BENZENE MONITORING: TECHNICAL ASPECTS OF THE OEL PROPOSAL OF 0.05 PPM

February 2019

The Risk Assessment Committee of ECHA (RAC) has produced an opinion, recommending that the 8 hour time weighted average (TWA) Occupational Exposure Limit (OEL) for benzene is lowered from 3.25 mg/m^3 (1 ppm) to 160 µg/m^3 (0.05 ppm) and that biological limit values (BLV) of 0.7 µg benzene /L urine and 2 µg SPMA/g creatinine are introduced. Several countries have already decided to significantly decrease the OEL for benzene. This recommendation needs to be considered in relation to the European Standard EN689 *Workplace exposure - Measurement of exposure by inhalation to chemical agents - Strategy for testing compliance with occupational exposure limit values* which was recently updated (May 2018) (see **APPENDIX A** for further details).

If the Commission's Advisory Committee on Safety and Health accept the RAC recommendation, industry will need to review their benzene exposure assessments as summarized in the following points:

- **Update air monitoring methodology.** The exposure data have to be compared with an OEL 20 times lower than the existing one. Air monitoring methodology should be able to detect at least 1/10th of the OEL, i.e. 16 µg/m^3.

- It is suggested to have a **Limit of Quantification (LOQ)** below the proposed OEL value, possibly of the order of 1 ppb (3.2 µg/m^3) since, according to EN689:2018 there might be actions at values of 1/10th of the OEL. Current standard methodologies are mostly aimed at measuring concentration against a target limit value of 1 or 0.5 ppm and are therefore not suitable. Nevertheless, many papers have been published describing methods capable to detect concentrations of benzene of 1 ppb or less. In the methodologies reported, air sampling is performed by active or by diffusive sampling. Sampling duration must be at least 8h for diffusive sampling. In order to assess the need for further controls for short tasks, shorter sampling times might be needed. The retained benzene is extracted by thermal desorption or chemical desorption with CS_2 followed by analysis via gas chromatography with FID or mass detectors. The lowest LOQ are usually obtained by combining active sampling with thermal desorption and GC-MS. Passive sampling devices are frequently used and can be used to compare with LOQ compatible with the proposed OEL. Real Time monitoring techniques have also significantly improved. Current commercially available instruments can detect benzene down to 50 ppb and up to 200 ppm by applying a specific benzene pre-filter. More details on benzene air monitoring methodologies are in **APPENDIX B.**

- **Validate biological monitoring methodology.** Several methods are available that have been validated for biomonitoring of benzene exposures at airborne concentrations of ~ 0.3 ppm (8h TWA) benzene and higher. From the available scientific studies, urinary trans,trans-muconic acid (ttMA) is not suitable for biomonitoring of benzene exposures below 0.3 ppm (8h TWA) due to the relatively high background values of ttMA. Both urinary benzene and S-phenylmercapturic acid (SPMA) are considered useful biomarkers for low-level benzene exposure because there is no background. Both biomarkers are sufficiently sensitive to pick up benzene exposures equivalent to 0.05 ppm (8h TWA) and lower. However, airborne concentrations of benzene have not been monitored and so there is critical question on background levels and accuracy of the method that needs to be assessed at such low levels. The overall conclusion is that there is a strong need to reliably assess correlations between low concentrations of airborne benzene and urinary SPMA. Until then, the scientific basis for the selection of a BLV is unclear. More details on the biological monitoring of benzene are in **APPENDIX C.**

- The **number of measurements** needed to demonstrate compliance must increase (**APPENDIX A**) to have a more valid statistical approach. **Periodic re-assessments** will need to be more frequent. With an OEL 20 times lower than the current, newly generated exposure data will be closer to this OEL which will require, according to European Standards, shorter interval between periodic measurements. Clause 7 of EN689:2018 specifies the requirement for setting intervals between periodic measurements that are set according to the fraction of the OEL that is met 1/10, 1/4, 1/2 (e.g. 16 µg/m^3, 24 µg/m^3, 32 µg/m^3). More details in **APPENDIX A.**

- **Exposure from non-occupational sources.** Smoking habits and background levels should be taken into account for airborne and biomonitoring measurements. At the proposed OEL and BLV of 0.7 µg benzene/L urine and 2 µg SPMA/g creatinine confounding factors are relevant and need to be considered. Non-occupational exposed smokers may have higher levels. For biomarkers, cotinine monitoring and use of a questionnaire could help to avoid data misinterpretation. For inhalation exposure, application of EN689:2018 sets some actions starting from 1/10 of the OEL, i.e. 16 µg/m^3 considering the RAC proposal. Background levels might therefore be close to that value. In **APPENDIX D** data on non -occupational exposure to benzene are reported.

In summary, if the benzene OEL is lowered as recommended by RAC, the petroleum industry would need to consider:

1. Monitoring methods should target a lower OEL and therefore must be updated accordingly.

2. The number of samples needed for the survey will be higher. With an OEL of 160 µg/m^3 a statistical approach is probably needed to demonstrate compliance and therefore at least 6 measurements for each Similar Group of Exposure (SEG) of workers will be needed.

3. The frequency of measurements might increase depending on the results of the surveys. It might be necessary to repeat the measurements after 12 months if the Geometric Mean (GM) of the distribution is 1/2 of the OEL.

4. Exposure from non-occupational sources in exposure evaluation should be considered.

APPENDIX A – Application of EN689:2018 to the proposed OEL

EN689:2018 specifies a strategy to perform representative measurements of exposure by inhalation to chemical agents in order to demonstrate the compliance with OEL.

According to Clause 5, occupational exposure assessment begins with a Basic Characterization (5.1) that can lead to:

- *Exposure > OEL (non-compliance)*

Appraiser shall report this and advise on a programme to reduce exposures, using Risk Management Measures (RMMs), before making measurements to test compliance;

- *Exposure <<< OEL (compliance)*

Appraiser shall decide if measurements are necessary or not. If measurements are unnecessary, the appraiser shall report this and advise on a reassessment.

- Information on exposure *insufficient:* appraiser shall continue to develop a sampling plan.

The proposed RAC OEL will lead to performing measurements to demonstrate compliance.

If information of exposure is insufficient, measurements need to be performed. The results of the survey are compared with the OEL (Clause 5.5 *Comparison of results with OEL)*.

Preliminary test and/or a statistical test can be applied.

Preliminary test is described in clause 5.5.2 of the standard. It requires 3 to 5 measurements for each Similar Group of Exposure (SEG). The possible outcomes are:

COMPLIANCE	NO DECISION	NON COMPLIANCE
N° 3 measurements: all data <0.1 OEL (16 µg/m^3 benzene)	*N° 3 measurements: 1 data <0.1 OEL* (16 µg/m^3 benzene)	*If ONE measurement > OEL* (160 µg/m^3 benzene)
N° 4 measurements: all data <0.15 OEL (24 µg/m^3 benzene)	*N° 4 measurements: 1 data <0.15 OEL* (24 µg/m^3 benzene)	
N° 5 measurements: all data <0.2 OEL (32 µg/m^3 benzene)	*N° 5 measurements: 1 data <0.2 OEL* (32 µg/m^3 benzene)	

In the situation of NO DECISION additional measurements are needed, at least a total of 6, in order to apply the **statistical test** (clause 5.5.3).

According to clause 5.5.3 to be compliant, less than 5% of exposure of the SEG, with 70% of confidence, should exceed the OEL (ANNEX F).

APPENDIX B – Air Monitoring Methodology

- Air sampling can be performed by active sampling (passing air actively through a sorbent tube) or by diffusive sampling with badge or sorbent tube. The retained benzene is extracted for analysis by thermal desorption or chemical desorption with CS_2 followed by analysis via gas chromatography with FID or MS detectors.

- Current monitoring methodologies that can used as a reference are:

EN ISO 16017-1 Indoor, ambient and workplace air Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/ capillary gas chromatography - Pumped sampling
EN ISO 16017-2 Indoor, ambient and workplace air Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/ capillary gas chromatography – Diffusive sampling

EN ISO-16017 Part 1 is applicable to the measurement of airborne vapours of VOCs in a concentration range of approximately 0.5 $\mu g/m^3$ to 100 mg/m^3 for an individual component. ISO-16017 Part 2 is applicable to the measurement of airborne vapours of VOCs in a concentration range of approximately 2 $\mu g/m^3$ to 100 mg/m^3 individual organic component for an exposure time of 8h. Modified EPA TO 17/1999, developed for air quality monitoring, could also be applicable. Methodologies for diffusive sampling are reported in MDHS 88 (chemical desorption) and MDHS 80 (thermal desorption).

Concawe report 8/02 *Method for monitoring exposure to gasoline vapour in air – revision 2002* recommends use of active sampling considered more reliable for gasoline.

Use of diffusive samplers, as shown in the table, is increased since, being less cumbersome, they are more easily acceptable to workers. A number of organic vapor diffusive samplers, solvent desorption badges and thermal/solvent desorption tubes are available commercially. Solvent desorption badges have been widely applied to monitor exposure of the region of a few tens of ppb (9). Passive samplers' application to lower concentrations, less than 1 ppb, have been studied for air quality monitoring purposes, but sampling time is greater than 8 hours. Variability in uptake rate, background VOC concentration in sampling media, effect of temperature and back-diffusion issues for different types of diffusive samplers have been analyzed (8, 10). Applicability of diffusive samplers to 8 hours exposure have been studied (11, 12, 13) targeting exposure at air quality level.

There is a need for methods that allow for the detection of low levels of benzene over a short period of time. The active sampling methods have not been validated for such low levels, and passive samplers are not applicable.

Below a table with a summary of the most frequently used techniques for sampling and analysis of benzene as reported in published paper.

Sampling equipment	Adsorbent	Flow rate/sampling duration (or volume sampled)	Desorption	Analysis technique	Detector	LOQ/LOD	Notes
Active	Graphitized Charcoal	50 ml/min for 8h	Thermal	GC	MS	LOQ 0,5 µg/m^3	UNI EN ISO 16017-1 2002 Ramirez et al Talanta 82(2010) 719-727
Active	Active Charcoal cartridge	200 ml/min from 15 minutes up to 8h	Chemical CS_2 (low benzene content)	GC	MS	LOQ 1 µg/m^3	Ramirez et al Talanta 82(2010) 719-727
Diffusive samplers (radial type)	Graphitized carbon (Carbograph 4)	34.6 ml/min /8h	Thermal	GC	FID	LOD 0.2 µg/m^3 24 hours	Pennequin-Cardinal et al. Talanta, 2005, 65, 1233–1240
Diffusive samplers (radial type)	Graphitized carbon (Carbograph 4)	34.6 ml/min /8h	Thermal	GC	FID or MS	LOQ 0.05 µg/m^3 7 days	C. Cocheo et al. J. Environ. Monit., 2009, 11, 297–306
Diffusive samplers (radial type)	Activated carbon cartridge	80 ml/min /8h	CS_2	GC	FID or MS	LOQ 0.05 µg/m^3 2 days	C. Cocheo et al. J. Environ. Monit., 2009, 11, 297–306 MDHS88
Passive - stainless steel tube, 9 mm internal diameter - 90 mm length equipped with diffusion chamber	Chromosorb 106	6h sampling time	Thermal	GC	FID	LOQ 6 µg/m^3 (0.002 ppm)	Cancer Epidemiol Biomarkers Prev 2005;14:2237-2244. Silvia Fustinoni ,Dario Consonni, Laura Campo et al.
Real time monitoring instruments							
Portable Sensors for Ambient Air Monitoring of Benzene and VOCs				Handheld benzene detector with benzene pre-filter tube	PID	Lowest LOD declared by manufacture (see reference) 10 ppb	L. Spinelle , M.Gerboles, T.Sauerwald Sensors 2017, 17, 1520; doi:10.3390/s17071520

Appendix C – Biomonitoring of benzene exposure and BLV

RAC considers only benzene in urine (BU), trans,trans-muconic acid (ttMA), and S-phenylmercapturic acid (SPMA). It does not consider benzene in blood (BB) as RAC do not support invasive methods.

RAC relies on the evaluation by the MAK Kommission of the Deutsche Forschungsgemeinschaft that issued a rationale for their biological exposure values in early 2018 (Kraus 2018). In this document the MAK Kommission derived biological reference values (BAR) and re-evaluated the exposure equivalents for carcinogenic substances (EKA) for the urinary benzene metabolites SPMA and ttMA in 2016. The existing exposure equivalents for carcinogenic substances (EKA) for the benzene metabolites were re-evaluated and extended especially to the low exposure range. For the parameter benzene in urine, new EKA were established. Sampling time is at the end of exposure or the end of the working shift.

Taking results of studies with persons of the general population without occupational exposure to benzene into consideration, with sufficient number of cases and current biomonitoring methods, biological reference values (BAR) of 0.3 µg SPMA/g creatinine, 150 µg ttMA/g creatinine and 0.3 µg benzene/l urine were established.

The published EKA data for SPMA do not match with the biological exposure limits (BEI) as set by the American Conference of Governmental Industrial Hygienists (ACGIH). This triggered a detailed look at how the EKA values were derived.

SPMA (S Phenyl Mercapturic Acid)

The MAK Kommission excluded methods that applied ELISA methods for determination of SPMA, which is a valid approach as the available methods (Fracasso et al. 2010; Aston et al. 2002; Fustinoni et al. 2005) are validated at relatively high levels of SPMA (corresponding to airborne levels of benzene of 0.5 to 1 ppm) and inherently not suitable for applications at lower levels.

The Kommission only considered GC-based methods and found six studies that report low-level benzene exposures and corresponding SPMA values.

In a study on 50 non-smoking policemen, a median exposure of 20.55 (range 13-98 to 32.48) µg/m^3 was reported corresponding to SPMA levels of 0.35 (range 0.21 to 0.69) µg/g creatinine (Angelini et al. 2011). There were two studies by the group of Manini and co-workers (Manini et al. 2006; Manini et al. 2008), but one, the 2006 study, was disregarded since the values reported did not match the other four (4) studies. The other study reports an average airborne benzene concentration (in 24 individuals) of 6.1 µg/m^3 with a range of 0.3 to 9.5 µg/m^3 and median SPMA concentrations (in 80 individuals) of 0.42 with 25 and 75% percentiles of 0.2 and 1.07 µg/g creatinine, respectively.

In a study by Carrieri and co-workers, 20 non-smoking petrochemical workers were measured on 9 consecutive days, an average airborne concentration of benzene of 0.0561 (median 0.0132, range < 0.003 to 924) mg/m^3 was found to correspond with urinary SPMA values of 1,14 (median 0,48, range < 0.06 to 18.63) µg/g creatinine (Carrieri et al. 2010).

The study by Mansi and co-workers (Mansi et al. 2012) is problematic since the reported airborne value of benzene of 0.0368 (range 0.004–0.292) mg/m^3 was measured in both smokers and non-smokers and not necessarily on the same day as the urine samples for determination of SPMA were collected. This is not surprising given the fact that the study was not designed to establish a correlation between airborne exposures to benzene and urinary excretion of SPMA.

The study by Maestri et al. is the most extensive: in 231 non-smoking workers exposed to an airborne benzene exposure averaging 11.4 µg/m^3 (range 0.4 to 220 µg/m^3 as measured in 227 workers) an average urinary SPMA of 1.2 (range 0.2 to 8.8) µg/g creatinine was found. In 102 non-smoking controls an average urinary SPMA of 0.7 (range 0.1 to 4.0) µg/g creatinine was found (Maestri et al. 2005). After logarithmic transformation of the data, a very weak correlation (r^2 0.18) was found between airborne levels of benzene and the urinary levels of SPMA.

To calculate the correlation between low-level benzene exposure and urinary SPMA, the MAK Kommission selected the studies by Manini et al., 2008, Carrieri et al., Angelini et al., and Mansi et al. However, it is unclear how they did this since the various studies report median and average values. As indicated, the study by Mansi et al. is confounded by data obtained in smokers and, for unclear reasons the most extensive study (by Maestri et al.) is not taken into account. A correlation was obtained that was not statistically significant and this relation was nevertheless used to calculate SPMA values of 1.5 and 3 µg/g creatinine, corresponding to airborne concentrations of benzene of 0.1 and 0.2 mg/m^3.

For the higher airborne benzene concentrations (≥ 0.5 mg/m^3), the MAK Kommission used the study by Van Sittert et al. (van Sittert, Boogaard, and Beulink 1993). This is the first study that validated the correlation between airborne benzene concentrations and urinary SPMA and combined data from 12 studies in 6 countries from 333 workers (613 samples) and 48 controls. A good correlation between airborne benzene and urinary SPMA was found and this correlation was applied by the MAK Kommission to calculate their EKA values. However, this method applied S-benzylmercapturic acid as internal standard which caused issues at lower concentrations where, especially in samples prepared from more concentrated urines, peaks may shift leading to failure to integrate the entire peaks for the selected mass fragments leading to underestimation of the actual concentrations of S-PMA. For that reason a deuterated internal standard (ring-d_5-SPMA) was synthesized. With the improved method another validation study was conducted, comprising 12 studies in 5 countries with 434 samples of 133 workers in settings where we had previously found the highest exposure levels (Boogaard and van Sittert 1995, 1996). The resulting regression line for SPMA is given by:

Airborne benzene (mg/m^3, 8-h TWA) = 0.0758 x urinary SPMA (µg/g creatinine) – 0.317 (r = 0.968).

This regression line gives higher values for the lower concentrations than the previous regression line as indicated in the table below.

Airborne benzene		Urinary SPMA [µg/g creatinine]
[mL/m^3]	[mg/m^3]	
(0.15) (*)	(0.5)	(10.7)
0.3	1.0	17.4
0.6	2.0	30.6
1.0	3.3	47.7
2.0	6.5	89.9

(*) The method was not validated at values below 0.3 ppm

When one uses the 'old' regression line (van Sittert, Boogaard, and Beulink 1993), the values calculated for 0.1 and 0.2 mg/m^3 would yield negative values, which indicates that the values proposed by the MAK Kommission do not fit the trend, i.e. the line is bent upwards at lower concentrations. Using the 'new' regression line, which is not validated for airborne concentration below 1 mg/m^3, values of 5.5 and 6.8 µg/g creatinine are calculated. These values seem relatively high in view of the results of the studies with low airborne concentrations. The overall conclusion is that there is a strong need to reliably assess correlations between low concentrations of airborne benzene and urinary SPMA.

ttMA (trans trans muconic acid)

A series of studies have been conducted to assess the correlation between urinary ttMA and airborne low-level (< 0.1 mg/m^3) concentrations of benzene and, although several values have been reported, the data are scattered and it is obvious that no clear correlation exists (Campagna et al. 2012; Carrer et al. 2000; Carrieri et al. 2010; Fracasso et al. 2010; Fustinoni et al. 2005; Manini et al. 2006; Manini et al. 2008; Mansi et al. 2012). The MAK Kommission concluded that urinary ttMA is not suitable for exposure assessment at concentrations below 1 mg/m^3 (0.3 ppm). This conclusion is also based on the fact that the 95-percentile for the general population is approximately 150 µg ttMA/g creatinine. In addition, dietary uptake of sorbic acid contributes to ttMA excretion and could lead to urinary values as high as 700 µg/g creatinine. Nevertheless, the MAK Kommission proposed a series of EKA values based on a partially reported study by Bader et al. (Bader et al. 2014) in operators, both smokers and non-smokers, involved in maintenance work on steam-cracker installations and aromatics plants (Bader 2017, personal communication). In these studies airborne benzene concentrations were not measured but only ttMA, SPMA , and BU. ttMA and SPMA were found to be reasonably well correlated (Spearman's R = 0.753 for linear correlation and Pearson's R = 0.697 after double logarithmic transformation). Using the 172 data points reported by Bader et al. (Bader et al. 2014) and after logarithmic transformation, a value of 25 µg SPMA/g creatinine would correspond to 405 – 630 µg ttMA/g creatinine, which was rounded to 500 µg ttMA/g creatinine. The value of 25 µg SPMA/g creatinine was considered to correspond to 0.6 ppm airborne benzene and the value of 500 µg ttMA/g creatinine was subsequently linearly scaled to set EKA values corresponding to 0.3, 1.0 and 2.0 ppm.

BU (Urinary Benzene)

It is good to consider that historically determination of BU has been considered difficult due to the inherent volatility of benzene which may cause evaporation from urinary samples and the potential contamination with benzene in the working place during collection. For the derivation of the EKA there were only 4 studies available (Campagna et al. 2012; Fustinoni et al. 2005; Manini et al. 2008; Manini et al. 2006). As indicated above, the MAK Kommission did not take one study (Manini et al. 2006) into account as it did not 'fit' the other three studies. The three remaining studies only report mean values and no correlation between airborne benzene concentration and BU. Only non-smokers were considered in the evaluations. The 2008 study by Manini et al. reports a median airborne benzene concentration (in 24 individuals) of 6.1 µg/m^3 with 25 and 75% percentiles of 0.3 and 9.5 µg/m^3, respectively, and median BU concentrations (in 80 individuals) of 0.16 with 25 and 75% percentiles of 0.13 and 0.26 µg/L, respectively but the authors specifically state that no statistical significant correlation between airborne benzene and BU could be established. This may be due to the fact that airborne benzene levels were determined in only 24% of the individuals. Furthermore, it is surprising that the airborne levels measured vary more than 30-fold whereas the BU values only 2-fold. In the study by Campagna et al., an average airborne benzene value of 30 (range 12-123) µg/m^3 (in 19 individuals) with a corresponding BU of 267 (range 151-557) ng/L was reported. The authors report a statistical correlation between airborne benzene and BU. In the study by Fustinoni et al. for two groups of non-smoking workers airborne values of 22 (range 9 – 361) and 61 (range 11-478) µg/m^3 in 49 and 46 individuals, respectively, with corresponding BU values of 151 (range 25-943) and 342 (range 42-2836) ng/L. In both groups, the pre-shift BU values (256, range 98-846 ng/L and 459, range 147-2708 ng/L, respectively) were higher than the post-shift values. The authors report a statistical correlation (after log-transformation) of airborne benzene values and BU, where the correlation with pre-shift samples was slightly higher than for post-shift samples.

The MAK Kommission took the four values from the three studies as indicated above and calculated a correlation between the airborne values and the BU values (ignoring that both for airborne benzene and BU some values were average and other median values) and found a highly statistically significant correlation which they extrapolated to calculate EKA values of 0.48 and 0.83 µg/L corresponding to 0.1 and 0.2 mg/m^3 airborne levels, respectively.

The MAK Kommission found no studies with reported airborne benzene levels greater than 0.06 mg/m^3 but decided not to extrapolate beyond 0.2 mg/m^3 but rather apply the correlation found between BU and the two other urinary biomarkers (ttMA and SPMA)(Bader et al. 2014). The correlation depends on whether you use ttMA or SPMA and also on whether you apply creatinine correction. It is unclear (not reported) which data are finally applied, but a consistent set of values with the extrapolated values for low concentrations of benzene was found.

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APPENDIX D - Exposure from non-occupational sources

Inhalation exposure:

a) Outdoor levels: Concawe published in 1999 report 2/99 "Environmental exposure to benzene". In the 2016 report (Air quality in Europe) EEA says *"Between 2000 and 2014, both benzene and toluene show a decrease of more than 70 %, which reflects mainly the reduction close to traffic sources, taking into consideration the station selection. For the period 2005–2014, twice as large and more representative benzene and toluene data sets are available. Although observed trends are smaller during those 10 years, they are still significant at the majority of stations, confirming the decrease in concentrations".*

Most of the measured data in Europe comply with the Air Quality Limit of 5 µg/m^3 (in 2015 there were only two stations in Croatia with concentrations above this level (reference Annual mean benzene concentrations in 2015 –EEA).

b) Indoor levels of benzene were in the Concawe report 2/99.
More recently, the AIRMEX study (2) reports exposure and concentration data from 2003-2008:

	N° of measurements	Min µg/m^3	Max µg/m^3	AM µg/m^3	Median µg/m^3	95^{ih} percentile µg/m^3
Outdoor	108	0.4	15.2	3.2	2.1	8.0
Public Building/Schools	188	0.5	63.7	4.4	2.6	11.9
Private Houses	96	0.4	32.1	2.8	1.9	4.9
Personal Inhalation	146	0.7	26.4	4.7	3.5	13.6

Among the indoor sources: cigarette smoking, use of incense.

c) Food: From a recent publication on **Risk assessment of benzene in food samples of Iran's market:**
"Benzene concentration in carbonated beverages, fruit juices, pickle, lime juices, mayonnaise and salad dressing were 3.57 ± 1.70, 5.17 ± 3.63, 4.37 ± 2.24, 4.99 ± 0.54, 1.38 ± 0.87 and 1.47 ± 0.83 µg/L, respectively, being in all cases below the acceptable limit (10 µg/L) proposed by the World Health Organization (WHO) as a reference for drinking water".

d) Biological monitoring: Data from published paper show values above the proposed BLV for general population (6,14).

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The scope of Concawe's activities has gradually expanded in line with the development of societal concerns over environmental, health and safety issues. These now cover areas such as fuels quality and emissions, air quality, water quality, soil contamination, waste, occupational health and safety, petroleum product stewardship and cross-country pipeline performance.

Our mission is to conduct research programmes to provide impartial scientific information in order to:

- Improve scientific understanding of the environmental health, safety and economic performance aspects of both petroleum refining and the distribution and sustainable use of refined products;
- Assist the development of cost-effective policies and legislation by EU institutions and Member States;
- Allow informed decision making and cost-effective legislative compliance by Association members.

Concawe endeavours to conduct its activities with objectivity and scientific integrity. In the complex world of environmental and health science, Concawe seeks to uphold three key principles: sound science, transparency and cost-effectiveness.

Transparency Register: 19227706301-14