
Water aggressiveness evaluation and optimized lining choice

*Évaluation de l'agressivité de l'eau et choix optimal des revêtements
intérieurs*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 5, *Ferrous metal pipes and metallic fittings*, Subcommittee SC 2, *Cast iron pipes, fittings and their joints*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Water aggressiveness evaluation and optimized lining choice

1 Scope

This document provides details about the aggressiveness factors, evaluation indicators of raw water, or inlet water of ductile iron pipe system and relevant lining information applicable to ductile iron pipes, fittings and accessories used in water mains and distribution system.

This document is intended to serve as a tool for estimating the properties of certain water and their effect on internal linings of ductile iron pipes, fittings and accessories used in water mains and distribution system which are specified in ISO 2531, ISO 16631 and can be used to decide the most appropriate protective measures to ensure long term durability of pipeline.

It is not always possible to definitively determine the aggressive parameters of certain water, and fully considered by limited test and evaluation. Therefore, the history information of the evaluated water, experiences of local water works can be taken for reference.

The aggressiveness evaluation of water can be carried out before determining the internal lining materials of certain pipeline, and the evaluation and relevant tests can be done by qualified laboratories and engineers.

Water that leads to high-level scaling in the pipeline is believed aggressive.

Drainage and waste water are not in the scope of this document, the internal protection of drainage and waste water can be recommended by pipe suppliers.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2531, *Ductile iron pipes, fittings, accessories and their joints for water applications*

ISO 16631, *Ductile iron pipes, fittings, accessories and their joints compatible with plastic (PVC or PE) piping systems, for water applications and for plastic pipeline connections, repair and replacement*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2531 and ISO 16631 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 scaling

dissolvable salts, residues of water pipeline inner surface reaction and other solids deposit on the inner surface of pipeline components, which will reduce the cross-sectional area and increase the head loss

Note 1 to entry: Scaling is sometimes also harmful to water quality and pipeline service life. The scaling process is normally related to the water chemical stability, temperature, flow rate, inner surface roughness of the pipeline component.

3.2 corrosive water

type of water which attacks metal component (pipe, fitting, accessories) without an internal coating

Note 1 to entry: The chemical reactions produce ferrous and then ferric hydroxides, forming nodules and tuberculation, which eventually reduce the component's cross-sectional area and significantly increase head loss, reduce the service life of metal pipeline components.

3.3 water aggressiveness

propensity to react with materials containing calcium such as hydraulic binders

Note 1 to entry: Depending on the chemical analysis, mineral content, pH and temperature of the water, three cases can occur:

- Water in calco-carbonic equilibrium does not attack or deposit calcium carbonate at a given temperature.
- Scaling water tends to deposit calcium salts (carbonates, etc.) on the pipeline components' inner surface.
- Aggressive water can attack certain components of cement mortar containing calcium (lime, calcium silicate and calcium silicoaluminate).

Note 2 to entry: Normally, ductile iron pipe components are supplied with linings, and cement mortar linings are the standard internal protection, so aggressive water and water aggressiveness are mostly used in this document. But the reaction with uncoated metal surface is also considered and described in some parts of this document.

4 Water aggressiveness evaluation

4.1 Normal internal corrosion mechanics

Internal corrosion mechanics of ferrous pipeline system have been studied for decades, according to the state of art, major pipeline internal corrosion problems can be traced to the stability of calcium magnesium carbonate system and iron system in the water. The status and the change of stability of these systems can lead to the deposition and dissolvment of carbonate and ferrous compound, which is the major reason of lining failure, red water, yellow water, scaling and related secondary corrosion.

The stability of calcium magnesium carbonate system and iron system are complex systemic ion balance problem related to multiple positive and negative ions, and highly related to water temperature. Considering those factors one by one is not a good way to get comprehensive information of the water aggressiveness, those factors are a united system and can be considered systematically.

Many indexes and indicators are concluded to evaluate the aggressiveness or stability of water.

4.2 Internal protection of ductile iron pipe

Ductile iron pipes are normally supplied with internal linings. There can be some special applications without internal linings. Linings are believed an effective way to protect the pipe when they are used appropriately. It is possible to categorize all existing linings as isolation barriers (polymeric linings), active protection (cement mortar lining), or their combination (cement mortar lining+seal coat). Cement mortar linings are standard internal protection of ductile iron pipes, and currently, most of ductile iron pipes are lined by cement mortar lining.

Other linings or internal protections can exist or can be developed as the updating pursue of water quality and pipeline service time.

Suitable lining choice based on water aggressiveness evaluation is beneficial to ensure the durability of lining protection in the long term and reduce the negative effect on water quality.

4.3 Water aggressiveness evaluation for ductile iron pipe system

Ductile iron pipes and fittings are used at any part of the water distribution system. They will influence other pipeline sections by the flowing water and be influenced as well. The interaction of ductile iron pipe and water can be considered based on the stability of calcium magnesium carbonate system and iron system. The interaction of water and cement mortar can also be considered at the same time.

In this document, multiple indicators with comprehensive consideration of aggressive factors based on calcium magnesium carbonate system, iron system, and also the interaction of water and cement mortar material are used to evaluate the aggressiveness of water.

4.4 Main corrosive aggressive factors

4.4.1 The pH value: the pH value of water is a measure of the concentration of the hydrogen ion concentration (H^+ or H_3O^+). The pH scale ranges from 0 to 14. Values less than 7,0 are considered acidic, values greater than 7,0 are considered alkaline, and 7,0 is considered neutral. Drinking water pH values typically range from 6,0 to 10. At higher pH values, there is less of a tendency for metal surfaces in contact with drinking water to dissolve and dissociate, which is why pH adjustment is a common component of an effective corrosion control treatment strategy. Maintaining a consistent target pH throughout the distribution system is always critical to minimizing lead and copper levels at the tap and minimizing discoloured-water complaints, even if other corrosion control methods are employed.

Another important consideration with regard to pH is its impact on other water quality parameters. It plays a significant role in the carbonate balance in that it impacts buffer capacity and dissolved inorganic carbon (DIC) concentrations. It also influences other corrosion-related parameters, such as oxidation-reduction potential (ORP) and corrosion inhibitor effectiveness.

4.4.2 Alkalinity: alkalinity is the capacity of water to neutralize acid. It is the sum of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), and hydroxide (OH^-) anions and is typically reported as milligrams per litre as calcium carbonate (mg/L as $CaCO_3$). Waters with high alkalinities tend to have high buffering capacities or a strong ability to resist changes in pH. Low-alkalinity waters are less able to neutralize acids or resist changes in pH.

4.4.3 Total dissolved solids/ionic strength: total dissolved solids (TDS) can have an impact on corrosion, though the effect can be less than other corrosion-related parameters. High TDS concentrations are generally associated with high concentrations of ions (e.g. Na^+ , Ca^{2+} , Mg^{2+} , Cl^- , CO_3^{2-} , SO_4^{2-}) that increase the conductivity of the water. Corrosion is an electrochemical reaction in which electrons from the anodic surface are transferred to the cathodic surface. The increased conductivity resulting from high TDS concentrations increases the ability of the water to complete the electrochemical circuit and conduct a corrosive current.

If sulfate and chloride are major anionic contributors to the TDS, the TDS is likely to show increased corrosivity toward iron-based materials. If the TDS is composed primarily of bicarbonate and hardness ions, the water will probably not be corrosive toward iron based or cementitious materials but can probably be highly corrosive toward copper. Low-TDS waters can also be corrosive and increase lead solubility. Low-TDS waters often have a strong tendency to dissolve (corrode) materials with which they are in contact in order to reach electro neutrality. Uniform corrosion is an electrochemical process in which the water solution in contact with the cathode provides the chemicals to accept the electrons donated by the pipe wall. The pipe wall, acting as an anode, then releases the oxidized metal ion to the water. Water has a limited capacity to accept dissolved species. Thus, although high-TDS waters have many electron receptors, low-TDS waters have the ability to accept a large number of anions and cations, resulting in a subsequent dissolution of existing pipe scales and corrosion of pipe surfaces.

TDS is a surrogate for the ionic strength of a solution. The ionic strength is a measure of the force of the electrostatic field caused by the presence of ions in a solution. More simply, the presence of anions and cations in solution increases the conductivity of the solution and can increase corrosion unless offset by passivating layers on the pipe surface. It is possible to determine the ionic strength as shown in [Formula \(1\)](#).

$$I=2,5\times 10^{-5}\times TDS \quad (1)$$

where: I = ionic strength; TDS = total dissolved solids concentration, in mg/L.

4.4.4 Dissolved inorganic carbon: DIC is the sum of all DIC-containing species and is one of the most critical parameters for controlling internal corrosion. It includes dissolved aqueous carbon dioxide gas (CO_2 or H_2CO_3), bicarbonate ion (HCO_3^-), and carbonate ion (CO_3^{2-}) in a particular water, and DIC is usually expressed as milligrams per litre of carbon (mg/L as C) or milligrams per litre of calcium carbonate (mg/L as CaCO_3). Although DIC and alkalinity are similar, they are not the same water quality parameter. DIC varies according to water temperature, pH, ionic strength, and alkalinity.

4.4.5 Hardness: hardness is a characteristic that represents the presence of dissolved multi-valence cations, primarily calcium and magnesium, in water and is reported as an equivalent concentration of calcium carbonate (CaCO_3). Hardness can be taken into consideration when corrosion control is selected and implemented because it can create scaling problems within the treatment plant, distribution system infrastructure, and customer plumbing. In this regard, hardness is an important parameter to be considered in developing a corrosion control program and evaluating the amount of pH adjustment that is permissible without causing scale problems.

4.4.6 Dissolved oxygen: dissolved oxygen (DO) can play important roles in both corrosion reactions and metals release. Oxygen can serve as an electron acceptor in the corrosion cell, allowing for metal oxidation at the pipe surface and release of ionized metal species into the water. Thus, new metal surfaces that are exposed to water containing DO will corrode faster compared to anaerobic water.

4.4.7 Oxidation–reduction potential: ORP, also frequently referred to as redox potential, is a measure of water’s capability to oxidize and is reported as electrical potential (volts, V, or millivolts, mV).

4.4.8 Metal ions and anions: it is possible to indicate metals in water as total metal and dissolved metal, dissolved metal ions such as: Ca^{2+} , Mg^{2+} , Fe^{3+} , Mn^{2+} , Al^{3+} . Their dissolution balance affect the water quality and scale formation. Some metal ions are regularly monitored deal to their effect on human health such as lead, they are normally limited in local water quality specifications. Some anions are highly related to the crystallization corrosion of concrete, their mechanisms are introduced in [Annex C](#).

4.5 Water evaluation indicators and their trigger value

Water aggressiveness is evaluated by comprehensive indicators. Normally, two equilibrium systems are considered for ductile iron pipe internal protection: iron equilibrium system and carbonate equilibrium. As ductile iron pipes are normally supplied with cement mortar linings, the aggressiveness of water to cement material can be evaluated.

In this document, five indicators can be used to evaluate the water aggressiveness. Their calculation and trigger value are showed in [4.5.1](#), [4.5.2](#), [4.5.3](#), [4.5.4](#), and [4.5.5](#). Other water evaluation indicators or scaling tendency indicators are possible.

4.5.1 Langelier saturation index (LSI)

$$LSI = pH - pH_s \quad (2)$$

where:

LSI is the Langelier saturation index;

pH is the pH value;

pH_s is the saturation pH (the calculation of pH_s is shown in [Annex A](#)).

The indications for the LSI are based on the following values:

LSI < 0 water is under saturated with respect to calcium carbonate and has a tendency to remove existing calcium carbonate protective coatings in pipelines;

LSI = 0 water is considered to be neutral, neither scale-forming nor scale removing;

LSI > 0 water is supersaturated with respect to calcium carbonate and scale forming can occur.

4.5.2 Ryznar stability index (RSI)

$$RSI = 2pH_s - pH \quad (3)$$

where:

RSI is the Ryznar stability index;

pH is the pH value;

pH_s is the saturation pH (the calculation of pH_s is shown in [Annex A](#)).

RSI is normally used together with LSI; they are based on the same thermodynamic hypothesis.

RSI < 5,0 heavy scale will form;

RSI = 5,0~6,0 light scale;

RSI = 6,0~7,0 little scale or corrosion;

RSI = 7,0~7,5 corrosion significant;

RSI = 7,5~9,0 heavy corrosion;

RSI > 9,0 corrosion intolerable.

4.5.3 Calcium carbonate precipitation potential (CCPP)

The CCPP predicts both tendencies to precipitate or to dissolve $CaCO_3$ and quantity that can be precipitated or dissolved. It is also known as calcium carbonate precipitation capacity (CCPC).

The CCPP is defined as the quantity of $CaCO_3$ that theoretically precipitate from oversaturated waters or dissolved by undersaturated waters during equilibration.

$$CCPP = 100 * ([Ca^{2+}]_i - [Ca^{2+}]_{eq}) \quad (4)$$

Unit: mg- $CaCO_3$ /L.

where:

$[Ca^{2+}]_i$ — $[Ca^{2+}]$ concentration of water sample, in mol/L;

$[Ca^{2+}]_{eq}$ — $[Ca^{2+}]$ concentration of water in $CaCO_3$ equilibrium status.

CCPP = 0~4 no scaling or little scale CCPP = 0~-5 slight corrosion

CCPP = 4~10 light scale CCPP = -5~-10 corrosion

CCPP = 10~15 heavy scale CCPP ≤ -10 heavy corrosion

CCPP ≥ 15 very heavy scale

CCPP is not suitable for hand calculation. It can be calculated by software or determined by experiments.

4.5.4 Larson ratio (LR)

$$LR = \frac{[Cl^-] + [SO_4^{2-}]}{[HCO_3^-]} \quad (5)$$

Unit: mol/L

LR shows the effect of anions in water, which is significantly related to iron-equilibrium and aggressiveness to cement materials.

LR < 0,5 non corrosive water;

LR = 0,5~1 slight corrosion;

LR > 1 corrosive, bigger value, heavier corrosive.

4.5.5 Aggressive index (AI)

$$AI = pH + \lg(Ca * Alk) \quad (6)$$

where:

Ca is the hardness, in mg- $CaCO_3$ /L;

Alk is the total alkali, in mg- $CaCO_3$ /L.

AI shows the aggressiveness to cement material.

AI < 10 heavy aggressive;

AI = 10~12 aggressive;

AI > 12 not aggressive.

4.5.6 Evaluation chart

The following chart can be used to evaluate the aggressiveness of certain water sample. The way to evaluate water stability of certain water sample is shown in [Table 1](#).

Table 1 — Water stability evaluation chart

Evaluation index	Indication	Water sample name	Calculation result	Evaluation conclusion
LSI	LSI <0 water is under saturated with respect to calcium carbonate and has a tendency to remove existing calcium carbonate coatings in pipelines; LSI = 0 water is considered to be neutral, neither scale-forming nor scale removing; LSI >0 water is supersaturated with respect to calcium carbonate and scale forming can occur.			
RSI	RSI <5,0 heavy scale will form; RSI = 5,0~6,0 light scale; RSI = 6,0~7,0 little scale or corrosion; RSI = 7,0~7,5 corrosion significant; RSI = 7,5~9,0 heavy corrosion; RSI >9,0 corrosion intolerable.			
CCPP ^a	CCPP ≤-10 heavy corrosion; CCPP = -10~-5 corrosion; CCPP = -5~0 slight corrosion; CCPP = 0~4 no scaling or little scale; CCPP = 4~10 light scale; CCPP = 10~15 heavy scale; CCPP ≥15 very heavy scale.			
LR	LR <0,5 water is not corrosive; LR = 0,5~1 slight corrosion; LR >1 corrosive, bigger value, heavier corrosive.			
AI	AI <10 heavy aggressive; AI = 10~12 aggressive; AI >12 not aggressive.			
^a If the evaluation results of LSI and RSI are contradictory, CCPP can be considered to get correct indication of the carbonate equilibrium status in certain waters.				

5 Sampling and testing

Water is changing all the time. Natural water source can be affected by seasonal changes or other environmental changes. Those changes can be considered.

Temperature is important for sampling and testing. Water temperature change affects the solubility of salts. The current or estimated pipeline service temperature can be considered during the sampling and testing. Also, the temperature change led by seasonal changes or weather effects can be considered.

If there are more than one water sources used, they can be sampled, tested and evaluated separately and the worse one can be considered for ductile iron pipe internal protection solution.

Relevant ISO standards for water sampling and testing of certain parameters are listed in [Annex B](#).

5.1 Sampling

Representative and adequate water samples are critical to the aggressiveness evaluation. It is possible to follow national water sampling standards, regulations or routine. The water sample can be raw

water from water source, or the inlet water of ductile iron pipes, decided by the location of ductile iron pipe in the pipeline system.

5.2 Testing

Basic parameters and supplemental parameters are listed in [Table 2](#). It is possible to follow national test standards if they exist. Basic parameters are needed to finish the evaluation indicator calculation, and supplemental parameters can help to get better understanding of the water aggressiveness. Other parameters can be added depending on the case study.

Historical data are important to understand the water quality change. For certain water sources, local water works can have historical data.

Table 2 — Water aggressiveness evaluation parameters

Basic	Supplemental
Temperature	Iron (total and solve)
pH	NH ₄ ⁺
Hardness	Sulfide
Total alkalinity	Dissolved oxygen
Cl ⁻	Disinfectant residual
SO ₄ ²⁻	
Conductivity/TDS	
Ca ²⁺	
Mg ²⁺	
HCO ₃ ⁻	

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6 Optimized lining choice based on water evaluation

Based on the evaluation results of indices given in [4.5](#), it is the manufacture’s responsibility to give suggestions for suitable lining.

7 Steps for water aggressiveness evaluation and optimized lining choice

The following steps are normally conducted:

1. Collection of historical data of certain water sources, with the consideration of seasonal changes and local specific properties, if any.
2. Making of a sampling plan and determine the sampling time, location, capacity, etc. when water temperature and content show periodical changes according to the historical data. Sampling can be done separately at representational time or at the worst status for the pipeline internal protection.
3. Testing the samples according to the aggressiveness parameter chart and paying attention to the difference between the test temperature and the original water source temperature. Test results can be corrected accordingly if necessary.
4. Calculation of the evaluation indexes, manually or using a software.
5. Combination of the evaluation indexes and historical data, and determination of the aggressiveness of water.
6. Based on the evaluation conclusions, the optimized lining choice suggestions in [Clause 6](#) are combined along with other special considerations of case study, and the internal anti-corrosion solution is determined.

Annex A (informative)

pH_s

A.1 pH_s

pH_s is the pH value when the content of CaCO₃ reaches the saturation status; it is concluded to evaluate the stability of water. If the CaCO₃ content is more or less than that of the equilibrium content, the water is chemically unstable.

pH_s is affected by many factors. It is mainly related to the bicarbonate alkalinity, Ca²⁺ and water temperature. There are usually two calculation methods used. For manual calculation, the lookup table method can be used. Softwares are also a convenient way to do the calculation and are available in different areas. The constants for pH_s calculation are shown in [Table A.1](#).

A.2 Lookup table method

$$pH_s = 9,3 + N_s + N_t - N_h - N_a \quad (\text{A.1})$$

where:

N_s is the dissolved solid constant;

N_t is the temperature constant;

N_h is the calcium hardness constant (measured as CaCO₃, mg/L);

N_a is the total alkali constant (measured as CaCO₃, mg/L).

Table A.1 — Constants for pH_s calculation

TDS (mg/L)	N_s	Water temperature (°C)	N_t	Calcium hardness (mg/L CaCO ₃)	N_h	Total alkali (mg/L CaCO ₃)	N_a
50	0,07	0~2	2,6	10~11	0,6	10~11	1,0
75	0,08	2~6	2,5	12~13	0,7	12~13	1,1
100	0,10	6~9	2,4	14~17	0,8	14~17	1,2
200	0,13	9~14	2,3	18~22	0,9	18~22	1,3
300	0,14	14~17	2,2	23~27	1,0	23~27	1,4
400	0,16	17~22	2,1	28~34	1,1	28~34	1,5
600	0,18	22~27	2,0	35~43	1,2	35~43	1,6
800	0,19	27~32	1,9	44~45	1,3	44~55	1,7
1 000	0,20	32~37	1,8	56~69	1,4	56~69	1,8
		37~44	1,7	70~87	1,5	70~87	1,9
		44~51	1,6	88~110	1,6	88~110	2,0
		51~55	1,5	111~138	1,7	111~138	2,1
		56~64	1,4	139~174	1,8	139~174	2,2
		64~72	1,3	175~220	1,9	175~220	2,3

Table A.1 (continued)

TDS (mg/L)	N_s	Water temperature (°C)	N_t	Calcium hardness (mg/L CaCO ₃)	N_h	Total alkali (mg/L CaCO ₃)	N_a
		72~82	1,2	230~270	2,0	230~270	2,4
				280~340	2,1	280~340	2,5
				350~430	2,2	350~430	2,6
				440~550	2,3	440~550	2,7
				560~690	2,4	560~690	2,8
				700~870	2,5	700~870	2,9
				880~1 000	2,6	880~1 000	3,0

A.3 APHA-AWWA-WEF method

The calculation of pH_s :

$$pH_s = pK_2 - pK_s + p[Ca^{2+}] + p[HCO_3^-] + 5pf_m \tag{A.2}$$

$$[Ca^{2+}] = [Ca^{2+}]_t - [Ca^{2+}]_{ip} \tag{A.3}$$

$$[HCO_3^-] = \frac{[Alk]_t - [Alk]_0 + 10^{(pf_m - pH)} - 10^{(pf_m + pH - pK_w)}}{1 + 0,5 \times 10^{(pH - pK_2)}} \tag{A.4}$$

$$pf_m = A \left(\frac{\sqrt{I}}{1 + \sqrt{I}} - 0,3I \right) \tag{A.5}$$

where:

- P is the preceding a variable designates, (- log 10) of that variable;
- K_2 is the second dissociation constant for carbonic acid, at the water temperature;
- K_s is the solubility product constant for CaCO₃ at the water temperature;
- f_m is the activity coefficient for monovalent species at the specified temperature;
- $[Ca^{2+}]$ is the calcium ion concentration, mol/L;
- $[Ca^{2+}]_t$ is the total calcium, mol/L;
- $[Ca^{2+}]_{ip}$ is the calcium associated with ion pairs such as CaHCO₃⁺, CaSO₄⁰ and CaOH⁺; calcium associated with ion pairs is not available to form CaCO₃;
- $[HCO_3^-]$ is the bicarbonate ion concentration, mol/L;
- $[ALK]_t$ is the total alkalinity, as determined by acid titration to the carbonic acid end point, mol/L;
- $[ALK]_0$ is the alkalinity contributed by NH₃⁰, H₃SiO₄⁻, HPO₄²⁻, B(OH)₄⁻, CH₃COO⁻, HS⁻, and ion pairs such as CaHCO₃⁺ and MgOH⁺. These contributions usually are small compared to the contributions of components normally considered (HCO₃⁻, CO₃²⁻, OH⁻ and H⁺);
- A is the constant related to water temperature;

I is the ion strength, mol/L, in the absence of a complete water analysis, estimate I from conductivity or total dissolved solids (TDS):

$$I = \text{TDS (mg/L)}/40\,000 \text{ or } I = \text{Conductivity } (\mu\text{S/cm}) \cdot 1,6 \cdot 10^{-5}.$$

The terms $[Ca^{2+}]_{ip}$ and $[ALK]_0$ are difficult to calculate without computers, therefore they are usually neglected for hand calculations when waters are approximately neutral (pH 6,0 to 8,5) with alkalinity greater than about 50 mg/L as $CaCO_3$. The simplified version of [Formula \(A.2\)](#) under such condition is :

$$pH_s = pK_2 - pK_s + p[Ca^{2+}]_t + p[ALK]_t + 5pf_m \tag{A.6}$$

To save computation time, values for pK_2 , pK_s and A have been precalculated for the selected temperatures which are given in [Table A.2](#).

Table A.2 — Precalculated values for pK and A at selected temperatures

Temperature °C	pK ₂	pK _s			pK _w	A
		Calcite	Aragonite	Vaterite		
5	10,55	8,39	8,24	7,77	14,73	0,494
10	10,49	8,41	8,26	7,80	14,53	0,498
15	10,43	8,43	8,28	7,84	14,34	0,502
20	10,38	8,45	8,31	7,87	14,16	0,506
25 ^a	10,33	8,48	8,34	7,91	13,99	0,511
30	10,29	8,51	8,37	7,96	13,83	0,515
35	10,25	8,54	8,41	8,00	13,68	0,520
40	10,22	8,58	8,45	8,05	13,53	0,526
45	10,20	8,62	8,49	8,10	13,39	0,531
50	10,17	8,66	8,54	8,16	13,26	0,537
60	10,14	8,76	8,64	8,28	13,02	0,549
70	10,13	8,87	8,75	8,40	-	0,562
80	10,13	8,99	8,88	8,55	-	0,576
90	10,14	9,12	9,02	8,70	-	0,591
^a pf_m estimated from TDS values at 25 °C are as follows: TDS 100 200 400 800 1 000 pf_m 0,024 0,033 0,044 0,060 0,066						

Annex B (informative)

Relevant test standards

Table B.1 — Relevant test standards

Category	Standard reference	Title
Sampling	ISO 5667-1:2020	Water quality — Sampling — Part 1: Guidance on the design of sampling programmes and sampling techniques
	ISO 5667-3:2018	Water quality — Sampling — Part 3: Preservation and handling of water samples
	ISO 5667-4:2016	Water quality — Sampling — Part 4: Guidance on sampling from lakes, natural and man-made
	ISO 5667-5:2006	Water quality — Sampling — Part 5: Guidance on sampling of drinking water from treatment works and piped distribution systems
	ISO 5667-6:2014	Water quality — Sampling — Part 6: Guidance on sampling of rivers and streams
	ISO 5667-7:1993	Water quality — Sampling — Part 7: Guidance on sampling of water and steam in boiler plants
	ISO 5667-8:1993	Water quality — Sampling — Part 8: Guidance on the sampling of wet deposition
	ISO 5667-9:1992	Water quality — Sampling — Part 9: Guidance on sampling from marine waters
	ISO 5667-10:2020	Water quality — Sampling — Part 10: Guidance on sampling of waste water
	ISO 5667-11:2009	Water quality — Sampling — Part 11: Guidance on sampling of groundwaters
	ISO 5667-12:2017	Water quality — Sampling — Part 12: Guidance on sampling of bottom sediments from rivers, lakes and estuarine areas
	ISO 5667-13:2011	Water quality — Sampling — Part 13: Guidance on sampling of sludges
	ISO 5667-14:2014	Water quality — Sampling — Part 14: Guidance on quality assurance and quality control of environmental water sampling and handling
	ISO 5667-15:2009	Water quality — Sampling — Part 15: Guidance on the preservation and handling of sludge and sediment samples
	ISO 5667-16:2017	Water quality — Sampling — Part 16: Guidance on biotesting of samples
	ISO 5667-17:2008	Water quality — Sampling — Part 17: Guidance on sampling of bulk suspended solids
	ISO 5667-19:2004	Water quality — Sampling — Part 19: Guidance on sampling of marine sediments
	ISO 5667-20:2008	Water quality — Sampling — Part 20: Guidance on the use of sampling data for decision making — Compliance with thresholds and classification systems

Table B.1 (continued)

Category	Standard reference	Title
	ISO 5667-21:2010	Water quality — Sampling — Part 21: Guidance on sampling of drinking water distributed by tankers or means other than distribution pipes
	ISO 5667-22:2010	Water quality — Sampling — Part 22: Guidance on the design and installation of groundwater monitoring points
	ISO 5667-23:2011	Water quality — Sampling — Part 23: Guidance on passive sampling in surface waters
	ISO 5667-24:2016	Water quality — Sampling — Part 24: Guidance on the auditing of water quality sampling
Dissolved oxygen	ISO 5813:1983	Water quality — Determination of dissolved oxygen — Iodometric method
	ISO 5814:2012	Water quality — Determination of dissolved oxygen — Electrochemical probe method
Calcium and magnesium	ISO 6058:1984	Water quality — Determination of calcium content — EDTA titrimetric method
	ISO 6059:1984	Water quality — Determination of the sum of calcium and magnesium — EDTA titrimetric method
	ISO 7980:1986	Water quality — Determination of calcium and magnesium — Atomic absorption spectrometric method
COD Iron	ISO 6060:1989	Water quality — Determination of the chemical oxygen demand
	ISO 6332:1988	Water quality — Determination of iron — Spectrometric method using 1,10-phenanthroline
Manganese	ISO 6333:1986	Water quality — Determination of manganese — Formaldoxime spectrometric method
Nitrite	ISO 6777:1984	Water quality — Determination of nitrite — Molecular absorption spectrometric method
Ammonium	ISO 6778:1984	Water quality — Determination of ammonium — Potentiometric method
	ISO 7150-1:1984	Water quality — Determination of ammonium — Part 1: Manual spectrometric method
	ISO 5664:1984	Water quality — Determination of ammonium — Distillation and titration method
Phosphorus	ISO 6878:2004	Water quality — Determination of phosphorus — Ammonium molybdate spectrometric method
Turbidity	ISO 7027-1:2016	Water quality — Determination of turbidity — Part 1: Quantitative methods
	ISO 7027-2:2019	Water quality — Determination of turbidity — Part 2: Semi-quantitative methods for the assessment of transparency of waters

Table B.1 (continued)

Category	Standard reference	Title
Free chlorine and total chlorine	ISO 7393-1:1985	Water quality — Determination of free chlorine and total chlorine — Part 1: Titrimetric method using N,N-diethyl-1,4-phenylenediamine
	ISO 7393-1:1985/Cor 1:2001	Water quality — Determination of free chlorine and total chlorine — Part 1: Titrimetric method using N,N-diethyl-1,4-phenylenediamine — Technical Corrigendum 1
	ISO 7393-2:2017	Water quality — Determination of free chlorine and total chlorine — Part 2: Colorimetric method using N,N-dialkyl-1,4-phenylenediamine, for routine control purposes
	ISO 7393-3:1990	Water quality — Determination of free chlorine and total chlorine — Part 3: Iodometric titration method for the determination of total chlorine
Colour	ISO 7887:2011	Water quality — Examination and determination of colour
Electrical conductivity	ISO 7888:1985	Water quality — Determination of electrical conductivity
Nitrate	ISO 7890-3:1988	Water quality — Determination of nitrate — Part 3: Spectrometric method using sulfosalicylic acid
TOC and DOC	ISO 8245:1999	Water quality — Guidelines for the determination of total organic carbon (TOC) and dissolved organic carbon (DOC)
Chloride	ISO 9297:1989	Water quality — Determination of chloride — Silver nitrate titration with chromate indicator (Mohr's method)
	ISO 15682:2000	Water quality — Determination of chloride by flow analysis (CFA and FIA) and photometric or potentiometric detection
Alkalinity	ISO 9963-1:1994	Water quality — Determination of alkalinity — Part 1: Determination of total and composite alkalinity
	ISO 9963-2:1994	Water quality — Determination of alkalinity — Part 2: Determination of carbonate alkalinity
Sodium (Na) and potassium (K)	ISO 9964-1:1993	Water quality — Determination of sodium and potassium — Part 1: Determination of sodium by atomic absorption spectrometry
	ISO 9964-2:1993	Water quality — Determination of sodium and potassium — Part 2: Determination of potassium by atomic absorption spectrometry
	ISO 9964-3:1993	Water quality — Determination of sodium and potassium — Part 3: Determination of sodium and potassium by flame emission spectrometry

Table B.1 (continued)

Category	Standard reference	Title
Dissolved anions	ISO 10304-1:2007	Water quality — Determination of dissolved anions by liquid chromatography of ions — Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate
	ISO 10304-1:2007/ COR 1:2010	Water quality — Determination of dissolved anions by liquid chromatography of ions — Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate — Technical Corrigendum 1
	ISO 10304-3:1997	Water quality — Determination of dissolved anions by liquid chromatography of ions — Part 3: Determination of chromate, iodide, sulfite, thiocyanate and thiosulfate
	ISO 10304-4:2022	Water quality — Determination of dissolved anions by liquid chromatography of ions — Part 4: Determination of chlorate, chloride and chlorite in water with low contamination
pH	ISO 10523:2008	Water quality — Determination of pH
Dissolved sulfide	ISO 10530:1992	Water quality — Determination of dissolved sulfide — Photometric method using methylene blue
Aluminium	ISO 10566:1994	Water quality — Determination of aluminium — Spectrometric method using pyrocatechol violet
Selected organic nitrogen and phosphorus compounds	ISO 10695:2000	Water quality — Determination of selected organic nitrogen and phosphorus compounds — Gas chromatographic methods
Chromium(VI)	ISO 11083:1994	Water quality — Determination of chromium(-VI) — Spectrometric method using 1,5-diphenylcarbazide
	ISO 23913:2006	Water quality — Determination of chromium(-VI) — Method using flow analysis (FIA and CFA) and spectrometric detection
Ammonium nitrogen	ISO 11732:2005	Water quality — Determination of ammonium nitrogen — Method by flow analysis (CFA and FIA) and spectrometric detection
Nitrogen	ISO 11905-1:1997	Water quality — Determination of nitrogen — Part 1: Method using oxidative digestion with peroxodisulfate
Suspended solids	ISO 11923:1997	Water quality — Determination of suspended solids by filtration through glass-fibre filters
Aluminium	ISO 12020:1997	Water quality — Determination of aluminium — Atomic absorption spectrometric methods
Easily released sulfide	ISO 13358:1997	Water quality — Determination of easily released sulfide
Nitrite nitrogen and nitrate nitrogen	ISO 13395:1996	Water quality — Determination of nitrite nitrogen and nitrate nitrogen and the sum of both by flow analysis (CFA and FIA) and spectrometric detection
Li ⁺ , Na ⁺ , NH ₄ ⁺ , K ⁺ , Mn ²⁺ , Ca ²⁺ , Mg ²⁺ , Sr ²⁺ , Ba ²⁺	ISO 14911:1998	Water quality — Determination of dissolved Li ⁺ , Na ⁺ , NH ₄ ⁺ , K ⁺ , Mn ²⁺ , Ca ²⁺ , Mg ²⁺ , Sr ²⁺ and Ba ²⁺ using ion chromatography — Method for water and waste water

Table B.1 (continued)

Category	Standard reference	Title
Dissolved bromate	ISO 15061:2001	Water quality — Determination of dissolved bromate — Method by liquid chromatography of ions
Trace elements	ISO 15586:2003	Water quality — Determination of trace elements using atomic absorption spectrometry with graphite furnace.
Orthophosphate and total phosphorus contents	ISO 15681-1:2003	Water quality — Determination of orthophosphate and total phosphorus contents by flow analysis (FIA and CFA) — Part1: Method by flow injection analysis (FIA)
	ISO 15681-2:2018	Water quality — Determination of orthophosphate and total phosphorus contents by flow analysis (FIA and CFA) — Part2: Method by continuous flow analysis (CFA)
Chemical oxygen demand index	ISO 15705:2002	Water quality — Determination of the chemical oxygen demand index (ST-COD-small-scale sealed -tube method)
Soluble silicate	ISO 16264:2002	Water quality — Determination of soluble silicates by flow analysis (FIA and CFA) and photometric detection
Dissolved oxygen	ISO 17289:2014	Water quality — Determination of dissolved oxygen-optical sensor method
Mercury	ISO 17852:2006	Water quality — Determination of mercury — Method using atomic fluorescence spectrometry
Total organic carbon	ISO 20236:2018	Water quality — Determination of total organic carbon (TOC), dissolved organic carbon (DOC), total bound nitrogen (TNb) and dissolved bound nitrogen (DNb) after high temperature catalytic oxidative combustion
Total nitrogen after UV digestion	ISO 29441:2010	Water quality — Determination of total nitrogen after UV digestion — Method using flow analysis (CFA and FIA) and spectrometric detection
Selected non-polar substances	ISO/TS 28581:2012	Water quality — Determination of selected non-polar substances — Method using gas chromatography with mass spectrometric detection (GC-MS)
Sulfates	ISO 22743:2006/ COR1:2007	Water quality — Determination of sulfates — Method by continuous flow analysis (CFA)
Certain explosives and related compounds	ISO 22478:2006	Water quality — Determination of certain explosives and related compounds — Method using high-performance liquid chromatography (HPLC) with UV detection
Total alkalinity in sea water	ISO 22719:2008	Water quality — Determination of total alkalinity in sea water using high precision potentiometric titration

Table B.1 (continued)

Category	Standard reference	Title
Selected parameters by discrete analysis systems	ISO 15923-1:2013	Water quality — Determination of selected parameters by discrete analysis systems — Part 1: Ammonium, nitrate, nitrite, chloride, orthophosphate, sulfate and silicate with photometric detection
	ISO/TS 15923-2:2017	Water quality — Determination of selected parameters by discrete analysis systems — Part 2: Chromium(VI), fluoride, total alkalinity, total hardness, calcium, magnesium, iron, iron(II), manganese and aluminium with photometric detection
Result equivalency	ISO/TS 16489:2006	Water quality — Guidance for establishing the equivalency of results
Quality control	ISO/TS 13530:2009	Water quality — Guidance on analytical quality control for chemical and physicochemical water analysis
Interlaboratory comparisons	ISO/TS 20612:2007	Water quality — Interlaboratory comparisons for proficiency testing of analytical chemistry laboratories
Selection of a representative matrix	ISO/TS 21231:2019	Water quality — Characterization of analytical methods — Guidelines for the selection of a representative matrix

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Annex C (informative)

Type and characteristics of water-related concrete corrosion

Table C.1 — Type and characteristic of water-related concrete corrosion

Type	Characteristic	Monitor parameters
Decomposition corrosion	<p>Water with extremely low TDS, or hardness lower than 1,5 mmol/L, or when the concentration of H⁺, CO₂, free carbonic acid and some salts are extremely low, the cement will be dissolved, Ca(OH)₂ will be neutralized, or CaO, Ca(OH)₂ and other contents will be dissolved and lost, which will decrease the alkalinity and concrete strength. Such as:</p> $\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 \downarrow + \text{H}_2\text{O}, \text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Ca(HCO}_3)_2(\text{soluble})$ $3\text{CaO} \cdot \text{Si}_2\text{O}_3 \cdot 3\text{H}_2\text{O} \rightarrow 3\text{CaCO}_3 \downarrow + 2\text{SiO}_2 + 3\text{H}_2\text{O}$ $2\text{NH}_4\text{Cl} + \text{Ca(OH)}_2 \rightarrow 2\text{NH}_3 \uparrow + \text{CaCl}_2(\text{soluble}) + 2\text{H}_2\text{O}$	<p>pH</p> <p>Aggressive CO₂</p>
Crystallization corrosion	<p>Some salts in water will seep into the concrete, hydrate the concrete or compound with some chemicals in concrete, and form stable hydration crystals, expand and lead to bulging breaks, which will affect concrete durability. Such as:</p> $\text{MgSO}_4 + \text{Ca(OH)}_2 \rightarrow \text{Mg(OH)}_2 \downarrow + \text{CaSO}_4(\text{hydration crystal})$ $3\text{CaO} \cdot \text{Al}_2\text{O}_3 + 3\text{CaSO}_4 + 32\text{H}_2\text{O} \rightarrow 3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 32\text{H}_2\text{O}(\text{Ettringite})$	<p>SO₄²⁻</p>
Crystallization-decomposition complex corrosion	<p>Some chemicals in water will react with some concrete content and cement, both decomposition and crystallization corrosion exist, usually the anions will lead to crystallization corrosion and cations will lead to decomposition corrosion. Such as:</p> $(\text{NH}_4)_2\text{SO}_4 + \text{Ca(OH)}_2 \rightarrow 2\text{NH}_3 \uparrow + \text{CaSO}_4 + 2\text{H}_2\text{O}$ $3\text{CaO} \cdot \text{Al}_2\text{O}_3 + 3\text{Na}_2\text{SO}_4 + 3\text{Ca(OH)}_2 + 32\text{H}_2\text{O} \rightarrow 3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 32\text{H}_2\text{O}(\text{Ettringite}) + 6\text{NaOH}$ $\text{MgCl}_2 + \text{Ca(OH)}_2 \rightarrow \text{Mg(OH)}_2 \downarrow + \text{CaCl}_2(\text{soluble})$ $\text{MgSO}_4 + \text{Ca(OH)}_2 \rightarrow \text{Mg(OH)}_2 \downarrow + \text{CaSO}_4$	<p>Mg²⁺</p> <p>NH₄⁺</p> <p>SO₄²⁻</p> <p>NO₃⁻</p> <p>Cl⁻</p>

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