Nederlandse Organisatie voor
toegepast-natuurwetenschappelijk
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for Applied Scientific Research

**TNO Quality of Life**

Analytical Research
Utrechtseweg 48
P.O.Box 360
3700 AJ Zeist
The Netherlands

www.tno.nl

P +31 30 694 41 44
F +31 30 694 48 94

[redacted]@tno.nl

[redacted]

**TNO Report**

Final | V7054

# Migration study of [redacted]

| | |
|---|---|
| Date | 6 October, 2006 |
| Authors | [redacted]D. |
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# Summary

At the request of Solvay Solexis a study was performed to determine the residual content of [redacted] in a fluoropolymer sample. [redacted] is a chlorofluoropolyether acid [redacted] used as an emulsifier/dispersing agent during the polymerisation process of fluoropolymers.
The analytical method for the determination of the residual content of [redacted] in a fluoropolymer consisted of a hot extraction with methanol/water (80/20; v/v) and analyses of the extract with the use of liquid chromatography in combination with mass spectrometry.

[redacted]

In the blank (extraction solvent without the use of sample material) a background signal of approximately <10% of the lowest calibration standard was measured. This low background signal has no significant influence on the final results because the detected concentrations of [redacted] were below the LOD.

Recoveries measured were adequate *viz.* between 93 and 103% at the concentration level of 42.7 ng/ml extract which corresponds with 79 $\mu$g per kg fluoropolymer.
The analytical method was suitable for the determination of the residual content of [redacted] in fluoropolymer at the concentration of 10-200 ng/ml extract which corresponds with approximately 20-370 $\mu$g [redacted] per kg fluoropolymer. The repeatability and linearity were satisfactory.

The overall migration of the fluoropolymer in 95% ethanol and iso-octane under migration conditions of respectively 6 hours at 60°C and 4 hours at 60°C was < 1$\mu$g/ 6 $dm^2$. Further characterization of the migration substances with NMR did not show any significant reaction product.

# Contents

# 1 Introduction

Solvay Solexis, has requested to determine the residual content of [redacted]; CAS no. 329238-24-6) in a fluoropolymer. [redacted] is used as an emulsifier/dispersing agent during the polymerisation process of fluoropolymers. These fluoropolymers are processed to produce a range of articles for repeat use like parts for food processing equipment, tubes, tapes and coatings on cooking utensils. After the manufacture, [redacted] can migrate into foodstuffs coming into contact with that product. With the described analytical method the residual content of chlorofluoropolyether acids in the final fluoropolymer product is determined. The residual content can be used to calculate the worst case migration of [redacted] from fluoropolymers into foodstuffs.
Additional the overall migration from the fluoropolymer sample into 95% ethanol and iso-octane was determined. The migration substances were characterized by NMR.

# 2 Procedure

The study consists of a hot extraction with methanol/water (80/20; v/v) of a fluoropolymer sample produced with the use of [redacted]. The extraction was performed for 8 hours. The extraction solvent is analysed for containing [redacted] by the use of liquid chromatography in combination with mass spectrometry. The extraction procedure was repeated with a fresh amount of methanol/water. This second extract was also tested for containing residues of [redacted].

The maximum amount of [redacted] used in the polymerization recipe is [redacted]

A recovery study is performed by adding [redacted] to the sample material. Repeatability of the analysis is tested by performing the analysis in triplicate.

The overall migration of fluoropolymer was determined by the incubation of the fluoropolymer into 95% ethanol and iso-octane. After incubation de solvent was evaporated and the amount of residue was determined gravimetrically. The residue was characterized by NMR.

The analysis of the residual content was performed in May 2006.
The overall migration and characterization of the migrating substances was performed in August-September 2006.

## 2.1 Sample materials

Solvay Solexis, Bollate (Mi) Italy, provided sample material for the testing. The samples were provided with a unique TNO sample code. The samples were received in May 2006 and stored at room temperature. The reference substance [redacted] was received in april 2006.

Table 1: Sample used for the study

| TNO sample ID | Solvay Solexis sample ID | remark |
|---|---|---|
| 0939-02-0202 | [redacted] | Used for reference |
| 0939-02-0951 | Fluoropolymer [redacted] | Sheets approximately 13.5x13.5x0.04cm |

[redacted] propane, 1,1,1,2,2,3,3-heptafluoro-3-[(trifluoroethenyl)oxy]-, polymer with tetrafluoroethene and trifluoro(trifluoromethoxy)ethene.

## 2.2 Determination of the residual content

The sheets of fluoropolymer were cut into pieces of ca. 1x3 cm. A test-sample of approximately 27 g is transferred to a conical flask of 100 ml. To the sample 50 ml of the extraction solvent methanol/water (80/20; v/v) was added. The hot extraction was performed for 8 hours. After the extraction an aliquot of the extract was transferred to an HPLC vial. The remaining extraction solvent was decanted and the extraction was repeated with a fresh amount of 50 ml methanol/water (80/20;v/v).

From the collected first and second extracts 50 µl was injected into the HPLC and analysed for containing [redacted] as described in Appendix 1.
The extraction was repeated by using methanol/water (80/20) containing 0.1% ammonia. By addition of ammonia the less volatile [redacted] ammonium salt was formed and so the possibility of evaporation of the [redacted] during the extraction procedure was reduced.

Blank values were obtained by treatment of 50 ml of extraction solvent in the same way as described above (without adding fluoropolymer).

All experiments were carried out in triplicate.

Typical chromatograms obtained for the determination of [redacted] in methanol/water (blank), in methanol/water containing 0.1 % ammonia and in the first extract of a fluoropolymer samples are presented in Figures 1 and 2.

## 2.3 Calibration curve

A stock solution of [redacted], containing 0.534 µg/ml, was prepared by dissolving 26.70 mg [redacted] into 50 ml methanol/water (80/20;v/v).
The stock solution was diluted by transferring 1 ml to a volumetric flaks of 20 ml and addition of methanol/water (80/20) to a final volume of 20 ml. The diluted stock solution contained 26.7 ng/ml of [redacted]
From the diluted stock solution 0, 10, 20, 40, 80, 120, 160 and 200 µl were transferred to a set of volumetric flask of 25 ml. The volumetric flasks were filled up to the mark with methanol/water (80/20;v/v) and mixed thoroughly. The solutions thus obtained contain approximately 0, 10.68, 21.36, 42.76, 85.44, 128.16, 170.88, 213.60 ng of [redacted] per ml.

The calibration standards were analysed by LC-MS as described in Appendix 1 of this report. A typical LC-MS chromatogram obtained for the calibration standard of 10.68 ng/ml in methanol/water (80/20;v/v) is presented in Figure 3.

In the chromatograms obtained, the peak heights of the specific MRM ions of [redacted] were measured. From these data, the calibration curve was constructed and the correlation coefficient was calculated.

A graphical plot of the calibration curve and the raw data and statistical parameters are presented in Figures 5 and 6.

## 2.4 Recovery experiment by standard addition to the test sample

The sheets of fluoropolymer were cut into pieces of ca. 1x3 cm. A test sample of approximately 27 g was transferred to a conical flask of 100 ml. To the test sample 50 ml of the extraction solvent methanol/water (80/20;v/v) and 80 µl of diluted stock solution of [redacted] were added. In this way the sample extract contains (0.08(ml)*26.70(ng/ml)*1000/50(ml)=) 42.72 ng [redacted] per ml. This corresponds with 42.72(ng/ml)*50(ml)/27(g of test-sample) = 79 ng per g fluoropolymer (=µg/kg). The sample was treated as described in item 2.2.

The recovery experiment was repeated by using methanol/water (80/20) containing 0.1% ammonia.

Typical chromatograms obtained for a standard addition of [redacted] to the test sample is presented in Figure 4a without the addition of ammonia, and Figure 4b with the addition of ammonia to the extraction solvent.

## 2.5 Overall migration

### *2.5.1 95% ethanol*

A test sample of [redacted] fluoropolymer (2 sheets with the dimension 13x13.4 cm one-sided, corresponding with contact area of 3.484 $dm^2$) was immersed in 100 ml 95% ethanol. After incubation period 6 hours at 60°C the samples were removed and after evaporating of the solvents under controlled conditions, the residues were estimated gravimetrically. The test was performed in duplicate. From the results the overall migration in mg/6 $dm^2$ was determined.

### *2.5.2 Iso-octane*

A test sample of [redacted] fluoropolymer (2 sheets with the dimension 13x13.4 cm one-sided, corresponding with contact area of 3.484 $dm^2$) was immersed in 100 ml iso-octane. After incubation period of 4 hours at 60°C the samples were removed and after evaporating off the solvents under controlled conditions, the residues are estimated gravimetrically. The test was performed in duplicate. From the results the overall migration in mg/6 $dm^2$ was determined.

## 2.6 Characterization of the migrating substances by NMR

The residue obtained under item 2.5 was characterized by NMR. Prior to NMR spectroscopy, the residue was dissolved in 1 ml deuterated chloroform ($CDCl_3$) containing 0.05 % tetramethylsilane (TMS). An aliquot of 600 µl of the solution was transferred to 5 mm NMR tubes. 1D NMR spectra were recorded on a Bruker AVANCE 600 MHz spectrometer operating at a resonance frequency of 600.13 MHz a probe temperature of 27°C. 1D $^1$H-NMR experiments were acquired using the pulse sequence 'zg'. Free induction decays (FIDs) were collected into 64K data points using a spectral width of 12376 Hz. 45 Degree pulses were used with an acquisition time of 2.65 s and a relaxation delay of 5.0 s. The spectra were acquired by accumulation of 256 FIDs. Spectra were recorded using a spectral width of 8000 Hz. Chemical shifts of all spectra are expressed in ppm by reference to TMS (0.00 ppm). Resolution enhancement and noise reduction of the spectra was performed using an exponential window function with a line broadening of 0.3 Hz and a manual baseline correction was applied.

# 3 Results

## 3.1 Actual content of [redacted] in the test sample

The results obtained for the actual content of [redacted] in the test sample of fluoropolymer are presented in Table 1.
The [redacted] consists of different oligomers [redacted] all oligomers have there own specific MRM (Multiple-Reaction-Monitoring)ions. [redacted]

From the results it was concluded that although traces of [redacted] were detected in the first extracts of the fluoropolymer sample, all concentrations were lower than the LOD. The responses monitored in the second extracts of the sample did not significant differ from the blank (extract without fluoropolymer). In the blank a background signal of approximately < 10% of the lowest calibration standard was measured. This low background signal has no significant influence on the final results because the detected concentrations of [redacted] were below the LOD.

Furthermore there was no significant difference between the samples extracted with and without the addition of ammonia. Therefore it was concluded that no [redacted] was evaporated by using methanol/water as the extraction solvent.

## 3.2 Detection limit

The concentration of the lowest calibration solution, 10.68 ng/ml, was set as the detection limit. A detection limit of 10.68 ng/ml corresponds to a residual content of 20 ng per kg fluoropolymer. The sum of peak heights of all detected MRM ions were used for the construction of the calibration curve.
[redacted]

## 3.3 Recovery

The results obtained for the determination of the recovery of [redacted] from fluoropolymer is presented in Table 2.

The results are corrected for the responses observed in the samples without the addition of [redacted]
The results obtained for the recovery samples extracted with and without ammonia did not show significant differences.
Recoveries measured were adequate *viz.* between 93 and 103% at the concentration level of 42.7 ng/ml extract which corresponds with (42.7*50/27) 79 ng/g (=79 µg/kg) of fluoropolymer sample.

### 3.4 Repeatability and linearity

Repeatability of the method was demonstrated by calculation the standard deviation of the recovery of the standard addition of [redacted] to the test sample. The measured standard deviation was 7% for the extraction with methanol/water (80/20;v/v) and 8% for the extraction with methanol/water (80/20;v/v) containing 0.1% of ammonia.

The calibration curve appeared to be linear in the range of 10.68 to 213.6 ng/ml for the sum of peak heights plotted against the concentration (Fig 6). The correlation coefficient was 0.9995.

### 3.5 Overall migration

Results obtained for the overall migration are presented in Table 3. From the results it is concluded that although the duplicate analyses differ significant – due to the low amount measured - the total amount of migration substances in 95% ethanol and iso-octane are < 1 mg/6 $dm^2$.

### 3.6 Characterization of migrating substances with NMR

$^1$H-NMR spectra of the 95% ethanol migration residue obtained from [redacted] (fluoropolymer) sample and a blank sample are shown in Figures 7 and 8, respectively. The spectra of the iso-octane migration residue obtained for the sample of fluoropolymer and a blank sample are shown in Figures 9 and 10, respectively. Tentative $^1$H chemical shifts were assigned by means of ACD/HNMR prediction software (ACDlabs, Toronto) and are listed in Table 4. Signals present in both, the fluoropolymer extracts and in their blanks originate from compound introduced during the extraction procedure and the NMR sample preparation; i.e. residual solvent (7.26 ppm), acetic acid (2.10 ppm_water (1.56 ppm), TMS (0.00 ppm). Due to the absence of protons in the fluoropolymer and monomers there off are not visible for $^1$H-NMR. The signals present in the extract samples and absent in their blanks are assigned as proton containing migrants. Due to the low intensities en pure resolution of the signals further assignment was not possible.
Final conclusions is that no significant peaks are detected due to reaction products of the fluoropolymer.

# 4 Conclusions

The detection limit for the determination of [redacted] in samples of fluoropolymer was 20 µg/kg. From this result the worst case migration (M) of [redacted] to foodstuff can be calculated. Therefore the following formula has to be applied: M=(Q*A*Ld*D)/1000
Assuming that: Q= conc in mg/kg in fluoropolymer= 0.020 mg/kg, A= area of the food contact material in $dm^2$, conventionally set at 600 $cm^2$, Ld= thickness of food contact material = 0.04 cm and D=fluoropolymer density is 2 g/cm3
The worst case migration into foodstuff is M=(0.020*600*0.04*2)/1000=0.001 mg/kg.

It was found that the residual content of [redacted] in the fluoropolymer was <20 µg/kg corresponding with a worst case migration of < 1 µg per kg foodstuff.

The results obtained from the recovery experiments of [redacted] demonstrate that the method is accurate and repeatable for the determination of chlorofluoropolyether acids. The mean recoveries at the concentration level of 42.7 ng/ml extract were 99±7% for the extraction with methanol/water and 101±8% for the extraction with methanol/water containing 0.1% ammonia.

The overall migration of the fluoropolymer in 95% ethanol and iso-octane under migration conditions of respectively 6 hours at 60°C and 4 hours at 60°C was < 1µg/ 6 $dm^2$. Further characterization of the migration substances with NMR did not show any significant reaction product.

# 5 Signatures

[redacted]

[redacted]

[redacted]
Technician

[redacted]
Manager Operations
Analytical Research Department

# 6 Tables

Table 1 Residual content of [redacted] in the fluoropolymer test sample

| TNO ID of test sample[3] | Conc. in first MeOH/$H_2O$ extract[1] (ng/ml) | Conc in second MeOH/$H_2O$ (ng/ml) | Conc. in $\mu$g per kg of fluoropolymer test sample[2] |
|---|---|---|---|
| 0939-02-0951 A | < 10 | < 10 | < 20 |
| 0939-02-0951 B | < 10 | < 10 | < 20 |
| 0939-02-0951 C | < 10 | < 10 | < 20 |
| | | | |
| 0939-02-0951 D | < 10 | < 10 | < 20 |
| 0939-02-0951 E | < 10 | < 10 | < 20 |
| 0939-02-0951 F | < 10 | < 10 | < 20 |

[1] LOD = 10 ng/ml; concentrations in second extracts were <LOD.

[2] Residual content is calculated by using the following formula: Concentration of [redacted] in extract (ng/ml)*50(ml)/27(gram of test sample) ng/g (=$\mu$g/kg)

[3] Samples A,B,C are extracted with methanol/water (80/20;v/v) and the samples D,E,F are extracted with methanol/water (80/20;v/v) containing 0.1% ammonia.

Table 2 Recovery of [redacted] from the fluoropolymer test sample

| TNO ID of test sample[2] | Conc. added (ng/ml) | Conc in first[1] MeOH/$H_2O$ (ng/ml) | Recovery (%) |
|---|---|---|---|
| 0939-02-0951 A | 42.7 | 39.6 | 93 |
| 0939-02-0951 B | 42.7 | 45.6 | 107 |
| 0939-02-0951 C | 42.7 | 41.3 | 97 |
| | | | |
| | | Average | 99 |
| | | SD | 7 |
| | | | |
| 0939-02-0951 D | 42.7 | 39.2 | 92 |
| 0939-02-0951 E | 42.7 | 45.8 | 107 |
| 0939-02-0951 F | 42.7 | 44.2 | 104 |
| | | | |
| | | Average | 101 |
| | | SD | 8 |

[1] Recoveries are corrected for the 'blank sample'=sample without addition of [redacted]; LOD = 10 ng/ml; results of second extractions: <10 ng/ml

[2] Samples A,B,C are extracted with methanol/water (80/20;v/v) and the samples D,E,F are extracted with methanol/water (80/20;v/v) containing 0.1% ammonia.

Table 3 Overall migration

| Sample | Simulant | Time/temp | Overall migration in mg/ 6 $dm^2$ |
|---|---|---|---|
| Sample 0939/02/0951 | 95% ethanol | 6 hours at 60°C | 0.27 |
| | | | 0.68 |
| | | **mean** | 0.48 |
| Sample 0939/02/0951 | Iso-octane | 4 hours at 60°C | 0.45 |
| | | | 0.95 |
| | | **mean** | 0.7 |

Table 4 $^{1}H$ NMR chemical shift* of compounds present in **A**) 95% ethanol extract of the fluoropolymer, **B**) 95% ethanol extract of a blank , **C**) iso-octane extract of fluoropolymer and **D**) iso-octane extract of a blank samples, recorded in $CDCl_3$ at 27°C.

| Chemical Shift (ppm) | Compound | Functional Group | Presence in sample | | | |
|---|---|---|---|---|---|---|
| | | | **A** | **B** | **C** | **D** |
| 8.11 | n.d.** | n.d. | × | - | × | × |
| 7.43 | satellite of chloroform | CH | × | × | × | × |
| 7.26 | chloroform | CH | × | × | × | × |
| 7.09 | satellite of chloroform | CH | × | × | × | × |
| 7.3 – 6.9 | migrant | n.d. | × | - | × | - |
| 6.6 – 6.4 | migrant | n.d. | × | - | × | - |
| 5.3 – 5.2 | migrant | n.d. | × | - | × | - |
| 4.69 | migrant | n.d. | × | - | × | - |
| 4.4 – 4.2 | migrant | n.d. | × | - | × | - |
| 4.2 – 4.1 | migrant | n.d. | × | - | × | - |
| 4.1 – 4.0 | migrant + contaminant | n.d. | × | - | × | × |
| 3.96 | n.d. | n.d. | × | × | × | × |
| 3.8 - 3.3 | n.d. | n.d. | × | - | - | - |
| 3.67 | n.d | n.d. | × | × | × | × |
| 3.49 | n.d | n.d. | × | × | × | × |
| 2.86 | contaminant in iso-octanol | n.d. | - | - | × | × |
| 2.58 | contaminant in iso-octanol | n.d. | - | - | × | × |
| 2.5 - 2.2 | migrand + other compound | n.d. | × | × | × | × |
| 2.10 | acetic acid | $CH_3$ | × | × | × | × |
| 2.0 – 1.5 | water | - | × | × | × | × |
| 1.5 – 1.3 | n.d. | Alkyl R$CH_2$CH$_3$ | × | × | × | × |
| 1.3 – 1.2 | n.d. | Alkyl R$CH_2$CH$_3$ | × | × | × | × |
| 0.9 – 0.8 | n.d. | Alkyl, $CH_3$ | × | × | × | × |
| 0.10 | satellite of TMS | $CH_3$ | × | × | × | × |
| 0.00 | internal reference TMS | $CH_3$ | × | × | × | × |
| -0.10 | satellite of TMS | $CH_3$ | × | × | × | × |

* In ppm relative to the signal of internal TMS at 0.00 ppm
** n.d., not determined. Functional groups are not determined due to multiple possibilities

# 7 Figures

Figure 1a Representative LC-MS chromatogram of blank extraction solvent (methanol/water=80/20; v/v); [redacted]

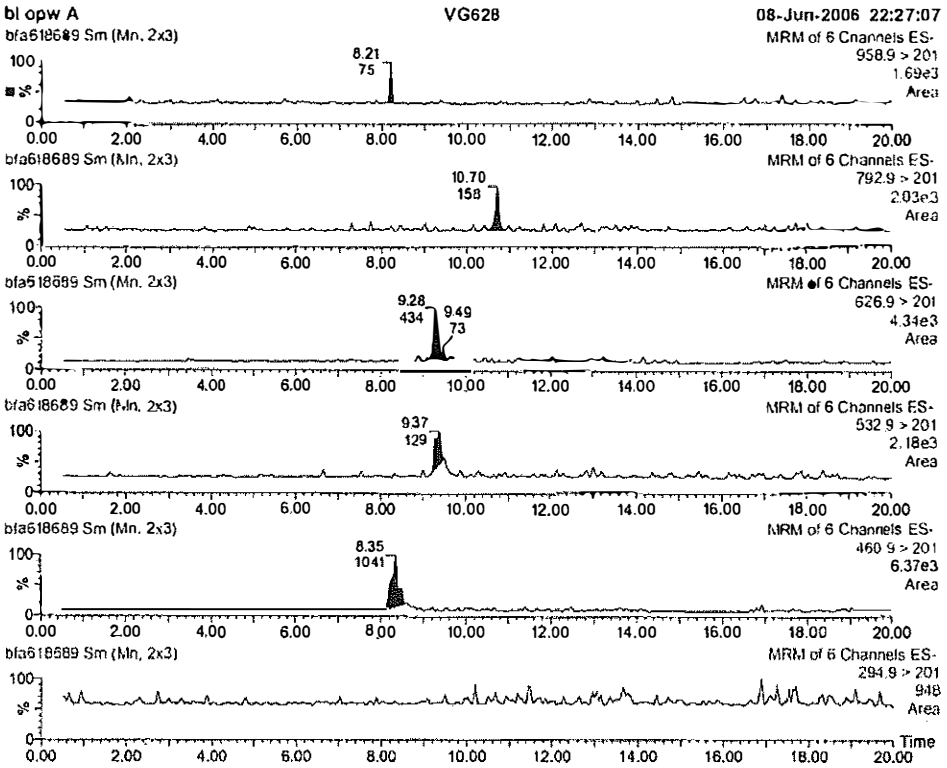


Figure 1b Representative LC-MS chromatogram of blank extraction solvent methanol/water (80/20;v/v) containing 0.1% ammonia. [redacted]

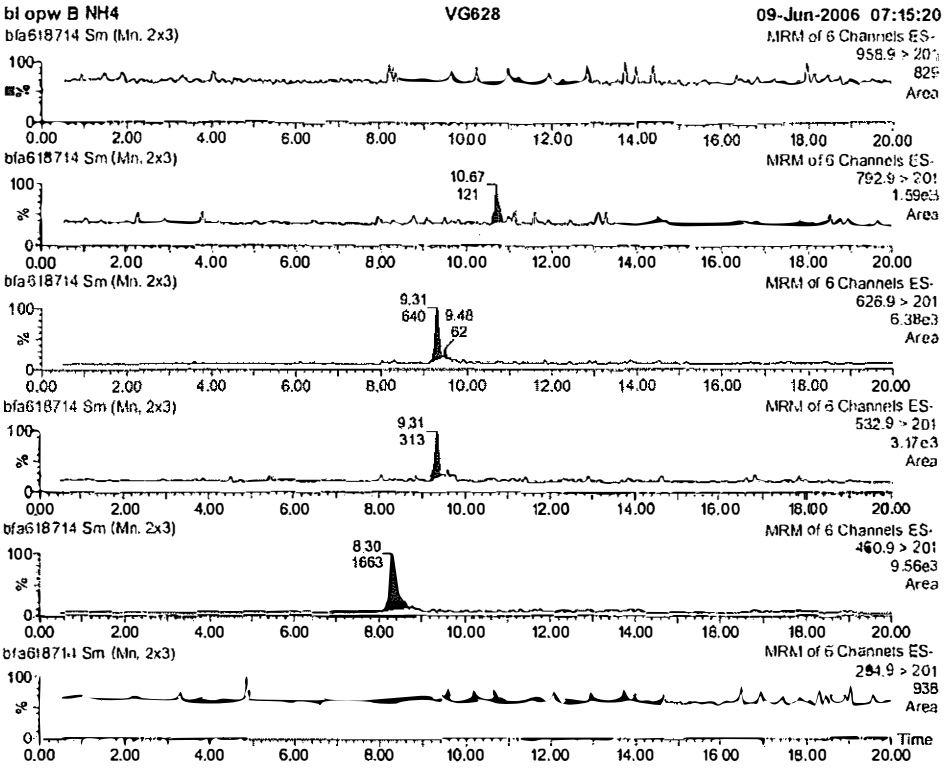


Figure 2a Representative LC-MS chromatogram of a first extract of a fluoropolymer sample. Extraction solvent methanol/water (80/20;v/v). [redacted]

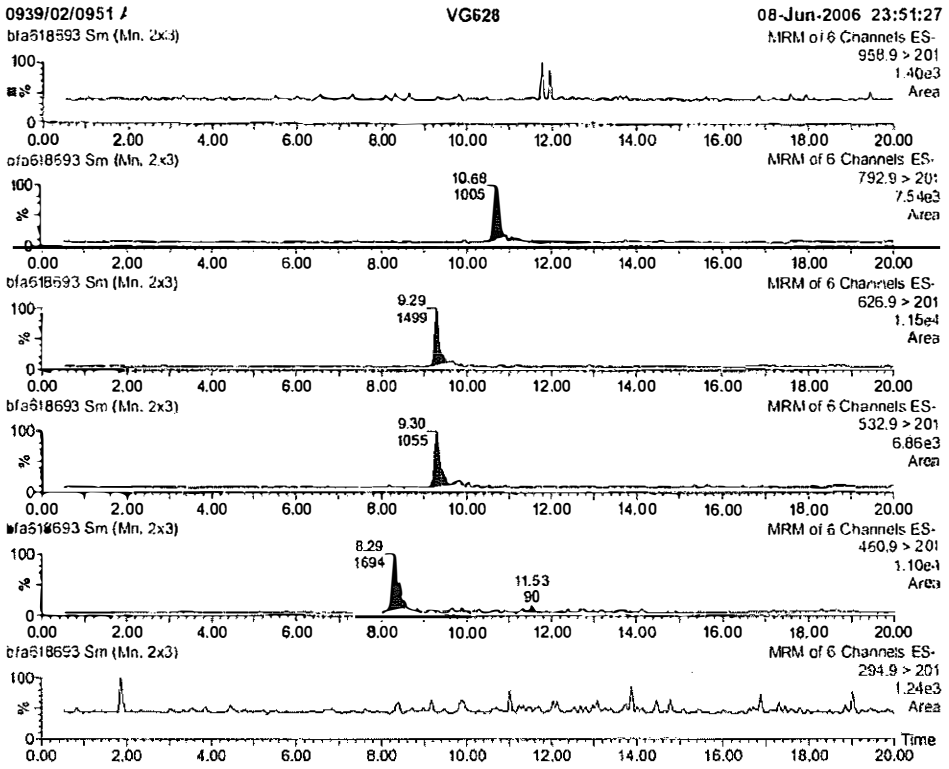


Figure 2b Representative LC-MS chromatogram of a first extract of a fluoropolymer sample. Extraction solvent methanol/water (80/20;v/v) containing 0.1% ammonia. [redacted]

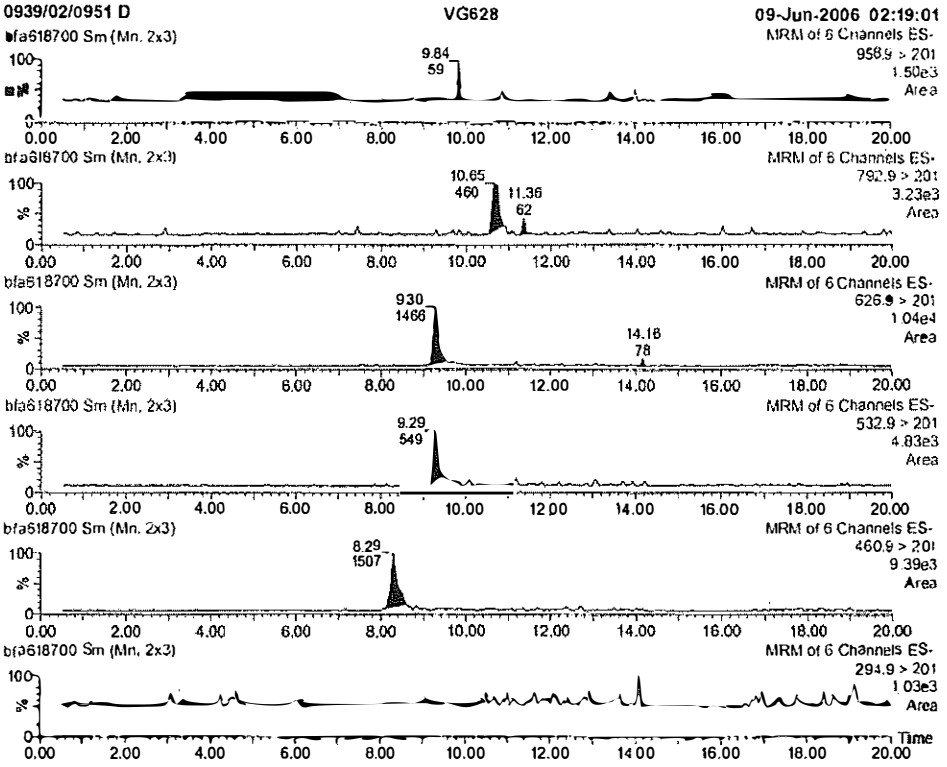


Figure 3 Representative LC-MS chromatogram of a calibration standard of 10.68 ng/ml (LOD).[redacted]

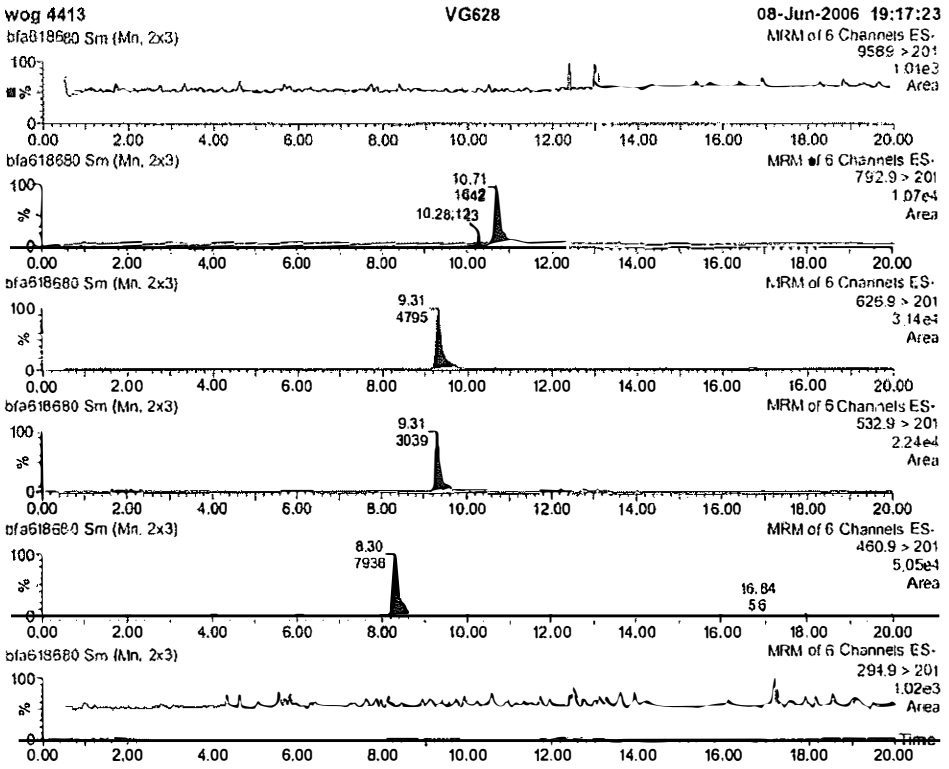


Figure 4a Represenative LC-MS chromatogram of the first extract after standard addition of 42.7 ng/ml to the sample of fluoropolymer. Extraction solvent methanol/water=80/20 (v/v). [redacted]

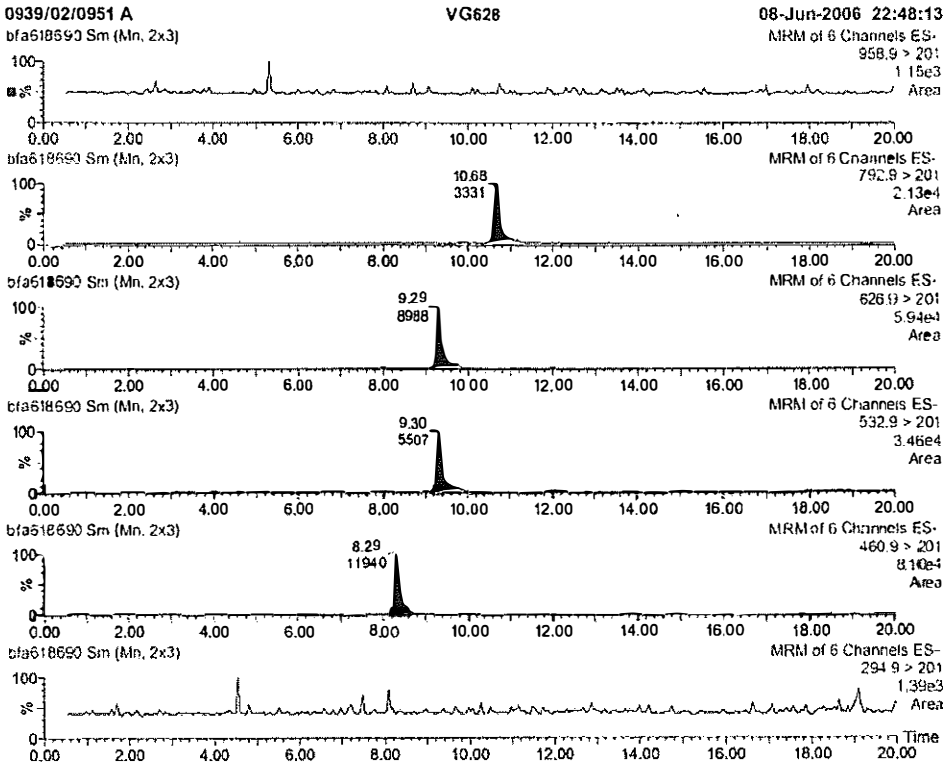


Figure 4b Represenative LC-MS chromatogram of the first extract after standard addition of 42.7 ng/ml to the sample of fluoropolymer. Extraction solvent methanol/water=80/20 (v/v) containing 0.1% of ammonia. [redacted]

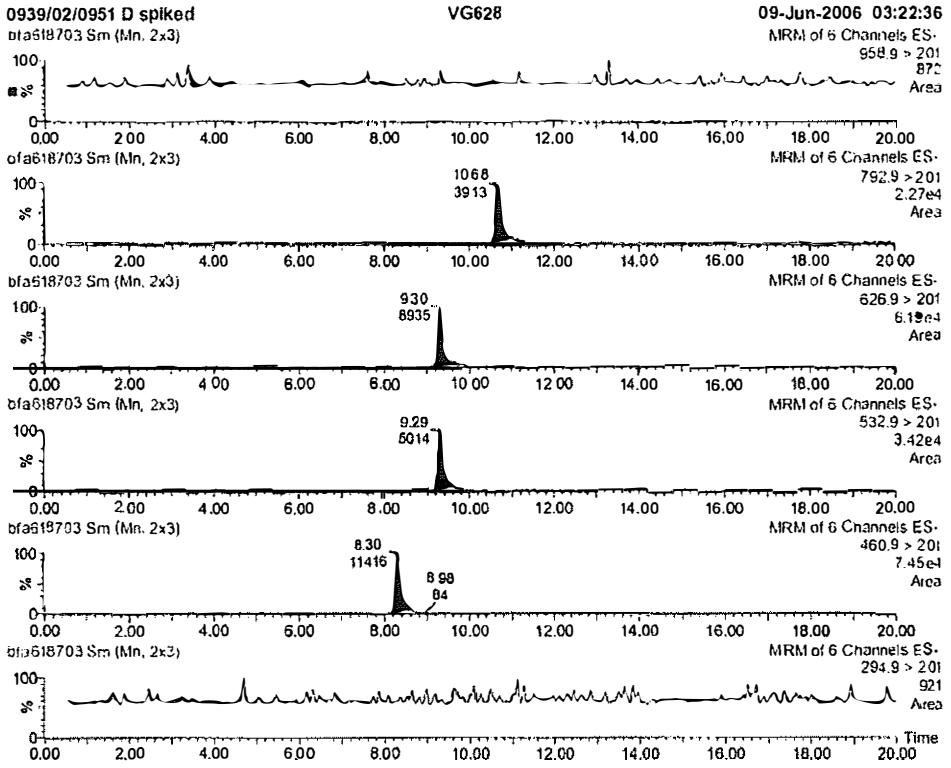


Figure 5 The raw data and statistical parameters of the calibration curve of [redacted]

| (ng/ml) | (area) | analyte |
|---|---|---|
| 0,00 | 1783,00 | 1,783E+03 |
| 10,68 | 9079,00 | 9,079E+03 |
| 21,36 | 17965,00 | 1,797E+04 |
| 42,76 | 30303 | 3,030E+04 |
| 85,44 | 57995 | 5,800E+04 |
| 128,16 | 86417 | 8,642E+04 |
| 170,88 | 109608 | 1,096E+05 |
| 213,6 | 142900 | 1,429E+05 |
| 0,00 | 4600 | 4,600E+03 |
| 10,68 | 8535 | 8,535E+03 |
| 21,36 | 15325 | 1,533E+04 |
| 42,76 | 29834 | 2,983E+04 |
| 85,44 | 58566 | 5,857E+04 |
| 128,16 | 86496 | 8,650E+04 |
| 170,88 | 113441 | 1,134E+05 |
| 213,6 | 145209 | 1,452E+05 |

| **Statistical evaluation**<br>**Calculated statistical parameters** | **Linear Regression**<br>**f(x) = a * x + b** |
|---|---|
| Intercept of upper confidence bound ($Y_{upo}$) | 7202,1288 |
| Intercept of lower confidence bound ($Y_{low}$) | -2487,2119 |
| Standard error of estimate Y Est ($S_{yx}$) | 1727,1798 |
| Standard error of the procedure $S_{x0}$ | 2,6403 |
| Slope a | 654,1558 |
| Standard errror of slope a | 5,7991 |
| Intercept of Xi ($Y_i$ = 0) | -3,6038 |
| Intercept b (Xi = 0) | 2357,4585 |
| Standard error of intercept b | 651,4300 |
| Correlation coefficient r | 0,9995 |
| Response lowest calibration value | 1783,00000 |
| Response highest calibration value | 145209,00000 |
| Degrees of freedom (df = n-2) | 14 |
| t-value 99%, one-tailed: $t_{(0.01;df)}$ | 2,62449 |
| Within laboratory detection limit (WDL) | 7,406 |

Figure 6 Typical calibration curve of [redacted]

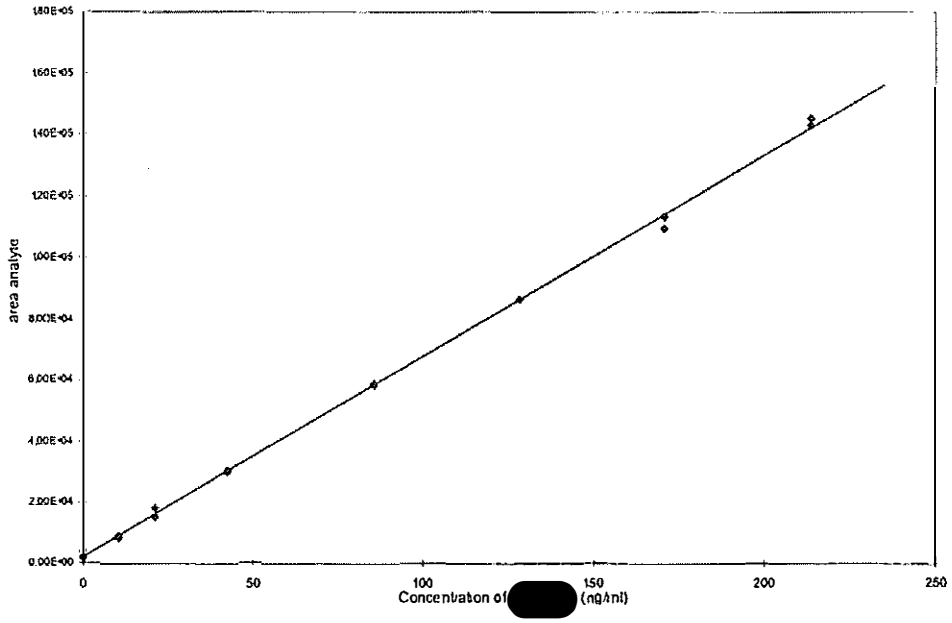


Figure 7 600 MHz $^1$H-NMR spectrum of the migrating substances of the fluoropolymer into 95% ethanol, desolved in $CDCl_3$ containing 0.05% TMS.

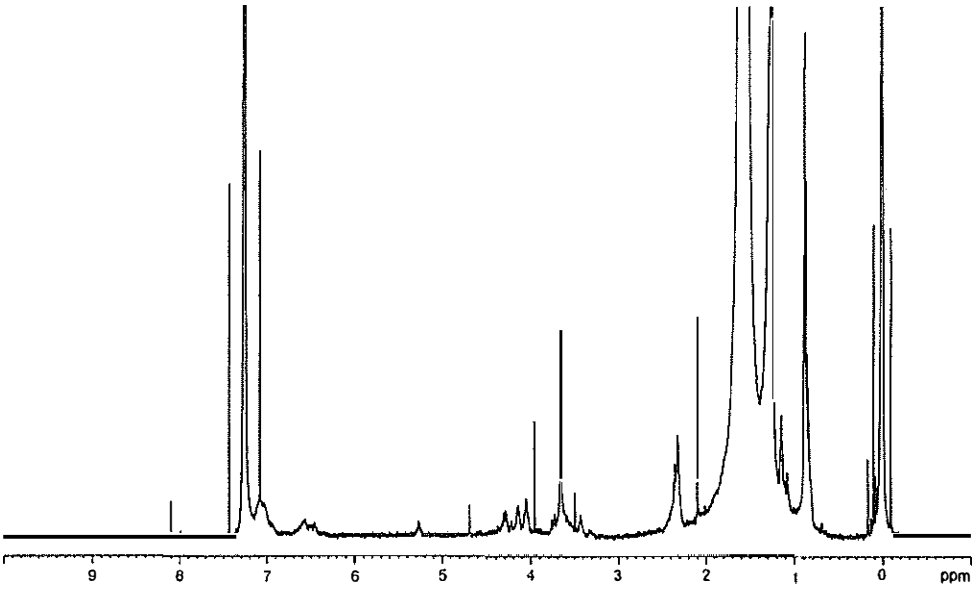



Figure 8 600 MHz $^1$H-NMR spectrum of the blank 95% ethanol after migration, desolved in $CDCl_3$ containing 0.05% TMS.

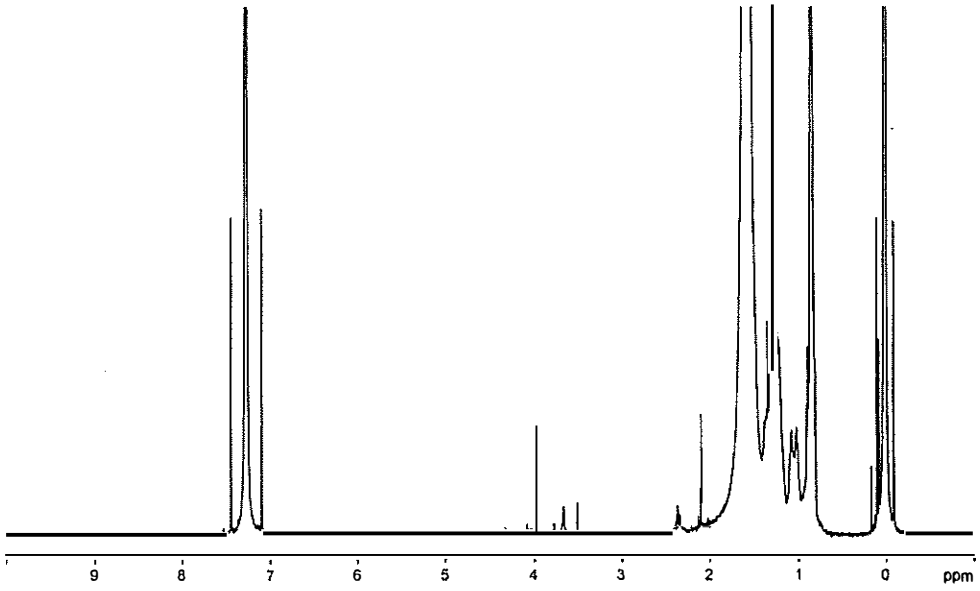


Figure 9 600 MHz $^1$H-NMR spectrum of the migrating substances from the fluoropolymer into Iso-octane, desolved in $CDCl_3$ containing 0.05% TMS.

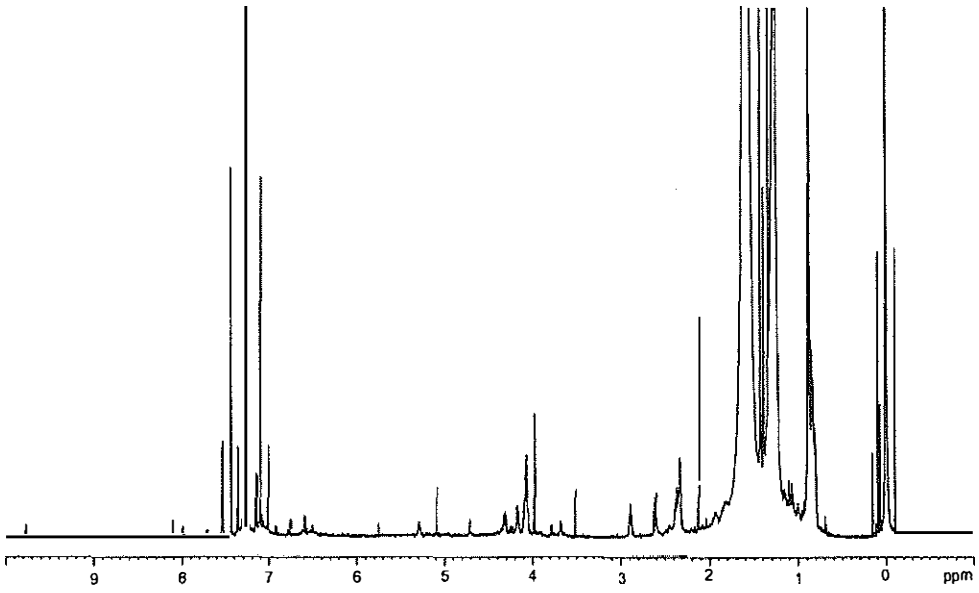
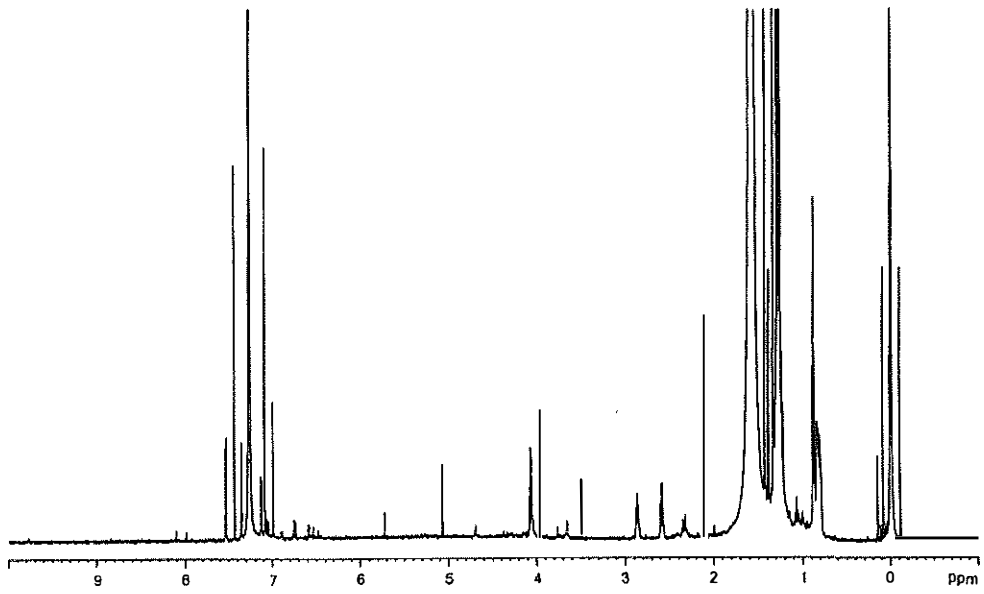



Figure 10 600 MHz $^1$H-NMR spectrum of the blank sample iso-ocatane desolved in $CDCl_3$ containing 0.05% TMS.



# 8 Appendix

B01 Determination of chlorofluoropolyether acids in fluoropolymer

# Determination of chlorofluoropolyether acids in fluoropolymer

## 1 Introduction

[redacted] is a chlorofluoropolyether acid [redacted] used as an emulsifier/dispersing agent during the polymerisation process of fluoropolymers. These fluoropolymers are processed to produce a range of articles for repeat use like parts for food processing equipment, tubes, tapes, coatings on cooking utensils.
After the manufacture, chlorofluoropolyether acids can migrate into foodstuffs coming into contact with that product.
The analytical method described the determination of the residual content of chlorofluoropolyether acids in the final fluoropolymer product.

## 2 Scope

This method describes the determination of chlorofluoropolyether acids in methanol/water extracts obtained from fluoropolymer samples produced by the use of chlorofluoropolyether acids [redacted].
The method is appropriate for the quantitative determination of chlorofluoropolyether acids in approximate analyte concentration range of 10 to 200 ng/ml methanol/water.

## 3 Principle

The fluoropolymer sample is extracted with methanol/water (80/20;v/v) containing 0.1% ammonia. The extract is analysed for the content of chlorofluoropolyether acids by LC-MS. Quantification is done by means of an external standard calibration.

## 4 Reagents

Reagents and solvents shall be of analytical quality unless otherwise stated.

### *4.1 Analytes*

4.1.1 Chemical description: chloro-fluoropolyethers acid ~90%
CAS Name: 1-Propene, 1,1,2,3,3,3-hexafluoro-, telomers with chlorotrifluoroethene, oxidized, reduced, hydrolized
Trade Name: [redacted]
Molecular Weight: [redacted]
CAS No.:329238-24-6
70Structural Formula: [redacted]

### *4.2 Chemicals*

4.2.1 Water deionized, purified with Barnstead NanoPure Infinity Purifier), HPLC quality water

4.2.2 Ammonium acetate (Merck art 1116)

4.2.3 Methanol, HPLC grade (Rathburn art RH1019)

4.2.4 Ammonia 25% (Merck art 31.05.04)

4.2.5 Ethanol, for spectroscopy (Merck art 1.000980)

4.2.6 Acetic acid (glacial) 100% (Merck art 1.00063)

*4.3 Solutions*

4.3.1 Standard stock solution of [redacted] in methanol/water (80/20; v/v) (approximate 0.6 mg/ml).

Weigh to the nearest 0.1 mg, approximately [redacted] mg of [redacted] (4.1.1) in a 50 ml volumetric flask and dissolve in methanol/water (80/20; v/v). Fill the volumetric flask up to the mark with methanol/water. Close and mix thoroughly.
Calculate the actual concentration in mg [redacted] per ml.

Repeat the procedure to obtain a second standard stock solution.

NOTE: The two primary standard solutions of analyte shall be checked against one another. The response factor, i.e. detector response divided by concentration of analyte solution, of the two primary standard solutions shall not differ more than 5%. If there is agreement within 5 %, subsequent diluted standard solutions are made from only one of the primary standard solutions.
If the levels of the two independently prepared stock solutions do not correspond to within ± 5% then both stock solutions shall be discarded, and new solutions shall be prepared.

4.3.2 Diluted stock solution

Transfer to a volumetric flaks of 20 ml, 1 ml of the stock solution of 0.6 mg/ml (4.3.1) and add methanol/water (80/20) to a final volume of 20 ml. The diluted stock solution contains 30 ng/ml of [redacted].

4.3.3 0.1% Ammonia in methanol

Mix 4 ml ammonia 25% (4.2.4) with 996 ml methanol (4.2.3).

4.3.4 Extraction solvent (0.1% ammonia in methanol:water = 8:2)

Mix 800 ml 0.1% ammonia in methanol (4.3.3) with 200 ml water (4.2.1). Extraction solvent is used with and without the addition of ammonia.

4.3.5 Ammonium acetate solution (1 mol/l)

Dissolve 77,08 g ammonium acetate (4.2.3) in water (4.2.2) and adjust to a volume of 1000 ml with water.

4.3.6 Eluent A:
5mM Ammonium acetate solution
Mix 5 ml of 1 M ammonium acetate solution (4.3.3) with 995 ml water (4.2.2).

4.3.7 Eluent B:
10mM Ammonium acetate in methanol

Mix 10 ml of 1 M ammonium acetate solution (4.3.4) with 990 ml methanol (4.2.3).

## 5 Apparatus

NOTE:An instrument or item of apparatus is listed only where it is special or made to a particular specification, usual laboratory glassware and equipment being assumed to be available.

LC-MS system whose main components include a High Performance Liquid Chromatograph preferably with an automatic injector or 100 µl injection loop, and a mass spectrometer (MS) detector operated in negative electrospray ionisation mode (ESI-).
HPLC column, capable of producing a symmetric peak of [redacted], and capable to separate [redacted] from interfering peaks originating from sample matrix or extracting solvent.

The following chromatographic conditions have been found to be suitable:

NOTE: Depending on the type of equipment used for the determination, the appropriate operating conditions are to be established.

**Liquid Chromatography**

The LC-equipment operates under control of the MS data system using LC method files.
HPLC chromatograph: Waters Alliance 2690 separations module.

Use eluent A (4.3.6) and B (4.3.7).

Column: Aqua 5µ C18 125A column; dimensions 150 x 3 mm

Linear gradient:

| Time (min) | Eluent A (%) | Eluent B (%) |
|---|---|---|
| 0 | 40 | 60 |
| 2 | 40 | 60 |
| 2.10 | 10 | 90 |
| 13.00 | 10 | 90 |
| 13.10 | 40 | 60 |
| 14.00 | 40 | 60 |

Flow rate: 0,3 ml/min
Injection volume: 50 µl
Autosampler temperature: 20°C

Column temperature: 30°C
Runtime: 20 min

NOTE: Retention time obtained for [redacted]

**Mass Spectrometry**

The mass spectrometer is controlled using the MassLynx 4.0 software
MS: Waters Ultima triple quadrupole MS in the negative electrospray ionisation mode.

| MS conditions | |
|---|---|
| Ionisation: | [redacted] |
| Interface: | ESI |
| Scanmode: | [redacted] |
| m/z values detected: | [redacted] |
| Start time: | 0.5 min |
| End time: | 20 |
| Collision energy (eV) | 20-42 |

## 6 Sample preparation

### *6.1 Test sample preparation*

Cut the sample into pieces of approximately 1x3 cm. Weight into a conical flask approximately 27 g of sample material. Add 50 ml of the extraction solvent methanol/water (80/20;v/v). Reflux the sample for 8 hours and transfer an aliquoate of the extract to an HPLC vial. Discard the remaining extraction solvent and repeat the extraction with a fresh amount of 50 ml methanol/water (80/20;v/v). Inject 50 µl of the first and second extract into the HPLC and analyse the extracts for containing Fluorolink 7800:7850.

### *6.2 Blank sample preparation*

Treat extraction solvent in the same way as described in 6.1.

### *6.3 Recovery experiments*

Add to the approximately 27 g of the sample material 80 µl of standard solution [redacted] (30 µg/ml see item 6.4). This corresponds with an addition of 85 µg per kg sample material. Treat the spiked sample as described in section 6.1. The final extract thus obtained contains approximately 48 ng of [redacted] per ml extract.

*6.4* *Calibration sample preparation*

Transfer, into a series of eight 25 ml volumetric flasks 0, 10, 20, 40, 80, 120, 160 and 200 µl of the diluted standard stock solution (4.3.2). Fill the Transfer to a volumetric flaks of 20 ml, 1 ml of the stock solution of 0.6 mg/ml (4.3.1) and add methanol/water (80/20) to a final volume of20 ml. The diluted stock solution contains 30 µg/ml of [redacted]. up to the mark with methanol/water (80/20;v/v) and mix thoroughly. The solutions thus obtained contain approximately 0, 12, 24, 48, 96, 144, 192 and 240 ng of [redacted] per ml.

## 7 Procedure

*7.1* *LC-MS analysis*

NOTE: When starting measurements, baseline stability and response linearity of the detector should be examined, together with verification of the detection limit.
The same operating conditions of the LC-MS system shall be maintained through out the analysis of all test samples and solutions set out in section 6. Each test sample shall be analysed at least in triplicate.

*7.2* *Sample treatment*

Extracts of the samples, recovery samples, blanks, as well as calibration samples prepared in section 6 are analysed by LC-MS.
Identify the [redacted] peak on the basis of the retention time and the specific MRM ions measure the peak height.

7.2.1 Calibration solutions

Inject each of the calibration samples (6.4) into the HPLC column. Measure the peak height of the six MRM ions of [redacted] in the chromatogram obtained and plot the sum of these peak heights against the concentration of [redacted] in the calibration samples in ng per ml methanol/water as calculated in section 6.4.

NOTES: The calibration curve should be linear. The correlation coefficient should be 0,996 or better. If correlation requirement is not met, new standard solutions shall be prepared from the original stock solutions. Analysis of the standard solutions and construction of the calibration graph shall be repeated.
The two sets of calibrant solutions made from independently prepared stock solutions should be cross-checked and should agree to ± 5 % of one another on the basis of peak ratio measurement.

7.2.2 Test samples and blank solutions

Inject 50 µl of the solutions obtained according to section 6.1 and 6.2 into the LC-MS system, using the conditions given in 5.16.
[redacted]

*7.3 Quantification*

7.3.1 Calculating of [redacted] concentration in the test samples

Graphical determination:

Using the peak heigh values obtained from the test samples according to 7.2.2, read the [redacted] concentration of the methanol/water (80/20;v/v) extract from the calibration graph (7.2.1) in ng/ml.

Calculation from the regression parameters:

NOTE: An EXCEL computer programme was developed which preferably should used to construct a calibration curve, and to calculate the correlation coefficient and other statistical data (according DIN 32645).

Use the measured peak area as obtained in 7.2.2 in the following formula.

If the regression line equation is

y [log (peak area)] = a * x [µg/ml] + b,

then the [redacted] concentration in the methanol/water $C_{FLU,extr}$ is
$C_{FLU,extr} = (y-b)/a$

Both procedures yield directly the [redacted] concentration in the methanol/water solution in ng/ml.

NOTE: The method applying calculation from the regression parameters should be the preffered one.

7.3.2 Calculation of the specific [redacted] migration
Calculate the residual content of [redacted] in the fluoropolymer sample as follows:

RC (ng/g) = $C_{FLU,extr}$(ng/ml) * V / G

in which:
$C_{FLU,extr}$ = concentration of [redacted] in methanol/water solution as obtained in 7.3.1
V = volume of isopropanol solution (ml)
G = gram of test sample

## 8 Validation

### *8.1 Recovery and repeatability*

Recovery and repeatability (SD of the recovery; n=3) of the method were for the standard addition to the sample material at the concentration level of 42.7 ng/ml: 99±7% for the extraction with methanol/water (80/20;v/v) and 101±8% for the extraction with methanol/water containing 0.1% of ammonia.

### *8.2 Detection limit*

The detection limit, based on the calibration curve was the lowest calibration point i.e. 10.68 ng/ml.

## 9 Test report

The test report shall contain, as a minimum, the following:

- an identification
- name of the laboratory
- name of the person responsible for the analysis
- date of the report
- date of the analysis
- chemical name of the analyte
- a reference to the method of analysis
- the performance characteristics of the method
- sample details, such as:
  - * type of food/food simulant/material/article
  - * date of receipt of the sample, its origin and its denotation
  - * date of preparation of the laboratory sample
  - * conditions of storage of sample and laboratorium sample
- results expressed in µg/kg fluoropolymer.
- results should be reported as the average value from two or more determinations satisfying the repeatability criterion in section 8.3.
- reasons for modification of the method of analysis, if applied.