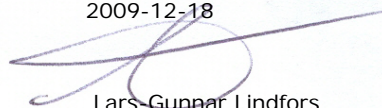


Results from the Swedish National Screening Programme 2008

Sub-report 2. Biocides: Glutaraldehyde

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Title and subtitle of the report Results from the Swedish National Screening Programme 2008 Sub-report 2. Biocides: Glutaraldehyde	
Summary As an assignment from the Swedish EPA, IVL has during 2008/2009 performed a “Screening Study” of glutaraldehyde. In addition, formaldehyde and acetaldehyde were also measured. In Sweden the major usage of glutaraldehyde is as a slimicide in the paper and pulp industry. The compound is also used as a disinfectant in hospitals, as a biocide for water treatment in water recirculating systems and off-shore operations, in the petroleum industry, in the live stock and aquaculture industries, as a fixative in histology, as hardener in x-ray film processing, for tanning of leather, and also in cosmetics. The compound has high water solubility, is reactive and is of low persistence. It is not expected to accumulate in soil, sediment or biota. Thus in the environment, water is the compartment that may be of concern. In previous studies, glutaraldehyde has been found in air and effluent water sampled at hospitals, and in water from pulp and paper industry. A sampling program was developed based on usage pattern, chemical properties and fate, and results from previous studies. It included samples from the vicinity of potential point sources, samples representing diffuse emission pathways, and samples from background areas. Glutaraldehyde could only be found in samples associated with the identified point sources related to the usage of the compound, i.e. in effluent water from a paper mill and in air and effluent water from an hospital. It could however not be found in samples from potential point sources representing the end of product life cycles, i.e. air and water from recycling companies or leachate water from a landfill. Further, it could not be found in samples representing diffuse sources or background areas. Glutaraldehyde may thus affect the environment at the site of usage, but the results indicate a low potential for dispersal in the environment. Concentrations found were below toxicity values found in the literature. Thus, all together glutaraldehyde does not appear to pose a risk to the environment.	
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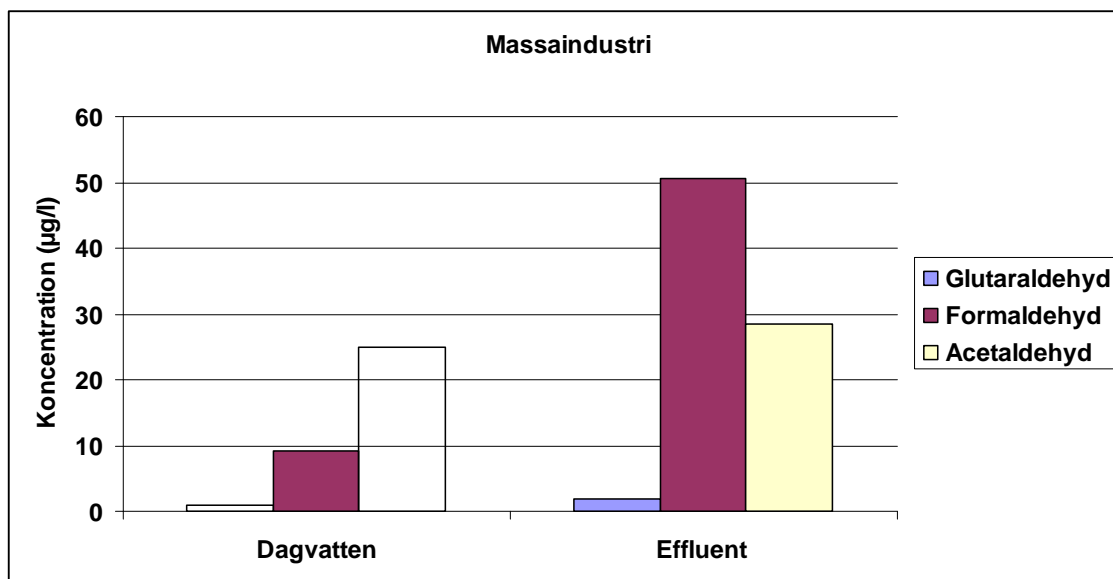
Sammanfattning

IVL Svenska Miljöinstitutet AB har på uppdrag av Naturvårdsverket under 2008/2009 genomfört en screening av glutaraldehyd. Dessutom analyserades proverna avseende formaldehyd och acetaldehyd.

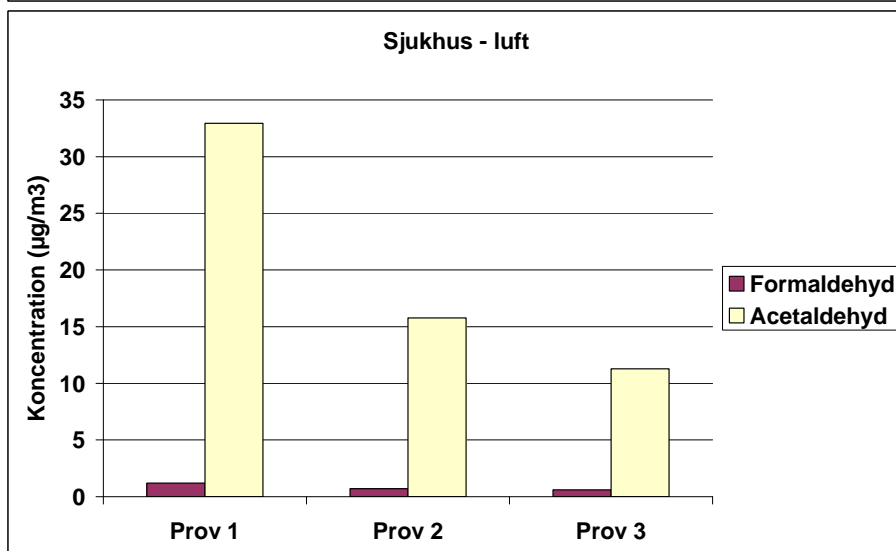
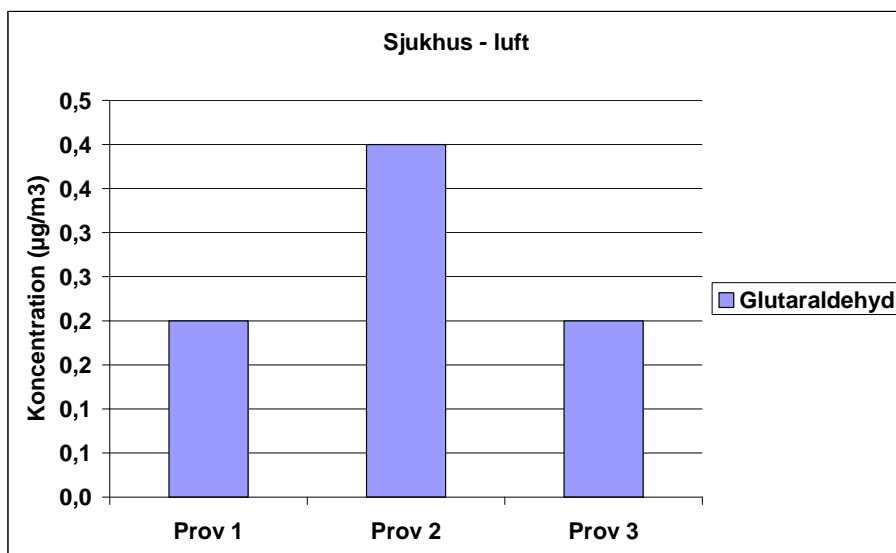
Glutaraldehyd är en biocid som i Sverige till största delen används inom pappers och massaindustrin. Ämnet används också i desinficeringsmedel, framför allt inom sjukvården. Andra användningsområden är behandling av vatten i olika recirkuleringsystem, inom petroleumindustrin, som bekämpningsmedel vid djurhållning och inom akvakultur. Vidare används glutaraldehyd vid framkallning av röntgenfilm, fixering av vävnad för histologiska undersökningar, vid behandling av läder, samt i kosmetika.

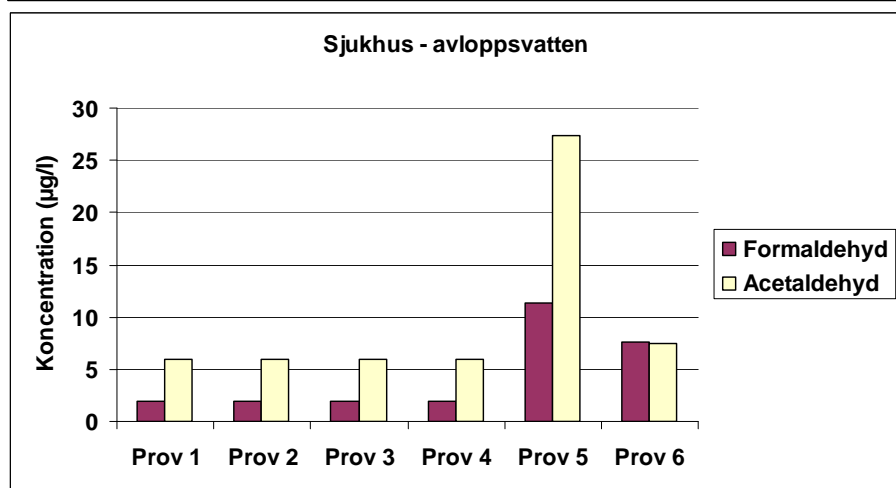
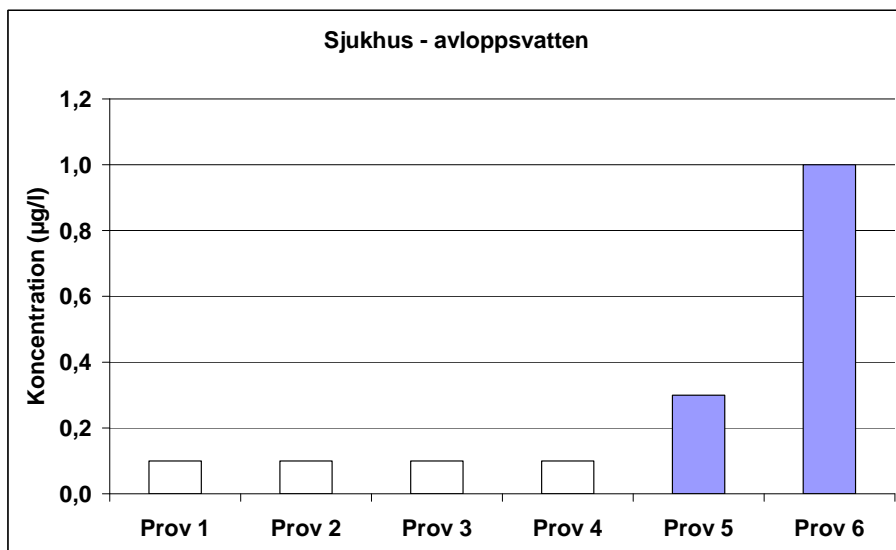
Glutaraldehyd har hög vattenlöslighet, förväntas ej ackumulera i fasta matriser, är reaktivt och är relativt lättnedbrytbart. Ett provtagningsprogram togs fram utifrån glutaraldehyds användning, kemiska egenskaper, samt resultat från tidigare bestämningar av substansen.

Glutaraldehyd återfanns endast i prover tagna i anslutning till de punktkällor som identifierats utifrån användning av substansen; massaindustri samt sjukhus. I anslutning till en massaindustri provtogs dagvatten samt vatten från en fibersedimentationsbassäng. I provet från bassängen uppmättes 2 µg/l, medan halten i dagvattenprovet var under kvantifieringsgränsen (< 1 µg/l). I provet från bassängen återfanns även formaldehyd och acetaldehyd, medan endast formaldehyd kunde uppmätas i dagvattenprovet, se figur nedan.



Glutaraldehyd återfanns i låga halter (0,2-0,4 $\mu\text{g}/\text{m}^3$) i luftprover från ett sjukhus. Ämnet återfanns även i låga halter (0,3-1,0 $\mu\text{g}/\text{l}$) i två av sex avloppsvattenprover från sjukhuset. I de prover från sjukhuset i vilka glutaraldehyd kunde uppmätas återfanns även formaldehyd samt acetaldehyd, se figurerna nedan. Formaldehyd och acetaldehyd återfanns även i lakvatten från en deponi, i avloppsvatten, samt i ytvatten från Stockholm. Acetaldehyd återfanns även i ett luftprov från Göteborg, medan formaldehyd kunde uppmätas i ett ytvatten från en bakgrundssjö.





Glutaraldehyd återfanns ej i luft eller dagvatten från återvinningsstationer, i lakvatten från en deponi, eller i prover representerande diffusa källor (luft och ytvatten från urban miljö, vatten från kommunala avloppsverk). Ämnet kunde inte heller återfinnas i luft eller ytvatten från bakgrundsområden.

Sammantaget visar resultaten att glutaraldehyd har potential att påverka miljön i närheten av dess användning, men att ämnet ej sprids vidare i miljön. De halter som uppmättes var lägre än toxicitetsvärden hämtade ur litteraturen. Denna studie ger alltså ingen indikation på att glutaraldehyd utgör någon risk för den svenska miljön.

Summary

As an assignment from the Swedish EPA, IVL has during 2008/2009 performed a "Screening Study" of glutaraldehyde. In addition, formaldehyde and acetaldehyde were also measured.

In Sweden the major usage of glutaraldehyde is as a slimicide in the paper and pulp industry. The compound is also used as a disinfectant in hospitals, as a biocide for water treatment in water recirculating systems and off-shore operations, in the petroleum industry, in the live stock and aquaculture industries, as a fixative in histology, as hardener in x-ray film processing, for tanning of leather, and also in cosmetics.

The compound has high water solubility, is reactive and is of low persistence. Given the low K_{ow} , glutaraldehyde is not expected to accumulate in soil, sediment or biota. Thus in the environment, water is the compartment that may be of concern. In previous studies, glutaraldehyde has been found in air and effluent water sampled at hospitals, and in water from pulp and paper industry.

A sampling program was developed based on usage pattern, chemical properties and fate, and results from previous studies. It included samples from the vicinity of potential point sources, samples representing diffuse emission pathways, and samples from background areas.

Glutaraldehyde could only be found in samples associated with the identified point sources related to the usage of the compound, i.e. in effluent water from a paper mill and in air and effluent water from a hospital. It could however not be found in samples from potential point sources representing the end of product life cycles, i.e. air and water from recycling companies or leachate water from a landfill. Further, it could not be found in samples representing diffuse sources or background areas.

Glutaraldehyde may thus affect the environment at the site of usage, but the results indicate a low potential for dispersal in the environment.

Concentrations found were below toxicity values found in the literature. Thus, all together glutaraldehyde does not appear to pose a risk to the environment.

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1 Introduction

As an assignment from the Swedish Environmental Protection Agency, a screening study has been performed by IVL during 2008/2009. This screening includes biocides, unintentionally produced substances and fuel additives. These substances/substance groups are emitted and distributed in the environment via a variety of sources, e.g. different point sources and/or diffusive sources. Table 1 shows the major reason for their concern as well as the number of the report where individual results are presented.

Table 1. Substances / substance groups included in the screening.

Substance / Substance group		Banned/ restricted	HPV ^a	Indications of toxicity	B/p ^b	Sub- report #
Biocides	3-Iodo-2-propynyl butyl carbamate (IPCB) 2,2-Dibromo-2- cyanoacetamide (DBNPA)			x		1
	Glutaraldehyde		x	x		2
	Difenacoum	x		x	x	3
Unintentionally produced substances	Nitro-PAH 3-Nitrobenzantron Oxy-PAH Heterocyclics Brominated dioxins and aromatics			x	x	4
Fuel additives	Methyl <i>tert</i> -butyl ether (MTBE) Ethyl <i>tert</i> -butyl ether (ETBE)		x	x	x	5

^{a)} High Production Volume

^{b)} Bioaccumulation/Persistence

The overall objectives of the screening studies were to determine the concentrations of the selected substances in a variety of media in the Swedish environment, to highlight important transport pathways, and to assess the possibility of current emissions in Sweden.

Due to the variety in emission sources and use as well as differences in chemical properties, the screening has been carried out in five subprojects. This sub-report concerns the screening of **glutaraldehyde**. In addition, formaldehyde and acetaldehyde were measured. Results for the other chemicals are presented in sub-reports 1, 3, 4 and 5.

2 Chemical properties, fate and toxicity

2.1 Properties and fate

Figure 1 shows the chemical structure of glutaraldehyde and Table 2 shows some chemical and physical data of the compound.



Figure 1. Chemical structure of glutaraldehyde.

Glutaraldehyde is an oily liquid at room temperature with a density of 1.06 g/mL. It is miscible with water, alcohol and benzene. Monomeric glutaraldehyde can polymerize by aldol condensation reaction yielding unsaturated poly-glutaraldehyde. This reaction usually occurs at alkaline pH values.

Table 2. Chemical and physical data of glutaraldehyde (ChemIDPlus).

CAS#	MW (g/mol)	Boiling Point (°C)	Melting Point (°C)	Log K _{ow}	Water Solubility (kg/L)	Vapor Pressure
111-30-8	100.1	188	-14	-0.18	0.17 at 20 °C	0.66 mm Hg

Glutaraldehyde is predicted to have moderate to high mobility in soils and sediment, experimentally derived K_{oc} values varies between 120 and 500 (reviewed by Leung, 2001). It does thus not accumulate in these matrices. It may however adsorb to solids through the process of chemisorption due to the reaction with functional groups of e.g. proteins (Emmanuel *et al.*, 2005). Considering the low K_{ow}, the low partitioning to soils and sediments, and the high water solubility, glutaraldehyde is expected to end up in the aquatic compartments of the ecosystem.

In the aquatic environment glutaraldehyde is stable to abiotic degradation at acidic to neutral pH, but degrades under alkaline conditions. The compound is readily biodegradable in the freshwater environment and has the potential for biodegradation in marine waters. Under aerobic conditions it is fully metabolized to carbon dioxide and water, whereas under anaerobic conditions the metabolites 1,5-pentanediol and 3-formyl-6-hydroxy-2-cyclohexene-1-propanal have been found (reviewed by Leung, 2001). Given the low K_{ow}, glutaraldehyde is not expected to bioaccumulate.

In Leung (2001) an experimentally derived partitioning coefficient between air and water of $1.84 \cdot 10^{-3}$ can be found, whereas Emmanuel *et al.* (2005) give an estimate of $4.44 \cdot 10^{-6}$. Thus glutaraldehyde is only to a limited extent expected to volatilize from the aquatic environment.

2.2 Toxicity

Glutaraldehyde is a biocide and is thus used due to its toxic properties. It is a cross-linking agent reacting with amino- and thiol-groups (Beije and Lundberg, 1997; Okuda *et al.*, 1991). Due to the

chemical properties and use patterns, the potential risks concerns occupational exposure and the aquatic environment, whereas risks to the public health and the terrestrial compartment are considered low (OECD SIDS, 1998). Glutaraldehyde has been shown to be genotoxic in vitro causing mutations in bacterial and mammalian cells and sister chromatid exchanges and chromosomal aberrations in mammalian cells (Beije and Lundberg, 1997), but it is not classified as a human carcinogen (KEMI, 2009). Occupational exposure may cause irritation to the skin, eyes and respiratory tract including allergic reactions and asthma (Beije and Lundberg, 1997). A maximum acceptable level of glutaraldehyde in air of 0.8 mg/m³ has been set by the Swedish Work Environment Authority (AFS 2005:17). Glutaraldehyde is also toxic to aquatic organisms. The toxicity differs between species and life stages and appears to be more detrimental to small organisms lacking protective covering (Sano *et al.*, 2005). Due to the biocidal properties and use pattern, glutaraldehyde could potentially impair the microbial steps in waste water treatment. In Leung (2001) a NOEC value regarding bacterial inhibition of 5 mg/l can be found. In Table 3 below, some toxicity values for glutaraldehyde are presented.

Table 3. Toxicity values for glutaraldehyde.

Compartment	Species	Conc.	Comment	Reference
Air	Occupational exposure	0.8 mg/m ³	Ceiling	AFS 2005:17
Marine water Freshwater	Algae, fish, molluscs and crustaceans	0.029-24 mg/l 0.31-9 mg/l	NOEC NOEC	Reviewed by Leung, 2001
Freshwater	<i>P. subcapitata</i> (algae) <i>C. dubia</i> (crustacean) <i>O. mykiss</i> (fish)	0.7-1.3 mg/l 2.4 mg/l 1.3 mg/l	96 h NOEC NOEC, survival & reprod. NOEC, hatch rate	Sano <i>et al.</i> , 2005
Freshwater		0.009 mg/l	PNEC based on acute toxicity to algae, crustacean and fish	OECD SIDS, 1998
Water/waste water	Bacteria	5 mg/l	NOEC, bacterial inhibition	Review by Leung, 2001

3 Production, use and emissions

Glutaraldehyde occurs in 200 preparations in Sweden in 2007 and 299 tonnes were used in the same year (SPIN, 2009). It is not produced in Sweden but is imported as raw material (KEMI, 2005). In Sweden the major usage of the raw material is as a slimicide in the paper and pulp industry. Glutaraldehyde is also imported as products where most of the import is as a biocide used as bactericide, slimicide, chemical preservative, etc. Other products containing glutaraldehyde that are imported are cleaning and disinfection products, mainly used in hospitals.

The compound is also used as a biocide for water treatment in water recirculating systems and off-shore operations, in the petroleum industry, in live stock and aquaculture industries, as a fixative in histology, as hardener in x-ray film processing, for tanning of leather, and also in cosmetics (OECD SIDS, 1998). Glutaraldehyde has also been considered for treating vessel ballast water in order to prevent spreading of non-indigenous species (Sano *et al.*, 2005).

4 Previous measurements in the environment

Glutaraldehyde has previously been measured in air and effluent waters sampled in hospitals, and in process and effluent waters from a paper mill and a de-inking plant.

In hospitals in England, air concentrations between 0.003 and 0.17 mg/m³ have been found (Beije and Lundberg 1997). The highest concentrations were found during the cleaning of suction bottles with a solution containing glutaraldehyde. Concentrations of 0.25 to 0.50 mg/m³ were found in Danish hospitals at a Surgical Department (Beije and Lundberg 1997). In an Italian hospital occupational air exposure of employees working in endoscope units during the process of replacing glutaraldehyde, have been studied (Pacenti *et al.*, 2006). Background concentrations varied between < 6 - 90 mg/m³, whereas during the replacement process concentrations exceeding 2000 mg/m³ were found.

Glutaraldehyde has also been detected in hospital effluent waters. Bolliot *et al.* (2008) determined glutaraldehyde concentrations in five periodic samples taken over 24 hours. In effluents sampled during the night, glutaraldehyde concentrations were below 1 µg/l, but for the samples taken during the day concentrations of 2.1 and 3.9 µg/l (before and after lunch respectively) were found. Variation of glutaraldehyde in hospital effluents over a week has been studied by Jolibois *et al.* (2002). Concentrations found were below 0.5 mg/l, except for a sample from Monday morning that contained 3.72 mg/l. Thus, concentrations of glutaraldehyde in hospital effluents vary diurnally and over the week, reflecting the periodicity of activities in the hospital.

In process waters from a paper mill and a de-inking plant, concentrations in the range 4-56 mg/l have been measured (OECD SIDS, 1998). Concentrations in white water effluents from the mill were below 1 mg/l. In the de-inking plant, glutaraldehyde could also be found in the clarifier, but in effluents from the clarifier concentrations were below the detection limit 5 mg/l.

5 Sampling strategy and study sites

A sampling strategy was developed in order to determine concentrations of glutaraldehyde in different matrices in the Swedish environment.

The sampling program was based on the identification of possible sources due to usage patterns, the predicted distribution of the compound in the environment, and results from previous measurements. The sampling programme is summarized in Table 4, details on the samples can be found in Table A1 in the Appendix.

Due to the physical and chemical properties, i.e. low Log K_{ow} and high water solubility, the focus of the screening has been air and water. The identified point sources were paper and pulp industry, recycling companies and a hospital. For these, air, storm water and effluent water were sampled. Leachate water from one landfill was also included.

Samples representing diffuse sources were collected in the cities Gothenburg and Stockholm, where air and surface water were sampled. From sewage treatment plants (STPs), sludge, influent and effluent water samples were taken.

In order to determine background levels, air samples from Råö, and surface water from three lakes classified as reference lakes by the Swedish Museum of National History, were collected.

Since glutaraldehyde is readily biodegradable, reacts with functional groups of e.g. proteins, and is not expected to accumulate in soil, sediment or biota, these matrices were not considered to be of relevance.

Table 4. Sampling program for glutaraldehyde.

Site	Air	Surface water	Storm water	Industry water	STP water (in)	STP water (out)	STP sludge	Leachate water	Total
Background									
Råö	3								3
Lakes		3							3
Diffuse sources									
Urban area	3	3							6
STPs					4	4	4		8
Point sources									
Paper & pulp industry	2		1	1					4
Recycling companies	3		3						6
Hospital	3			6					9
Landfill								3	3
Total	14	6	4	7	4	4	4	3	46

6 Methods

6.1 Sampling

All glass equipment used was muffled (400 °C) before use.

6.1.1 Air

The air samples were collected on pentafluorobenzyl hydroxylamine (PFBHA) coated C18-cartridge (C18-Sepac Classic C18) (Ho *et al.*, 2002) using a low volume air sampler with a flow of a ~200 ml/min. Sampling duration varied between 2 to 24 hours. After sampling, the cartridges were plugged and stored in a freezer until analysis.

6.1.2 Water

The water samples (surface water, WWTP, storm water) were collected in amber glass bottles containing CuSO₄, preventing microbial degradation of the aldehydes (HSDB, 2005). The samples were stored at 4°C and analysed within one week.

6.1.3 Sludge

De-watered sludge samples were collected from the anaerobic chambers by staff at the different sewage treatment plants. The sludge was transferred into glass jars and stored in a freezer (-20 °C) until analysed.

6.2 Analysis

6.2.1 Air samples

The cartridges were eluted with hexane and the excess of reagent was washed away with H₂SO₄ (0,2 M) prior to GC-ECD analysis.

6.2.2 Water samples

A 20 ml volume of water samples was adjusted to pH 4 with potassium hydrogen-phthalate and the analytes derivatised (35°C in 2 hours) with the reagent pentafluorobenzyl hydroxylamine (PFBHA). The produced derivatives (oximes) were extracted under acidic conditions with hexane. Some reagent was co-extracted and the extracts were therefore processed through an acidic wash prior to GC-ECD analysis.

6.2.3 Sludge

Sludge samples were extracted with ultra pure water for 2 hours at 40°C. The samples were centrifuged and the clear supernatants were safeguarded and used for analysis following the same procedure as for water samples.

6.3 Instrumentation

The extracts containing the oximes were analysed on a 5890A gas chromatograph (Agilent) fitted with an electron capture detector (ECD). The injection, 1 µl, was done in splitless mode at 240°C with an auto injector (Agilent 7673A). The fused silica capillary column (Rxi-5ms 15 m × 0.25 mm i.d. × 0.25 µm film thickness, Restek) was held at 45°C for 1 min., ramped 5°C/min to 190°C, 20°C/min to 300°C, and held at 300°C for 5 min. Helium was used as carrier gas. The analytes were identified by their characteristic retention times. Quantification was based on comparison of the peak area to the known peak area of the standard analytes.

6.3.1 Quality control

The following quality criteria were used to ensure correct identification and quantification of the target compound: (a) the retention times should match those of the standard compounds within ± 0.05 min.

Internal standard (recovery standard added to the samples) approach was used for quantification, thus all reported values were recovery-corrected according to the recovery standard. Acceptable recovery rate was set to >50 %. Analytical method blanks and field blanks were included for each sample batch analysed to assess background interferences and possible contamination of the samples.

The limit of quantification (LOQ) was defined as 10 times the standard deviation of the noise of the blank samples but in consideration of the actual sample noise in the target analytes “retention

window” in the chromatograms. Possible background levels of analytes were subtracted from measured sample values (Keith, 1991; Miller and Miller, 1993).

7 Results

Glutaraldehyde was only found in samples representing potential point sources. Formaldehyde was found in samples representing point sources, diffuse sources, and in one background sample, whereas acetaldehyde was found in samples representing point sources and diffuse sources. The results are further presented below. All the results from the measurements of the aldehydes can be found in Table A2 in the Appendix.

7.1 Point sources

Glutaraldehyde was found in effluent water from a paper mill sampled in the settling basin, and in air and effluent water samples from a hospital. The results are presented in Figure 2, 3 and 4.

In the effluent water sample 2 µg/l glutaraldehyde was found, whereas in the storm water sample the concentration was below LOQ (< 1 µg/l), see Figure 2. The effluent water also contained formaldehyde and acetaldehyde, but only formaldehyde was found in the storm water.

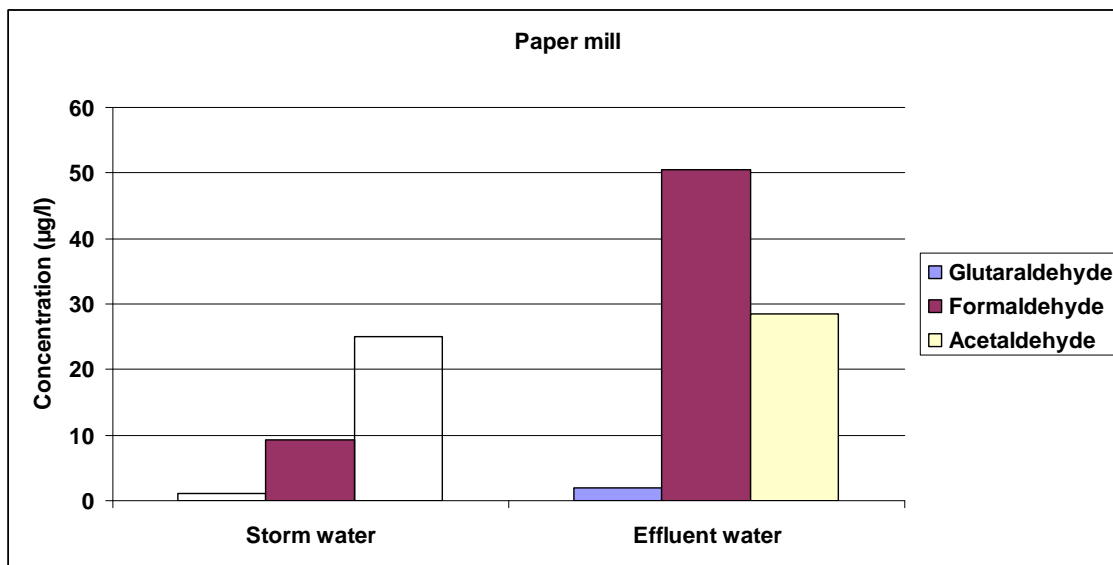


Figure 2. Concentrations of aldehydes in water samples from a paper mill. An unfilled bar indicate that the substance could not be detected, the height of the bar indicate LOQ.

Concentrations of aldehydes in air and water samples from Karolinska University hospital are presented in Figures 3 and 4, respectively. Glutaraldehyde was found in all three air samples, concentrations found were in the range 0.2-0.4 µg/m³, see Figure 3. Formaldehyde and acetaldehyde were found in the concentration ranges 0.6-1.2 µg/m³ and 11-33 µg/m³ respectively. Aldehydes were found in two out of six water samples from the hospital, see Figure 4.

Concentrations of glutaraldehyde, formaldehyde, and acetaldehyde were 0.3 and 1.0 µg/l, 1 and 7.6 µg/l, and 27 and 7.5 1.0 µg/l, respectively.

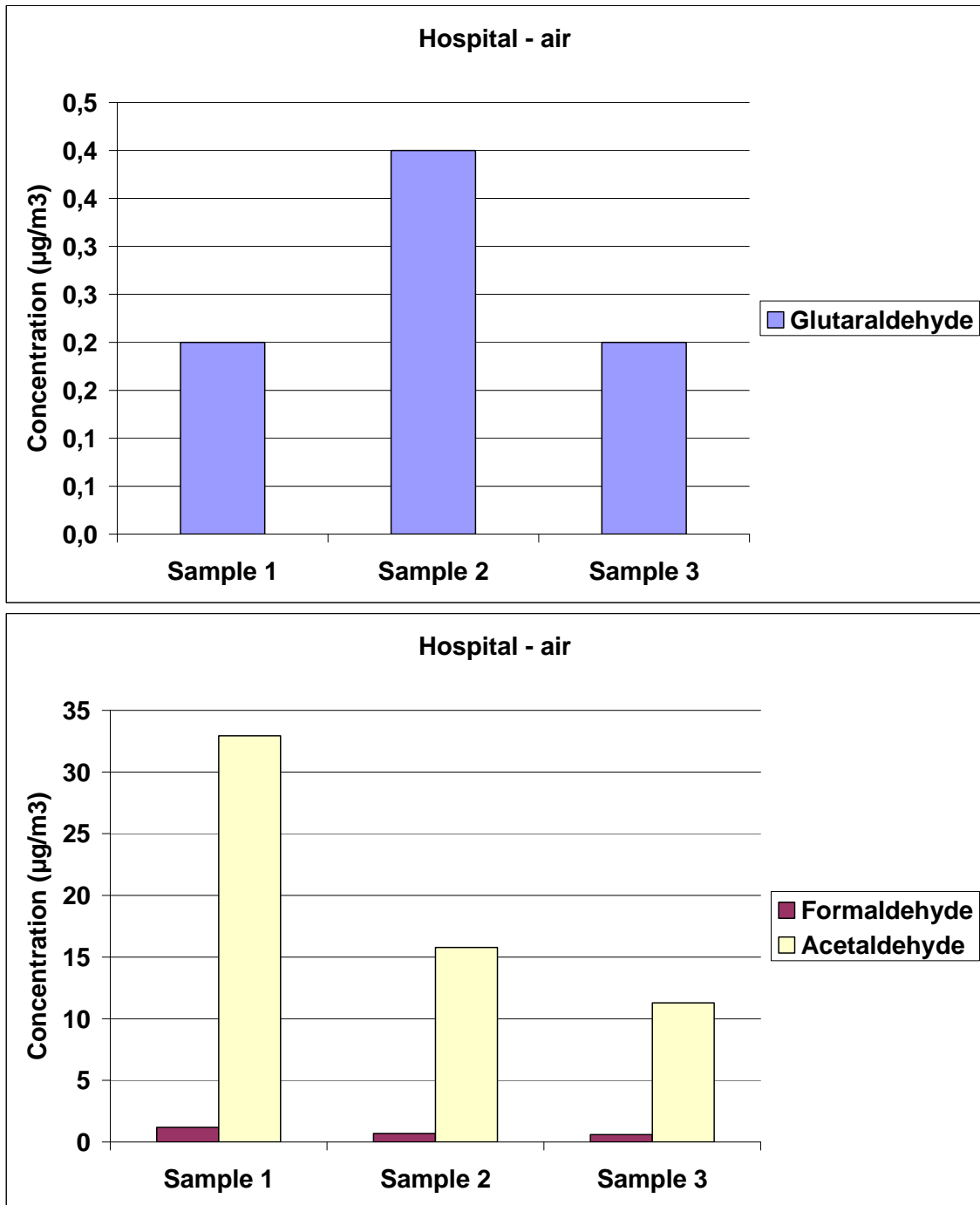


Figure 3. Concentrations of aldehydes in air samples from Karolinska University hospital.

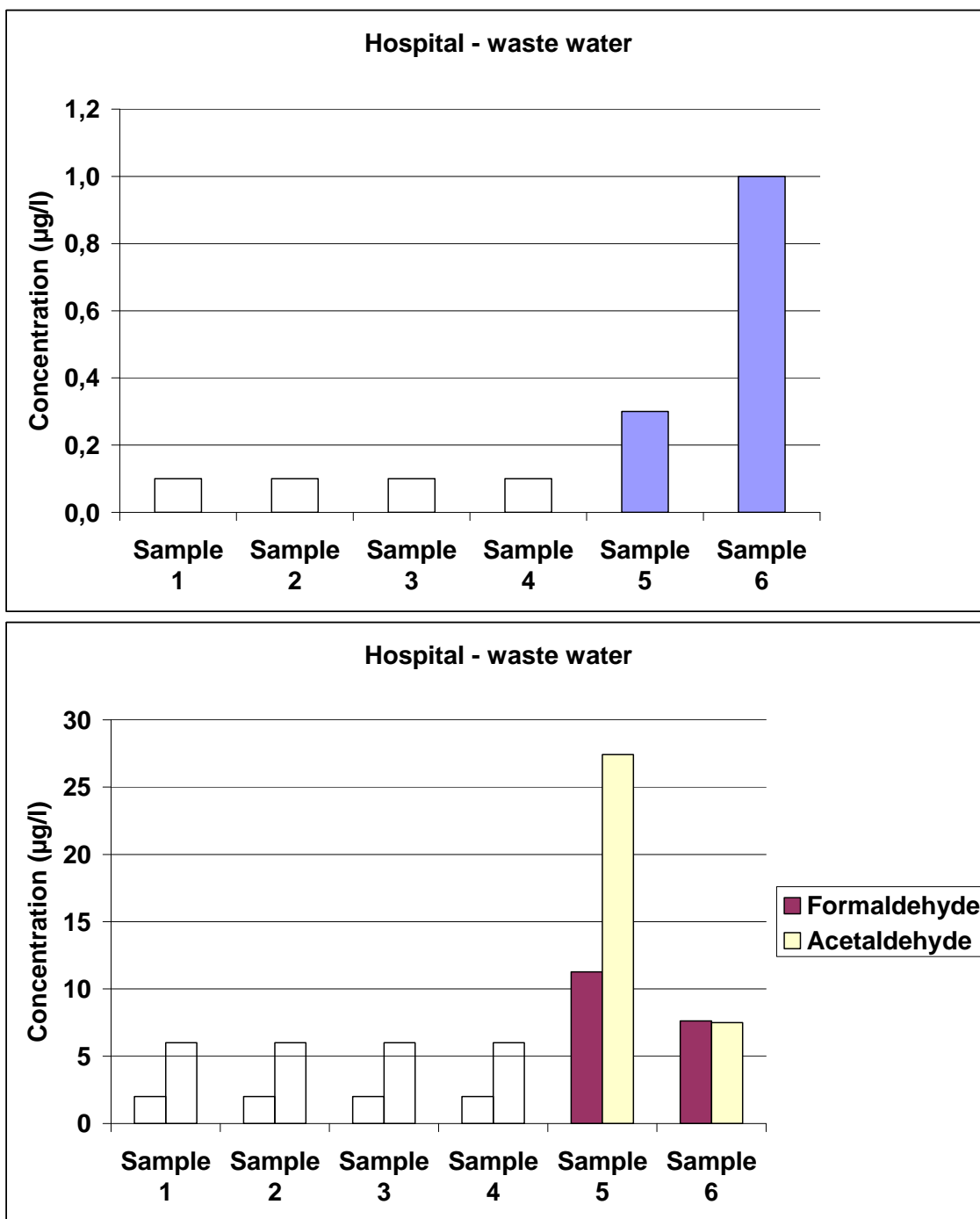


Figure 4. Concentrations of aldehydes in water samples from Karolinska University hospital. An unfilled bar indicate that the substance could not be detected, the height of the bar indicate LOQ.

Glutaraldehyde could not be found in the leachate water samples from Högbytorp landfill (< 1 µg/l), but both formaldehyde and acetaldehyde were found in the samples, see Figure 5.

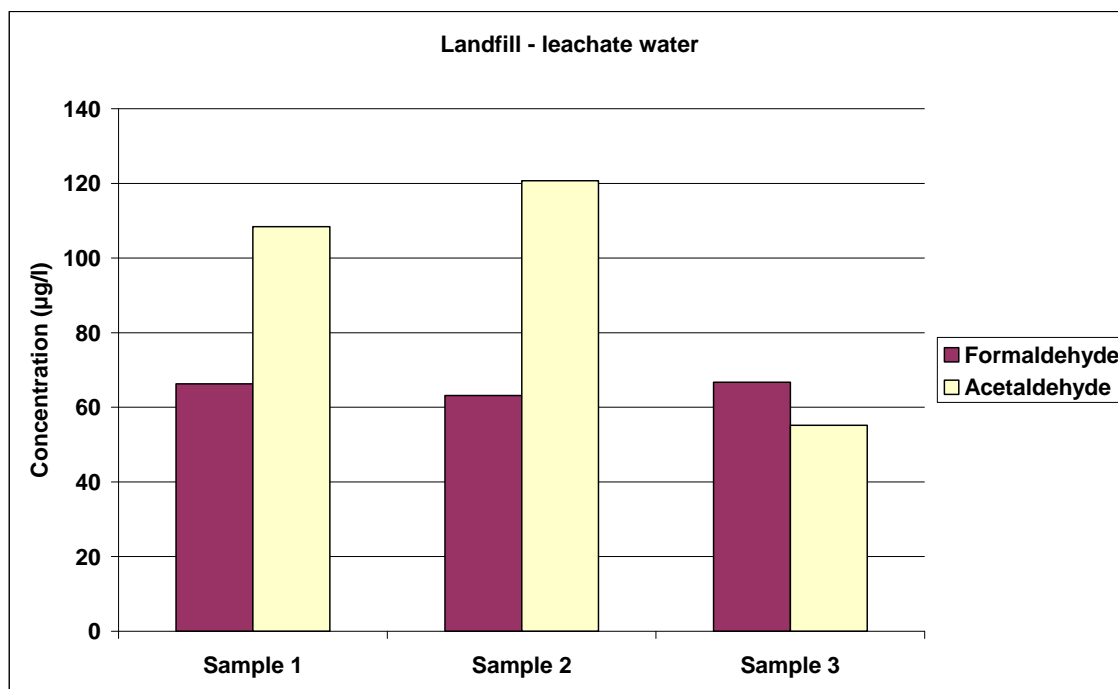


Figure 5. Concentrations of formaldehyde and acetaldehyde in leachate water from a landfill.

None of the aldehydes measured could be detected in air or water sampled at the recycling companies.

7.2 Diffuse sources

7.2.1 Sewage treatment plants

Concentrations of glutaraldehyde were below LOQ (1 µg/l) in all influent and effluent water samples from STPs. Concentrations were also below LOQ (10 µg/kg TS) in STP sludge samples.

Formaldehyde and acetaldehyde were found in both influent and effluent waters from the STPs, see Figure 6. Concentrations of formaldehyde were above LOQ (6 µg/l) in three out of four influent and in all effluent water samples. For three of the included STPs, concentrations were higher in effluent compared to influent waters. Acetaldehyde were found above LOQ (25 µg/l) in influent water from two of the STPs, but concentrations were below LOQ in all effluent water samples. Both formaldehyde and acetaldehyde could also be found in sludge from the STPs, see Figure 7.

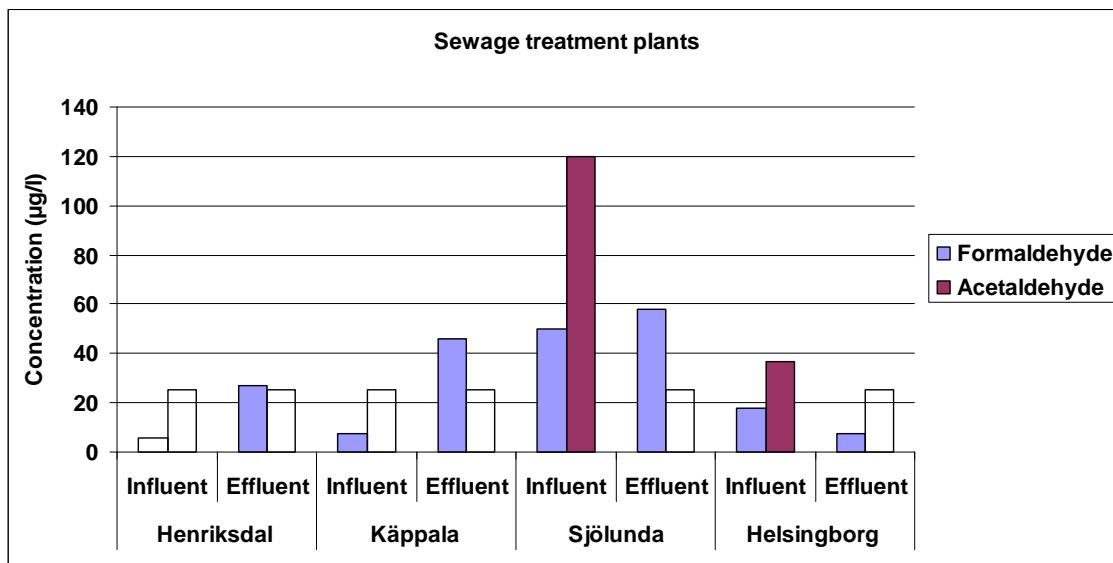


Figure 6. Concentrations of formaldehyde and acetaldehyde in influent and effluent waters from STPs. An unfilled bar indicate that the substance could not be detected, the height of the bar indicate LOQ.

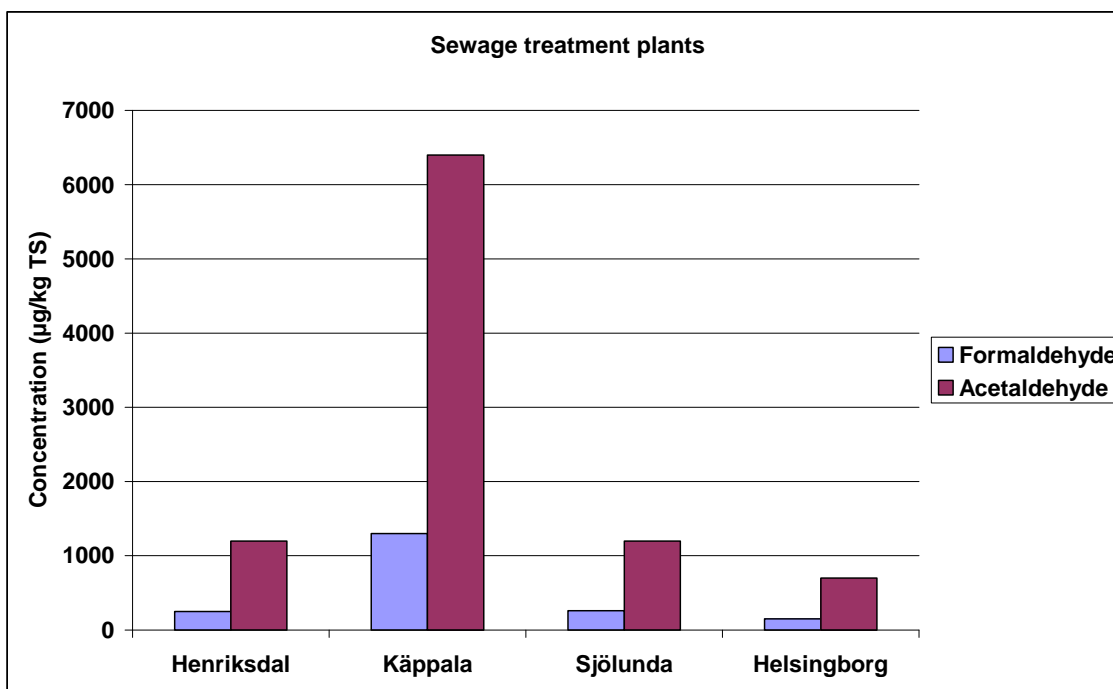


Figure 7. Concentrations of formaldehyde and acetaldehyde in sludge from STPs.

7.2.2 Urban environment

Concentrations of glutaraldehyde were below the LOQs in all samples from the urban environment. It could not be detected in surface waters from Stockholm ($< 1 \mu\text{g/l}$), or in air samples from Gothenburg ($< 0.002 - < 0.02 \mu\text{g/m}^3$). Both formaldehyde and acetaldehyde were found in surface water samples from the city of Stockholm, concentration found were in the ranges

35-49 µg/l and 30-52 µg/l respectively, see Figure 7. Formaldehyde was not found in any of the air samples from Gothenburg ($< 0.02 - < 0.1 \mu\text{g}/\text{m}^3$), whereas acetaldehyde was found in one of the samples at a concentration of $2.6 \mu\text{g}/\text{m}^3$.

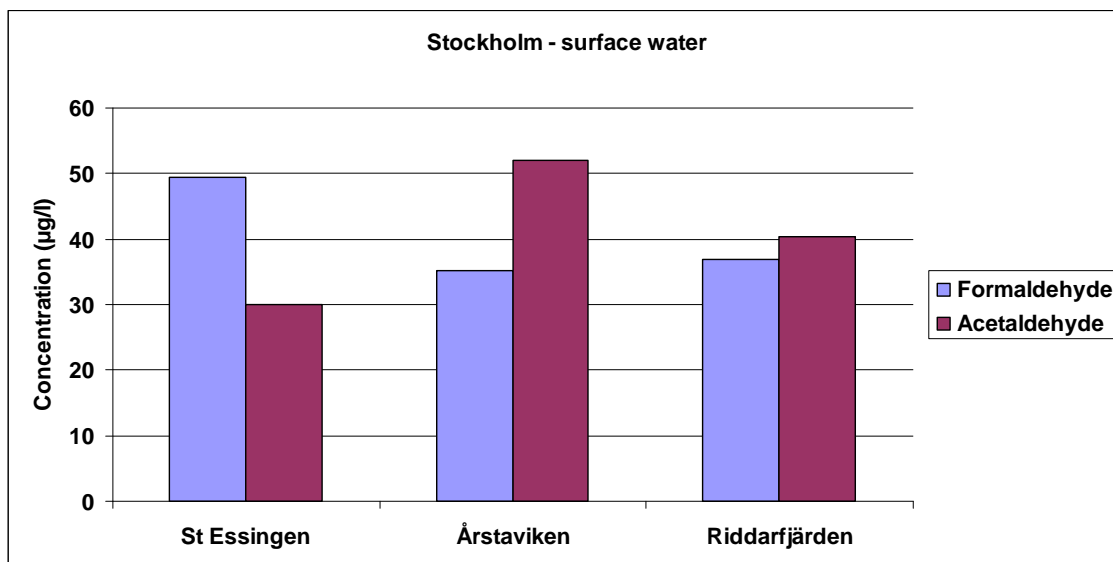


Figure 8. Concentrations of formaldehyde and acetaldehyde in surface waters from the city of Stockholm.

7.3 Background areas

Glutaraldehyde could not be detected in air or surface waters from background areas, levels of quantification were $0.001 \mu\text{g}/\text{m}^3$ and $1 \mu\text{g}/\text{l}$, respectively.

Formaldehyde was found in one of the background samples, the surface water sample from lake Largen contained $14 \mu\text{g}/\text{l}$, whereas concentrations of acetaldehyde were below LOQ in all background samples.

8 Discussion

Glutaraldehyde was only found in samples from a hospital and a paper mill, potential point sources with a known usage of the compound. It could not be detected in samples from potential point sources handling products at the end of the product lives, water and air from recycling companies and leachate water from a landfill. Further, it could not be detected in samples representing diffuse sources or background areas. This indicates that the compound may affect the environment at the site of usage, but it does not seem to spread far away. This is what could be expected due to the reactivity and low persistence of the compound.

The concentrations found in the samples representing point sources were lower compared to what has been found in previous studies, see chapter 4. Potential explanations to this may e.g. be sampling distances to the site of usage, periodicity in usage patterns, and/or differences in and the voluntary reduction of total usage volumes.

A comparison of concentrations found with toxicity values from the literature, see chapter 2.2, indicate that glutaraldehyde do not constitute a risk to the environment. Concentrations found in effluent waters were below the NOEC for bacterial inhibition of relevance for microbial processes in waste water treatment. They were also below the toxicity values found for the aquatic environment.

Formaldehyde and acetaldehyde were found in water samples from the hospital, a paper mill, STPs, and in leachate water from a landfill. Both compounds were also found in surface water samples from the city of Stockholm, formaldehyde also in surface water from one of the background lakes.

For formaldehyde there is a lack of chronic toxicity values for a robust risk assessment with regard to the aquatic environment. Concentrations found were above the PNEC 5.8 µg/l, derived from acute toxicity data and an assessment factor of 1000, given in the OECD SIDS Initial Assessment Profile for formaldehyde (OECD SIDS, 2002). However, a higher value, a “chronic aquatic life water quality criterion” of 1.61 mg/l, has been derived by Hohreiter and Rigg (2001) in accordance with a USEPA guideline.

Concentrations of formaldehyde found in air were below the level limit value 0.6 mg/m³ set by the Swedish Work Environment Authority (AFS 2005:17).

9 Conclusions

Glutaraldehyde could only be found in samples associated with identified point sources related to the usage of the compound, i.e. in effluent water from a paper mill and in air and effluent water from a hospital. It could however not be found in samples from potential point sources representing the end of product life cycles, i.e. air and water from recycling companies or water from a landfill. Further, it could not be found in samples representing diffuse sources or background areas.

Glutaraldehyde may thus affect the environment at the site of use, but the results indicate a low potential for dispersal in the environment.

The concentrations found were below toxicity values found in the literature. Thus, all together glutaraldehyde does not appear to pose a risk to the environment.

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Appendix. Sample characteristics and results

Table A1. Sample characteristics.

Sample ID	Category	Site	Matrix	Notes	Sampling Date
7850	Background	Råö	Air	Sample 1	2009-02-25 - 2009-02-27
7851	Background	Råö	Air	Sample 2	2009-02-27 - 2009-03-10
7852	Background	Råö	Air	Sample 3	2009-03-27 - 2009-03-30
7681	Background	Lake Gårdsjön	Surface water		2008-11-20
7615	Background	Lake Tärnan	Surface water		2008-11-30
7616	Background	Lake Largen	Surface water		2008-11-31
7834	Point Source	Högbytorp, Landfill	Leachate water	prior treatment	2009-04-22
7835	Point Source	Högbytorp, Landfill	Leachate water	after biological treatment	2009-04-22
7836	Point Source	Högbytorp, Landfill	Leachate water	after pond	2009-04-22
7799	Point Source	Gruvön, Paper mill	Air		2009-03-05 - 2009-03-06
7800	Point Source	Gruvön, Paper mill	Air		2009-03-05 - 2009-03-05
7786	Point Source	Gruvön, Paper mill	Storm water		2009-03-04
7785	Point Source	Gruvön, Paper mill	Effluent water	Settling basin	2009-03-03
7944	Point Source	Karolinska University Hospital	Air	Sample 1	2009-09-07 - 2009-09-08
7945	Point Source	Karolinska University Hospital	Air	Sample 2	2009-09-08
7946	Point Source	Karolinska University Hospital	Air	Sample 3	2009-09-08 - 2009-09-09
7947	Point Source	Karolinska University Hospital	Effluent water	Sample 1. Inside Thorax	2009-09-07
7948	Point Source	Karolinska University Hospital	Effluent water	Sample 2. Inside Thorax	2009-09-07
7949	Point Source	Karolinska University Hospital	Effluent water	Sample 3. Outside Thorax	2009-09-09
7950	Point Source	Karolinska University Hospital	Effluent water	Sample 4. Outside Thorax	2009-09-09
7951	Point Source	Karolinska University Hospital	Effluent water	Sample 5. Thorax area	2009-09-09
7952	Point Source	Karolinska University Hospital	Effluent water	Sample 6. Hospital area	2009-09-09
7791	Point Source	Skräppekärr, Recycling company	Air		2009-03-18 - 2009-03-19
7792	Point Source	Skräppekärr, Recycling company	Air		2009-03-17 - 2009-03-18
7793	Point Source	Skräppekärr, Recycling company	Air		2009-03-19 - 2009-03-20

Sample ID	Category	Site	Matrix	Notes	Sampling Date
7815	Point Source	Paper recycling company	Storm water	Distance 25 m	2009-03-31
7816	Point Source	Paper recycling company	Storm water	Distance 75 m	2009-03-31
7817	Point Source	Paper recycling company	Storm water	Distance 100 m	2009-03-31
7803	Diffuse, urban	Göteborg, Femman	Air	Sample 1	2009-03-10 - 2009-03-11
7802	Diffuse, urban	Göteborg, Femman	Air	Sample 2	2009-03-10
7804	Diffuse, urban	Göteborg, Femman	Air	Sample 3	2009-03-11 - 2009-03-12
7589	Diffuse, urban	Stockholm, St Essingen	Surface water		2008-11-08
7591	Diffuse, urban	Stockholm, Årstaviken	Surface water		2008-11-10
7590	Diffuse, urban	Stockholm, Riddarfjärden	Surface water		2008-11-08
7722	Diffuse, STP	Stockholm, Henriksdal STP	Influent water	Day sample	2008-12-16
7764	Diffuse, STP	Stockholm, Henriksdal STP	Effluent water	Day sample	2008-12-16
7652	Diffuse, STP	Stockholm, Henriksdal STP	Sludge		2008-12-10
7724	Diffuse, STP	Stockholm, Käppala STP	Influent water	Day sample	2008-12-16
7765	Diffuse, STP	Stockholm, Käppala STP	Effluent water	Day sample	2008-12-16
7726	Diffuse, STP	Stockholm, Käppala STP	Sludge		2008-12-15
7780	Diffuse, STP	Malmö, Sjölunda STP	Influent water	Day sample	2009-02-23
7781	Diffuse, STP	Malmö, Sjölunda STP	Effluent water	Day sample	2009-02-23
7782	Diffuse, STP	Malmö, Sjölunda STP	Sludge		2009-02-23
7843	Diffuse, STP	Helsingborg, STP	Influent water		2009-04-21
7844	Diffuse, STP	Helsingborg, STP	Effluent water		2009-04-21
7549	Diffuse, STP	Helsingborg, STP	Sludge		2008-09-24

Table A2. Measured concentrations of aldehydes (nd: not determined).

Sample ID	Category	Site	Matrix	Unit	Glutaraldehyde	Formaldehyde	Acetaldehyde-b
7850	Background	Råö	Air	µg/m ³	<0.001	<0.01	<0.05
7851	Background	Råö	Air	µg/m ³	<0.001	<0.01	<0.05
7852	Background	Råö	Air	µg/m ³	<0.001	<0.01	<0.05
7681	Background	Lake Gårdsjön	Surface water	µg/l	<1	nd	nd
7615	Background	Lake Tärnan	Surface water	µg/l	<1	<6	<25
7616	Background	Lake Largen	Surface water	µg/l	<1	14	<25
7834	Point Source	Högbytorp, Landfill	Leachate water	µg/l	<1	66	110
7835	Point Source	Högbytorp, Landfill	Leachate water	µg/l	<1	63	120
7836	Point Source	Högbytorp, Landfill	Leachate water	µg/l	<1	67	55
7799	Point Source	Gruvöns Bruk	Air	µg/m ³	<0.02	<0.02	<2
7800	Point Source	Gruvöns Bruk	Air	µg/m ³	<0.02	<0.16	<2
7786	Point Source	Gruvöns Bruk	Storm water	µg/l	<1	9.2	<25
7785	Point Source	Gruvöns Bruk	Effluent water	µg/l	2	50	28
7944	Point Source	Karolinska University Hospital	Air	µg/m ³	0.2	1.2	33
7945	Point Source	Karolinska University Hospital	Air	µg/m ³	0.4	0.7	16
7946	Point Source	Karolinska University Hospital	Air	µg/m ³	0.2	0.6	11
7947	Point Source	Karolinska University Hospital	Effluent water	µg/l	<0.1	<2	<6
7948	Point Source	Karolinska University Hospital	Effluent water	µg/l	<0.1	<2	<6
7949	Point Source	Karolinska University Hospital	Effluent water	µg/l	<0.1	<2	<6
7950	Point Source	Karolinska University Hospital	Effluent water	µg/l	<0.1	<2	<6
7951	Point Source	Karolinska University Hospital	Effluent water	µg/l	0.3	11	27
7952	Point Source	Karolinska University Hospital	Effluent water	µg/l	1.0	7.6	7.5
7791	Point Source	Skräppekärr, Recycling company	Air	µg/m ³	<0.002	<0.02	<0.2
7792	Point Source	Skräppekärr, Recycling company	Air	µg/m ³	<0.002	<0.02	<0.2
7793	Point Source	Skräppekärr, Recycling company	Air	µg/m ³	<0.002	<0.02	<0.2
7815	Point Source	Paper recycling company	Storm water	µg/l	<1	<6	<25
7816	Point Source	Paper recycling company	Storm water	µg/l	<1	<6	<25
7817	Point Source	Paper recycling company	Storm water	µg/l	<1	<6	<25
7803	Diffuse, urban	Göteborg, Femman sample 1	Air	µg/m ³	<0.003	<0.02	<0.2

Sample ID	Category	Site	Matrix	Unit	Glutaraldehyde	Formaldehyde	Acetaldehyde-b
7802	Diffuse, urban	Göteborg, Femman sample 2	Air	µg/m ³	<0.02	<0.1	2.6
7804	Diffuse, urban	Göteborg, Femman sample 3	Air	µg/m ³	<0.002	<0.02	<0.2
7589	Diffuse, urban	Stockholm, St Essingen	Surface water	µg/l	<1	49	30
7591	Diffuse, urban	Stockholm, Årstaviken	Surface water	µg/l	<1	35	52
7590	Diffuse, urban	Stockholm, Riddarfjärden	Surface water	µg/l	<1	37	40
7722	Diffuse, STP	Stockholm, Henriksdal STP	Influent water	µg/l	<1	<6	<25
7764	Diffuse, STP	Stockholm, Henriksdal STP	Effluent water	µg/l	<1	27	<25
7652	Diffuse, STP	Stockholm, Henriksdal STP	Sludge	µg/kg TS	<10	250	1200
7724	Diffuse, STP	Stockholm, Käppala STP	Influent water	µg/l	<1	7.2	<25
7765	Diffuse, STP	Stockholm, Käppala STP	Effluent water	µg/l	<1	46	<25
7726	Diffuse, STP	Stockholm, Käppala STP	Sludge	µg/kg TS	<10	1300	6400
7780	Diffuse, STP	Malmö, Sjölanda STP	Influent water	µg/l	<1	50	120
7781	Diffuse, STP	Malmö, Sjölanda STP	Effluent water	µg/l	<1	58	<25
7782	Diffuse, STP	Malmö, Sjölanda STP	Sludge	µg/kg TS	<10	260	1200
7843	Diffuse, STP	Helsingborg, STP	Influent water	µg/l	<1	18	37
7844	Diffuse, STP	Helsingborg, STP	Effluent water	µg/l	<1	7	<25
7549	Diffuse, STP	Helsingborg, STP	Sludge	µg/kg TS	<10	150	700