kg TS
chlorhexidine	Gotland	R	Visby ARV, slam	<0,01	mg/kg TS
chlorhexidine	Gävleborg	N	Gysinge ARV, slam	<0,01	mg/kg TS
chlorhexidine	Stockholm	N	Henriksdal ARV, slam	<0,01	mg/kg TS
chlorhexidine	Södermanland	R	Strängnäs ARV, slam	<0,01	mg/kg TS
chlorhexidine	Södermanland	R	Ekeby ARV, slam	<0,01	mg/kg TS
chlorhexidine	Värmland	R	Fiskartorpet ARV, slam	<0,01	mg/kg TS
chlorhexidine	Värmland	R	Sjöstadsverket ARV, slam	<0,01	mg/kg TS
chlorhexidine	Västernorrland	N	Bällsta ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Dalarna	N	Krylbo ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Dalarna	N	Borlänge ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Dalarna	N	Främby ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Gotland	R	Visby ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Gävleborg	N	Gysinge ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Stockholm	N	Henriksdal ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Södermanland	R	Strängnäs ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Södermanland	R	Ekeby ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Värmland	R	Fiskartorpet ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Värmland	R	Sjöstadsverket ARV, slam	<0,01	mg/kg TS
p-chloroaniline	Västernorrland	N	Bällsta ARV, slam	<0,01	mg/kg TS
4-tert-octylphenol	Stockholm	N	Henriksdal ARV, slam	1,300	mg/kg TS
4-tert-octylphenol	Södermanland	N	Ekeby ARV, slam	0,510	mg/kg TS
4-tert-octylphenol	Dalarna	N	Borlänge ARV, slam	0,370	mg/kg TS
4-tert-octylphenol	Dalarna	N	Krylbo ARV, slam	0,250	mg/kg TS
4-tert-octylphenol	Gotland	N	Visby ARV, slam	0,240	mg/kg TS
4-tert-octylphenol	Värmland	N	Sjöstadsverket ARV, slam	0,200	mg/kg TS
4-tert-octylphenol	Gävleborg	N	Gysinge ARV, slam	0,110	mg/kg TS
4-tert-octylphenol	Södermanland	N	Strängnäs ARV, slam	0,069	mg/kg TS
4-tert-octylphenol	Västernorrland	N	Bällsta ARV, slam	0,054	mg/kg TS
4-tert-octylphenol	Värmland	N	Fiskartorpet ARV, slam	<0,07	mg/kg TS
4-nonylphenol	Dalarna	N	Borlänge ARV, slam	18,000	mg/kg TS
4-nonylphenol	Dalarna	N	Krylbo ARV, slam	14,000	mg/kg TS
4-nonylphenol	Södermanland	N	Ekeby ARV, slam	12,000	mg/kg TS
4-nonylphenol	Värmland	N	Sjöstadsverket ARV, slam	8,300	mg/kg TS
4-nonylphenol	Stockholm	N	Henriksdal ARV, slam	7,700	mg/kg TS
4-nonylphenol	Södermanland	N	Strängnäs ARV, slam	5,000	mg/kg TS
4-nonylphenol	Gotland	N	Visby ARV, slam	4,100	mg/kg TS
4-nonylphenol	Västernorrland	N	Bällsta ARV, slam	2,600	mg/kg TS
4-nonylphenol	Gävleborg	N	Gysinge ARV, slam	2,400	mg/kg TS
4-nonylphenol	Värmland	N	Fiskartorpet ARV, slam	1,900	mg/kg TS

Sediment

compound	county	national/regional	Sample name/location	Concentration	Unit
chlorhexidine	Skåne	N	Källby ARV, damm 1, sediment	<0,01	mg/kg TS
chlorhexidine	Södermanland	N	Mellanfjärden, sediment	<0,01	mg/kg TS
chlorhexidine	Västernorrland	N	Ljungan nedströms Bällsta ARV, sediment	<0,01	mg/kg TS
chlorhexidine	Södermanland	N	Djulösjön, sediment	<0,01	mg/kg TS
chlorhexidine	Värmland	N	Varnumsviken, sediment diffus	<0,01	mg/kg TS
chlorhexidine	Södermanland	N	Eskilstunaån, sediment nedströms Ekeby ARV	<0,01	mg/kg TS
chlorhexidine	Västra Götalan	N	badsjö 2 sediment	<0,25	mg/kg TS
p-chloroaniline	Skåne	N	Källby ARV, damm 1, sediment	<0,01	mg/kg TS
p-chloroaniline	Södermanland	N	Mellanfjärden, sediment	<0,01	mg/kg TS
p-chloroaniline	Västernorrland	N	Ljungan nedströms Bällsta ARV, sediment	<0,01	mg/kg TS
p-chloroaniline	Södermanland	N	Djulösjön, sediment	<0,01	mg/kg TS
p-chloroaniline	Västra Götalan	N	badsjö 2 sediment	<0,1	mg/kg TS
p-chloroaniline	Värmland	N	Varnumsviken, sediment diffus	<0,01	mg/kg TS
p-chloroaniline	Södermanland	N	Eskilstunaån, sediment nedströms Ekeby ARV	<0,01	mg/kg TS
4-tert-octylphenol	Skåne	N	Källby ARV, damm 1, sediment	0,040	mg/kg TS
4-tert-octylphenol	Södermanland	N	Mellanfjärden, sediment	<0,01	mg/kg TS
4-tert-octylphenol	Västernorrland	N	Ljungan nedströms Bällsta ARV, sediment	<0,015	mg/kg TS
4-tert-octylphenol	Södermanland	N	Djulösjön, sediment	<0,02	mg/kg TS
4-tert-octylphenol	Värmland	N	Varnumsviken, sediment diffus	<0,02	mg/kg TS
4-tert-octylphenol	Södermanland	N	Eskilstunaån, sediment nedströms Ekeby ARV	<0,015	mg/kg TS
4-nonylphenol	Skåne	N	Källby ARV, damm 1, sediment	3,700	mg/kg TS
4-nonylphenol	Västra Götalan	N	badsjö 2 sediment	0,030	mg/kg TS
4-nonylphenol	Södermanland	N	Mellanfjärden, sediment	<0,1	mg/kg TS
4-nonylphenol	Västernorrland	N	Ljungan nedströms Bällsta ARV, sediment	<0,15	mg/kg TS
4-nonylphenol	Södermanland	N	Eskilstunaån, sediment nedströms Ekeby ARV	<0,15	mg/kg TS
4-nonylphenol	Södermanland	N	Djulösjön, sediment	<0,2	mg/kg TS
4-nonylphenol	Värmland	N	Varnumsviken, sediment diffus	<0,2	mg/kg TS

Soil

compound	county	national/regional	Sample name/location	Concentration	Unit
chlorhexidine	Södermanland	N	Katrineholm 1 jordbruksmark	<0,01	mg/kg TS
chlorhexidine	Södermanland	N	Katrineholm 2 jordbruksmark	<0,01	mg/kg TS
chlorhexidine	Södermanland	N	Katrineholm 3 jordbruksmark	<0,01	mg/kg TS
p-chloroaniline	Södermanland	N	Katrineholm 1 jordbruksmark	<0,01	mg/kg TS
p-chloroaniline	Södermanland	N	Katrineholm 2 jordbruksmark	<0,01	mg/kg TS
p-chloroaniline	Södermanland	N	Katrineholm 3 jordbruksmark	<0,01	mg/kg TS
4-tert-octylphenol	Södermanland	N	Katrineholm 1 jordbruksmark	<0,001	mg/kg TS
4-tert-octylphenol	Södermanland	N	Katrineholm 2 jordbruksmark	<0,001	mg/kg TS
4-tert-octylphenol	Södermanland	N	Katrineholm 3 jordbruksmark	<0,001	mg/kg TS
4-nonylphenol	Södermanland	N	Katrineholm 1 jordbruksmark	<0,01	mg/kg TS
4-nonylphenol	Södermanland	N	Katrineholm 2 jordbruksmark	<0,01	mg/kg TS
4-nonylphenol	Södermanland	N	Katrineholm 3 jordbruksmark	<0,01	mg/kg TS

Fish mussle

compound	county	national/regional	Sample name/location	Concentration	Unit	fat (%)
chlorhexidine	Skåne	N	Källby ARV, damm 1, fisk (karp)	<0,1	mg/kg vv	-
chlorhexidine	Dalarna	R	Runn Främbyviken, fisk (abborre)	<0,1	mg/kg vv	0,44
chlorhexidine	Värmland	R	Varnumsviken, fisk (abborre)	<0,1	mg/kg vv	0,53
chlorhexidine	Skåne	N	Krageholmssjön, fisk (abborre)	<0,1	mg/kg vv	-
chlorhexidine	Södermanland	N	Mellanfjärden, fisk (abborre)	<0,1	mg/kg vv	0,61
chlorhexidine	Skåne	N	Hammarsjön, fisk (abborre)	<0,1	mg/kg vv	-
chlorhexidine	Södermanland	N	Eskilstunaån, fisk (abborre) nedströms Ekeby ARV	<0,1	mg/kg vv	0,68
p-chloroaniline	Skåne	N	Källby ARV, damm 1, fisk (karp)	<0,05	mg/kg vv	-
p-chloroaniline	Dalarna	R	Runn Främbyviken, fisk (abborre)	<0,05	mg/kg vv	0,44
p-chloroaniline	Värmland	R	Varnumsviken, fisk (abborre)	<0,05	mg/kg vv	0,53
p-chloroaniline	Skåne	N	Krageholmssjön, fisk (abborre)	<0,05	mg/kg vv	-
p-chloroaniline	Södermanland	N	Mellanfjärden, fisk (abborre)	<0,05	mg/kg vv	0,61
p-chloroaniline	Skåne	N	Hammarsjön, fisk (abborre)	<0,05	mg/kg vv	-
p-chloroaniline	Södermanland	N	Eskilstunaån, fisk (abborre) nedströms Ekeby ARV	<0,05	mg/kg vv	0,68
4-tert-octylphenol	Skåne	N	Källby ARV, damm 1, fisk (karp)	0,014	mg/kg vv	-
4-tert-octylphenol	Dalarna	N	Runn Främbyviken, fisk (abborre)	<0,002	mg/kg vv	0,44
4-tert-octylphenol	Värmland	N	Varnumsviken, fisk (abborre)	<0,002	mg/kg vv	0,53
4-tert-octylphenol	Skåne	N	Krageholmssjön, fisk (abborre)	<0,002	mg/kg vv	-
4-tert-octylphenol	Södermanland	N	Mellanfjärden, fisk (abborre)	<0,002	mg/kg vv	0,61
4-tert-octylphenol	Skåne	N	Hammarsjön, fisk (abborre)	<0,002	mg/kg vv	-
4-tert-octylphenol	Södermanland	N	Eskilstunaån, fisk (abborre) nedströms Ekeby ARV	<0,002	mg/kg vv	0,68
4-nonylphenol	Skåne	N	Källby ARV, damm 1, fisk (karp)	0,530	mg/kg vv	-
4-nonylphenol	Dalarna	N	Runn Främbyviken, fisk (abborre)	0,021	mg/kg vv	0,44
4-nonylphenol	Värmland	N	Varnumsviken, fisk (abborre)	<0,02	mg/kg vv	0,53
4-nonylphenol	Skåne	N	Krageholmssjön, fisk (abborre)	<0,02	mg/kg vv	-
4-nonylphenol	Södermanland	N	Mellanfjärden, fisk (abborre)	<0,02	mg/kg vv	0,61
4-nonylphenol	Skåne	N	Hammarsjön, fisk (abborre)	<0,02	mg/kg vv	-
4-nonylphenol	Södermanland	N	Eskilstunaån, fisk (abborre) nedströms Ekeby ARV	<0,02	mg/kg vv	0,68