Umwelt Bundesamt

German Environment Agency

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EVALUATION CRITERIA DOCUMENT

Evaluation Criteria Document for enamels and ceramic materials in contact with drinking water (Enamel and Ceramics Evaluation Criteria Document)[1,2]

English translation – only the German document version is legally binding

1 Notified in accordance with Directive (EU) 2015/1535 of the European Parliament and of the Council of 9 September 2015 laying down a procedure for the provision of information in the field of technical regulations and of rules on Information Society services (OJ L 241 of 17 September 2015, p. 1).

2 Notified under No. 2025/0325/DE

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1 Introduction

Under section 14 of the German Drinking Water Ordinance (TrinkwV), materials for the construction or maintenance of installations for the abstraction, treatment and distribution of drinking water to be used in contact with drinking water, shall not

1. directly or indirectly compromise the protection of human health,
2. adversely affect the colouring, odour or taste of water or
3. promote the enhancement of microbial growth or
4. release substances into the drinking water in greater amounts than are considered unavoidable under the generally accepted codes of practice.

This evaluation criteria document specifies the above general hygiene requirements for materials listed within the scope of application pursuant to section 15 (1) of the TrinkwV.

Materials within the scope of this evaluation criteria document are in accordance with the requirements of section 14 of the TrinkwV if they comply with the requirements set out in this evaluation criteria document. Pursuant to section 15 (2) TrinkwV, the present evaluation criteria document is mandatory after a period of two years after its publication (i.e., since 12 august 2021) in the German Federal Gazette. Since this date, the entrepreneur or other owner of a water supply must, pursuant to section 13 (2) TrinkwV, ensure that for the construction or maintenance of installations for the abstraction, treatment or distribution of drinking water only such enamels, other vitreous materials, ceramic materials and mixed metal oxide coatings are used that meet the requirements of the present evaluation criteria document. Evidence that a product complies with the requirements of this evaluation criteria document may be demonstrated, for example, in form of a certificate from a certifier accredited for the drinking water sector.

According to the revised EU Drinking Water Directive (Directive (EU) 2020/2184), uniform European requirements will be imposed in future on materials in contact with drinking water. These regulations will replace the present evaluation criteria document.

2 Scope of application

This evaluation criteria document applies to all enamels, other vitreous (glass-like) materials, ceramic materials and mixed metal oxide coatings in contact with drinking water.

3 Principle of assessment

Enamels, other vitreous materials, ceramic materials and mixed metal oxide coatings must only contain the constituents listed in this evaluation criteria document.

By means of a migration test of the finished product or a representative test specimen (e. g. an enamelled plate), the release of specific elements is examined.

The requirements with respect to the release of elements are designed such that the corresponding limits defined in the TrinkwV, or if there are none, the relevant guideline values established by the German Environment Agency (UBA) or the World Health Organization (WHO) are not entirely exhausted by the quantities released from enamels, other vitreous materials, ceramic materials or mixed metal oxide coatings (see also 7.3).

4 Inclusion of other materials

Necessary information to include further materials in the positive lists of this evaluation criteria document are described in the following information:

https://www.umweltbundesamt.de/en/document/consideration-of-additional-materials-for-inclusion

5 Terms

Definition of terms *[German expression in brackets]*	
Component *[“Bauteil“]*	A component is the smallest, not dismountable unit which is manufactured as a single product or part of an assembled product.
Conversion factor (F_c) *[“Konversionsfaktor“]*	The conversion factor serves to calculate c_{tap} and is based on worst case assumptions on contact times of drinking water with the respective products or components and their surface-to-volume ratios in drinking water distribution.
Elements *[“Elemente“]*	in the context of this evaluation criteria document, are all chemical elements and dissolved species of these.
Enamel manufacturer *[“Emailhersteller“]*	is the factory manufacturing the vitreous enamel.
Enameller *[“Emaillierer“]*	denotes the plant that places vitreous enamel on workpieces, by which a composite material is formed.
Migration water *[“Migrationswasser“]*	is the test water after contact with the test specimen(s) according to specified contact conditions.
Product *[“Produkt“]*	A product is a clearly identifiable manufactured part, with its final shape and surface, that a manufacturer or trader/distributor provides on the market and that is intended to come into contact with drinking water.
Product group *[“Produktgruppe“]*	A product group includes different products or components with the same conversion factor that are comparable in terms of their frequency of use in drinking water distribution and their surface-to- volume ratio.
Reference concentration *[“Prüfwert” (PW)]*	Reference concentration is the maximum admissible concentration of a species migrating from the material into the drinking water. The reference concentration is derived from the respective limit value of the German TrinkwV or another health-based guideline value.
Risk group *[“Risikogruppe“]*	The risk group of a product or component made of enamels or ceramic materials is derived according to the applicable conversion factor for the product or component and is decisive for the inspection and evaluation scheme.
Test specimen *[“Prüfkörper“]*	Test specimen is a product or specifically manufactured sample that is taken representatively for testing and evaluation of one or several products.
Test water *[“Prüfwasser“]*	is the fully demineralised water (VE) according to DIN EN 12873-1 used for the migration test.

6 Description of materials

6.1 Enamel including other vitreous materials

6.1.1 Positive list for enamels and other vitreous materials

Enamels and other vitreous materials in contact with drinking water may only contain constituents listed in Table 1.

Table 1: Positive list of accepted constituents of enamel and other vitreous materials

Substance	Content in %		Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.		Min.	Max.
SiO_2	25	100	K_2O	0	10	P_2O_5	0	5.0
Na_2O	0	30	Li_2O	0	10	SnO_2	0	5.0
ZrO_2	0	30	ZnO	0	10	SrO	0	5.0
B_2O_3	0	20	Al_2O_3	0	5.0	Cr_2O_3	0	3.0
TiO_2	0	16	CoO	0	5.0	CuO	0	3.0
BaO	0	15	Fe_2O_3	0	5.0	NiO	0	3.0
CeO_2	0	15	MgO	0	5.0	Sb_2O_3	0	1.0
CaO	0	10	MnO_2	0	5.0	HfO_2	0	0,1
F	0	10	MoO_3	0	5.0			

Inorganic sulfur species as contaminants with total content up to 0.5% may be disregarded.

Chloride as impurity with a content up to 0.5% may be disregarded.

6.1.2 Enamel

Enamel is a vitreous material formed by melting at 1 200 – 1 300 °C and quenching (fritting) with inorganic composition, mainly oxidic composition (see Table 1).

The ground enamel frit is applied to ferrous metals by melting at more than 480 °C. The resulting enamelling combines the strength and elasticity of metals with the hardness and chemical resistance of glass. When enamelling, enamel and metal react with each other in an electrochemical reaction, and a composite material is created. As a result, enamel adheres to the metal surface with up to 100 N/mm². The enamelling cannot be infiltrated, is diffusion-tight and is temperature-resistant up to 300 °C.

Enamels used for drinking water should have a high resistance to water.

Enamelled components that meet the requirements of this evaluation criteria document possess hygienic suitability for use with all drinking water.

6.1.3 Glass

Glass is an inorganic non-metallic, mostly oxidic material, which is obtained by complete melting of a mixture of raw materials (e. g. quartz sand) at high temperatures. The homogeneous liquid obtained during melting is cooled down to the solid state (usually without crystallisation). Unlike enamels, this material is not applied to a metallic material. Glass is a material mainly made of purified sand (SiO_2). As additives, alkali metal salts (Na_2O and K_2O) are added to reduce the high melting point of SiO_2 (approx. 1 700 °C). The addition of Al_2O_3

reduces brittleness. Glasses used for drinking water should have a high resistance to water. Glass components according to Table 1 which meet the requirements of this evaluation criteria document possess hygienic suitability for use with all drinking water.

6.1.3.1 Borosilicate glass

For borosilicate glass, the following positive list (see Table 2) applies as a derogation[3], which is associated with a lower testing effort.

The boron that gives the glass its name is added in the form of B_2O_3.

Table 2: Positive list of accepted constituents of borosilicate glass

Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.
SiO_2	80	100	K_2O	0	4.2
B_2O_3	7.0	13	Na_2O	0	4.2
Al_2O_3	0	2.4			

6.2 Ceramic materials

Ceramic is an inorganic, non-metallic material. Ceramic products are commonly shaped at room temperature from a ceramic base material (such as kaolin or clay) available either in granulate form for dry pressing or in plastic form. The subsequent sintering process then leads to the typical characteristics such as diffusion resistance or chemical stability. Sintering temperatures are between 1 050 °C and 2 500 °C depending on the material. Crystalline structures are formed, which also contain some proportion of a vitreous phase. Ceramics exhibit high strength and hardness, are corrosion-resistant, and can generally be used at temperatures up to near the sintering temperature. Ceramics are also very resistant to water.

6.2.1 Oxide ceramics

Oxide ceramics include ceramics made of Al_2O_3 and SiO_2 (see Table 3), ZrO_2 (see Table 4) or hard ferrites (see Table 5). Hard ferrites are compounds of an iron oxide with other metallic oxides of the general form: $Me_xFe_yO_z$. They are the basis of oxide-ceramic materials with magnetic properties, which are therefore used for specific products in contact with drinking water.

[3] By extending the scope of the positive list for enamels (see table 1) also for other vitreous materials, borosilicate glasses correspond to both positive lists. The positive list for borosilicate glass (see table 2) remains valid because certificates have already been issued in this respect. However, this positive list will be obsolete in future European regulations.

Table 3: Positive list of accepted constituents of Al_2O_3 and SiO_2 ceramics

Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.
Al_2O_3	0	99.99	TiO_2	0	2.5
SiO_2	0	92	B_2O_3	0	2.0
CaO	0	8.0	Cr_2O_3	0	2.0
Fe_2O_3	0	4.0	SrO	0	0.5
MnO_2	0	3.5	Y_2O_3	0	0.4
K_2O	0	3.0	BaO	0	0.2
MgO	0	3.0	HfO_2	0	0.1
Na_2O	0	3.0	P_2O_5	0	0.1
ZrO_2	0	3.0			

Inorganic sulfur species as contaminants with total content up to 0.5% may be disregarded.

Table 4: Positive list of accepted constituents of ZrO_2 ceramics

Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.
ZrO_2	5.0	99	TiO_2	0	0.5
Al_2O_3	0	95	Pr_2O_3	0	0.2
Y_2O_3	0	8.5	CaO	0	0.1
SiO_2	0	5.0	Fe_2O_3	0	0.1
MgO	0	4.0	K_2O	0	0.1
HfO_2	0	2.0	Na_2O	0	0.1

Table 5: Positive list of accepted constituents of hard ferrite ceramics

Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.
FeO/Fe_2O_3	80	95	Cr_2O_3	0	0.2
BaO	0	16	CuO	0	0.1
SrO	0	12	Li_2O	0	0.1
SiO_2	0	5.0	MgO	0	0.1
Al_2O_3	0	3.0	Na_2O	0	0.1
CaO	0	3.0	NiO	0	0.1
MnO	0	3.0	Pd	0	0,1
La_2O_3	0	2.0	P_2O_5	0	0.1
B_2O_3	0	1.0	TiO_2	0	0.1
CoO	0	0.8	WoO_3	0	0,1
Bi_2O_3	0	0.4	ZnO	0	0.1

Inorganic sulfur species as contaminants with total content up to 0.5% may be disregarded. Chloride as impurity with a content up to 0.5% may be disregarded.

6.2.2 Non-oxide ceramics

As non-oxide ceramics, silicon carbides (see Table 6 and Table 7), tungsten carbides (see Table 8) and silicon nitrides (see Table 9) are used for contact with drinking water.

Table 6: Positive list of accepted constituents of silicon carbide (SiC) ceramics

Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.
SiC	78	100	Al	0	2.0
Si	0	22	Fe	0	0.2
ZrB_2	0	11	Hf	0	0.2
Al_2O_3	0	5.0	Ti	0	0.2
C	0	5.0	Ca	0	0.1
B	0	3.0	MgO	0	0.1
Fe_2O_3	0	3.0	Na	0	0.1
SiO_2	0	3.0	Ni	0	0.1
Y_2O_3	0	3.0			

Table 7: Positive list of accepted constituents of silicon carbide with free carbon (SISIC-C) ceramics

Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.
SiC	55	90	Al	0	0.2
C	5.0	40	Fe	0	0.2
Si	2.0	15	Ti	0	0.2
SiO_2	0	2.5	Ca	0	0.1
B	0	0.5	Ni	0	0.1

Table 8: Positive list of accepted constituents of tungsten carbide (WC) ceramics

Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.
WC	90	100	Cr_3C_2	0	1.0
Ni	0	8.0	Mo	0	1.0

Table 9: Positive list of accepted constituents of silicon nitride (SN) ceramics

Substance	Content in %		Substance	Content in %	
	Min.	Max.		Min.	Max.
Si_3N_4	78	97	MgO	0	4.0
Al_2O_3	0	7.0	Y_2O_3	0	3.0
SiO_2	0	7.0	ZrO_2	0	3.0
La_2O_3	0	6.0	CaO	0	2.0
TiO_2	0	5.0	Fe_2O_3	0	1.0

6.2.3 Ceramic materials made of carbon

Graphites

Graphites have specific technical properties. The starting materials include lignite, coal or petrol coke, which are mixed with a binding agent such as tar or a plastic resin, and then annealed at 600 °C to 1 000 °C. This produces the substances known as carbon graphites, which are used for such applications as slide bearings, sealing rings or pumps components. In another optional manufacturing step, referred to as graphitisation, these carbon graphites are annealed once again at up to 3 000 °C. This causes the individual graphite crystals to enlarge, causing an increase in density. Contaminants are burned off to improve purity. These electro-graphites exhibit good sliding properties and improved thermal and electrical conductivity. For graphites that have been impregnated with an organic resin, the resin should be assessed separately based on the Evaluation criteria for plastics and other organic materials in contact with drinking water (KTW-BWGL), Annex B.

Amorphous Carbon layers

Ceramic or metallic materials may be covered with a carbon coating to achieve good sliding properties. These coatings may be produced using a number of different methods. This leads to the formation of crystalline layers of graphite and diamond. Amorphous carbon layers (diamond-like carbon, DLC) are subdivided into several types in accordance with the VDI *Guideline: VDI 2840 Carbon layers - Principles, layer types and characteristics.*

Carbon fibres

In order to improve the strength of ceramic materials, carbon fibres may be used. These are made of organic fibres, such as viscose or polyacrylonitrile fibres, that are transformed into carbon by pyrolysis.

6.3 Coatings

6.3.1 Mixed metal oxide (MMO) coatings

Titanium external current anodes for cathodic tank interior protection of storage water heaters made of enamelled, low-alloy steel or stainless steel and titanium external flow anodes for cathodic protection of filter vessels in drinking water treatment made of unalloyed steel (outside the drinking water installation with a permanent flow) or low-alloy steel can be combined with a mixed metal oxide coating of iridium oxide (IrO_2) and tantalum oxide (Ta_2O_5) with a mass ratio of 50% : 50% and 85% : 15% (m/m).

The coating of the titanium anodes includes the following manufacturing steps:

In order to remove impurities and adjust surface roughness, the titanium surface is degreased, wet etched (e.g. with hydrochloric acid) and/or sandblasted. After rinsing and drying, an aqueous or alcoholic solution of the salts of iridium and tantalum (e. g. H_2IrCl_6 and $TaCl_5$) is applied by spraying or immersion, which is followed by drying at about 100 °C. After that, the titanium substrates are calcinated at about 500 °C, whereby the oxides of iridium and tantalum are formed and organic compounds are evaporated. The coating steps (application of salts, drying and calcination) are repeated until the maximum layer thickness of 20 µm is reached.

If the respective products are manufactured as described above, it is not necessary to test the products in accordance with Chapter 8.

6.3.2 Zirconium oxide coating

Metallic materials can be coated with zirconium oxide using physical vapor deposition (PVD process). The coating can be classified as a ceramic coating. The composition of the coating must comply with Table 4, and the products or components must be tested in accordance with Chapter 8.

7 Drinking water hygienic requirements for enamels and ceramic materials

7.1 General

This evaluation criteria document defines requirements for the hygienic suitability of products or components in contact with drinking water according to the scope defined in Chapter 2. It does not contain specifications for technical suitability. Products or components must be suitable for their intended use. Corresponding requirements are listed e.g. in the technical regulations.

Requirements to ensure safe drinking water (see Table 10) are formulated using the risk-based approach for the use of materials in individual products or components. The conversion factors compiled in Table 14 of the products or components to be assessed are used as the basis for classification.

Table 10: Risk group and risk-based requirements

Risk group	Conversion factors F_c in d/dm	Requirement on composition	Requirement on element release or organic compounds
P1	$F_c \geq 0.5$	Yes applies to formulation	Yes applies to product or component Enamel: also test plates produced by the enameller
P2	$0.05 \leq F_c < 0.5$	Yes applies to formulation	Yes applies to product or component Enamel: also test plates produced by the enamel producer
P3	$0.005 \leq F_c < 0.05$	Yes Applies to formulation	No
P4	< 0.005	No	No

Note: Drinking water is neither influenced visually nor with regard to flavour by enamel and ceramic materials, so that respective testing is not necessary. It is also not necessary to test for enhancement of microbial growth, since the smooth surface and the lack of organic nutrients of the materials do not promote microbial growth.

7.2 Composition requirement

All constituents with a content exceeding 0.02% (w/w) in the material must be specified.

Enamels and other vitreous materials may only contain constituents listed in Table 1. The specified contents are mandatory but may be modified on request. Lead and cadmium may be present only as impurities in small quantities that are technically unavoidable and have not been added intentionally. The content of these elements each must be less than 0.02% (w/w) and has to be declared for the mixture.

Borosilicate glass may either contain constituents listed in Table 2 or alternatively constituents listed in Table 1. The specified content is mandatory but may be modified upon request. Lead and cadmium may be present only as impurities in small quantities that are technically unavoidable and have not been added intentionally. The content of lead and cadmium each must be less than 0.02% (m/m) and expressed in the composition.

Ceramic materials may only contain constituents listed for the relevant material in Table 3 through Table 9. The specified contents are mandatory but may be modified on request. Lead and cadmium may be present only as impurities in small quantities that are technically unavoidable and have not been added intentionally. The content of these elements each must be less than 0.02% (w/w) and has to be declared for the mixture.

For **ceramic materials made of carbon**, there are no specific composition requirements provided that the manufacturing methods meet the requirements listed under 6.2.3.

For **mixed metal oxide coatings (MMO)**, the composition requirement shall be that only iridium oxide (IrO_2) and tantalum oxide (Ta_2O_5) in a mass ratio between 50%: 50% and 85%: 15% (m/m) may be contained. The manufacture shall comply with the information under 6.3.

Zirconium oxide coatings may only contain constituents listed for the relevant material in Table 4. The specified contents are mandatory but may be modified on request. Lead and cadmium may be present only as impurities in small quantities that are technically unavoidable and have not been added intentionally. The content of these elements each must be less than 0.02% (w/w) and has to be declared for the mixture. Requirements for release of elements or organic compounds

During proper use, the release of elements from products must not exceed the limit values of the German Drinking Water Ordinance (TrinkwV) in supplied drinking water. Where the TrinkwV does not define a limit value for a specific element, the guideline value as published by UBA or WHO should be observed. The reference concentrations (see Table 11) have been reduced to a relative proportion of the respective limit or guideline value in order to take into account other possible sources. These relative proportions are different for each element. The release must be kept as low as possible in accordance with the minimisation principle (section 7 (4) TrinkwV, section 14 TrinkwV). As a consequence, the reference concentration for enamel and ceramic materials is typically limited to 10% of the respective limit- or guideline value. For banned constituents (lead and cadmium) that may be present in the product as impurity, the relative proportion of the reference concentration has been reduced to 5%.

Cobalt, manganese and aluminium are important constituents of enamels. For cobalt there are no other known paths of entry into drinking water. For this reason, the relative proportion of the reference concentration in terms of the guideline value may be set to 90% for cobalt. Since for lanthanum there are also no other known paths of entry into drinking water, a 90% relative proportion is assumed for the reference concentration here as well. For manganese and aluminium there are no expected paths of entry from other materials used in drinking water supply. For this reason, the reference concentration for manganese and aluminium may be set to 50% of the limits defined in the TrinkwV. The 50% relative proportion also applies to cerium, titanium and zirconium, since these elements also have no other known relevant paths of entry into the drinking water.

Based on test results hitherto submitted to the German Environmental Agency, the maximum expected concentrations of bismuth, hafnium, praseodymium and tungsten at the tap are assumed to be less than 0.1 µg/l. A reference concentration of 0.1 µg/l is therefore defined for these elements. This will be followed unless additional information on the toxicology of the substance is available.

Reference concentrations have been compiled in the following Table 11.

Table 11: Reference concentrations (PW) for various elements

Element	Basis of reference concentration	Proportion of the limit value/ guideline value	Reference concentration in µg/l
Aluminium	TrinkwV	50%	100
Antimony	TrinkwV	10%	0.5
Barium	UBA	10%	70
Bismuth	UBA		0.1
Lead	TrinkwV	5%	0.5
Boron	TrinkwV	10%	100
Cadmium	TrinkwV	5%	0.15
Cerium	UBA	50%	20
Chromium	TrinkwV	10%	5
Hafnium	UBA		0.1
Cobalt	UBA	90%	9
Copper	TrinkwV	10%	200
Lanthanum	UBA	90%	2.7
Manganese	TrinkwV	50%	25
Molybdenum	WHO	10%	7
Nickel	TrinkwV	10%	2
Palladium	UBA		0.1
Praseodymium	UBA		0.1
Strontium	UBA	10%	210
Titanium	UBA	50%	70
Tungsten	UBA		0.1
Yttrium	UBA	10%	3.5
Zirkonium	UBA	50%	5.0

Carbon-containing ceramics (all ceramics that contain carbon, including carbides) must be examined for the release of benzo[a]pyrene as well as polycyclic aromatic hydrocarbons (PAHs). This should be subject to the criteria of Table 12.

Table 12: Reference concentrations (PW) for PAH

Polycyclic aromatic hydrocarbons	Basis of reference concentration	Proportion oft he limit value/ guideline value	Reference concentration in µg/l
Benzo[b]fluoranthene Benzo[k]fluoranthene Benzo[ghi]perylene	TrinkwV	10%	0.01 for the sum of 4 PAH

Indeno[1,2,3-cd]pyrene			
Benzo[a]pyrene	TrinkwV	10%	0.001

8 Testing

8.1 Component testing – material testing

The hygienic suitability for use in drinking water systems must be proved for the component.

With respect to enamel however, testing may be done on commercial enamel frit instead of the enamelled components produced from it, provided that its composition is subject to a monitoring system and account is taken for the specific conditions of the enamelling process. In that case, the relevant enamelled components do not need to be tested in accordance to this evaluation criteria document.

8.2 Examination of the composition

8.2.1 Enamel/other vitreous materials

An analysis of the composition of the component or test specimen or enamel frit must be undertaken. This may be done using X-ray fluorescence analysis or a wet chemical method.

The objective of composition testing is:

1) to verify the requirement that enamels/other vitreous materials only contain constituents listed in Table 1 (see 6.1)
2) to define the elements to be assessed in the migration water, and
3) to identify the product.

8.2.2 Borosilicate glass

An analysis of the composition of the component or test specimen must be undertaken. The objective of composition testing is:

1) to check the requirement that the composition of the borosilicate glass corresponds to the appropriate positive list (see Table 2);
2) to define the elements to be assessed in the migration water, and
3) to identify the product.

8.2.3 Ceramic materials

An analysis of the composition of the component or test specimen must be undertaken. The objective of composition testing is:

1) to verify the requirement that ceramic materials have the composition specified in the respective positive list (see Table 3 through Table 9)
2) to define the elements to be assessed in the migration water, and
3) to identify the product.

8.2.4 Ceramic materials made of carbon

For ceramic materials made of carbon an analysis of the composition is not required.

8.2.5 Mixed metal oxide coatings (MMO)

If the mixed metal oxide coatings are manufactured as described in Chapter 6.3, a test of the composition is not necessary.

8.2.6 Zirconium oxide coatings

An analysis of the composition of the component or test specimen must be undertaken. The objective of composition testing is:

1) to check the requirement that the composition of the borosilicate glass corresponds to the appropriate positive list (see Table 4);
2) to define the elements to be assessed in the migration water, and
3) to identify the product.

8.3 Migration testing

8.3.1 Test principle

In repeated contact tests with fully demineralised water (=test water) at 23 °C ± 2 °C (cold water test), 60 °C ± 2 °C (warm water test) or 85 °C ± 2 °C (hot water test), the test specimens are assessed for migration of the constituents. In Table 13, test conditions for the various components are listed depending on their intended use.

Table 13: Test conditions for components

Component group	Test conditions
Components intended exclusively for cold-water use	Cold water test at 23 °C ± 2 °C
Components normally in contact with both warm and cold water (e. g. mixing blocks on a tap)	Warm water test at 60 °C ± 2 °C
Components for drinking-water heaters	Warm water test at 60 °C ± 2 °C
Components for drinking-water heaters that normally dispense hot water near the boiling point	Hot water test at 85 °C ± 2 °C

The migration test is carried out according to DIN EN 12873-1. Each sample is subjected to a specific sample pre-treatment consisting of a rinsing phase, a stagnation phase and a second rinsing phase. Pre-treatment of the sample is followed by migration periods (stagnation in closed test apparatus) at a defined ratio of test specimen surface to water volume. At the end of each migration period, the migration water must be replaced with fresh test water. The migration water obtained from predefined migration periods are used for subsequent testing.

8.3.2 Test specimen

The respective component or product is to be used as the test specimen.

For testing enamels, purposely produced plates (test plates) may be used instead of test specimens. These must be made of the same material as the component to be enamelled. Plates of dimensions 105 x 105 mm should be used. For attachment, a hole of about 5 mm in diameter should be drilled in the samples, with the centre 4 mm from the edge. Pre-treatment and enamelling must reflect normal production conditions. The obverse of the sample is protected against corrosion by means of a thin enamel layer. After drying, the enamel layer is stoved to the test specimen together with the regular products, under otherwise normal conditions.[4] In case the test is not executed on the component but on purposely produced test plates instead, a report of the production of the sample shall be compiled and attached to the test report (see 9).

8.3.3 Test execution

Sample preparation and subsequent migration testing shall be done according to DIN EN 12873-1.

A demineralized test water according to DIN EN 12873-1 shall be used.

To determine the release of elements from enamelled products or products with ceramic components, glass containers or glass recipients must not be used. Migration testing of carbon-containing ceramics and subsequent analysis of polycyclic aromatic hydrocarbons in turn shall be done exclusively in glass containers or glass recipients.

At least two parallel migration tests and one blind test shall be performed simultaneously.

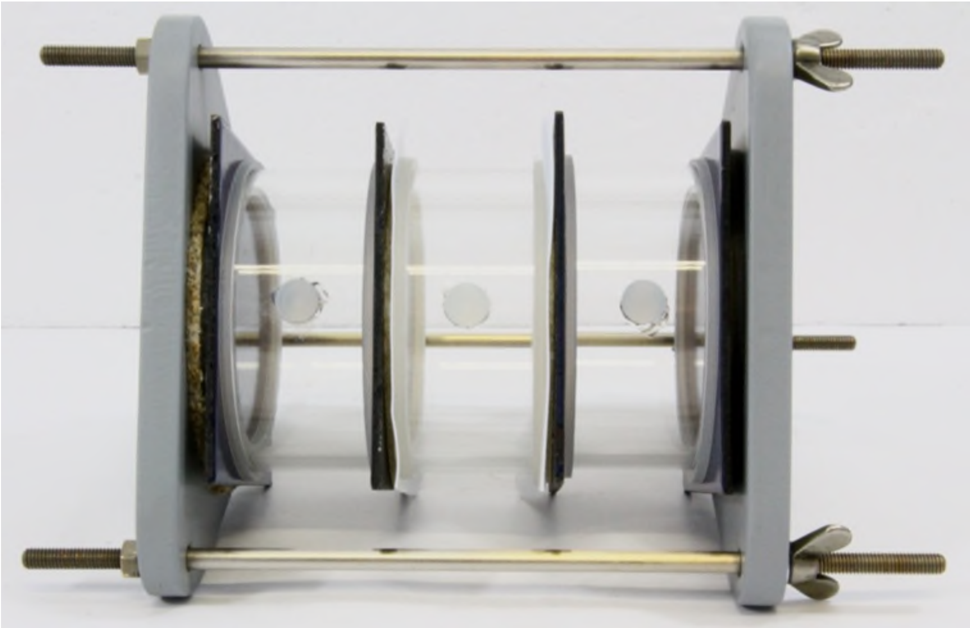
When testing components, a test surface to water volume (S/V) ratio of at least 5 dm^{-1} shall be configured. When testing purposely produced test plates as referred to in section 8.3.2, the test setup shall be dimensioned such that a test surface to water volume (S/V) ratio of 5 dm^{-1} ± 10% is obtained.

Figure 1 shows an appropriate setup for migration testing of enamelled plates. Of the three test chambers in the setup, the test water in two of the chambers is in contact with two enamelled plates each, whereas the blank trial runs in the middle chamber.

Figure 2 shows a test setup where funnels containing the migration water are pressed against the enamel plates. However, different test setups are possible.

4 Samples must reflect the requirements for samples pursuant to DIN 4753-3:2017-08.

Figure 1



Exemplary setup for migration testing of enamelled test plates (for a better view, the setup shown contains glass parts, which should not be used in actual testing) (photo: TÜV Süd)

Figure 2

Alternative test setup (photo: German Environment Agency)

In warm water and hot water testing, the test water must reach the required test temperature after at most one hour. This may be ensured e. g. by using pre-heated test water.

In cold water testing, at least the three migration periods described in DIN EN 12873-1 should be implemented. If c_{tap} (for calculation see 8.3.5) is above the criterion for at least one element in the third migration period (see Table 11) or shows an increasing trend, the test may be extended by performing 9 migration periods pursuant to Annex 1 of this evaluation criteria document. In the additional migration periods, the migration waters have to be analysed only for those parameters that have failed to meet the requirements during the regular test running until the third migration period.

For the warm water and hot water tests, at least the first seven migration periods as defined in Annex 2 of this evaluation criteria document should be performed. If c_{tap} (for calculation see 8.3.5) is above the criterion for at least one element in the seventh migration period (see Table 11) or shows a rising trend, the test may be extended to 22 migration periods according to Annex 2 of this evaluation criteria document. In the additional migration periods, the migration waters have to be analysed only for those parameters that have failed to meet the requirements during the regular test.

8.3.4 Analysis of migration waters

Annex 1 lists the migration water samples to be retrieved for the relevant migration periods in the analyses of the cold water test, Annex 2 correspondingly lists relevant samples for the warm water and hot water tests. The migration waters should be acidified immediately with concentrated HNO_3 to yield 2% (v/v) acid to prepare the sample for element content determination (not for PAH testing).

Enamels/vitreous materials

Those elements of the enamels/other vitreous materials for which a criterion has been defined pursuant to Table 11 should be assessed. Additionally, lead and cadmium content of the migration water being analysed shall be determined. The analysis should be undertaken by an adequate measurement method, e. g. ICP-MS as described in DIN EN ISO 17294-1.

Borosilicate glass

Those elements of borosilicate glass assigned with a test value in accordance with Table 11 shall be determined. Additionally, lead and cadmium content of analysed migration waters shall also be determined. The analysis shall be performed by means of an appropriate measurement method, e. g. ICP-MS in accordance with DIN EN ISO 17294-1.

Ceramic materials

Those elements of the ceramic material for which a criterion has been defined pursuant to Table 11 should be assessed. Additionally, lead and cadmium content of the migration water being analysed shall be determined. The analysis should be undertaken by an adequate measurement method, e. g. ICP-MS as described in DIN EN ISO 17294-1.

Ceramic materials made of carbon

When testing ceramic materials made of carbon, the PAH content of the migration water quantities being analysed should be determined according to Table 12.

Mixed metal oxide coatings (MMO)

If the mixed metal oxide coatings are manufactured as described in Chapter 6.3, migration tests are not necessary.

Zirconium oxide coatings

Those elements of the coating for which a criterion has been defined pursuant to **Table 11** should be assessed. Additionally, lead and cadmium content of the migration water being analysed shall be determined. The analysis should be undertaken by an adequate measurement method, e. g. ICP-MS as described in DIN EN ISO 17294-1.

8.3.5 Evaluation of the test results

The concentrations measured in the migration tests ($c_{measured}$) are converted into maximum expected concentrations at the tap (c_{tap}):

$$c_{tap} = \frac{Fc(c_{measured} - c_{blind})}{S/_{V} \quad t}$$

$c_{measured}$	respective element concentration of sample migration trial in µg/l
c_{blind}	respective element concentration of the blind trial in µg/l
F_C	component-specific conversion factor according to Table 14 in d/dm
S/V	the surface-to-volume ratio in dm^{-1}, where S is the surface area of the component in dm^2, and V the volume brought into contact with the component in dm^3
t	contact time in d

Table 14: Product groups with corresponding conversion factors

Product group		Conversion factor F_C in d/dm
Pipes	with ID < 80 mm (ID=inside diameter)	20
	with 80 mm ≤ ID < 300 mm	10
	with ID ≥ 300 mm	5
Ancillaries	for pipes with ID < 80 mm	2
	for pipes with 80 mm ≤ ID < 300 mm	1
	for pipes with ID ≥ 300 mm	0.5
Components of ancillaries where the proportion of surface area in contact with water < 10% in fitting	for pipes with ID < 80 mm	0.2
	for pipes with 80 mm ≤ ID < 300 mm	0.1
	for pipes with ID ≥ 300 mm	0.05
Small components of ancillaries where the proportion of surface area in contact with water < 1% in fitting	for pipes with ID < 80 mm	0.02
	for pipes with 80 mm ≤ ID < 300 mm	0.01
	for pipes with ID ≥ 300 mm	0.005
Tanks and components of tanks	in drinking water installations, Water volume < 10 l	4

Product group		Conversion factor Fc in d/dm
with a wetted surface portion ≥ 10% in the tank	in drinking water installations, water volume ≥ 10 l	2
	outside drinking water installations	1
Components of tanks with a wetted surface portion ‹ 10% in the tank	in drinking water installations, Water volume ‹ 10 l	0.4
	in drinking water installations, water volume ≥ 10 l	0.2
	outside drinking water installations	0.1
Small-area components of tanks with a wetted surface portion ‹ 1% in the tank	in drinking water installations, Water volume ‹ 10 l	0.04
	in drinking water installations, water volume ≥ 10 l	0.02
	outside drinking water installations	0.01
Products with a negligible influence on the quality of drinking water	Special products for tanks and distribution outside drinking water installations	‹0.005

The results of the parallel migration tests (duplicate testing) shall be reported individually in the test report. For purposes of assessment, the average ($\bar{c}_{tap}$) of the duplicate test results shall be used.

The requirements are regarded as fulfilled for the **cold water test** if for all parameters to be determined, it holds that:

$\bar{c}_{tap} \leq PW$ for the third or, in case of extended testing, for the ninth migration period

The requirements are regarded as fulfilled for the **warm water and hot water tests** if for all parameters to be determined, it holds that:

$\bar{c}_{tap} \leq PW$ for the seventh or, in case of extended testing, for the 22nd migration period

In addition, the concentrations of the elements to be determined must not show an increasing trend.

Note: *There is a rising trend in the measured concentrations for the formulation-specific requirements parameter, if for example the following criteria are fulfilled simultaneously:*

- *the measured concentration of the relevant migration period is over $^1/_{10}$ of the migration limit, and*
- *the measured concentration of the relevant migration period has doubled significantly (i.e. more than can be accounted for by measurement uncertainty) compared to the lowest measured concentration, and*
- *the measured concentration of the relevant migration period is the highest measurement value of the migration series.*

9 Test report

The test report referring to this evaluation criteria document must meet the requirements for test reports according to DIN EN 12873-1.

When testing purposely produced test plates, the report shall in particular specify under which conditions, where and by whom the test plates were produced.

10 Taking Effect

The 4th amendment enters into force one day after its publication in the German Federal Gazette (Bundesanzeiger).

Annex 1 Migration periods for the extended cold water test

Week	Migration period	Total contact time in days	End of the migration period	Contact time in days per migration	Analysis
1	0 (pre-treatment)	1	Tuesday	1	No
1	1	4	Friday	3	Yes
2	2	7	Monday	3	Yes
2	3	10	Thursday	3	Yes
3	4	14	Monday	4	No
3	5	17	Thursday	3	Yes
4	6	21	Monday	4	No
4	7	24	Thursday	3	Yes
5	8	28	Monday	4	No
5	9	31	Thursday	3	Yes

Annex 2 Migration periods for the extended warm water or hot water test

Week	Migration period	Total contact time in days	End of the migration period	Contact time in days per migration	Analysis
1	0 (pre-treatment)	1	Tuesday	1	No
1	1	2	Wednesday	1	Yes
1	2	3	Thursday	1	Yes
1	3	4	Friday	1	Yes
2	4	7	Monday	3	No
2	5	8	Tuesday	1	No
2	6	9	Wednesday	1	No
2	7	10	Thursday	1	Yes
2	8	11	Friday	1	No
3	9	14	Monday	3	No
3	10	15	Tuesday	1	No
3	11	16	Wednesday	1	No
3	12	17	Thursday	1	Yes
3	13	18	Friday	1	No
4	14	21	Monday	3	No
4	15	22	Tuesday	1	No
4	16	23	Wednesday	1	No
4	17	24	Thursday	1	Yes
4	18	25	Friday	1	No
5	19	28	Monday	3	No
5	20	29	Tuesday	1	No
5	21	30	Wednesday	1	No
5	22	31	Thursday	1	Yes

Annex 3 Exemplary overview of the different products in the respective product group

The following table contains exemplary products or components for the respective product groups (see Table 14). For the assignment of the components into the product groups, the actual wetted surface parts of the individual components must be taken into account. The surface portions of components made of the same materials must be summed up.

Product group[5]	Products (examples)
Pipes (P1)	Flange pipes (usually < 1 m length)
Ancillaries (P1)	Valves, fittings
Components of ancillaries where the surface portion in contact with water < 10% in ancillary (P2)	Valve housings and lids
Small componentsancillaries where the surface portion in contact with water < 1% in the ancillary (P3)	Ceramic bearings and ceramic shafts in drinking water pumps
Containers (P1)	Enamelled storage drinking water heaters
Components of containers (P2)	
Small components of containers with a wetted surface portion < 1% (P3)	Glass tubes for level indication in drinking water storage tanks
Products with negligible impact on drinking water quality (P4)	pH glass electrodes outside the drinking water installation

[5] see Table 10