REPORT

# Results from the Swedish National Screening Programme 2008

## Subreport 5: Methyl *tert*-butyl ether (MTBE) and Ethyl *tert*-butyl ether (ETBE)

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**Report Summary**

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Subreport 3: Methyl *tert*-butyl ether (MTBE) and ethyl *tert*-butyl ether (ETBE)

**Summary**

Methyl *tert*-butyl ether (MTBE) and ethyl *tert*-butyl ether (ETBE) are mainly used as additives to gasoline in order to enhance the combustion efficiency. As an assignment from the Swedish Environmental Protection Agency, IVL has performed a screening study of MTBE and ETBE. The overall objective of the screening was to determine concentrations in a variety of media in the Swedish environment, in order to judge if the substances are commonly occurring in the Swedish environment. A further aim was to determine key sources and highlight major transport routes.

**Keyword**

MTBE, ETBE, sceening, surface water, traffic storm water, ground water, drinking water, wells, air, soil, background

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# Summary

As an assignment from the Swedish Environmental Protection Agency, IVL has performed a screening study of methyl tertial-butyl ether (MTBE) and ethyl tertial-butyl ether (ETBE).

MTBE and ETBE are mainly used as additives in gasoline in order to enhance the combustion efficiency. The annual amount of MTBE used in Sweden is about 400 000 tonnes, but the usage of ETBE in Sweden was classified as confidential according to the SPIN database (SPIN, 2009).

The overall objective of the screening was to determine concentrations in a variety of media in the Swedish environment, in order to judge if the substances are commonly occurring in the Swedish environment. A further aim was to determine key sources and highlight major transport routes. A national sampling program was developed, consisting of in total 63 samples of storm water, ground water, drinking water, wells, surface water, soil and air.

The table below shows the detected ranges for MTBE and ETBE in various matrices and type areas.

| Area type | | Point source | n | Urban / Diffuse / Indoor | n | Traffic related | n | Background | n | $N_{tot}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Air (µg/m$^3$) | MTBE<br>ETBE | <0.2-5.8<br><0.1-0.7 | 11 | 0.11-1.1<br><0.13-0.99 | 14 | <0.08-2.5<br><0.1-<0.2 | 9 | 0.09-0.49<br><0.05-<0.2 | 3 | **37** |
| Surface water (ng/L) | MTBE<br>ETBE | <10 - 10<br><7-9 | 3 | 32<br>7.6 | 1 | | | <10<br><7 | 2 | **6** |
| Drinking water (ng/L) | MTBE<br>ETBE | | | <10-34<br><7 | 3 | | | | | **3** |
| Ground water (ng/L) | MTBE<br>ETBE | | | 240<br>31 | 1 | 14<br><7 | 1 | <10<br><7 | 1 | **3** |
| Well water (ng/L) | MTBE<br>ETBE | | | 14-140<br><7-7.9 | 4 | | | | | **4** |
| Storm water (ng/L) | MTBE<br>ETBE | | | | | 69-77<br>19-20 | 3 | | | **3** |
| STP water(ng/L) | MTBE<br>ETBE | | | 110(in)-120(out) | 2 | | | | | **2** |
| Soil (ng/g dw) | MTBE<br>ETBE | 11-50<br><0.57-<0.89 | 3 | 37<br><0.69 | 1 | | | 22<br><0.81 | 1 | **5** |
| **TOTAL no samples** | | **17** | | **26** | | **13** | | **7** | | **63** |

The following main conclusions were drawn from the current project:

- Methyl-tert-butyl ether occurs frequently in the Swedish atmosphere, at point sources as well as in background areas.
- Ethyl-tert-butyl ether is rarely found in the Swedish environment, and when detected, concentrations were significant lower than for MTBE
- Highest levels in air were found at the gas station during refuelling, which confirms that this is an important source of fuel additive emissions to the atmosphere. MTBE and ETBE concentrations in air, soil and surface waters at other potential point sources were in the same order of magnitude as those found in background areas.

- The ratios of MTBE concentrations in outdoor/indoor air were between 1.0-1.8 (average: 1.4).
- Both MTBE and ETBE were present in urban surface water.
- MTBE, but not ETBE, was occasionally detected in drinking water.
- The cleaning efficiency of MTBE and ETBE in Ryaverken STP is poor.
- The concentrations and estimated daily exposure found in the current screening project are a factor of **29 – $1.7\times10^9$ lower** than established risk levels, thus no effects are expected to occur as a result of MTBE neither to humans, nor other organisms.
- Considering the fact that MTBE and ETBE are found in Swedish environment and that the usage these substances can change, future follow up studies are recommended.
- The results from the evaluation of diffuse sampling compared to active sampling showed that sampling with the more cost efficient diffusive samplers could be used as an indicative method

# Sammanfattning

IVL har på uppdrag av Naturvårdsverket utfört en screeningundersökning av metyl-tert-butyl-eter (MTBE, CAS 1634-04-4) och etyl-tert-butyl-eter (ETBE, CAS 637-92-3). MTBE och ETBE används till största delen som drivmedelstillsatser för att förbättra förbränningseffektiviteten i bensin. Den årliga användningen av MTBE i Sverige är cirka 400 000 ton, medan användningen av ETBE är konfidentiell (Produktregistret).

Syftet med föreliggande screening var att bestämma förekomsten av MTBE och ETBE i ett antal matriser från den svenska miljön, samt att identifiera huvudsakliga källor och viktiga transportvägar i miljön. Totalt 63 prover bestående av avloppsvatten, dagvatten, grundvatten, ytvatten, dricksvatten, brunnsvatten, jord och luft ingick i studien. Provtagningsprogrammet redovisas i tabellen nedan och en karta med mätplatserna på den svenska västkusten utmärkta visas i figur nedan.

| Mätplats | Luft | Dricks-vatten | Brunnar | ARV vatten | Dag-vatten | Yt-vatten | Grund-vatten | Jord | Totalt |
|---|---|---|---|---|---|---|---|---|---|
| **Bakgrund** | | | | | | | | | |
| Svenska västkusten | 3 | 1 | 2 | | | 2 | 1 | 1 | **10** |
| **Diffusa källor** | | | | | | | | | |
| Kommunalt ARV | | | | 2 | | | | | **2** |
| Göteborg, urban miljö | 6 | 2 | | | | 1 | 1* | 1 | **11** |
| Gaturum | 9 | | | | 3 | | 1 | | **13** |
| Inomhus | 8 | | | | | | | | **8** |
| **Punktkällor** | | | | | | | | | |
| Preemraff Lysekil AB | 3 | | 2 | | | 1 | | 1 | **7** |
| Stenungsund | 5 | | | | | 2 | | 1 | **8** |
| Bensinstation | 3 | | | | | | | 1 | **4** |
| **Totalt** | **37** | **3** | **4** | **2** | **3** | **6** | **3** | **5** | **63** |

* Urbant grundvattenprov från Stockholm.

### Mätningar runt punktkällor

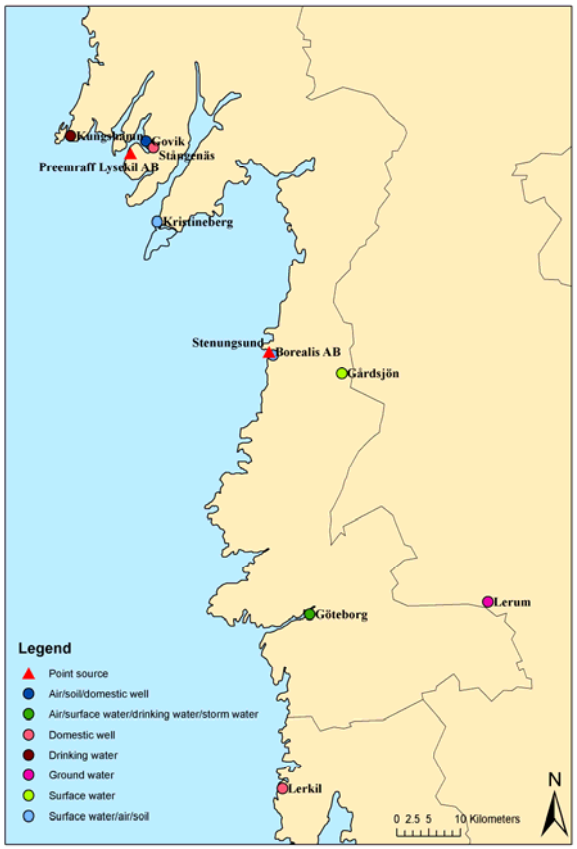
Luftmätningar utfördes vid tre tillfällen, på en bakgrundsstation, Kristineberg, och vid punktkällorna Preemraff Lysekil AB och Borealis AB. Mätningarna vid dessa platser genomfördes under samma dagar.

Inte vid någon av dessa platser, inkluderat mätplatsen i närheten av ETBE tillverkningen vid Borealis AB i Stenungsund, kunde ETBE detekteras.

Vid bakgrundsstationen uppmättes MTBE i koncentrationer mellan 0.09 och 0.49 μg/m$^3$. Inte vid någon av mätningarna erhölls högre luftkoncentrationer av MTBE vid mätplatsen i närheten av Preemraff Lysekil AB än vid bakgrundsstationen.

Ytvattenprov insamlades från en bakgrundssjö, Gårdsjön, och från en bäck respektive å i närheten av punktkällorna Preemraff Lysekil AB och Borealis AB. MTBE- eller ETBE-halter över kvantifieringsgränserna kunde inte påvisas i något av dessa prover. I ett ytvattenprov från ett dike

nära Borealis AB i Stenungsund uppmättes dock 10 ng/l MTBE och 9 ng/l ETBE. Diket rinner längs med en väg med hög trafikbelastning, vilket sannolikt har påverkat halterna.




Provpunkternas placering.

Inte i något av jordproverna från bakgrundsstationen eller från någon av de båda punktkällorna kunde ETBE koncentrationer över kvantifieringsgränsen (0.9 ng/g DW) detekteras. Halten av MTBE i jord var 22 ng/g DW vid bakgrundsstationen, 11 ng/g DW i närheten av Preemraff Lysekil AB och 50 ng/g DW i närheten av Borealis AB.

Eftersom det är ETBE som tillverkas vid Borealis AB har den något förhöjda halten av MTBE jämfört med bakgrundsstationen sannolikt ett annat ursprung än från industrin.

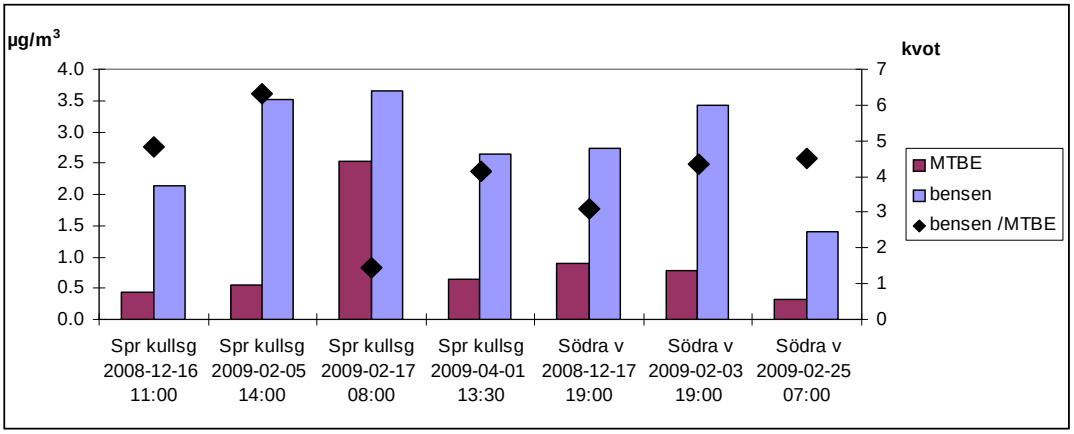
**Luftmätningar i urban miljö**

Resultaten från luftmätningarna i urban miljö uppvisade skillnader i halterna av MTBE jämfört med ETBE. Uppmätta MTBE koncentrationer i luft var över kvantifieringsgränsen vid alla mätplatser medan halterna av ETBE i de flesta fall låg under kvantifieringsgränsen. Luftkoncentrationerna av MTBE vid den urbana mätplatsen på ovan tak höjd var 0.11-1.1 µg/m$^3$, vilket är i samma haltområde som i visats i urban bakgrund i Zürich, Schweiz.

ETBE i luft uppmättes vid en bensinstation men var bara en tiondel av MTBE-halterna. Provtagningstiden var ungefär en halvtimma och under denna tid tankades flera bilar. Vid denna

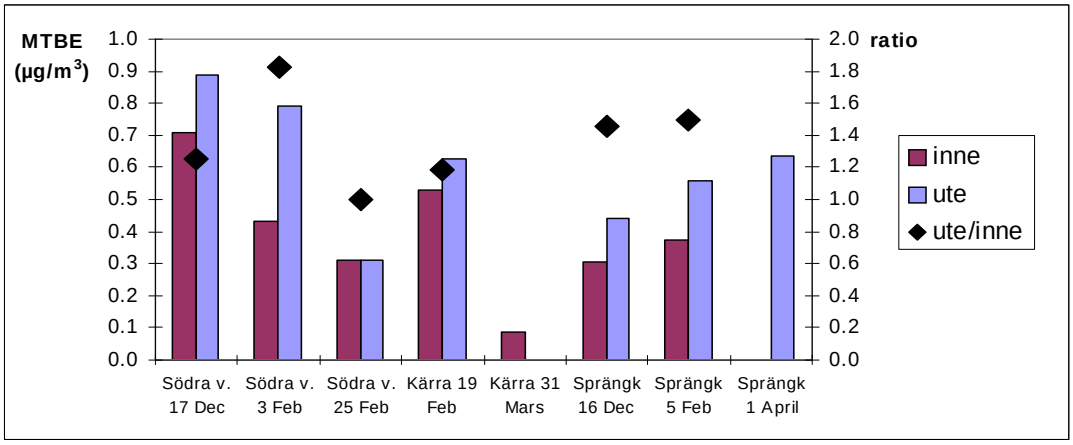
specifika bensinstation såldes bensin av flera olika varumärken, vilket indikerar en generellt större användning av MTBE än ETBE.

I figuren nedan visas uppmätta halter i gaturum av bensen och MTBE samt kvoterna mellan dessa. Vid gaturummet varierade halterna av MTBE mellan 0.31-2.5 µg/m³ och kvoten mellan bensen/MTBE varierade från 1.4 till 6.2 med ett medelvärde på 3.9. Kvoterna mellan bensen/MTBE vid tak mätningarna varierade mellan från 1.4 till 6.8 med medelvärde 3.2 . Skillnaden i kvoter indikerar en större trafikpåverkan på halterna i gaturum jämfört med ovan tak, precis som förväntat.




MTBE- och bensenhalter uppmätta vid gaturumsmätningar samt kvoternabensen/MTBE.

Luftprovtagning inomhus utfördes i anslutning till gaturumsmätningarna. Proverna togs på första våningen i huset närmast provtagningspunkten utomhus. De uppmätta lufthalterna inomhus låg inom spannet <0.10-0.71 µg/m³. Kvoten mellan luftkoncentrationer av MTBE utomhus/inomhus var 1.0-1.8 med ett medelvärde på 1.4.




MTBEhalter uppmätta inomhus och utomhus samt kvoterna ute/inne.

**Mätningar i vatten**

Både MTBE och ETBE återfanns i samtliga vattenprover från urban miljö. Halterna i de tre dagvattenproverna varierade endast mellan 71-77 ng/l MTBE och 19-20 ng/l ETBE. Halterna av MTBE, 240 ng/l och ETBE 31 ng/l i grundvattenprovet från urban miljö i Ulvsunda, Stockholm,

var högre än i dagvattenproverna och i det urbana ytvattnet *(32 ng/l MTBE och 8 ng/l ETBE)* från centrala Göteborg.

Halter av MTBE över kvantifieringsgränsen (10 ng/l) återfanns i ett av tre kommunala dricksvatten prover, i vilket 34 ng/l MTBE detekterades. Inte i något av de tre dricksvattnen proven kunde ETBE (<7 ng/l) detekteras. Provplatser och uppmätta halter i kommunala dricksvatten visas i tabell 2.

Komunala dricksvattenprover och resultat

| Provplats | Enhet | MTBE | ETBE | Bensen | Toluen | Etyl-bensen | *m+p*-Xylen | *o*-Xylen |
|---|---|---|---|---|---|---|---|---|
| Göteborg, Södra vägen | ng/l | 34 | <7.0 | <6.0 | 26 | 1.2 | 4.1 | 2.9 |
| Göteborg, Kärra | ng/l | <10 | <7.0 | <6.0 | 8.7 | 0.21 | 3.0 | |
| Kungshamn | ng/l | <10 | <7.0 | 8.3 | 20 | 1.6 | 7.2 | 1.6 |

MTBE-koncentrationerna i vattnet från de tre privata brunnar varierade mellan 34-140 ng/l. Provplatser och uppmätta halter i privata brunnar visas i tabell 3. ETBE över kvantifieringsgränsen (7 ng/l) detekterades i en av brunnarna. Lerkil ligger söder om Göteborg och brunnarna finns i villaområden utan större påverkan från industri eller trafik. Brunnen betecknad Govik är placerad några kilometer från Preemraff Lysekil AB fågelvägen, men inte på samma halvö. Transport från raffinaderiet till brunnen via grundvattnet borde inte vara möjlig.

Privata brunnar; prover och resultat

| Provplats | Enhet | MTBE | ETBE | Bensen | Toluen | Etyl-bensen | *m+p*-Xylen | *o*-Xylen |
|---|---|---|---|---|---|---|---|---|
| Lerkil | ng/l | 37 | 7.9 | 13 | 18 | 2.2 | 6.4 | 6.2 |
| Lerkil | ng/l | 140 | <7.0 | 7.5 | 7.0 | 0.54 | 2.3 | 1.5 |
| Govik | ng/l | 34 | <7.0 | <6.0 | 9.4 | 1.5 | 2.0 | |

Koncentrationerna av MTBE och ETBE i vatten från avloppsreningsverket Ryaverken i Göteborg var något högre än i dagvattenproverna. Skillnad på in- och utgående vatten gällande MTBE- och ETBE-halter var liten, vilket indikerar att dessa ämnen inte effektivt avlägsnas i reningsprocessen. Koncentrationerna av MTBE var 110 ng/l i ingående vatten och 120 ng/l i utgående vatten medan koncentrationerna av ETBE var 31 ng/l i ingående vatten och 26 ng/l i utgående vatten, se tabell 4.

ARV Ryaverken i Göteborg; Vattenprover och resultat

| Provplats | Typ | Enhet | MTBE | ETBE | Bensen | Toluen | Etylbensen | *m+p*-Xylen | *o*-Xylen |
|---|---|---|---|---|---|---|---|---|---|
| Ryaverken | Ingående vatten | ng/l | 110 | 31 | 35 | 1500 | 58 | 150 | 72 |
| Ryaverken | Utgående vatten | ng/l | 120 | 26 | 7.3 | 280 | 62 | 130 | 72 |

**Slutsatser**

- Metyl-tert-butyl-eter återfanns frekvent i svenska luftprover, både vid punktkällor och i bakgrundsområden.
- Etyl-tert-butyl-eter återfanns sällan i den svenska miljön och när den hittades var koncentrationerna lägre än för MTBE.
- De högsta luftkoncentrationerna av MTBE och ETBE uppmättes vid en bensinstation under tankning, vilket understryker att detta är en viktig källa för emissioner av bränsletillsatser till atmosfären. De uppmätta MTBE- och ETBE-koncentrationerna i luft,

jord och ytvatten vid andra potentiella punktkällor var i samma storleksordning som i bakgrundsområdena.

- Kvoterna av MTBE -koncentrationerna i luft utomhus/inomhus var mellan 1.0-1.8 (medel: 1.4).

- Både MTBE och ETBE återfanns i urbant ytvatten.

- MTBE återfanns i 1 av 3 kommunala dricksvatten och i alla provtagna privata brunnar. ETBE återfanns i ett enstaka brunnsvatten, men inte i de kommunala dricksvattenproverna.

- Reningseffektiviteten för MTBE och ETBE var låg i Ryaverkens STP.

- En riskuppskattning avseende MTBE baserad på de uppmätta koncentrationerna från denna screeningstudie har genomförts. Den uppskattade dagliga exponeringen blev en faktor 29 – $1.7\times10^{9}$ lägre än fastställda risknivåer.

- Då MTBE och ETBE förkommer frekvent i den svenska miljön och att användningen av dessa ämnen kan komma att ändras i framtiden rekommenderas framtida uppföljnings studier.

- En evaluering av diffusiva provtagare för MTBE och ETBE i luft visade att provtagning med de mer kostnadseffektiva diffusiva provtagarna kan användas som en indikativ metod.

# Table of contents

# 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-jod-2-proponyl butyl karbamat (IPCB) 2,2-Dibromo-2-cyanoacetamide (DBNPA) | | | x | | 1 |
| | Glutaraldehyde | | x | x | | 2 |
| | Difenacoum | x | | x | x | 3 |
| Un-intentionally produced substances | Nitro-PAH 3-Nitrobezantron Oxy-PAH Heterocyclics Brominated dioxins and aromatics | | | x | x | 4 |
| **Fuel additives** | **Methyl *tert*-butyl ether (MTBE) Ethyl *tert*-butyl ether (ETBE)** | | **x** | **x** | **x** | **5** |

[a] High Production Volume
[b] Bioaccumulation/Persistence

The overall objectives of the screening studies are 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.

This sub-report concerns the screening of **fuel additives MTBE and ETBE**. Results for the other chemicals are presented in subreport 1, 2, 3 and 4. MTBE and ETBE are mainly used as additives in gasoline in order to enhance the combustion efficiency.

# 2 Chemical properties, fate and toxicity

## 2.1 Properties and fate

The molecular structures of MTBE (CAS 1634-04-4) and ETBE (CAS 637-92-3) are shown in Figure 1 and the physical-chemical properties are presented in Table 2. MTBE has very high water solubility and low sorption to soil solids and thus moves through water systems with minimal retardation. The physical and chemical properties of MTBE differ from most other petroleum constituents, with the implication that when released to soil, MTBE may separate from the rest of the petroleum, reach the groundwater first and rapidly dissolve. Thus the methods used to remediate petroleum may not remove the MTBE from nature (EPA, 1998). This leads to an enhanced risk of contamination of groundwater and wells, even at long distances away from the source (Yuan, 2006). ETBE also has a high water solubility and low sorption potential, but relative to MTBE it is somewhat less likely to migrate long distances away from the source.

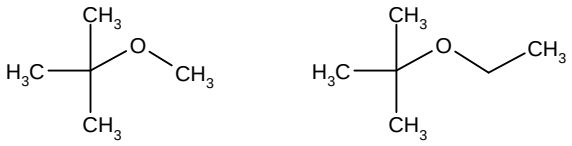



Figure 1. Structures of MTBE (CAS 1634-04-4) and ETBE (CAS 637-92-3).

Table 2. Physical and chemical properties of MTBE and ETBE (SRC, 2009)

| | **MTBE** | **ETBE** |
|---|---|---|
| Molecular formula | $CH_3OC(CH_3)_3$ | $CH3CH_2OC(CH_3)_3$ |
| Molecular weight (g/mol) | 88 | 102 |
| Melting point ($^0$C) | -108 | -94 |
| Boiling point ($^0$C) | 55.2 | 73.1 |
| Vapor pressure (mmHg at 25$^0$C) | 250 | 124 |
| Water solubility (mg/l at 20$^0$C) | 51000 | 12000 |
| Log $K_{ow}$ | 0.94 | 1.92 |
| Henry's Law Constant (atm m$^3$/mol) | 0.000587 | 0.00164 |

The biodegradation rates of MTBE in water and soil are low, thus the substance is regarded as fairly persistent. (ECB, 2002). Monitoring of MTBE in wells in the US has shown low reduction rate of MTBE concentrations which provides further evidence of the persistence. However, studies of surface water (lakes and reservoirs) have shown that MTBE volatilizes relatively quickly, thus removal from the aquatic system is likely to be dominated by volatilization and not degradation. (http://www.epa.gov/mtbe/faq.htm#concerns). Since MTBE and ETBE have low biodegradation rates in water (ECB, 2002) there may be a risk that they will be present in drinking water. In a study of 83 drinking water samples from 50 cities in Germany, MTBE was detected in 46% of the samples at concentrations from 17 to 700 ng $L^{-1}$ (Kolb & Püttman 2006a).

In the atmosphere, MTBE reacts essentially solely with the hydroxyl radicals (ECB 2002). In the summer, when there is enhanced photochemical activity, more MTBE will be attacked by hydroxyl radicals and will be degraded to *tert*-butyl formate (TBF). The atmospheric degradation half-life in summer and winter is approximately 3 and 6 days, respectively (Wallington et al., 1988; Squillace et al., 1996; Achten et al., 2001).

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 MTBE and ETBE. Physical-chemical properties were taken from Table 2. The degradation half-lives used were as follows; air: 170 h and 55 h for MTBE and ETBE respectively, water 550 h, soil 550 h and sediment 5500 hours. The data was based on degradation data obtained from HSDB (2009), as well as estimated data using the EPIWIN software (Meylan, 1999) and classified according to Mackay (2001). The adopted atmospheric half-life of 170 h (7 days) is similar to reported half-lives in wintertime (6 days – see reference above). Emission rates were set to 1000 kg/h, only for illustrative purposes. The outcome of the modeling exercise is shown in Table 3. The numbers given in the Table should be regarded as indicative, as they are dependent on model structure as well as chemical property data.

Table 3. Results from EQC modelling of MTBE and ETBE, using emission rates of 1000 kg/h.

| Emission medium | % in air | | % in water | | % in soil | | % in sediment | | Persistence (h) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MTBE | ETBE | MTBE | ETBE | MTBE | ETBE | MTBE | ETBE | MTBE | ETBE |
| Air | 96 | 98 | 3.7 | 1.7 | 0.3 | 0.3 | 0.008 | 0.006 | 73 | 45 |
| Water | 11 | 8.5 | 89 | 91 | 0.03 | 0.03 | 0.2 | 0.3 | 280 | 250 |
| Soil | 27 | 18 | 11 | 4.3 | 62 | 78 | 0.02 | 0.01 | 200 | 200 |
| ***All three*** | ***28*** | ***20*** | ***49*** | ***48*** | ***22*** | ***31*** | ***0.1*** | ***0.2*** | ***190*** | ***160*** |

The overall residence time in the system of both substances is predicted to be fairly low (7-8 days when emitted to all media). For ETBE, reactive processes account for the dominant contribution to the low residence time, whereas the removal processes of MTBE are dominated by advection. This implies that MTBE has a higher tendency to remain in the environment even if it is removed from the system, whereas ETBE is more likely to be efficiently degraded. The main removal processes are predicted to occur in the atmosphere for both substances, for ETBE atmospheric degradation accounts for 42 % of the total loss, whereas atmospheric advection is the main removal process for MTBE.

The model results emphasize the high volatility and water solubility of these substances, showing significant partitioning to air and water, regardless of emission media, and that sorption is fairly weak, considering the high partitioning percentage to air and water, even when soil is the main emission matrix. This was also stated in the European Risk Assessment Report for MTBE (ECB 2002).

MTBE has been found in precipitation, which indicates that MTBE may be deposited from the atmosphere (Achten et al., 2001). This study also showed a seasonal variation, since MTBE was only detectable at temperatures lower than about 10-15 °C. When washed out from the atmosphere, MTBE and ETBE are likely to be distributed to surface water and storm water. However, Pankow et al. (1997) has shown MTBE may be transported from urban air into shallow groundwater via infiltration and dispersion, including molecular diffusion. Even though wet deposition of MTBE may occur, the net transport between air and surfaces is likely to be reversed (i.e. from surface to air), due to the high volatility of the substance.

Kolb & Püttman (2006 b) analysed snow and rain samples from various locations in Germany, and concluded that atmospheric transfer of MTBE from urban to rural areas takes place. Due to lower atmospheric degradation rates this mostly occurred in wintertime. The results also suggested that MTBE is more effectively scavenged from the atmosphere by snow than by rain.

## 2.2 Human exposure and toxicity

Since MTBE and ETBE are highly volatile compounds, the human exposure route of most importance is inhalation via air. The main non-occupational exposure to gasoline is in connection to refuelling of cars. In addition, some evaporation of fuel from vehicles occurs, also when the vehicles are not in traffic. This can lead to a higher exposure indoors in homes with a garage attached to the house. When MTBE or ETBE containing fuels are used, these components can also be present at low concentrations in the exhaust gas (Warner-Selph and Harvey, 1990; Hamai et al., 1992). Human exposure to MTBE and ETBE may also occur through skin contact, for example at refuelling. Contamination of drinking water sources may also lead to a possibility of human exposure (e.g. Kolb & Püttman 2006a).

The addition of MTBE to automotive fuels in USA coincided with increasing complaints of symptoms like headache, nasal and throat or ocular irritation, nausea, vomiting, dizziness and sensations of "spaciness" or disorientation. A chamber exposure experiment was conducted to determine if exposure to pure MTBE would elicit similar responses. The volunteers were exposed to 5.0 mg/m$^3$ MTBE for 1 h. This level was selected to approximate a typical exposure experienced during refuelling. The results indicated that in young healthy persons this exposure did not increase the symptoms reported or give an increase in objective biomarkers of inflammation (Prah et al. 1994). At higher concentrations, however, such effects have been reported (See Table 4).

The predominant way of uptake of MTBE and ETBE is through inhalation although absorption through the skin and from the gastrointestinal tract does occur. The respiratory uptake of MTBE is somewhat higher, 40-45 %, compared to the uptake rate of ETBE of about 35 % (Nihlén 1998).

MTBE is mainly metabolized to form tertiary-butyl alcohol (TBA) and formaldehyde, while the predominant metabolites of ETBE are TBA and acetaldehyde. Two other identified metabolites are α-hydroxyisobutyric acid (HBA) and 2-methyl-1, 2-propanediol (MPD) (Nihlén 1998). The levels of MTBE and ETBE in the blood increase rapidly during exposure and start to decrease soon after the exposure ends. The concentration of the metabolite TBA increases slowly until it reaches a plateau (Prah et al. 1994). The TBA levels start to decrease approximately 2-4 hours after the exposure. MTBE is mainly excreted by exhalation, but distribution to fatty tissues and excretetion in urine together with TBA may also take place. MTBE and TBA have been detected in breast milk at slightly lower concentrations than in blood (Nihlén 1998).

Acute and reversible neurotoxic effects have been seen after exposure to high concentrations of MTBE and ETBE (Daughtrey et al. 1997, Bird et al. 1997, Dorman et al. 1997). Mutagenicity tests for MTBE (Mackerer et al. 1996, McKee et al.1997, Robinson et al. 1990) and ETBE (Zeiger et al. 1992) have been predominantly negative. MTBE tested negative for teratogenic and reproductive effects in rabbits and rats up to 8000 ppm and in mice up to 1000 ppm (Bevan et al. 1997a, Bevan et al. 1997b, Biles et al. 1987, Conaway et al 1985). Additional toxicity data for MTBE and ETBE are listed in Table 4.

Table 4. Toxicity data for MTBE and ETBE.

| Substance | Species | End-point | Exposure route | Observed effects | Dura-tion | Concen-tration | Reference |
|---|---|---|---|---|---|---|---|
| MTBE | Mouse | LD50 | Oral | | | 4 g/kg | Moreno et al., 1988 |
| ETBE | Rat | LD50 | Oral | | | >5 g/kg | Moreno et al., 1988 |
| MTBE | Mouse | LC50 | Inhalation | | 15 min | 39000 ppm | Marsh & Leake, 1950 |
| ETBE | Mouse | LC50 | Inhalation | | 15 min | 29000 ppm | Marsh & Leake, 1950 |
| MTBE | Male rat | Chronic effects | Inhalation | Kidney tumours | | 3000 ppm | Bird et al., 1997 |
| MTBE | Female rat | Chronic effects | Inhalation | Liver tumours | | 8000 ppm | Bird et al., 1997 |
| MTBE | Human (men) | Acute | Inhalation | Headache, mucous membrane irritation | 3 h | 75 ppm | Riihimäki et al., 1996 |
| MTBE | Human (men) | Acute effects | Inhalation | No/small effects | 2h | <50 ppm | Nihlén 1998 |
| ETBE | Human (men) | Acute effects | Inhalation | Throat irritation, minor pulmonary function impairments | 2h | <50 ppm | Nihlén 1998 |

Based on the vast amount of toxicity data availble for MTBE, the EU risk assessment report derived risk reducing concentrations and doses according to Table 5 below

Table 5. Caluclated PNEC-values and lowest/no observeble effect levels for MTBE.

| Parameter | Endpoint | Value | Unit |
|---|---|---|---|
| $PNEC_{aquatic}$ | | 2.6 | Mg/L |
| $PNEC_{aquatic,\ intermittent}$ | | 13.6 | Mg/L |
| $PNEC_{terrestrial}$ | | 0.730 | Mg/kg ww |
| $NOAEC_{inhalation}$ | Repeated dose | 2900 (800 ppm) | $mg/m^3$ |
| $NOAEC_{inhalation}$ | Carcinogenity | 400 | Ppm |
| $LOAL_{oral,carcinogenity}$ | Carcinogenity | 250 | Mg/kg |

# 3 Production and consumption

The commercial production of MTBE started in Europe in 1973 and in the US in 1979. The total world-wide production capacity in 1998 was 23.5 million tonnes and the actual production was 18 million tonnes. The estimated annual production of MTBE in the EU in 2006 was 3 million tonnes (The European Fuel Oxygenates Association, 2006).

Oxygenates can be produced both from petrochemical and agricultural feedstock. Methanol, derived primarily from natural gas, is one feedstock used in the production of MTBE. Ethanol, derived by a fermenting process from corn and other agricultural products, is used either directly as a fuel additive, or as a feedstock for the production of ETBE. Isobutylene, which is the other feedstock used in both MTBE and ETBE production, is also derived from natural gas, or as a by-product of petroleum refining (The European Fuel Oxygenates Association, 2006).

MTBE is the most widely produced oxygenate. An important reason for the widespread use of MTBE is feedstock flexibility. MTBE can be made inside the refinery, using petroleum-derived raw

materials, or it can be produced externally, using natural gas feedstock, thereby ensuring ready availability and reducing dependence on crude oil for the production of automotive fuels.

In Sweden, ETBE is manufactured at Borealis AB in Stenungsund. The Swedish use of MTBE has been 300 000 - 500 000 tonnes divided into about 50 different preparations in four main function categories (UC 62) during 2000 - 2006 (SPIN, 2009), see Figure 2. The usage of ETBE is classified as confidential according to the same database.

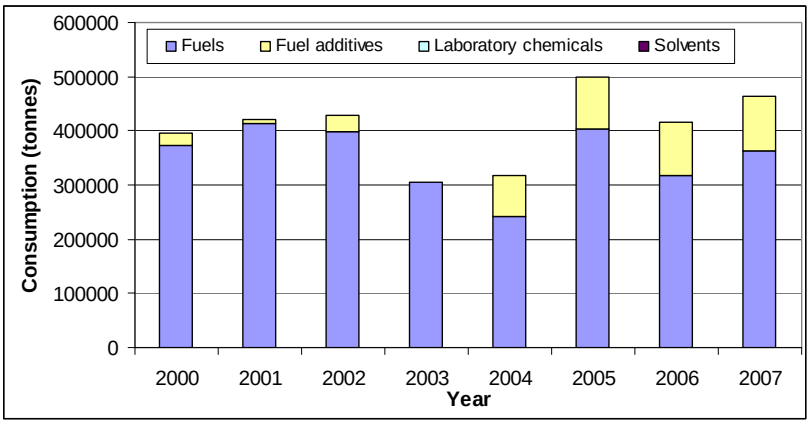



Figure 2. Use of MTBE in Sweden 2000-2007.

In Europe, MTBE contents in gasoline vary between about 0.2 and 14% (by volume), depending on country and grade. In Sweden the average MTBE concentration in petrol was 1.5% in 1997 (ECB, 2002). This can be compared to the MTBE concentration in petrol in other countries in 1997:

- Denmark 1.2%
- Finland 8.5%
- Germany 1.2%
- France 1.5%
- UK 1-5%
- USA 12-13%

# 4 Previous measurements in the environment

The literature on fuel additives in the environment is extensive. Table 6 summarizes some of the measurements of MTBE and ETBE in different environmental compartments mainly in Europe and North America.

Table 6. Measured MTBE and ETBE concentrations in different environmental compartments.

| Compart-ment | Content | Comment | Reference |
|---|---|---|---|
| **Surface Water** | 7-160 ng/l MTBE | German rivers Elbe, Oder, Rhein and Main. (Achten et al., 2001) | ECB, 2002 |
| | 420-480 ng/l MTBE | 2 creeks in Helsinki subject to diverse emissions from storm water (Helsinki, 2000) | ECB, 2002 |
| | <100 ng/l,<br>(1 sample at 200 ng/l MTBE) | UK rivers (Wrc, 1996) | ECB, 2002 |
| | 150-760 ng/l MTBE | 7 rivers in USA (Rieser et al., 1998 & Achten et al., 2001) | ECB, 2002 |
| | 390-6130 ng/l MTBE | Seawater at 17 boat harbours in Helsinki (Helsinki, 2000) | ECB, 2002 |
| **Ground water** | <20 µg/l MTBE | 101 groundwater sites, 75% above LOD (0.01 µg/l). Austria | ECB, 2002 |
| | 0.11-3.5 µg/l MTBE | Fredriksberg County, 5 of 16 above LOD. Denmark | ECB, 2002 |
| | Rural < 0.5 µg/l MTBE<br>Urban 15% > 0.5µg/l MTBE | 180 wells in urban and rural areas. Germany. | ECB, 2002 |
| | 13% above LOD (0.1 µg/l MTBE) | 800 sites, 3000 samples from England and Wales. | ECB, 2002 |
| | 15-160 µg/l MTBE | Northend/ UK | ECB, 2002 |
| | 74 non-urban sites, 24% above LOD (0.01 µg/l), median 0.18 µg/l MTBE<br><br>67 urban sites 63% above LOD (0.01 µg/l), median 0.06 µg/l MTBE | Germany | Kolb & Püttman, 2006c |
| | Median <0.05 µg/l ETBE, 0.13% above LOD (0.2 µg/l).<br>Median <0.17 µg/l MTBE, 3% above LOD (0.2 µg/l). | 1710 samples ETBE & 2422 samples MTBE, USA. Aquifer. | USGS 2006 |
| **Drinking water** | MTBE detected only at one site. Average 0.83 µg/l. | 37 000 analyzes of drinking water and surface waters. France. | ECB, 2002 |
| | 46% above LOD (10 ng/l)<br>17-712 ng/l MTBE | 83 finished drinking waters. Germany. | Kolb & Püttman, 2006a |
| | Median <0.05 µg/l ETBE, 0% above LOD (0.2 µg/l).<br>Median <0.17 µg/l MTBE, 3% above LOD (0.2 µg/l).. | 1215 samples ETBE & 1931 samples MTBE, USA. Domestic wells | USGS 2006 |
| | Median <0.07 µg/l ETBE, 0.12% | 818 samples ETBE & 913 samples | USGS 2006 |

| Compart-ment | Content | Comment | Reference |
|---|---|---|---|
| | above LOD (0.2 µg/l).<br>Median <0.08 µg/l MTBE, 5% above LOD (0.2 µg/l). | MTBE, USA. Public wells | |
| **Waste water** | 910 ng/l MTBE | Urban sewer network in Helsinki (Helsinki, 2000) | ECB, 2002 |
| **Sewage sludge** | | No data on concentrations in sewage sludge were found. | |
| **Storm water** | 200-8700 ng/l, mean 1500ng/l MTBE | USA. Urban storm water, 41 samples with detectable concentrations (7%). | ECB, 2002 |
| **Soil** | <0.02-1000 µg/g DW | Finland. Many samples have been affected by emissions from leaking fuel tanks. | ECB, 2002 |
| **Air** | Mean: 4.1-14 µg/$m^3$ & 250-1300 µg/$m^3$ MTBE | At sampling point in the vicinity of service stations and in the centre of the pump island. Finland 1995. Gasoline blends with 11% MTBE. | Vainotalo et al. 1998 |
| | Mean: 0.85- 10 µg/$m^3$ MTBE | 5 sites with high degree of urbanization. USA. 1997. | Pankrow et al., 2003. |
| | Mean: <0.4- 3.4 µg/$m^3$ MTBE | 5 sites with moderate degree of urbanization. USA. 1997. | Pankrow et al., 2003. |
| | Mean: <0.01, 0.06 & 0.75 µg/$m^3$ MTBE | 3 sites with low degree of urbanization (ambient). USA. 1997. | Pankrow et al., 2003. |
| | Mean: 5.1 µg/$m^3$ MTBE<br>range: 0.5-160 µg/$m^3$ MTBE | "hot spot" for VOCs,traffic, local sources and urban plume from Philadephia, USA. | Zhu et al., 2008 |
| | Mean: 5.4 µg/$m^3$ MTBE<br>range: 0.9-18 µg/$m^3$ MTBE | Residential area, 1000 m east of "hot spot". USA | Zhu et al., 2008 |
| | Mean: 0.43 µg/$m^3$ MTBE | 3-week campaign in Nov-dec 2005. Roveredo, Switzerland.<br>Residential wood burning | Gaeggler et al., 2008 |
| | Mean: 0.39 µg/$m^3$ MTBE | 2005. Zürich, urban background, Switzerland. | Gaeggler et al., 2008 |
| | Spring mean: 0.50 µg/$m^3$ MTBE<br>Summer mean: 0.64 µg/$m^3$ MTBE<br>Fall mean: 0.54 µg/$m^3$ MTBE<br>Winter mean: 0.32 µg/$m^3$ MTBE | 2005. Zürich, urban background, Switzerland. | Legreid et al., 2007 |
| | Mars mean: 2.0 µg/$m^3$ MTBE<br>June mean: 1.7 µg/$m^3$ MTBE<br>August mean: 2.2 µg/$m^3$ MTBE<br>November mean: 2.2 µg/$m^3$ MTBE | Urban background Helsinki, 2001. | Hellén et al. 2003 |
| | Geometric Mean: 0.11 µg/$m^3$ MTBE | 644 Personal exposure measurements. 36% above LOD. 1999-2000. USA. | Wang et al. 2009 |

| Compart-ment | Content | Comment | Reference |
|---|---|---|---|
| | Median 0.13-0.33 µg/m$^3$ MTBE | Several Canadian cities 1995-1996. 46 samples. | ECB, 2002 |
| | 0.81-11 µg/m$^3$ MTBE | Edmonton, Canada 1995-1996.<br>1 km from petroleum refinery | ECB, 2002 |
| | Indoor living area, mean: 7.6 µg/m$^3$ MTBE<br>Indoor living area no attached garage (n=68), mean: 1 µg/m$^3$ MTBE<br>Indoor living area with attached garage (n=15), mean: 10 µg/m$^3$ MTBE<br>Outdoor mean: 1.2 µg/m$^3$ MTBE<br>Garage mean: 131 µg/m$^3$ MTBE<br>Basement mean: 8.8 µg/m$^3$ MTBE<br>Hallway mean: 3.2 µg/m$^3$ MTBE | Boston, USA. 2004/2005. 83 residential homes | Dodson et al., 2008 |
| | 0.7 µg/m$^3$ MTBE | Annual mean concentration of MTBE in the atmosphere in USA 1987-1988 (US EPA, 1994) | ECB, 2002 |
| **Precipi-tation** | <10–85 ng/l MTBE | Germany | Achten et al., 2001 |
| **Snow** | 11-631 ng/l MTBE, detected in 65% of the samples | Germany | Kolb & Püttman, 2006b |

# 5 Sampling strategy and study sites

Based on the consumption pattern, physico-chemical properties and likely distribution pathways, a sampling strategy was developed in order to determine concentrations of MTBE and ETBE in different matrices in the Swedish environment (Table 7). The measurements of MTBE and ETBE were predominantly performed at the Swedish west coast. Details of the samples are given in Appendix 1 and the geographical locations of the sites are shown in Figure 3.

## 5.1 Background samples

Kristineberg in Fiskebäckskil was chosen for background sampling of air and soil since the impact from traffic and industry is expected to be negligible here. In addition, this site was operated by IVL for extensive air measurements of VOC throughout 2007. Gårdsjön, a forest lake north-east of Göteborg was used for background sampling of surface water, and Lerum, about 20 km east of Göteborg was used for background sampling of ground water.

## 5.2 Point sources

The oil refinery Preemraff Lysekil AB uses MTBE as an additive in fuel, and was therefore selected as a potential point source. This refinery is situated about 100 km north of Göteborg at the west coast of Sweden. During 2007-2008 IVL performed more than a year of hourly air measurements of about 30 different VOCs at the site Govik, situated in the prevailing wind direction from Preemraff Lysekil. Air samples from this site, were used in the screening exercise in order to benefit from the extensive amount of VOC data.

ETBE is manufactured at Borealis AB in Stenungsund (Figure 3). During November 2006 and February, May and August 2007 hourly air measurements of 8 VOCs, including benzene, were performed at the site Skolan in Stenungsund. This site is located about 1 km south-east of the ETBE manufacturing site. Air sampling at this site was included in the screening. At Ödsmål, north of Stenungsund and the ETBE manufacturing site, IVL measured benzene and toluene hourly during four different months 2006/2007. One air sample from Ödsmål was included in this program.

Since the most important non-occupational exposure of MTBE/ETBE tends to be refuelling of cars, air samples from a service station in Göteborg were included.

Surface water was collected from a small creek in the vicinity of the point source Preemraff Lysekil. Two different surface waters from the Stenungsund area were also included. One from a small river about 2 km north of the ETBE plant and one from a ditch less than 1 km north-east of the plant. The ditch is also exposed to heavy traffic.

Soil samples representing point sources were collected at former service station at Kapellplatsen in Göteborg, in Govik, close to the point source Preemraff Lysekil AB, and at Skolan, close to the ETBE plant in Stenungsund.

## 5.3 Diffuse sources

### 5.3.1 Urban background

A monitoring site at rooftop level in central Göteborg, 5an, was used as an urban background station for MTBE and ETBE in air. As an assignment from the Swedish Environmental Protection Agency, IVL measured 29 VOC “ozone precursors" on an hourly basis, during six weeks each year at this station. This monitoring site is also used by the Environmental Department of Göteborg City and measurements of other air pollutants such as ozone and nitrous oxides are performed here. Meteorological parameters such as wind speed, wind direction, temperature and global radiation are also measured at the same location. Data of additional parameters are not used or presented in this report, but may be received through the Environmental Department of Göteborg City. Drinking water originating from the river Göta Älv was also included.

### 5.3.2 Urban / Traffic related

Street level air measurements were performed at two streets within the Göteborg City centre; Sprängkullsgatan and Södra vägen, and at one suburban site in Kärra, about 20 km north of the

centre of Göteborg. Corresponding indoor measurements were made adjacent to the street level measurements.

Traffic related storm water was sampled at three sites in the centre of Göteborg; Gårda, Korsvägen and Odinsplatsen. Surface water from Fattighusån in the very centre of Göteborg was also sampled The Fattighusån origin from the river Mölndalsån, which run in parallel to the heavily trafficked motorway E6.

Urban soil was collected at a traffic related site, Allén, in the centre of Göteborg.

One ground water sample was collected from Skallsjö ängar at Lerum about 20 km east of Göteborg. This is a municipal water source with heavy traffic nearby. One groundwater sample representing another urban area was sampled at Ulvsunda in Stockholm.

### 5.3.3 Municipal STPs

Influent and effluent water from Rya sewage treatment plant (STP) in Göteborg were included in order to investigate the STPs as diffuse sources.

### 5.3.4 Drinking water

Drinking water from point source areas were collected from a well at Govik close to Preemraff Lysekil and from a domestic well further east on the same peninsula; Stångenäs. Two private household wells in Lerkil, south of Göteborg, were selected to represent background conditions of well water, since the traffic and industry is limited in the area. A drinking water sample from Kungshamn was included as a background sample. Kungshamn is situated on the Sotenäs peninsula at the west coast about 120 km north of Göteborg. This drinking water origin from Dale vatten, which is a lake on the same peninsula.

Table 7. Sampling program

| Site | Air | Drinking water | Domestic Wells | STP water | Storm water | Surface water | Ground water | Soil | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Background** | | | | | | | | | |
| Swedish west coast | 3 | 1 | 2 | | | 2 | 1 | 1 | **10** |
| **Diffuse sources** | | | | | | | | | |
| Municipal STPs | | | | 2 | | | | | **2** |
| Göteborg urban area | 6 | 2 | | | | 1 | 1* | 1 | **11** |
| Street level sampling | 9 | | | | 3 | | 1 | | **13** |
| Indoors | 8 | | | | | | | | **8** |
| **Point source** | | | | | | | | | |
| Preemraff Lysekil AB | 3 | | 2 | | | 1 | | 1 | **7** |
| Stenungsund | 5 | | | | | 2 | | 1 | **8** |
| Gas station | 3 | | | | | | | 1 | **4** |
| **Total** | **37** | **3** | **4** | **2** | **3** | **6** | **3** | **5** | **63** |

* Ground water from urban area in Stockholm.

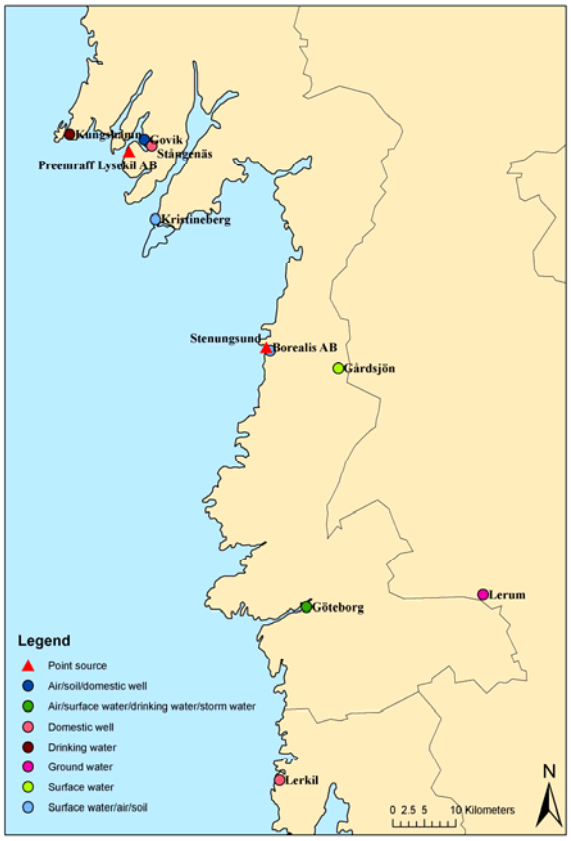



Figure 3 Location of sampling sites.

# 6 Methods

## 6.1 Sampling

Air sampling was performed by pumping air through tubes containing about 300 mg each of Tenax TA. The sampling flow was 100-300 ml/min and the total volume per sample ranged from 1 to 8 litres. All air sampling was performed as double sampling. Alternative air sampling with diffusive samplers containing Carbopack B was also conducted.

The staff at the sewage treatment plants collected the influent and effluent waters in preheated (200°C) 1 L glass bottles. The samples were stored in a cooler (+4°C) and were analysed the following day without conservation.

Surface and drinking water samples were collected in preheated (200°C) glass bottles. Samples were analysed directly after sampling or stored in a cooler (+4°C) and analysed the following day without conservation.

**Storm water** samples were collected in preheated (200°C) glass bottles during periods of sufficient precipitation. They were acidified and stored in a cooler (+4°C).

Pooled samples of surface **soil** (0-2 cm) from background as well as from affected areas were collected in preheated (200°C) glass jars and stored in a freezer (-18°C).

**Groundwater** was collected in preheated (200°C) glass bottles and stored in a cooler (+4°C). Sampling was kindly managed by Lotta Lewin-Pihlblad and Sven-Erik Gradstock, SGU, Geological Survey of Sweden.

## 6.2 Analysis

Water samples (100 ml) were purged with helium and the analytes were trapped on Tenax TA. Soil samples (about 1 g ww) were diluted in 100 ml of boiled and pre-purged milli-Q water before they were purged with helium and trapped on Tenax tubes. In this way all samples, from air, water and soil, were trapped on Tenax TA. All water and soil samples were purged and analysed twice.

Several procedural blanks were run among the samples. The possibility to correctly measure low concentrations is not only limited by instrument sensitivity, but also by the careful control of blank values.

The analysis of the Tenax TA adsorbent tubes was carried out on an automated thermal desorption instrument (ATD-400, Perkin-Elmer) attached to a gas chromatograph equipped with a flame ionisation detector (GC-FID). During the desorption stage the adsorbent tubes were heated to 250$^0$C during 5 minutes under a flow of helium. The desorbed components were refocused on a colt trap packed with Tenax-GR cooled to –30$^0$C. The trap was then heated rapidly to 250$^0$C in order to inject the retained analytes into the capillary column as a highly concentrated band of vapour. The analytes were separated on the analysis column (CP Sil 5 CB 50 m, 0.32 mm i.d., 1.2 μm) and detected with FID.

Quantification was based on comparison of the peak area to the known peak areas of various concentrations of the standard analytes. The calibration concerning MTBE, ETBE, benzene, toluene, ethylbenzene, xylenes, *n*-octane and *n*-nonane was controlled against certified standards on Tenax TA. The limit of detection (LOD) was defined as 5 times the blank samples standard deviation.

# 7 Results and discussion

Individual results for all samples are given in Appendix 2 and Appendix 3.

## 7.1 Background areas

Measured concentrations of MTBE and ETBE in background areas are reported in Table 8 as well as in Appendix 2.

Table 8 Background samples and results

| Site | Sampling date | Matrix | Unit | MTBE | ETBE | Benzene | Toluene |
|---|---|---|---|---|---|---|---|
| Kristineberg | 2009-01-28 | air | µg/m$^3$ | <0.15 | <0.14 | 0.55 | 0.49 |
| Kristineberg | 2009-02-18 | air | µg/m$^3$ | 0.49 | <0.18 | 1.3 | 1.5 |
| Kristineberg | 2009-03-03 | air | µg/m$^3$ | 0.09 | <0.05 | 0.52 | 0.22 |
| Gårdsjön | 2008-12-16 | surface water | ng/l | <10 | <7.0 | 12 | 18 |
| Gårdsjön | 2009-02-26 | surface water | ng/l | <10 | <7.0 | 13 | 41 |
| Kristineberg | 2009-01-28 | soil | ng/g DW | 22 | <0.81 | <1.6 | 940 |

The average MTBE concentration in background air at the Swedish west coast was 0.22 µg/m$^3$, counting non-detected levels as half the detection limit. This is comparable to the concentrations found at three background sites in USA, where mean concentrations were <0.01-0.75 µg/m$^3$ (Pankrow et al., 2003). In a three week campaign in November-December 2005 median concentrations of MTBE in Roveredo, a village in Switzerland, were 0.43 µg/m$^3$ (Gaeggler et al. 2008). At all three sampling occasions at Kristineberg the wind direction was south to south west and the wind speed was relatively low. ETBE concentrations in air were below LOQ at all three occasions.

Figure 4 shows the measured levels of MTBE compared to the levels of benzene and toluene and their monthly average in February 2007. As evident from the figure, the concentration of MTBE as well as benzene and toluene in air was slightly enhanced in the sample collected in February compared to the other two occasions and also compared to the average concentration in February 2007 for the two latter substances. This may be an indication of a general elevation of fuel additive concentrations in air in February 2008 compared to average conditions. The average concentrations of benzene and toluene were about a factor of 3.5 higher than the average concentration of MTBE measured in this project.

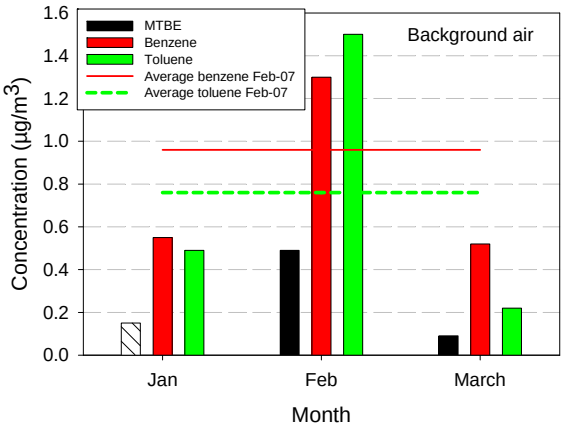



Figure 4. Results from measurements of MTBE and other solvents in background air. The striped bar represents levels below the detection limit.

The MTBE and ETBE concentrations found in soil collected at Kristineberg were 22 and <0.81 µg/ g DW respectively. The MTBE concentration seems high for background conditions. Soil concentrations of <0.02-1000 µg/g DW MTBE have been reported from Finland, but many of those samples were affected by leaking fuel tanks (ECB, 2002).

The concentrations in the two surface waters collected at Gårdsjön were below LOQ for both MTBE (<10 ng/l) and ETBE (<7 ng/l).

## 7.2 Point source areas

### 7.2.1 Gasoline station

Three air samples from the centre of the pump island at a service station in Göteborg were included in the screening. The average concentration of MTBE was 5.0 µg/m$^3$ and of ETBE 0.49 µg/m$^3$. The results are shown in Table 9.

Table 9. Gasoline station, samples and results

| Site | Matrix | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|
| Gasoline station | soil | ng/g DW | 18 | <0.57 | <1.1 | 100 | <0.14 | 0.25 | <1.6 |
| Gasoline station | air | µg/m$^3$ | 3.8 | 0.43 | 5.5 | 29 | 6.2 | 23 | 8.5 |
| Gasoline station | air | µg/m$^3$ | 5.8 | 0.36 | 3.7 | 16 | 4.7 | 11 | 5.9 |
| Gasoline station | air | µg/m$^3$ | 5.5 | 0.67 | 5.7 | 38 | 6.7 | 25 | 9.1 |

Mean MTBE concentrations in the centre of pump islands at service stations in Finland were 250-1300 µg/m$^3$ (Vainotalo et al., 1998). Again, part of the explanation for the higher concentrations measured in Finland is likely to be the higher content of MTBE in the gasoline in Finland compared to Sweden.

A soil sample was collected at a former service station were the fuel tanks were dug out. The ETBE concentration was below LOQ and the MTBE concentration was 18 ng/g DW which was below the concentrations from the urban traffic related site and the background site at Kristineberg.

### 7.2.2 Preemraff Lysekil AB

Measurements in the vicinity of the refinery Preemraff Lysekil AB were performed at the site Govik about 1 km north east of the refinery. Measurement results are shown in Table 10.

Table 10 Measurements in the vicinity of Preemraff Lysekil AB

| Sampling date | Matrix | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|
| 2009-01-28 | Soil | ng/g DW | 11 | <0.65 | <1.4 | 480 | 0.20 | 0.60 | <1.9 |
| 2009-03-03 | surface water | ng/l | <10 | <7.0 | 10 | 22 | 2.2 | 5.8 | |
| 2009-01-28 | Domestic well | ng/l | 14 | <7.0 | 21 | 490 | 230 | 7.1 | |
| 2009-01-28 | Air | µg/m$^3$ | <0.20 | <0.17 | 0.52 | 0.48 | 0.09 | 0.18 | 0.08 |
| 2009-02-18 | Air | µg/m$^3$ | 0.37 | <0.16 | 1.1 | 1.2 | 0.18 | 0.50 | 0.25 |
| 2009-03-03 | Air | µg/m$^3$ | 0.12 | <0.10 | 0.46 | 0.31 | 0.04 | 0.05 | |

At all three occasions air measurements of MTBE and ETBE were performed at Govik the wind direction was south to south west and the wind speed was relatively low. Therefore, impact on the air concentrations from the refinery could be expected even if the wind direction never was directly from the refinery towards Govik.

ETBE concentrations in air were below LOQ at all three occasions while MTBE concentrations varied from 0.12 µg/m³ on the 3rd of Mars to 0.37 µg/m³ on 18th of February. On 28th of January the MTBE concentration was below LOQ (<0.20 µg/m³).

The average concentrations in air from one year of hourly measurements during 2007 at Govik were 0.45 µg/m³ of benzene and 0.66 µg/m³ of toluene. Figure 7 shows the measured levels of MTBE compared to the levels of benzene and toluene and their monthly average in February 2007. On 18th of February 2008 both benzene and toluene concentrations were slightly higher than average in February 2007, but at the remaining two occasions the concentrations were slightly lower. Hence the MTBE concentration was higher on the occasion when concentrations of other VOCs showed probable impact from the refinery.

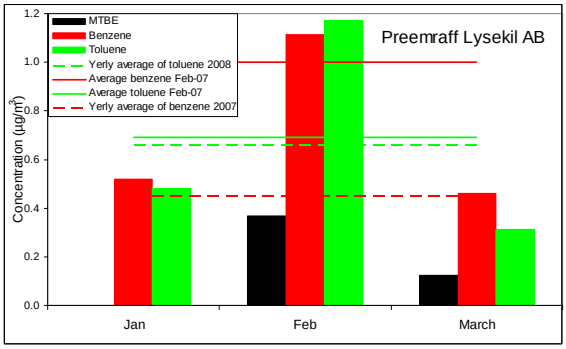



Figure 7 Results from measurements of MTBE and solvents in the vicinity of Preemraff Lysekil AB.

Measured MTBE concentrations 1 km from a refinery in Edmonton, Canada, 1995-1996 were 0.81-11 µg/m³ (ECB, 2002). At a comparison the measured MTBE concentrations of Govik were low.

One soil sample from Govik was analysed. The ETBE concentration was below LOQ and the MTBE concentration 11 ng/g DW. The MTBE concentration in soil from Govik was about half of the concentration in soil at the background site, Kristineberg, and one third of the concentration in soil at the urban traffic related site. The level of toluene was about half of the measured toluene levels at Kristineberg and at the urban site while remaining measured VOCs were in the same range at all three sites.

Surface water from a small creek in the vicinity of Govik was analysed and both MTBE and ETBE concentrations were below LOQ.

A domestic well in Govik, mainly used for garden water, was sampled and the ETBE concentration was below LOQ and the MTBE concentration 14 ng/l. Thus, the MTBE concentration of the well in Govik was lower than the MTBE concentrations of the wells in Lerkil while other measured VOCs were elevated in Govik.

### 7.2.3 Borealis AB, Stenungsund

Measurement results from Stenungsund are shown in Table 11 as well as in Appendix 2 and 3. At all three occasions when air measurements of MTBE and ETBE were performed at Stenungsund the wind direction was south to south west and the wind speed was relatively low. Hence no impact on air concentrations from the ETBE plant could be expected at Skolan.

Table 11 Measurements in the Stenungsund area

| Site | Sampling date | Matrix | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|---|
| Skolan | 2009-01-28 | soil | ng/g DW | 50 | <0.89 | <1.7 | **>2700** | 0.37 | 0.90 | <2.5 |
| Skolan | 2009-01-28 | air | µg/m$^3$ | <0.25 | <0.24 | 0.64 | 0.81 | 0.15 | 0.35 | 0.13 |
| Skolan | 2009-02-18 | air | µg/m$^3$ | 0.28 | <0.18 | 1.0 | 1.1 | 0.18 | 0.50 | 0.27 |
| Skolan | 2009-03-03 | air | µg/m$^3$ | 0.29 | <0.10 | 0.71 | 0.87 | 0.16 | 0.51 | |
| Ödsmål | 2009-02-18 | air | µg/m$^3$ | 0.35 | <0.20 | 0.97 | 0.91 | 0.15 | 0.38 | 0.16 |
| Downwind | 2009-01-28 | air | µg/m$^3$ | <0.23 | <0.24 | 0.93 | 1.0 | 0.21 | 0.62 | 0.35 |
| River | 2009-03-03 | surface water | ng/l | <10 | <7.0 | 11 | 15 | 2.6 | 4.4 | |
| Ditch | 2009-03-03 | surface water | ng/l | 10 | 9.0 | 9.9 | 27 | 1.0 | 4.5 | |

ETBE concentrations in air were below LOQ at all three occasions while MTBE concentrations varied from <0.25 -0.29 µg/m$^3$.

The average concentration in air at Skolan from one month of hourly measurements in February 2007 was 1.1 µg/m$^3$ of benzene and at Ödsmål in January 2007 1.2 µg/m$^3$. As shown in figure 8, the benzene concentrations at Skolan were lower than average of February 2007 on all three measurement occasions in 2009. The only measurement in Ödsmål gave a lower benzene concentration than average of January 2007. Hence, if the benzene concentrations are used as a measure of air quality the conclusion is that the air quality on the given occasions was better than usual in the winter season.

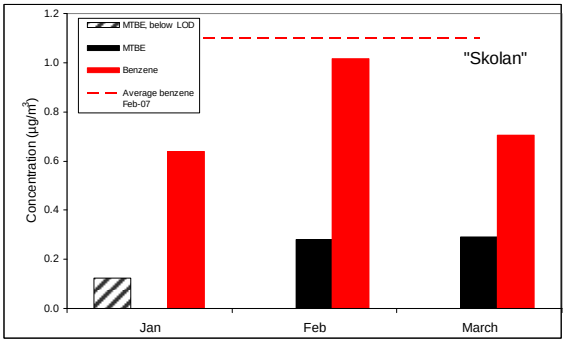



Figure 8 Results from measurements of MTBE and benzene at the site Skolan.

At one occasion, 28th of January, air was sampled downwind from Borealis AB. The concentrations of benzene, toluene, ethyl benzene and xylenes were slightly higher compared to skolan, but the concentrations of MTBE and ETBE were not elevated.

Two different surface waters were analysed. One from a small river about 2 km north of the ETBE plant and one from a ditch less than 1 km north east from the plant. The ditch is also exposed to heavy traffic. In the river both MTBE and ETBE were below LOQ and the concentrations in the ditch were just above LOQ; 10 ng/l MTBE and 9 ng/l ETBE.

One soil sample was collected at the site Skolan. The ETBE concentration was below LOQ (0.89 ng/g DW) but the MTBE concentration was about twice the concentration in soil at the background site and five times the concentration in soil in the vicinity of the refinery. The toluene concentration was over range in the analysis and indicates a contamination of the soil at the site.

## 7.3 Diffuse sources

### 7.3.1 Urban background - rooftop measurements

The results from air measurements in central Gothenburg, 5an are presented in Table 12. The concentrations of ETBE were below LOQ at all sampling occasions, while MTBE concentrations were in range 0.11-1.1 µg/m³.

Table 12 Air measurements at rooftop level

| Site | Sampling date | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m*+*p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|
| 5an | 2008-12-16 11:00 | µg/m³ | 0.46 | <0.25 | 1.5 | 1.8 | 0.47 | 1.3 | 0.52 |
| 5an | 2008-12-17 19:00 | µg/m³ | 0.66 | <0.25 | 2.1 | 2.5 | 0.62 | 2.1 | 0.62 |
| 5an | 2008-12-19 07:30 | µg/m³ | 0.46 | <0.16 | 1.0 | 3.3 | 0.44 | 1.6 | 0.61 |
| 5an | 2009-03-11 07:00 | µg/m³ | 1.1 | <0.13 | 1.5 | 4.2 | 2.2 | 3.7 | 1.2 |
| 5an | 2009-03-11 14:30 | µg/m³ | 0.59 | <0.13 | 1.2 | 2.2 | 0.46 | 1.8 | 0.54 |
| 5an | 2009-03-14 07:30 | µg/m³ | 0.11 | <0.13 | 0.75 | 1.1 | 0.12 | 0.42 | 0.09 |

The measured concentrations of MTBE and benzene are shown in Figure 9 as well as the ratio between benzene and MTBE. The benzene/MTBE ratio was in the range 2.0-3.2, except for two occasions. These were both among the three measurements that were performed around seven o'clock in the morning. At 07:30 on Friday 19 of December the ratio was 2.2, close to average. At 07:00 on Wednesday 11 of March, however, the ratio was only 1.4 which indicates a higher proportion of the VOCs having a traffic origin (Chang et al., 2003). The third morning measurement was performed on a Saturday when traffic influence was lower. This may explain why the ratio was as high as 6.8 on this occasion.

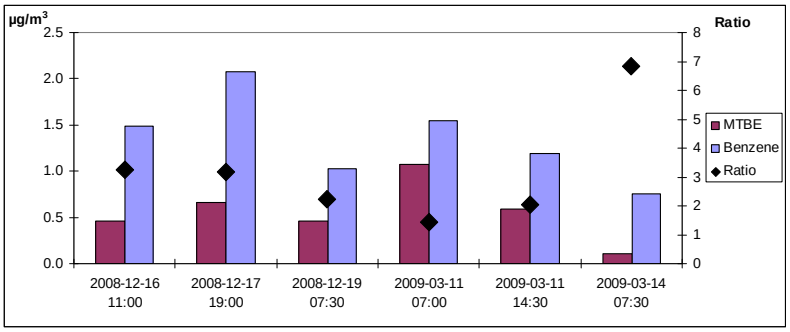



Figure 9. Measured MTBE and benzene concentrations at urban rooftop level and the ratio benzene/MTBE.

The MTBE concentrations measured at roof level in Gothenburg were in the same order of magnitude as detected levels in urban background air in Zurich, Switzerland, where the mean concentration was 0.39 µg/m³ (Gaeggler et al. 2008). Measurements at an urban background site in Helsinki 2001 gave a mean MTBE concentration of 2.2 µg/m³ in November and 2.0 µg/m³ in March (Hellén et al., 2003). The somewhat higher MTBE concentrations in Helsinki compared to 5an can partly be explained by the fact that the Finnish measurements were conducted at a central sports arena closer to the ground level and by the higher concentration of MTBE in Finish fuels compared to Swedish (see section 3).

## 7.3.2 Urban / traffic related

### *7.3.2.1 Street level measurements*

The nine measurements performed at street level showed MTBE concentrations in the range 0.31-2.5 µg/m³. The ETBE concentrations were below LOQ in all samples, see Table 13. At the suburban site, Kärra, the MTBE concentration was 0.63 µg/m³ at one occasion, which was in the same concentration level as in the streets with more dense traffic.

Table 13 Air measurements at street level

| Site | Sampling date | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|
| Sprängkullsgatan | 2008-12-16 | µg/m³ | 0.44 | <0.10 | 2.1 | 6.1 | 1.1 | 3.9 | 1.3 |
| Sprängkullsgatan | 2009-02-05 | µg/m³ | 0.56 | <0.22 | 3.5 | 6.9 | 1.2 | 4.3 | 1.7 |
| Sprängkullsgatan | 2009-02-17 | µg/m³ | 2.5 | <0.21 | 3.6 | 11 | 2.1 | 7.5 | 2.7 |
| Sprängkullsgatan | 2009-04-01 | µg/m³ | 0.64 | <0.10 | 2.6 | 7.2 | 1.3 | 4.4 | |
| Södra vägen | 2008-12-17 | µg/m³ | 0.89 | | 2.7 | 8.2 | 1.5 | 5.1 | 1.7 |
| Södra vägen | 2009-02-03 | µg/m³ | 0.79 | <0.22 | 3.4 | 9.5 | 1.9 | 6.4 | 2.2 |
| Södra vägen | 2009-02-25 | µg/m³ | 0.31 | <0.17 | 1.4 | 4.4 | 0.70 | 2.5 | 1.0 |
| Kärra, suburban air | 2009-02-19 | µg/m³ | 0.63 | <0.20 | 1.4 | 4.2 | 0.70 | 2.5 | 1.0 |
| Kärra, suburban air | 2009-03-31 | µg/m³ | <0.08 | <0.05 | 0.46 | 0.38 | 0.07 | 0.18 | |

At Sprängkullsgatan the measured VOC concentrations were in the same level at all four sampling occasions with exception of the elevated concentration of MTBE on the 17th of February. At this occasion the sampling was performed at 08:00 in the dense morning traffic. Also the ratio benzene/MTBE was different at this occasion which is illustrated in Figure 10.

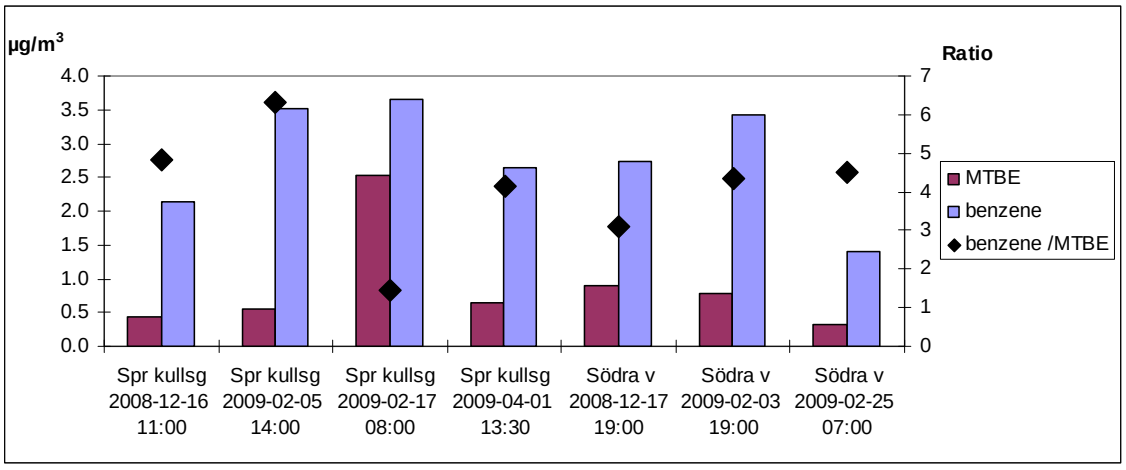



Figure 10. Measured MTBE and benzene concentrations at Sprängkullsgatan and at Södra vägen and the ratio benzene/MTBE.

### *7.3.2.2 Indoor air*

The indoor sampling was performed at the first floor right above street level, in connection to the street level sampling outside the house. Results are presented in Table 14.

Table 14. Indoor air measurements and results

| Site | Sampling date | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|
| Sprängkullsgatan | 2008-12-16 | µg/m$^3$ | 0.30 | <0.20 | 1.5 | 5.2 | 0.66 | 2.3 | 0.62 |
| Sprängkullsgatan | 2009-02-05 | µg/m$^3$ | 0.37 | <0.36 | 2.1 | 3.0 | 0.54 | 1.6 | 0.57 |
| Sprängkullsgatan | 2009-04-01 | µg/m$^3$ | <0.10 | <0.10 | 0.57 | 1.4 | 0.29 | 0.99 | 0.38 |
| Södra vägen | 2008-12-17 | µg/m$^3$ | 0.71 | | 2.1 | 5.4 | 1.0 | 3.2 | 1.1 |
| Södra vägen | 2009-02-03 | µg/m$^3$ | 0.43 | | 2.2 | 11 | 1.9 | 6.1 | 1.9 |
| Södra vägen | 2009-02-25 | µg/m$^3$ | 0.31 | | 0.73 | 3.3 | 0.46 | 1.6 | 0.54 |
| Kärra | 2009-02-19 | µg/m$^3$ | 0.53 | | 1.3 | 5.5 | 0.87 | 2.5 | 0.82 |
| Kärra | 2009-03-31 | µg/m$^3$ | 0.09 | <0.10 | 0.48 | 3.1 | 0.34 | 0.85 | |

The indoor concentrations of MTBE were in the range <0.10-0.71 µg/m$^3$. At all measurements at Sprängkullsgatan ETBE were below LOQ. At Södra vägen there was interference in the analysis of ETBE and no results were obtained.

At six occasions both the indoor and outdoor concentrations of MTBE were above LOQ and the ratios between them could be calculated. The average outdoor/ indoor ratio of MTBE was 1.4 and all ratios were in range between 1.0-1.8. The MTBE concentrations and outdoor/ indoor ratios are shown in Figure 11.

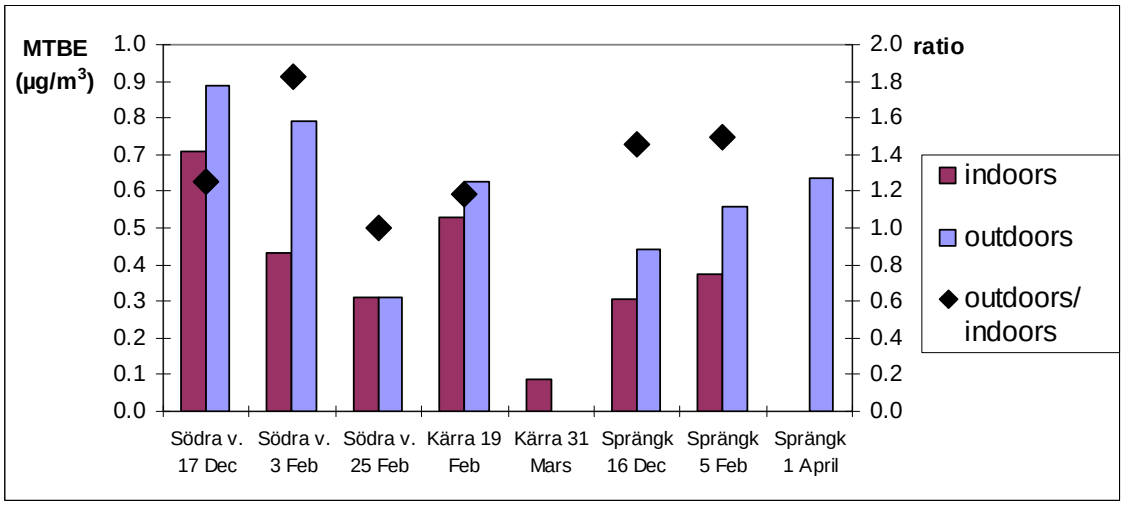



Figure 11. Measured MTBE concentrations indoor and outdoor at the same occasions and the ratio outdoor/indoor.

The measured indoor concentrations of MTBE of <0.10-0.71 µg/m$^3$ were just below the mean value of 1 µg/m$^3$ from 68 homes in Boston with no attached garages (Dodson et al., 2008). The outdoor mean in the Boston study was 1.2 µg/m$^3$, which makes the ratio outdoor/indoor 1.2 and about the same as in Göteborg.

#### 7.3.2.3 Urban soil

The traffic influenced urban soil sample contained 37 ng/g DW of MTBE and <0.69 ng/g DW of ETBE. The MTBE content was almost twice as high compared to the background sample from Kristineberg, indicating an impact of traffic also on the soil compartment.

#### 7.3.2.4 Urban surface water

The concentrations in the surface water collected at Fattighusån in the centre of Göteborg were 32 ng/l of MTBE and 7.6 ng/l of ETBE respectively. In spite of the geographical location of the river, right next to a highly trafficked motorway the MTBE concentration was in similar order of magnitude as concentrations found in the German rivers Elbe, Oder, Rhein and Main (7-160 ng/l ; ECB, 2002). The percentage of MTBE in fuel is about the same in Sweden as in Germany.

The concentrations found in the water sample from Göteborg were lower compared to samples from two creeks in Helsinki subjected to diverse emissions from storm water, where the MTBE concentrations were 420-280 ng/l (ECB, 2002). The concentrations in Göteborg were also lower than in the seven rivers of USA from where MTBE concentrations between 150-760 ng/l have been reported (ECB, 2002). The higher concentrations compared to surface water in Göteborg may be due to the higher rate of MTBE in gasoline in Finland and USA compared to Sweden.

#### 7.3.2.5 Traffic storm water

Traffic storm water was analysed from three locations in Göteborg. The results are shown in Table 15. The concentrations of MTBE and ETBE were in narrow ranges; 71 – 77 ng/l MTBE and 19-20 ng/l ETBE.

Table 15. Traffic storm water samples and result

| Site | Matrix | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|
| Gårda | Traffic storm water | ng/l | 77 | 20 | 110 | >31000 | 98 | 96 | 70 |
| Korsvägen | Traffic storm water | ng/l | 69 | 19 | 190 | 390 | 20 | 95 | 73 |
| Odinsplatsen | Traffic storm water | ng/l | 71 | 19 | 77 | 1000 | 18 | 62 | 54 |

#### 7.3.2.6 Groundwater

Groundwater was sampled at three locations according to Table 16. The background sample from a natural spring in Lerum contained no MTBE or ETBE above LOQ. However, at another site in Lerum characterised by heavy traffic the MTBE concentration was 14 ng/l. At an urban site Ulvsunda in Stockholm, MTBE and ETBE were found at concentrations of 240 and 31 ng/l respectively.

Table 16 Groundwater samples

| Municipality | SGU Stn # | Comment | MTBE ng/l | ETBE ng/l |
|---|---|---|---|---|
| Lerum | 10007:1 | Skallsjö ängar, municipal water source, heavy traffic nearby | 14 | <7 |
| Stockholm | 32B123 | Ulvsunda, Urban site | 240 | 31 |
| Lerum | 54:18 | Natural spring. Influenced only by air borne deposition | <10 | <7 |

When 101 ground water samples were analysed in Austria, 75% of them showed MTBE concentrations above 10 ng/l (ECB, 2002) and of 74 non-urban groundwater sites in Germany 13% had MTBE concentrations above 10 ng/l (LOQ) (Kolb and Püttman, 2006c).

Out of 67 urban groundwater sites in Germany, 63% of the samples contained MTBE in concentrations above 10 ng/l (LOQ) with the median of 60 ng/l MTBE (Kolb and Püttman, 2006c). The MTBE concentration of 240 ng/l in Ulvsunda was in a comparative level with the German samples.

In several studies, for example in Denmark, England, Wales and USA (ECB 2002 and USGS 2006), the high LOQs of 100-200 ng/l makes it difficult to compare the concentrations.

### 7.3.3 Sewage treatment plant

Influent and effluent water from the municipal sewage treatment plant (STP) Ryaverken in Göteborg were analysed. The ETBE concentration was only 16 % lower in the effluent water compared to the influent and the MTBE concentration was even somewhat higher in the effluent water (see Table 17), indicating negligible removal of these substances in STPs.

Table 17. STP Ryaverket, Göteborg. Water samples and results

| Site | Matrix | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|
| Ryaverken | Influent water | ng/l | 110 | 31 | 35 | 1500 | 58 | 150 | 72 |
| Ryaverken | Effluent water | ng/l | 120 | 26 | 7.3 | 280 | 62 | 130 | 72 |

An MTBE concentration of 910 ng/l was found in water from a sewer network in Helsinki (ECB, 2002). The difference in MTBE concentrations between Göteborg and Helsinki may be explained by the higher extent of MTBE in Finnish fuel compared to Swedish.

### 7.3.4 Municipal drinking water and domestic wells

Three drinking water samples and three samples from domestic wells were included in the program. The results are illustrated in Table 18. The ETBE concentrations were below LOD in all three analysed municipal drinking waters. MTBE was detected in one of the drinking water samples from Göteborg; Södra vägen, at 34 ng/l. The analysis results are comparative to the ones from Germany (Kolb and Püttman, 2006a).

Table 18. Municipal drinking water and domestic wells samples and results

| Type | Site | Unit | MTBE | ETBE | Benzene | Toluene | Ethylbenzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|
| Municipal | Göteborg, Södra vägen | ng/l | 34 | <7.0 | <6.0 | 26 | 1.2 | 4.1 | 2.9 |
| Municipal | Göteborg, Kärra | ng/l | <10 | <7.0 | <6.0 | 8.7 | 0.21 | 3.0 | |
| Municipal | Kungshamn | ng/l | <10 | <7.0 | 8.3 | 20 | 1.6 | 7.2 | 1.6 |
| Domestic well | Lerkil 1 | ng/l | 37 | 7.9 | 13 | 18 | 2.2 | 6.4 | 6.2 |
| Domestic well | Lerkil 2 | ng/l | 140 | <7.0 | 7.5 | 7.0 | 0.54 | 2.3 | 1.5 |
| Domestic well | Stångenäs | ng/l | 34 | <7.0 | <6.0 | 9.4 | 1.5 | 2.0 | |

The MTBE concentrations found in water from domestic wells were between 34-140 ng/l. In Germany, France and USA water from numerous wells have been analysed for MTBE. In all these studies the range of detection was very low since the LOQs were high; 200-500 ng/l. However, in Germany, 15% of the wells in urban areas showed MTBE concentrations above 500 ng/l (ECB, 2002).

In one of the wells in Lerkil the ETBE concentration was 7.9 ng/l while the concentrations were below LOQ in the other two samples, which can be compared to a study in the USA where ETBE was determined in 1215 domestic and in 818 public wells. In this study 0% was above 200 ng/l among the domestic and 0.12% among the public wells (USGS, 2006).

The well water sample collected near the point source (Stångenäs, near Preemraff Lysekil refinery), did not contain higher concentrations of MTBE or ETBE compared to the wells in Lerkil, south of Göteborg.

# 8 Risk characterisation

In order to judge if the detected levels in the current screening study may pose a risk to humans and/or the environment, a risk characterisation exercise was performed, according to the procedure outlined in the EU risk assessment report (ECB, 2002).

For aquatic and terrestrial organisms, the measured concentrations (MEC) were compared to the predicted no effect concentrations (PNEC) derived by ECB (2002), which are listed in Table 5.

- Surface water: MEC: 0.00001 – 0.00012 mg/L; yielding MEC/PNEC ratios of $3.8\times10^{-6}$-$4.6\times10^{-5}$
- Soil: MEC: 0.009 - 0.025 mg/kg dw (assuming 50 % dw); yielding MEC/PNEC ratios of 0.01 - 0.03

Thus, no risks are associated with environmental exposure of MTBE.

Regarding human exposure, Table 19 shows a scenario for human exposure based on the concentrations found in the current screening study. The exposure is calculated for a person living in a heavily trafficked urban area, frequently visiting indoor shopping centres and regularly refuelling cars, as well as consuming contaminated well water.

Table 19. Estimated exposure routes and daily dose for a person living in the urban area.

| Source/Area of interest | Exposure route[1] | Duration of exposure | Concentrations found | Dose (µg/day) |
|---|---|---|---|---|
| Urban street level | Inhalation of air at street level | 10-11 hours/day | <0.08-2.5 µg/m$^3$ | <0.7-23 |
| Contaminated drinking water | Oral intake | 2 L/day | <10-140 ng/L | <0.02-0.28 |
| Indoor shopping area | Inhalation | 0.5 - 1 h/day | <0.1-0.71 µg/m$^3$ | <0.04-0.6 |
| Petrol station | Inhalation | 1-5 min/day, 2-3 visits/week | 3.8 - 5.8 µg/m$^3$ | 0.01-0.2 |
| **Total daily dose** | | | | **0.01-24** |

[1]Inhalation volume was estimated as 20 m$^3$/24 h = 0.014 m$^3$/minute (ECB, 2002)

As evident from the Table, the daily dose was estimated to be 0.01-24 μg/day for an urbanised Swedish person – which corresponds to 0.0001-0.34 μg/kg/day for a 70-kg adult. This yields a margin of safety (MOS) of at least $\mathbf{7.3 \times 10^5}$ considering the LOAEL of 250 mg/kg, if the higher dose is assumed. Therefore, no risks for humans are anticipated to arise due to exposure to MTBE.

## 8.1 Evaluation of diffusive air samplers

Alternative air sampling with one week of diffusive sampling was conducted at several sites. Theoretical uptake rates were used to calculate air concentrations of MTBE and ETBE and the uptake rate of MTBE was confirmed with one week of active hourly sampling at the site 5an. Results from the diffusive samplers are shown in table 20.

Table 20. Diffusive samplers and results from one week sampling.

| Site | week | Sampling start | Unit | MTBE | ETBE | Benzene | Toluene | Ethyl-benzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|---|
| Sprängkullsgatan | 0850 | 2008-12-15 | μg/m³ | 1.5 | 0.21 | 1.4 | 3.7 | 0.89 | 3.1 | 1.2 |
| Sprängkullsgatan | 0903 | 2009-01-12 | μg/m³ | 1.3 | 0.62 | 1.5 | 3.4 | 0.84 | 3.0 | 1.2 |
| Sprängkullsgatan | 0905 | 2009-01-26 | μg/m³ | 1.5 | <0.10 | 2.0 | 5.3 | 1.2 | 4.0 | 1.7 |
| Råö | 0905 | 2009-01-26 | μg/m³ | 0.20 | <0.10 | 0.85 | 0.79 | 0.09 | 0.15 | 0.07 |
| Kärra | 0905 | 2009-01-26 | μg/m³ | 0.70 | <0.10 | 0.90 | 1.5 | 0.34 | 1.2 | 0.35 |
| Södra vägen | 0905 | 2009-01-27 | μg/m³ | 0.65 | <0.10 | 1.0 | 2.3 | 0.44 | 1.3 | 0.58 |
| 5an | 0851 | 2008-12-12 | μg/m³ | 0.39 | <0.10 | 1.1 | 1.2 | 0.24 | 0.77 | 0.38 |
| 5an | 0905 | 2009-01-26 | μg/m³ | 0.12 | <0.10 | 0.47 | 1.1 | <0.10 | 0.19 | <0.10 |
| 5an | 0906 | 2009-02-02 | μg/m³ | 0.54 | 0.14 | 1.5 | 1.9 | 0.29 | 0.74 | 0.34 |
| 5an | 0911 | 2009-03-11 | μg/m³ | 0.36 | <0.10 | 0.85 | 1.8 | 0.40 | 1.0 | 0.49 |

At Sprängkullsgatan diffusive samplers were exposed at three different weeks; 0850, 0903 and 0905. The MTBE concentrations were in the range 1.3-1.5 μg/m³ as weekly averages while ETBE concentrations were <0.10-0.62 μg/m³.

Also at the urban rooftop site 5an diffusive samplers were exposed at several weeks; 0851, 0905, 0906 and 0911. The weekly averages at 5an were 0.12-0.54 μg/m³ MTBE, witch is in the same magnitude as the Zurich winter mean of 0.32 μg/m³ in urban background (Legreid et al., 2007). The ETBE concentrations at 5an were <0.10-0.14 μg/m³.

During week 0905 diffusive sampling was conducted at five sites. The concentrations are shown in Figure 12. As expected the highest concentrations of MTBE were measured at the street level sites Sprängkullsgatan and Södra vägen as well as at the suburban site Kärra. Average MTBE concentrations were 0.12 μg/m³ at the rooftop site 5an and 0.20 μg/m³ at the background site Råö, south of Göteborg.

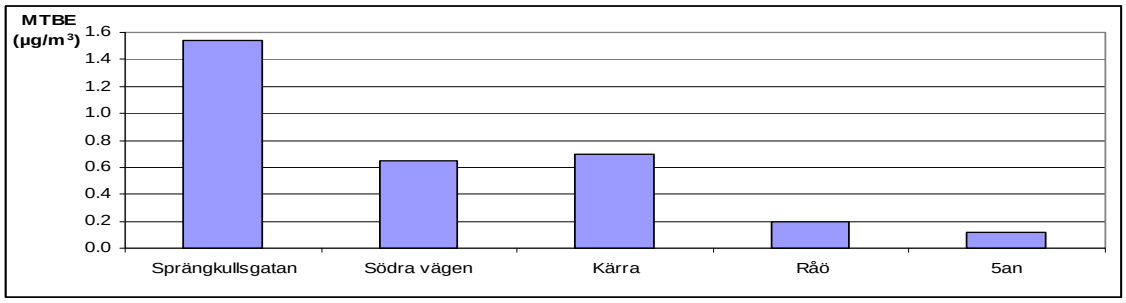



Figure 12 MTBE concentrations measured by diffusive sampling at different sites during week 0905.

# 9 Conclusions

The main conclusions to be drawn in the current project are the following:

- Methyl-tert-butyl ether occurs frequently in the Swedish atmosphere, at point sources as well as in background areas.
- Ethyl-tert-butyl ether is rarely found in the Swedish environment, and when detected, concentrations were significant lower than for MTBE
- Highest levels in air were found at the gas station during refuelling, which confirms that this is an important source of fuel additive emissions to the atmosphere. MTBE and ETBE concentrations in air, soil and surface waters at other potential point sources were in the same order of magnitude as those found in background areas.
- The ratios of MTBE concentrations in outdoor/indoor air were between 1.0-1.8 (average: 1.4
- Both MTBE and ETBE were present in urban surface water.
- MTBE, but not ETBE, was occasionally detected in drinking water.
- The cleaning efficiency of MTBE and ETBE in Ryaverken STP is poor.
- The concentrations and estimated daily exposure found in the current screening project are a factor of **29 – $1.7\times10^9$ lower** than established risk levels, thus no effects are expected to occur as a result of MTBE neither to humans, nor other organisms.
- Considering the fact that MTBE and ETBE are found in the Swedish environment and that the usage and emissions of these substances can change, future follow up studies are recommended.
- The results from the evaluation of diffuse sampling compared to active sampling showed that sampling with the more cost efficient diffusive samplers could be used as an indicative method.

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**Appendix 1** National program, Sample characteristics

| Sample # | Type | City / Municipality | Site | Matrix | Sampling date | N | E |
|---|---|---|---|---|---|---|---|
| 1 | Background | Fiskebäckskil | Kristineberg | soil | 2009-01-28 | N58$^0$14.86 | E11$^0$26.73 |
| 2 | Background | Fiskebäckskil | Kristineberg | air | 2009-01-28 | N58$^0$14.86 | E11$^0$26.73 |
| 3 | Background | Fiskebäckskil | Kristineberg | air | 2009-02-18 | N58$^0$14.86 | E11$^0$26.73 |
| 4 | Background | Fiskebäckskil | Kristineberg | air | 2009-03-03 | N58$^0$14.86 | E11$^0$26.73 |
| 5 | Background | Stenungsund | Gårdsjön | surface water | 2008-12-16 | N58$^0$03.06 | E12$^0$01.14 |
| 6 | Background | Stenungsund | Gårdsjön | surface water | 2009-02-26 | N58$^0$03.06 | E12$^0$01.14 |
| 7 | Background | Lerum | SGU Stn 54:18 | groundwater | 2009-05-16 | N57$^0$44.37 | E12$^0$26.23 |
| 8 | Traffic related | Lerum | SGU Stn 10007:1 | groundwater | 2009-05-16 | N57$^0$47.35 | E12$^0$20.55 |
| 9 | Urban | Stockholm | SGU Stn 32B123, Ulvsunda | groundwater | 2009-03-20 | N59$^0$220.93 | E17$^0$57.63 |
| 10 | Point source | Preemraff Lysekil | Govik | soil | 2009-01-28 | N58$^0$21.69 | E11$^0$26.92 |
| 11 | Point source | Preemraff Lysekil | Govik | air | 2009-01-28 | N58$^0$21.69 | E11$^0$26.92 |
| 12 | Point source | Preemraff Lysekil | Govik | air | 2009-02-18 | N58$^0$21.69 | E11$^0$26.92 |
| 13 | Point source | Preemraff Lysekil | Govik | air | 2009-03-03 | N58$^0$21.69 | E11$^0$26.92 |
| 14 | Point source | Preemraff Lysekil | Govik | surface water | 2009-03-03 | N58$^0$21.69 | E11$^0$26.92 |
| 15 | Point source | Stenungsund | Borealis AB, Skolan | soil | 2009-01-28 | N58$^0$04.43 | E11$^0$49.98 |
| 16 | Point source | Stenungsund | Borealis AB, Skolan | air | 2009-01-28 | N58$^0$04.43 | E11$^0$49.98 |
| 17 | Point source | Stenungsund | Borealis AB, Skolan | air | 2009-02-18 | N58$^0$04.43 | E11$^0$49.98 |
| 18 | Point source | Stenungsund | Borealis AB, Skolan | air | 2009-03-03 | N58$^0$04.43 | E11$^0$49.98 |
| 19 | Point source | Stenungsund | Borealis AB, Ödsmål | air | 2009-02-18 | N58$^0$06.37 | E11$^0$49.22 |
| 20 | Point source | Stenungsund | Borealis AB, Downwind | air | 2009-01-28 | N58$^0$05.39 | E11$^0$49.98 |
| 21 | Point source | Stenungsund | Borealis AB, | surface water | 2009-03-03 | N58$^0$06.08 | E11$^0$50.96 |
| 22 | Point source | Stenungsund | Borealis AB, Downwind | surface water | 2009-03-03 | N58$^0$05.39 | E11$^0$49.98 |
| 23 | Point source | Göteborg | Gasoline station | soil | 2009-01-27 | N57$^0$47.46 | E11$^0$59.30 |
| 24 | Point source | Göteborg | Gasoline station | air | 2009-03-11 | N57$^0$47.46 | E11$^0$59.30 |
| 25 | Point source | Göteborg | Gasoline station | air | 2009-03-11 | N57$^0$47.46 | E11$^0$59.30 |
| 26 | Point source | Göteborg | Gasoline station | air | 2009-03-11 | N57$^0$47.46 | E11$^0$59.30 |
| 27 | Diffuse, urban | Göteborg | 5an | air | 2008-12-16 11:00 | N57$^0$42.53 | E11$^0$58.22 |
| 28 | Diffuse, urban | Göteborg | 5an | air | 2008-12-17 19:00 | N57$^0$42.53 | E11$^0$58.22 |
| 29 | Diffuse, urban | Göteborg | 5an | air | 2008-12-19 07:30 | N57$^0$42.53 | E11$^0$58.22 |
| 30 | Diffuse, urban | Göteborg | 5an | air | 2009-03-11 07:00 | N57$^0$42.53 | E11$^0$58.22 |
| 31 | Diffuse, urban | Göteborg | 5an | air | 2009-03-11 14:30 | N57$^0$42.53 | E11$^0$58.22 |

| Sample# | Type | City / Municipality | Site | Matrix | Sampling date | N | E |
|---|---|---|---|---|---|---|---|
| 32 | Diffuse, urban | Göteborg | 5an | air | 2009-03-14 07:30 | N57$^0$42.53 | E11$^0$58.22 |
| 33 | Diffuse, urban | Göteborg | Fattighusån | surface water | 2009-03-10 | N57$^0$42.40 | E11$^0$58.06 |
| 34 | Diffuse, urban | Göteborg | Gårda | Traffic storm water | 2009-02-23 | N57$^0$42.13 | E11$^0$59.60 |
| 35 | Diffuse, urban | Göteborg | Korsvägen | Traffic storm water | 2009-02-23 | N57$^0$41.82 | E11$^0$59.28 |
| 36 | Diffuse, urban | Göteborg | Odinsplatsen | Traffic storm water | 2009-02-23 | N57$^0$41.57 | E11$^0$59.12 |
| 37 | Street level | Göteborg | Sprängkullsgatan | air | 2008-12-16 | N57$^0$41.96 | E11$^0$57.65 |
| 38 | Street level | Göteborg | Sprängkullsgatan | air | 2009-02-05 | N57$^0$47.46 | E11$^0$59.30 |
| 39 | Street level | Göteborg | Sprängkullsgatan | air | 2009-02-17 | N57$^0$47.46 | E11$^0$59.30 |
| 40 | Street level | Göteborg | Sprängkullsgatan | air | 2009-04-01 | N57$^0$47.46 | E11$^0$59.30 |
| 41 | Street level | Göteborg | Södra vägen 71 | air | 2008-12-17 | N57$^0$41.65 | E11$^0$59.34 |
| 42 | Street level | Göteborg | Södra vägen 71 | air | 2009-02-03 | N57$^0$41.65 | E11$^0$59.34 |
| 43 | Street level | Göteborg | Södra vägen 71 | air | 2009-02-25 | N57$^0$41.65 | E11$^0$59.34 |
| 44 | Street level | Göteborg | Kärra, suburban air | air | 2009-02-19 | N57$^0$47.46 | E11$^0$59.30 |
| 45 | Street level | Göteborg | Kärra, suburban air | air | 2009-03-31 | N57$^0$47.46 | E11$^0$59.30 |
| 46 | Indoors | Göteborg | Sprängkullsgatan | air | 2008-12-16 | N57$^0$47.46 | E11$^0$59.30 |
| 47 | Indoors | Göteborg | Sprängkullsgatan | air | 2009-02-05 | N57$^0$47.46 | E11$^0$59.30 |
| 48 | Indoors | Göteborg | Sprängkullsgatan | air | 2009-04-01 | N57$^0$47.46 | E11$^0$59.30 |
| 49 | Indoors | Göteborg | Södra vägen 71 | air | 2008-12-17 | N57$^0$41.65 | E11$^0$59.34 |
| 50 | Indoors | Göteborg | Södra vägen 71 | air | 2009-02-03 | N57$^0$41.65 | E11$^0$59.34 |
| 51 | Indoors | Göteborg | Södra vägen 71 | air | 2009-02-25 | N57$^0$41.65 | E11$^0$59.34 |
| 52 | Indoors | Göteborg | Kärra | air | 2009-02-19 | N57$^0$47.46 | E11$^0$59.30 |
| 53 | Indoors | Göteborg | Kärra | air | 2009-03-31 | N57$^0$47.46 | E11$^0$59.30 |
| 54 | Diffuse, urban | Göteborg | Allén | soil | 2009-01-30 | N57$^0$42.31 | E11$^0$58.66 |
| 55 | Diffuse, urban | Göteborg | Ryaverken STP | influent | 2009-01-29 | N57$^0$41.86 | E11$^0$53.62 |
| 56 | Diffuse, urban | Göteborg | Ryaverken STP | effluent | 2009-01-29 | N57$^0$41.86 | E11$^0$53.62 |
| 57 | Diffuse | Göteborg | Södra vägen 71 | Drinking water | 2009-02-03 | N57$^0$41.65 | E11$^0$59.34 |
| 58 | Diffuse | Göteborg | Kärra | Drinking water | 2009-03-19 | N57$^0$47.46 | E11$^0$59.30 |
| 59 | Diffuse | Kungshamn | Tennisvägen | Drinking water | 2009-02-28 | N58$^0$21.71 | E11$^0$15.51 |
| 60 | Diffuse | Lerkil | Lerkil 1 | Domestic well | 2009-02-18 | N57$^0$27.65 | E11$^0$55.49 |
| 61 | Diffuse | Lerkil | Lerkil 2 | Domestic well | 2009-02-18 | N57$^0$27.99 | E11$^0$55.06 |
| 62 | Diffuse | Preemraff Lysekil | Stångenäs | Domestic well | 2009-02-18 | N58$^0$21.15 | E11$^0$28.87 |
| 63 | Diffuse | Preemraff Lysekil | Govik | Domestic well | 2009-01-28 | N58$^0$21.69 | E11$^0$26.92 |

**Appendix 2** National program, Results

| Sample# | Type | City / Municipality | Site | Matrix | Unit | MTBE | ETBE | Benzene | Toluene | Ethyl-benzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Background | Fiskebäckskil | Kristineberg | soil | ng/g DW | 22 | <0.81 | <1.6 | 940 | 0.23 | 0.53 | <2.2 |
| 2 | Background | Fiskebäckskil | Kristineberg | air | µg/m$^3$ | <0.15 | <0.14 | 0.55 | 0.49 | 0.09 | 0.21 | 0.09 |
| 3 | Background | Fiskebäckskil | Kristineberg | air | µg/m$^3$ | 0.49 | <0.18 | 1.3 | 1.5 | 0.24 | 0.71 | 0.28 |
| 4 | Background | Fiskebäckskil | Kristineberg | air | µg/m$^3$ | 0.09 | <0.05 | 0.52 | 0.22 | 0.04 | 0.04 | |
| 5 | Background | Stenungsund | Gårdsjön | surface water | ng/l | <10 | <7.0 | 12 | 18 | <2.0 | 3.6 | 6.1 |
| 6 | Background | Stenungsund | Gårdsjön | surface water | ng/l | <10 | <7.0 | 13 | 41 | 1.9 | 7.5 | 6.9 |
| 7 | Background | Lerum | SGU Stn 54:18 | groundwater | ng/l | <10 | <7.0 | <6.0 | <6.0 | <6.0 | <6.0 | <20 |
| 8 | Traffic related | Lerum | SGU Stn 10007:1 | groundwater | ng/l | 14 | <7.0 | <6.0 | <6.0 | <6.0 | <6.0 | <20 |
| 9 | Urban | Stockholm | SGU Stn 32B123, Ulvsunda | groundwater | ng/l | 240 | 31 | 390 | 45 | 26 | 280 | 52 |
| 10 | Point source | Preemraff Lysekil | Govik | soil | ng/g DW | 11 | <0.65 | <1.4 | 480 | 0.20 | 0.60 | <1.9 |
| 11 | Point source | Preemraff Lysekil | Govik | air | µg/m$^3$ | <0.20 | <0.17 | 0.52 | 0.48 | 0.09 | 0.18 | 0.08 |
| 12 | Point source | Preemraff Lysekil | Govik | air | µg/m$^3$ | 0.37 | <0.16 | 1.1 | 1.2 | 0.18 | 0.50 | 0.25 |
| 13 | Point source | Preemraff Lysekil | Govik | air | µg/m$^3$ | 0.12 | <0.10 | 0.46 | 0.31 | 0.04 | 0.05 | |
| 14 | Point source | Preemraff Lysekil | Govik | surface water | ng/l | <10 | <7.0 | 10 | 22 | 2.2 | 5.8 | |
| 15 | Point source | Stenungsund | Borealis AB, Skolan | soil | ng/g DW | 50 | <0.89 | <1.7 | **>2700** | 0.37 | 0.90 | <2.5 |
| 16 | Point source | Stenungsund | Borealis AB, Skolan | air | µg/m$^3$ | <0.25 | <0.24 | 0.64 | 0.81 | 0.15 | 0.35 | 0.13 |
| 17 | Point source | Stenungsund | Borealis AB, Skolan | air | µg/m$^3$ | 0.28 | <0.18 | 1.0 | 1.1 | 0.18 | 0.50 | 0.27 |
| 18 | Point source | Stenungsund | Borealis AB, Skolan | air | µg/m$^3$ | 0.29 | <0.10 | 0.71 | 0.87 | 0.16 | 0.51 | |
| 19 | Point source | Stenungsund | Borealis AB, Ödsmål | air | µg/m$^3$ | 0.35 | <0.20 | 0.97 | 0.91 | 0.15 | 0.38 | 0.16 |
| 20 | Point source | Stenungsund | Borealis AB, Downwind | air | µg/m$^3$ | <0.23 | <0.24 | 0.93 | 1.0 | 0.21 | 0.62 | 0.35 |
| 21 | Point source | Stenungsund | Borealis AB | surface water | ng/l | <10 | <7.0 | 11 | 15 | 2.6 | 4.4 | |
| 22 | Point source | Stenungsund | Borealis AB, Downwind | surface water | ng/l | 10 | 9.0 | 9.9 | 27 | 1.0 | 4.5 | |
| 23 | Point source | Göteborg | Gasoline station | soil | ng/g DW | 18 | <0.57 | <1.1 | 100 | <0.14 | 0.25 | <1.6 |
| 24 | Point source | Göteborg | Gasoline station | air | µg/m$^3$ | 3.8 | 0.43 | 5.5 | 29 | 6.2 | 23 | 8.5 |
| 25 | Point source | Göteborg | Gasoline station | air | µg/m$^3$ | 5.8 | 0.36 | 3.7 | 16 | 4.7 | 11 | 5.9 |
| 26 | Point source | Göteborg | Gasoline station | air | µg/m$^3$ | 5.5 | 0.67 | 5.7 | 38 | 6.7 | 25 | 9.1 |
| 27 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ | 0.46 | <0.25 | 1.5 | 1.8 | 0.47 | 1.3 | 0.52 |
| 28 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ | 0.66 | <0.25 | 2.1 | 2.5 | 0.62 | 2.1 | 0.62 |
| 29 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ | 0.46 | <0.16 | 1.0 | 3.3 | 0.44 | 1.6 | 0.61 |
| 30 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ | 1.1 | <0.13 | 1.5 | 4.2 | 2.2 | 3.7 | 1.2 |
| 31 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ | 0.51 | <0.13 | 1.2 | 1.5 | 0.33 | 1.2 | 0.85 |

| Sample# | Type | City / Municipality | Site | Matrix | Unit | MTBE | ETBE | Benzene | Toluene | Ethyl-benzene | *m+p*-Xylene | *o*-Xylene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ | 0.11 | <0.13 | 0.75 | 1.1 | 0.12 | 0.42 | 0.09 |
| 33 | Diffuse, urban | Göteborg | Fattighusån | surface water | ng/l | 32 | 7.6 | 13 | 41 | 17 | 71 | 28 |
| 34 | Diffuse, urban | Göteborg | Gårda | Traffic storm water | ng/l | 77 | 20 | 110 | **>31000** | 98 | 96 | 70 |
| 35 | Diffuse, urban | Göteborg | Korsvägen | Traffic storm water | ng/l | 69 | 19 | 190 | 390 | 20 | 95 | 73 |
| 36 | Diffuse, urban | Göteborg | Odinsplatsen | Traffic storm water | ng/l | 71 | 19 | 77 | 1000 | 18 | 62 | 54 |
| 37 | Street level | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.44 | <0.10 | 2.1 | 6.1 | 1.1 | 3.9 | 1.3 |
| 38 | Street level | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.56 | <0.22 | 3.5 | 6.9 | 1.2 | 4.3 | 1.7 |
| 39 | Street level | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 2.5 | <0.21 | 3.6 | 11 | 2.1 | 7.5 | 2.7 |
| 40 | Street level | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.64 | <0.05 | 2.6 | 7.2 | 1.3 | 4.4 | |
| 41 | Street level | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.89 | | 2.7 | 8.2 | 1.5 | 5.1 | 1.7 |
| 42 | Street level | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.79 | <0.22 | 3.4 | 9.5 | 1.9 | 6.4 | 2.2 |
| 43 | Street level | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.31 | <0.17 | 1.4 | 4.4 | 0.70 | 2.5 | 1.0 |
| 44 | Street level | Göteborg | Kärra, suburban air | air | µg/m$^3$ | 0.63 | <0.20 | 1.4 | 4.2 | 0.70 | 2.5 | 1.0 |
| 45 | Street level | Göteborg | Kärra, suburban air | air | µg/m$^3$ | <0.08 | <0.05 | 0.46 | 0.38 | 0.07 | 0.18 | |
| 46 | Indoors | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.30 | <0.20 | 1.5 | 5.2 | 0.66 | 2.3 | 0.62 |
| 47 | Indoors | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.37 | <0.36 | 2.1 | 3.0 | 0.54 | 1.6 | 0.57 |
| 48 | Indoors | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | <0.10 | <0.10 | 0.57 | 1.4 | 0.29 | 0.99 | 0.38 |
| 49 | Indoors | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.71 | | 2.1 | 5.4 | 1.0 | 3.2 | 1.1 |
| 50 | Indoors | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.43 | | 2.2 | 11 | 1.9 | 6.1 | 1.9 |
| 51 | Indoors | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.31 | | 0.73 | 3.3 | 0.46 | 1.6 | 0.54 |
| 52 | Indoors | Göteborg | Kärra | air | µg/m$^3$ | 0.53 | | 1.3 | 5.5 | 0.87 | 2.5 | 0.82 |
| 53 | Indoors | Göteborg | Kärra | air | µg/m$^3$ | 0.09 | <0.10 | 0.48 | 3.1 | 0.34 | 0.85 | |
| 54 | Diffuse, urban | Göteborg | Allén | soil | ng/g DW | 37 | <0.69 | <1.3 | 1100 | 0.20 | 0.66 | <1.9 |
| 55 | Diffuse, urban | Göteborg | Ryaverken STP | influent | ng/l | 110 | 31 | 35 | 1500 | 58 | 150 | 72 |
| 56 | Diffuse, urban | Göteborg | Ryaverken STP | effluent | ng/l | 120 | 26 | 7.3 | 280 | 62 | 130 | 72 |
| 57 | Diffuse | Göteborg | Södra vägen 71 | Drinking water | ng/l | 34 | <7.0 | <6.0 | 26 | 1.2 | 4.1 | 2.9 |
| 58 | Diffuse | Göteborg | Kärra | Drinking water | ng/l | <10 | <7.0 | <6.0 | 8.7 | 0.21 | 3.0 | |
| 59 | Diffuse | Kungshamn | Tennisvägen | Drinking water | ng/l | <10 | <7.0 | 8.3 | 20 | 1.6 | 7.2 | 1.6 |
| 60 | Diffuse | Lerkil | Lerkil 1 | Domestic well | ng/l | 37 | 7.9 | 13 | 18 | 2.2 | 6.4 | 6.2 |
| 61 | Diffuse | Lerkil | Lerkil 2 | Domestic well | ng/l | 140 | <7.0 | 7.5 | 7.0 | 0.54 | 2.3 | 1.5 |
| 62 | Diffuse | Preemraff Lysekil | Stångenäs | Domestic well | ng/l | 34 | <7.0 | <6.0 | 9.4 | 1.5 | 2.0 | |
| 63 | Diffuse | Preemraff Lysekil | Govik | Domestic well | ng/l | 14 | <7.0 | 21 | 490 | 230 | 7.1 | |

**Appendix 3** National program, Results from air samples, extra analytes

| Sample# | Type | City / Municipality | Site | Matrix | Unit | *n*-Bythyl-acetate | *2*-Methyl-pentane | *3*-Methyl-pentane | n-Hexane | cyclo-Hexane | iso-Octane | *n*-Heptane | *n*-Octane | *n*-Nonane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Background | Fiskebäckskil | Kristineberg | air | µg/m$^3$ | <0.10 | 0.11 | 0.07 | 0.11 | <0.03 | 0.03 | 0.08 | 0.22 | 0.12 |
| 3 | Background | Fiskebäckskil | Kristineberg | air | µg/m$^3$ | <0.10 | 1.1 | 0.57 | 0.58 | 0.15 | 0.11 | 0.33 | 0.36 | 0.34 |
| 4 | Background | Fiskebäckskil | Kristineberg | air | µg/m$^3$ | <0.10 | 0.11 | 0.06 | 0.08 | <0.03 | 0.03 | 0.06 | 0.09 | 0.12 |
| 11 | Point source | Preemraff Lysekil | Govik | air | µg/m$^3$ | <0.10 | 0.10 | 0.08 | 0.13 | 0.03 | 0.04 | 0.12 | 0.26 | 0.11 |
| 12 | Point source | Preemraff Lysekil | Govik | air | µg/m$^3$ | <0.10 | 0.77 | 0.44 | 0.50 | 0.12 | 0.08 | 0.29 | 0.34 | 0.22 |
| 13 | Point source | Preemraff Lysekil | Govik | air | µg/m$^3$ | 0.17 | 0.14 | 0.06 | 0.08 | <0.03 | 0.03 | 0.07 | 0.13 | 0.14 |
| 16 | Point source | Stenungsund | Borealis AB, Skolan | air | µg/m$^3$ | <0.10 | 0.21 | 0.15 | 0.13 | 0.07 | 0.05 | 0.11 | 0.22 | 0.15 |
| 17 | Point source | Stenungsund | Borealis AB, Skolan | air | µg/m$^3$ | <0.10 | 0.47 | 0.25 | 0.30 | 0.09 | 0.15 | 0.19 | 0.28 | 0.27 |
| 18 | Point source | Stenungsund | Borealis AB, Skolan | air | µg/m$^3$ | 0.16 | 0.28 | 0.14 | 0.14 | 0.05 | 0.04 | 0.11 | 0.17 | 0.21 |
| 19 | Point source | Stenungsund | Borealis AB, Ödsmål | air | µg/m$^3$ | <0.10 | 0.57 | 0.43 | 1.9 | 0.12 | 0.12 | 0.38 | 1.1 | 0.28 |
| 20 | Point source | Stenungsund | Borealis AB, Downwind | air | µg/m$^3$ | 0.11 | 0.26 | 0.15 | 0.22 | 0.07 | 0.07 | 0.18 | 0.33 | 0.24 |
| 24 | Point source | Göteborg | Gasoline station | air | µg/m$^3$ | 0.45 | 8.9 | 5.1 | 2.5 | 1.7 | 0.29 | 2.7 | 2.2 | 1.8 |
| 25 | Point source | Göteborg | Gasoline station | air | µg/m$^3$ |  | 12 | 5.7 | 4.1 | 8.4 | 2.6 | 5.3 | 7.8 | 17 |
| 26 | Point source | Göteborg | Gasoline station | air | µg/m$^3$ | <0.30 | 10 | 5.6 | 2.8 | 1.3 | 0.53 | 2.4 | 1.8 | 1.6 |
| 27 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ |  | 0.35 | 0.14 | 0.34 | 0.17 | <0.12 | 0.28 | 0.29 |  |
| 28 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ |  | 0.58 | 0.26 | 0.67 | 0.34 | 0.16 | 0.36 | 0.36 |  |
| 29 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ | 0.24 | 0.65 | 0.34 | 0.56 | 0.18 | 0.50 | <0.20 | 0.71 | 0.32 |
| 30 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ |  | 0.59 | 0.41 | 0.57 | 0.35 | 0.12 | 0.27 | 0.24 |  |
| 31 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ |  | 0.26 | 0.12 | 0.22 | 0.12 | 0.10 | 0.21 | 0.85 |  |
| 32 | Diffuse, urban | Göteborg | 5an | air | µg/m$^3$ |  | 0.08 | <0.07 | <0.07 | <0.07 |  | 0.08 | 0.50 |  |
| 33 | Street level | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.67 | 1.5 | 0.72 | 0.86 | 0.61 | 0.51 | <0.20 | 0.77 | 0.38 |
| 38 | Street level | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.12 | 2.0 | 1.3 | 0.84 | 0.49 | 0.15 | 0.73 | 0.91 | 0.59 |
| 39 | Street level | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.11 | 4.5 | 2.5 | 1.0 | 1.4 | 0.26 | 1.1 | 0.98 | 0.72 |
| 40 | Street level | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.22 | 3.4 | 1.1 | 0.58 | 0.48 | 0.11 | 0.77 | 0.54 | 1.5 |
| 41 | Street level | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.55 | 2.1 | 0.96 | 1.4 | 0.50 | 0.66 | <0.20 | 0.53 | 0.27 |
| 42 | Street level | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.11 | 2.4 | 1.3 | 0.92 | 0.72 | 0.11 | 0.96 | 0.75 | 0.67 |
| 43 | Street level | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.24 | 0.85 | 0.81 | 1.0 | 0.33 | 0.18 | 0.86 | 0.68 | 0.52 |
| 44 | Street level | Göteborg | Kärra, suburban air | air | µg/m$^3$ | <0.10 | 1.3 | 0.81 | 0.40 | 0.47 | 0.16 | 0.46 | 0.61 | 0.65 |
| 45 | Street level | Göteborg | Kärra, suburban air | air | µg/m$^3$ | 0.30 | 0.39 | 0.31 | 1.5 | 0.07 | 0.05 | 0.13 | 0.13 | 0.04 |

| Sample# | Type | City / Municipality | Site | Matrix | Unit | *n*-Bythyl-acetate | *2*-Methyl-pentane | *3*-Methyl-pentane | n-Hexane | cyclo-Hexane | iso-Octane | *n*-Heptane | *n*-Octane | *n*-Nonane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | Indoors | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.67 | 0.64 | 0.37 | 1.2 | 0.71 | 0.42 | <0.20 | 1.1 | 0.34 |
| 47 | Indoors | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.31 | 0.63 | 0.34 | 0.46 | 0.12 | 0.06 | 0.52 | 0.65 | 0.32 |
| 48 | Indoors | Göteborg | Sprängkullsgatan | air | µg/m$^3$ | 0.31 | 0.65 | 0.23 | 0.21 | 0.07 | 0.49 | 0.22 | 0.33 | 0.52 |
| 49 | Indoors | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 1.1 | 0.92 | 0.85 | 3.1 | 0.45 | 0.75 | 0.91 | 0.50 | 0.45 |
| 50 | Indoors | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.31 | 1.6 | 0.83 | 1.7 | 0.42 | 0.23 | 1.4 | 0.83 | 0.43 |
| 51 | Indoors | Göteborg | Södra vägen 71 | air | µg/m$^3$ | 0.35 | 1.2 | 0.39 | 1.0 | 0.15 | 0.18 | 0.63 | 0.48 | 0.33 |
| 52 | Indoors | Göteborg | Kärra | air | µg/m$^3$ | 0.34 | 1.4 | 0.46 | 0.50 | 0.26 | 0.14 | 0.67 | 0.63 | 0.44 |
| 53 | Indoors | Göteborg | Kärra | air | µg/m$^3$ | 0.55 | 0.71 | 0.25 | 0.33 | 0.09 | 0.05 | 0.43 | 0.42 | 0.34 |