Measurement Assurance of Phtalate Content: A Reference Material of Six Priority Phthalates in Methanol Solution

Anatoliy I. Krylov, Alena Yu. Mikheeva, Alexandra G. Budko, and Irina Yu. Tkachenko

Abstract The article provides information on the development of a new type of reference material (RM) of six priority phthalates (dimethyl phthalate, diethyl phthalate, di-n-butyl phthalate, benzyl butyl phthalate, di-2-ethyl hexyl phthalate, and di-n-octyl phthalate) in methanol solution, provided with metrological traceability to the GET 208–2019 (GET 208) national primary standard. The procedure for RM preparation and certification, including the homogeneity and stability assessment, is demonstrated. Pure organic substances (phthalates) characterised by the GET 208 primary standard were used as the starting material for the RM preparation using gravimetric and volumetric-gravimetric methods. The RM stability was assessed by an isochronous study. The mass fraction and mass concentration of individual phthalates in solution are the certified characteristics of the RM. The contributions from the purity of RM starting materials, preparation procedures, its heterogeneity and long-term instability were taken into account when calculating the uncertainty budget for the RM certified characteristics. The relative expanded uncertainty of certified values does not exceed 2%. As a result, the GSO (CRM) 11,366–2019 (6Ftlt-VNIIM) certified reference material of orthophthalic acid esters (phthalates) in methanol solution was developed and approved. The practical significance of using the GSO (CRM) 11,366–2019 consists in ensuring the metrological traceability of RMs to the corresponding SI units reproduced via the GET 208 national primary standard. The developed CRM can be used for different measuring tasks and metrological works.

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Keywords Reference material · Phthalates · Certified value · Uncertainty · Metrological traceability · Mass balance method · Homogeneity · Stability · Measurement assurance

Abbreviations Used in the Article

CERI	Chemicals Evaluation and Research Institute, Japan
CIL	Cambridge Isotope Laboratories, Inc., USA
CRM	Certified reference material
NIM	National Institute of Metrology, China
NIST	National Institute of Standards and Technology, USA
NMIJ	National Metrology Institute of Japan
RM	Reference material
BBP	Benzyl butyl phthalate
HPLC–UV	High-performance liquid chromatography-ultraviolet detection
GSO	Formal name of certified reference material in Russia
GC–MS	Gas chromatography-mass spectrometry
DBP	Di-n-butyl phthalate
DMP	Dimethyl phthalate
DOP	Di-n-octyl phthalate
DEHP	Di-2-ethylhexyl phthalate
DEP	Diethyl phthalate
VOC	Volatile organic compound
MB	Mass balance
MI	Methodological instructions
NC	Non-volatile compounds
MC	Major component
PVC	Polyvinyl chloride
PRPS	Primary reference pure substance
RSC	Related structural compound
RM	Reference material
CRM	Certified reference material
TR CU	Technical regulations of the Customs Union
POS	Pure organic substance

Introduction

Russia produces a wide range of certified reference materials (CRMs) used for ensuring the uniformity of measurements [1]. However, there are particular groups (or classes) of chemical substances not provided with appropriate CRMs, which are

in demand in various fields, including industry, agriculture, healthcare, ecology, etc. Another important question is the presence/absence of metrological traceability of reference materials (RMs), which determines their purpose and scope in analytical practice.

The esters of orthophthalic acid (phthalates) are large-scale products of the chemical industry, which are widely used as lubricating oils, anti-foaming agents, solvents, and carriers in various industrial processes, as well as in the cosmetics manufacture. Phthalates are most widely used as plasticisers in polyvinyl chloride (PVC) products obtained during the production of various polymeric materials for industrial, household, food, and medical purposes. The release of phthalates into environment is not only a result of their production and processing, but also a consequence of the widespread distribution of plastic in the form of consumer goods. In the bulk of a polymer, phthalates, as a rule, do not form strong bonds and are easily separated from finished products [2–5]. From the group of phthalates, six compounds are classified as priority organic pollutants: dimethyl phthalate (DMP), diethyl phthalate (DEP), di-n-butyl phthalate (DBP), benzyl butyl phthalate (BBP), di-2-ethyl hexyl phthalate (DEHP), and di-n-octyl phthalate (DOP) [6, 7].

Phthalates are low-toxic substances upon short-term exposure; however, under the conditions of long-term intake into the body, they can stimulate the occurrence of chronic diseases [8–12]. Based on scientific evidence from various sources, the European Union (EU) banned the use of DBP in the manufacture of cosmetics and toys in 2004 [13]. Later, the ban was extended over DEHP and BBP. Russia has also adopted a number of documents regulating the content of phthalates in packaging and products intended for children and adolescents, as well as in ambient air, textile, and shoe materials [13–19]. Methods for measuring the phthalate content in various matrices are prescribed in the Russian regulatory documents [20–26] and in the Technical Regulations of the Customs Union (CU).

Although phthalates belong to one of the most important groups of substances, until recently, no national (Russian) CRMs have been available for their measurement.

National metrological institutes in some countries and a number of commercial organisations produce a limited range of both certified reference materials (CRMs) and reference materials (RMs), information about which is summarized in Table. 1.

It is noteworthy that the assigned values in CRMs are characterised in terms of uncertainty (error) and established metrological traceability, which is the key difference between CRMs and RMs, for which these characteristics are not required [27].

A similar division on the basis of the presence/absence of metrological traceability of CRMs and RMs is recorded in the documents on standardization adopted by the Interstate Council for Standardization, Metrology, and Certification (Protocol No. 123-P of October 30, 2019) and put into effect in the Russian Federation [28].

The use of CRMs for performing measurements guarantees the highest accuracy and reliability, as well as the comparability of the results obtained, which is particularly important when performing measurements in areas subject to governmental

Table 1 Certified reference materials and reference materials for the phthalate group produced by foreign manufacturers

No	Manufacturer, country	Name of material	Reference number	Mass concentration[a], $\mu g/cm^3$
Certified reference materials (CRM)				
1	NIM, China	DMP in methanol	GBW (E) 100,221	230 (±2%)
		DEP in methanol	GBW (E) 100,222	238 (±2%)
		DEHP in methanol	GBW (E) 100,223	186 (±2%)
		BBP in methanol	GBW (E) 100,224	165 (±2%)
		DBP in methanol	GBW (E) 100,226	195 (±2%)
2	CERI, Japan	DEP in methanol	CERIjcss-0569	1000 (±0.8%)
		DEP in hexane	CERIjcss-0570	1000 (±0.7%)
		DBP in methanol	CERIjcss-0571	1000 (±0.8%)
		DBP in hexane	CERIjcss-0572	1000 (±1.0%)
		DEHP in methanol	CERIjcss-0573	1000 (±0.7%)
		DEHP in hexane	CERIjcss-0574	1000 (±0.9%)
		BBP in methanol	CERIjcss-0575	1000 (±0.4%)
		BBP in hexane	CERIjcss-0576	1000 (±0.6%)
		8 Phthalates in Methanol: Diethyl phthalate Di-2-ethyl hexyl phthalate Di-n-butyl phthalate Benzyl butyl phthalate Di-n-hexyl phthalate Dicyclohexyl phthalate Di-n-pentyl phthalate Di-n-propyl phthalate	CERIjcss-0619	100 (±0.5%) 100 (±1.0%) 100 (±0.5%) 100 (±0.5%) 100 (±1.0%) 100 (±1.0%) 100 (±0.5%) 100 (±1.5%)
3	NIST, USA	6 Phthalates in Methanol: DMP DEP DBP BBP DEHP DOP	NIST SRM 3074	55.6 ± 1.2 51.4 ± 1.7 51.2 ± 1.2 52.2 ± 1.4 58.6 ± 1.3 48.2 ± 1.4
Reference materials (RM)				
4	CIL, USA	BBP in nonane	ULM-7551-1.2	100

(continued)

Table 1 (continued)

No	Manufacturer, country	Name of material	Reference number	Mass concentration[a], μg/cm^3
		DEHP in nonane	ULM-6241-1.2	1000
		DEP in nonane	ULM-6174-1.2	100
		DMP in nonane	ULM-6783-1.2	100
		DBP in nonane	ULM-7466-1.2	100
		DOP in nonane	ULM-6129-1.2	100
5	Supelco (Merck), USA	EPA method of phthalic acid ester mixture	48,805-U	2000 (each)
		DEHP in methanol	47,994	2000

[a]The values of relative expanded uncertainty are given in brackets

regulation, during the implementation of interstate projects, etc., when it is necessary to recognize the measurement results at the international level (CIPM MRA Agreement of October 10, 1999 [29]).

In this work, we aimed to develop a CRM for the composition of a solution of six priority phthalates, provided with metrological traceability to SI units and reproduced by the GET 208–2019 (hereinafter—GET 208) National Primary Standard of Mass (molar) Fraction and Mass (molar) Concentration of Organic Components in Liquid and Solid Substances and Materials based on liquid and gas chromatography–mass spectrometry with isotope dilution and gravimetry (Table 2).

Materials and Methods

Selection and Preparation of the RM Starting Material

In order to produce a phthalate CRM, pure organic substances (POS) of the following phthalates were purchased: DMP, DEP, DBP, BBP, DEHP, and DOP (Sigma-Aldrich, Germany) with the declared purity from 98.4% to 99.8% (Table 3).

The POS were studied using the analytical equipment included in the GET 208–2019.[1]

The first step in determining the purity of organic substances was to confirm their identity. Phthalates were identified by gas chromatography-mass spectrometry

[1] GET 208-2019 National primary standard of the units of mass (molar) fraction and mass (molar) concentration of organic components in liquid and solid substances and materials based on liquid and gas chromatography–mass spectrometry with isotope dilution and gravimetry.). In: Federal Informational Fund on Maintaining the Unity of Measurements. https://fgis.gost.ru/fundmetrology/registry/12/items/1382717.

Table 2 Operational conditions for the determination of related structural compounds (RSC) and volatile organic compounds (VOC) by GC–MS

Chromatograph	
Column	HP5-MS, 30 m × 0.25 mm ID × 0.25 μm df
Injector temperature	280 °C
Carrier Gas (Helium) Flow in the Constant Flow mode	1 cm^3/min
Carrier gas mode	Constant Flow
Sample injection mode	Split 1/50
Column thermostat temperature programme	40 °C (5 min) – 10 °C / min – 280 °C (35 min)
Delay for solvent exit	Without delay
Sample volume	1 mm^3
Mass Spectrometer	
Ion source temperature	230 °C
Quadrupole temperature	150 °C
Energy of ionising electrons	70 eV
Registration mode	Total ionic current (TIC) in the range m/z 33–550

(GC–MS) using the NIST 14[2] library of mass spectra and chromatographic retention indices.

At the second stage, the POS were thoroughly investigated for the presence of four probable groups of impurities (related structural compounds—RSC, water, volatile organic compounds—VOC, and non-volatile compounds—NC). Subsequently, the mass fraction of the major component was calculated according to the formula "100% minus the sum of impurities" [30–32] in compliance with the internationally recognized indirect method of mass balance (MB) for determining the purity of components.

The determination of RSC and VOC impurities was performed by GC–MS on an Agilent 7890B/5977B instrument (Agilent Technologies, USA).

The operating parameters of the chromatograph and mass spectrometer are presented in Table 2.

The determination of the mass fraction of NC impurities was carried out by the gravimetric method using the calibrated GH-252 (AND, Japan) electronic balance of a special accuracy class. The mass fraction of NC was measured by the difference in the mass of the flask before and after sample evaporation under reduced pressure ($T = 200$ °C, $P = 1.33$ kPa (10 mm Hg)), the result was related to the sample mass of 50 g.

[2] NIST Mass Spectral Library 2014.

Table 3 The content of major component (MC) in pure organic substances (POS) and certified characteristics of primary reference pure substances (PRPS)

Name of the component	Commercial Product	PRPS	
	Mass fraction of MC, %	Mass fraction of MC, %	Expanded uncertainty, %
Dimethyl phthalate	99.8	99.60	0.09
Diethyl phthalate	99.7	99.79	0.05
Di-n-butyl phthalate	99.7	99.46	0.17
Benzyl butyl phthalate	98.4	98.83	0.18
Di-2-ethyl hexyl phthalate	99.6	99.78	0.12
Di-n-octyl phthalate	98.6	99.35	0.18

The determination of the mass fraction of water was carried out on a Mettler Toledo C30 coulometric KF titrator (Mettler Toledo, Switzerland), which implemented the coulometric Karl Fischer titration, using the basic settings of the device.

The CRM material was prepared by gravimetric and volumetric-gravimetric methods.

Methanol previously checked for the residual content of counter impurities was used as a solvent for the preparation of a pilot batch of the CRM.

The weights of individual phthalates were determined on a calibrated XPE26 (Mettler Toledo, Switzerland) balance of the 1st (special) accuracy class. The control of blunders and the study of the CRM homogeneity and stability were carried out by GC–MS according to the phthalate content.

Results and Discussion

Fully characterised pure organic substances are a basis for ensuring traceability in organic analysis [33]. Thus, the first necessary step for the production of a CRM and the formation of a chain of metrological traceability is a detailed study of POS with the aim of its attestation/certification.

Determination of Purity of the Phthalate POS

The major component was identified by GC–MS using the NIST 14 library of mass spectra and chromatographic retention indices. The relevant and reference DBP mass spectra are shown in Fig. 1 as an example.

It should be noted that the ion with m/z = 149 is the main characteristic ion in the phthalate mass spectra with electron ionization, while the intensity of other ionic fragments is less than 20%, and the signal of the molecular ion is less than 10%. Thus,

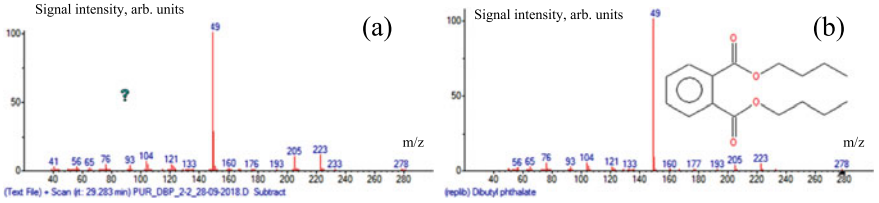

Fig. 1 Mass spectra: **a** relevant mass spectrum of the substance under study, **b** reference DBP mass spectrum from the NIST 14 mass spectral library

most phthalates have similar mass spectra, which makes their mass-spectrometric identification insufficient to confirm the identity of the major component. To increase the reliability of phthalate identification, we used the data on chromatographic retention indices. At least 80% coincidence of the obtained mass spectra with the reference ones and the deviation of retention indices not exceeding 5 units were taken as sufficient identification criteria.

Since phthalates are liquids with specified boiling points under normal conditions and, therefore, suitable for analysis by gas chromatography, the determination of RSC and VOC impurities was performed simultaneously and directly from the phthalate POS.

Identified RSC and VOC impurities were measured by an external standardization using point calibration characteristics under the assumption that the response factor of impurity relative to the corresponding standard is equal to 1. The following compounds were adopted as external standards:

- pentanol-1 for the impurities of aliphatic alcohols and ethers;
- acetic acid butyl ester for the impurities of aliphatic complex esters;
- benzoic acid for the impurities of aromatic carbonyl-containing compounds;
- 6 phthalates (DMP, DEP, DBP, BBP, DEHP, and DOP) for the impurities of phthalic acid ester.

In all investigated phthalate POS, characteristic impurities were registered, which presence was due to the production technology (alcohols, benzoic acid esters, phthalic anhydride, and isomeric phthalates). A typical mass chromatogram of phthalates, using DEHP as an example, is shown in Fig. 2.

As a result of the studies performed, it was found that the mass fraction of the sum of VOCs and RSCs in phthalates ranged from 0.17% to 1.12%.

The mass fraction of water was measured according to a conventional procedure using coulometric Karl Fischer titration. The content of water impurities in the investigated phthalates ranged from 0.027% to 0.105%.

To measure the content of non-volatile impurities, the gravimetric method was used, which consisted in measuring the mass of a sample before and after the evaporation of the major component (MC) and other volatile organic and inorganic substances. In all investigated phthalates, the mass fraction of impurities of non-volatile compounds was less than 0.0005%.

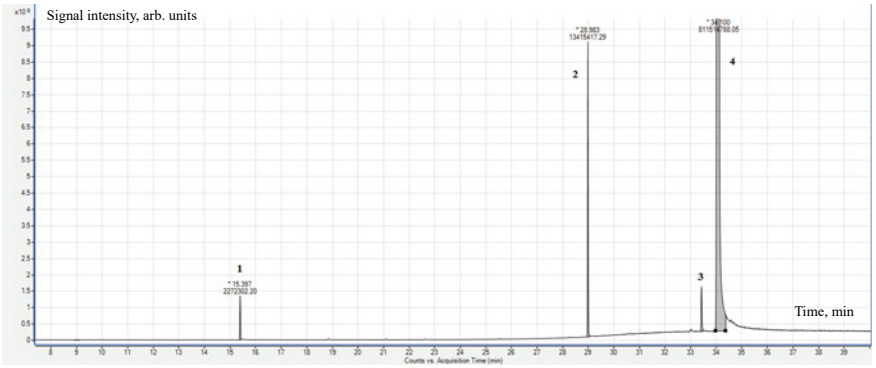

Fig. 2 Mass-chromatogram of DEHP: (1) 2-ethyl hexanol; (2) methyl-2-ethyl hexyl phthalate; (3) di-2-propyl pentyl phthalate; (4) DEHP

The generalized results of the measurements of the mass fraction of MC in POS and the certified characteristics of primary reference pure substances (PRPS) obtained on their basis are shown in Table 3.

Certification of the Phthalate RM in Solution

The value of the mass fraction and mass concentration of priority phthalates in the prepared solution (RM characterization) was established according to the calculation-experimental procedure of preparation.

The mass fraction of phthalates in the prepared solution (w_{an}, g/kg) was calculated taking into account the MC content in the corresponding PRPS (see Table 3) according to the general formula:

$$w_{an} = \frac{m_{ps} \cdot w_{ps}}{m_{sol} \cdot 100}, \tag{1}$$

where m_{ps} is the mass of the PRPS taken to prepare the solution, mg;

w_{ps} is the mass fraction of MC in the PRPS, %;

m_{sol} is the mass of solution, g.

The mass concentration of phthalates (ρ_{an}, g/dm^3) was calculated taking into account the MC content in the corresponding PRPS using the general formula:

$$\rho_{an} = \frac{m_{ps} \cdot w_{ps}}{V_{sol} \cdot 100}, \tag{2}$$

where V_{sol} is the volume of the prepared solution, cm^3.

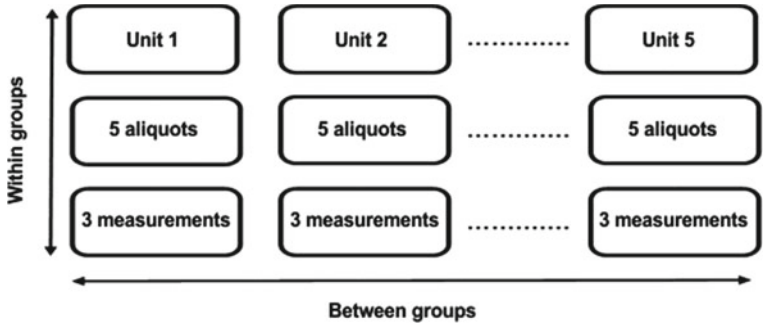

Fig. 3 Algorithm for studying the homogeneity of the RM for the composition of orthophthalic acid esters (phthalates) in methanol solution

RM homogeneity was evaluated by GC–MS. To this end, using the method of statistical selection, five specimens were selected from an experimental RM batch, and then from each specimen five aliquots of 0.25 cm^3 were taken. For each aliquot, three replicate determinations were carried out in accordance with the research algorithm shown in Fig. 3.

The obtained experimental data were processed in accordance with the ANOVA one-way analysis of variance, developed taking into account the provisions of [32, 34] and the methodology for studying the homogeneity and stability of CRMs given in the present paper. Calculations were performed for each phthalate under study.

No statistically significant alteration during the period of stability research was found. Based on the research results, it was concluded that the RM batch is homogeneous (for all phthalates $F < Fcr$). The contribution of uncertainty associated with material heterogeneity (u_h) was taken into account when calculating the uncertainty budget for the CRM characteristics (u_h was taken equal to 0.80%).

The RM stability was assessed during an isochronous study ("accelerated aging") [23]. Taking into account the recommended storage temperature range of the RM batch, the study of isochronous stability was carried out at a reference temperature of −18 °C and a test temperature of + 44 °C. The τ duration of the stability study (in days) was estimated by the formula:

$$\tau = \frac{T}{2^{\frac{t_1 - t_0}{10}}} \tag{3}$$

where T is the estimated shelf life of the RM unit, days;

t_0 and t_1 are the expected RM storage temperature of −18 °C and the storage temperature during accelerated aging of +44 °C, respectively.

Having fixed the values of storage temperature, and proceeding from the expected RM shelf life of at least 3 years, the τ duration of stability study was 14 days.

No statistically significant alteration was observed during the period of stability research. Based on the research results, the RM was acknowledged stable at the

selected storage and transportation temperatures. The contribution of uncertainty associated with the RM instability (u_{stab}) was taken into account when calculating the uncertainty budget (u_{stab} was taken equal to 0.52%).

According to the research results, the shelf life of the RM was 3 years.

The calculation of the uncertainty budget of the CRM certified characteristics was carried out according to the general formula:

$$u = \sqrt{u_{char}^2 + u_h^2 + u_{stab}^2}, \tag{4}$$

where u_{char} is the relative standard uncertainty of the CRM certification method (%), calculated by formula (5):

$$u_{char} = \frac{u_{char}\left(w(or\rho)_{an}\right)}{w(or\rho)_{an}} = \sqrt{\left(\frac{u_{w_{ps}}}{w_{ps}} \cdot 100\right)^2 + \left(\frac{u_{m_{ps}}}{m_{ps}} \cdot 100\right)^2 + \left(\frac{u_{m(orV)_{sol}}}{m(orV)_{sol}} \cdot 100\right)^2} \tag{5}$$

u_h is the relative standard uncertainty resulting from the CRM inhomogeneity (%), calculated by formulas (6) or (7) in accordance with [34, 35]:

$$u_h = \frac{u_h\left(w(or\rho)_{an}\right)}{w(or\rho)_{an}} = \frac{\sqrt{\frac{\left(\overline{SS}_H - \overline{SS}_e\right)}{3} \cdot \frac{M(orV)_0}{M(orV)}}}{w(orC)_{an}} \cdot 100, \tag{6}$$

$$u_h = \frac{u_h\left(w(or\rho)_{an}\right)}{w(or\rho)_{an}} = \frac{\frac{1}{3}\sqrt{\overline{SS}_e \cdot \frac{M(orV)_0}{M(orV)}}}{w(C)_{an}} \cdot 100 \tag{7}$$

u_{stab} is the relative standard uncertainty resulting from the CRM instability (%), calculated by formula (8) in accordance with [34, 35]:

$$u_{stab} = \frac{u_{stab}\left(w(or\rho)_{an}\right)}{w(or\rho)_{an}} = \frac{s_a \cdot t}{w(orC)_{an}} \cdot 100, \tag{8}$$

The relative expanded uncertainty (at k = 2) was calculated by the formula:

$$U\left(w(or\rho)_{an}\right) = 2 \cdot u, \tag{9}$$

The calculation results are summarized in Table 4.

Thus, the values of the CRM metrological characteristics were determined taking into account the results of:

- PRPS characterization;
- procedures for preparing the solution (according to the calculation-experimental procedure);
- studies of the CRM homogeneity;
- studies of the CRM stability.

Table 4 Uncertainty budget of the certified characteristics of phthalates in the CRM solution (mass fraction/mass concentration of the component)

NNo	Source of uncertainty	AAssessment type	Relative standard uncertainty, (contribution) % (Mass fraction)	Relative standard uncertainty, (contribution) % (Mass concentration)
1	Purity of PRPS	B	0.09	0.09
2	PRPS mass	B	0.0080	0.0080
3	Solution mass	B	0.010	–
	Solution volume	B	–	0.060
4	Inhomogeneity of RM	A	0.80	0.80
5	Instability of RM	A	0.52	0.52
Relative summarised standard uncertainty u			0.96	0.97
Relative expanded uncertainty ($k = 2$), U			1.92	1.94
Accepted			2	2

The metrological characteristics of the certified CRM batch are presented in Table 5.

As a result, the GSO (CRM) 11,366-2019 (6Ftlt-VNIIM) of orthophthalic acid esters (phthalates) in methanol solution was produced. The GSO (CRM) 11,366-2019 was used to calibrate analytical equipment in the development of a reference measurement procedure RMI VNIIM-243-02-2019 "Reference measurement procedure for

Table 5 Metrological characteristics of the CRM for the composition of phthalates in methanol solution

Name of substance (component)	Certified value of mass concentration of a component, mg/cm^3	Relative expanded uncertainty U at $k = 2$[a], %	Certified value of the mass fraction of a component, mg/g	Relative expanded uncertainty U at $k = 2$[a], %
DMP	2.04	2	2.58	2
DEP	2.05		2.59	
DBP	1.98		2.50	
BBP	1.98		2.51	
DEHP	2.02		2.55	
DOP	2.01		2.54	

[a]Corresponds to the limits of the permissible values of the relative error of the certified value of the CRM $\pm\ \delta$ (%) at $P = 0.95$

Table 6 RMSD of relative response factors obtained by HPLC–UV and GC–MS

Component	RMSD[a], %	
	GC–MS	HPLC–UV
DMP	0.57	0.12
DEP	0.55	0.10
DBP	0.80	0.11
BBP	0.80	0.11
DEHP	0.50	0.09
DOP	0.59	0.10

[a]Based on 15 measurements

the mass fraction of six priority phthalates (dimethyl phthalate, diethyl phthalate, di-n-butyl phthalate, benzyl butyl phthalate, di-2-ethyl hexyl phthalate and di-n-octyl phthalate) in objects based on polyvinyl chloride by gas chromatography–mass spectrometry with isotope dilution" [36].

The budget for the CRM uncertainty (see Table 4) shows that the contributions from the heterogeneity and instability of the material are the main components of the total standard uncertainty of the CRM certified values (up to 90%). We believe that this is due to the objective characteristics of the GC–MS method used for the study and does not indicate actual heterogeneity and/or instability of the CRM material.

To confirm this hypothesis, an experiment was designed using an alternative analytical method, high performance liquid chromatography with UV detection (HPLC–UV), which, in general, is characterized by a higher precision. The design of the experiment assumed an analysis of the aliquot of the CRM solution by the GC–MS and HPLC–UV methods under repeatability conditions. Based on the data obtained, the relative response factors of the analytes were calculated: DOP by DBP, other phthalates by DOP. The relative root-mean-square deviation (RMSD) of the measurement results obtained by different methods were determined (see Table 6).

Table 6 shows that, for the developed CRM, the contributions from inhomogeneity and instability significantly depend on the analytical method used (when using HPLC–UV, the RMSD of the measurement results improves by a factor of 5–7). Thus, if necessary, the accuracy characteristics of the GSO (CRM) 11,366–2019 can be noticeably improved by using an alternative procedure for assessing the homogeneity and/or stability of the CRM material.

Conclusion

As a result of the conducted studies, the GSO (CRM) 11,366-2019 (6Ftlt-VNIIM) for the composition of a solution of esters of orthophthalic acid (phthalates) in methanol was developed. The CRM is a solution of 6 individual phthalates in methanol packaged in (2.0 ± 0.1) cm^3 portions in hermetically sealed labelled glass ampoules with

a nominal volume of 5 cm^3 and a shelf life of 3 years. The CRM certified characteristics are the mass fraction and mass concentration of individual phthalates (dimethyl phthalate, diethyl phthalate, di-n-butyl phthalate, benzyl butyl phthalate, di-2-ethyl hexyl phthalate, and di-n-octyl phthalate).

The CRM is provided with metrological traceability to the GET 208-2019 national primary standard, which guarantees the recognition of measurement results at the international level. The application of the GSO (CRM) 11,366-2019 may increase the accuracy and reliability of measurement results in solving any measuring tasks and performing various types of metrological work. Such work can include the development and certification of reference measurement procedures and techniques, organization of accuracy control of the measurement methods by the standard addition method and calibration of measuring instruments, interlaboratory comparative testing, etc.

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Author Contributions A. I. Krylov: research supervision, concept and methodology development.

A. Yu. Mikheeva: analysis of literature data, design of experimental studies, critical analysis of experimental data, revision of the manuscript text.

A. G. Budko: collection of literature data, acquisition and analysis of experimental data, production of CRM, preparation of documents for CRM development and testing, manuscript draft preparation.

I. Yu. Tkachenko: collection of literature data, design of experimental studies, critical analysis of experimental data, revision of the manuscript text.

Conflict of Interest The article was prepared on the basis of a report presented at the IV International Scientific Conference "Reference Materials in Measurement and Technology" (St. Petersburg, December 1–3, 2020). The article was admitted for publication after the abstract was revised, the article was formalized and the review procedure was carried out.

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