INTERNATIONAL STANDARD

ISO

24416

First edition
2022-07

Water reuse in urban areas — Guidelines for water reuse safety evaluation — Stability evaluation of reclaimed water

Recyclage des eaux dans les zones urbaines — Lignes directrices concernant l'évaluation de la sécurité du recyclage de l'eau — Évaluation de la stabilité de l'eau réutilisée

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Foreword

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This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 2, *Water reuse in urban areas*.

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.

Introduction

With economic development and population growth, the demand for water resources is steadily increasing. Combined with the exploitation and utilization of water, numerous countries and regions have faced water shortages to different degrees. Increasing efforts has been made to solve the water crisis.

Water reuse has been recognized as a low-cost and effective means to alleviate water resource shortages. Wastewater usually contains a variety of pathogens, chemical pollutants and nutrients. Traditional water treatment cannot remove all pollutants. During the long-term utilization of reclaimed water, residual pollutants will affect human health (e.g. potential health risks to the public and workers handling the reclaimed water), ecological environment (e.g. pollution of receiving water, soil) and production safety (e.g. harmful effects on equipment operation such as corrosion, scaling and fouling). Therefore, water quality stability is a prerequisite to ensure water reuse. It is necessary to monitor and manage the quality of reclaimed water to ensure a safe supply. Chemical stability and biological stability are crucial aspects of water quality stability. Water quality instability usually leads to frequent occurrences of corrosion, scaling and fouling, bacterial regrowth, increasing energy consumption and reduced service life of relevant equipment.

There are limited guidelines or regulations specifically regarding water quality stability for urban purposes of reclaimed water at a global level. For different types of reclaimed water applications, the selection of stability evaluation parameters remains controversial. Stability evaluation and management of water quality are important to ensure safe utilization of reclaimed water. It is necessary to establish a standard for comprehensively evaluating the stability of reclaimed water.

This document aims to provide guidance on water quality stability of reclaimed water and provide stability parameters and methods based on different needs and utilization of reclaimed water. This document includes:

— standard terms and definitions;

— evaluation principles of water quality stability for reclaimed water;

— evaluation parameters of water quality stability for reclaimed water;

— the selection of stability evaluation parameters for pipeline networks and equipment related to reclaimed water;

— evaluation methods of water quality stability for reclaimed water.

Critical values of evaluation parameters for water quality stability are out of the scope of this document. The ranges of different evaluation parameters are provided for reference. The water stability control or management involving the reclamation treatment and/or the distribution system management (e.g. residual disinfectant) are also out of the scope of this document.

This document provides guidance on storage, transportation and application of reclaimed water. The beneficial aspects are reduction of energy consumption, expansion of service life of equipment and reduction of operation costs.

Water reuse in urban areas — Guidelines for water reuse safety evaluation — Stability evaluation of reclaimed water

1 Scope

This document provides parameters and methods for water quality stability evaluation of reclaimed water. This document can be used in various stages of water reclamation projects including storage, transportation, application and post-assessment.

This document considers the needs and utilization of reclaimed water and is applicable to the evaluation and management of water quality stability of reclaimed water from municipal wastewater sources, including chemical stability and biological stability.

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 20670, *Water reuse — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20670 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
assimilable organic carbon
AOC
organic carbon which can be used by microorganisms for assimilation

[SOURCE: ISO 23070:2020, 3.1]

3.2
corrosion
physicochemical interaction between a metallic material and its environment that results in changes in the properties of the metal and that can lead to significant impairment of the function of the metal, the environment or the technical system, of which these form a part

[SOURCE: ISO 8044:2020, 3.1, modified — Note 1 to entry removed.]

3.3
critical value
boundaries of acceptable values for evaluation parameters when water quality is stable

3.4
fouling
precipitation of suspended solids, including living organisms (biofouling) and chemical substances (inorganic or organic)

3.5
microbiologically influenced corrosion
MIC
corrosion (3.2) influenced by the action of microorganisms

[SOURCE: ISO 8044:2020, 4.37, modified — Note 1 to entry removed.]

3.6
scaling
crystalline scales caused by the oversaturation of chemical substances on metallic or non-metallic surfaces

4 Abbreviated terms

AI	aggressive index
AOC	assimilable organic carbon
ATP	adenosine triphosphate
BDOC	biodegradable dissolved organic carbon
BFR	biofilm formation rate
BGP	bacterial growth potential
CCPP	calcium carbonate precipitation potential
COD_{Cr}	chemical oxygen demand (dichromate method)
DO	dissolved oxygen
DBP	disinfection by-product
ILR	improved Larson corrosion index
LR	Larson corrosion index
LSI	Langelier saturation index
MAP	microbially available phosphorus
MIC	microbiologically influenced corrosion
MPN	most probable number
RI	Riddick corrosion index
RSI	Ryznar stability index
TDS	total dissolved solids
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids

5 Water quality stability

5.1 General

Water quality stability is the premise of reclaimed water use. The recommended parameters for water reuse safety in ISO 20761 include routine physical and chemical parameters, aesthetic parameters, microbial parameters, stability parameters and toxic and harmful chemicals.[1] Among stability parameters, chemical stability and biological stability are important aspects.

Chemical stability includes corrosion, scaling and fouling. Corrosion can be classified into many types, such as electrochemical corrosion, chemical corrosion, localized corrosion, pitting corrosion and layer corrosion. Detailed information is given in Annex A. Table 1 lists factors influencing the likelihood of corrosion. The main influencing factors include characteristics of equipment and pipelines, characteristics of the reclaimed water and operating conditions. Reclaimed water can be used in many fields for urban areas, such as industrial use, artificial landscape amenity, municipal non-potable use and groundwater recharge. Related equipment includes boilers and heat exchangers, irrigation equipment, air conditioning and toilet flushing devices. Related pipelines include steel and galvanized steel pipelines, concrete and cement pipelines, cement-mortar-lined metal pipelines, plastic pipelines, cast-iron and ductile-cast-iron pipelines and non-ferrous metal pipelines. Operating conditions include temperature, flow conditions and pressure conditions. Scaling is mainly dependent on two situations. One is the decrease in the solubility of ionic components, which lead to crystals precipitation when thermodynamic conditions change. The other is precipitation formed by reactions between different ionic components. Fouling is mainly caused by the precipitation of suspended chemicals. The extent of fouling is affected by hydraulic conditions, the roughness of the contact surfaces and the concentration, size and type of suspended chemicals.

Table 1 — Factors influencing the likelihood of corrosion

Characteristics of equipment and pipelines	Characteristics of the water	Operating conditions
— Chemical composition — Surface conditions — Design and construction	— Physico-chemical composition — Colloidal and particulate matter — Living organisms	— Temperature — Flow conditions, such as flow velocity, turbulence or laminar flow, continuous or intermittent pattern — Pressure conditions

Besides chemical stability, considering the possibility of opportunistic bacterial regrowth in reclaimed water, biological stability is also an important aspect of water quality stability. Biological stability includes MIC and biofouling. MIC is due to microbial activity involving bacteria, archaea and fungi. Within bacteria, sulfate-reducing bacteria, sulfur-oxidising bacteria, iron-oxidising or reducing bacteria, acid-producing bacteria and bacteria that excrete extra-cellular polymeric substances significantly affect corrosion. Among these, some microbes can coexist and their cooperative metabolisms can lead to increasing corrosion rates. Microbes can directly cause MIC by producing acids and they can accelerate the corrosion of pre-existing agents such as O_2 and CO_2 by damaging mineral passivation films on metal surfaces. Moreover, the major mechanisms of MIC include fixing anodic sites, formation of differential aeration or chemical concentration cells and cathodic depolarisation. MIC can cause corrosion to various materials such as carbon steel, stainless steel, aluminium alloy, magnesium, zinc and concrete.[2] Biofouling is caused by the excessive growth of biofilm. Biofilm is the aggregate of microbial cells formed by microorganisms developing layers of polymer-like materials, called extra-cellular polymeric substances, and attached at a surface-liquid interface. Microbial adhesion to surfaces is governed by surface-charge, -free energy and -roughness. Electrostatic, hydrophobic and chemical forces can cause microbial attachment to surfaces. Due to extra-cellular enzymes in the biofilm, microorganisms can utilize complex organic substrates, such as humic acids that are not easily biodegradable by microorganisms in bulk water, which enables the growth of different microorganisms present in bulk water. Biofilm can also protect microorganisms from disinfectants and toxins in the surrounding environment. The formation of biofilm is dependent on various environmental conditions,

such as salinity, temperature, conductivity, pH, DO level, BDOC and AOC content and hydrodynamic conditions. In addition, it is not recommended that caustics are used to reduce biofilm formation in pipeline networks, because some bacteria from biofilm can survive under unfavourable conditions (higher pH values).

Water quality stability is affected by many factors, including physical, chemical and biological factors. Examples of related influencing factors on water quality stability are shown in Table 2 and Table 3.

Table 2 — Examples of related influencing factors on chemical stability

Influencing factors	Notes of significance
Calcium and magnesium ions	Calcium and magnesium ions determine water hardness. Low hardness is beneficial for passivation film formation on the inner wall of pipeline networks, which can prevent further corrosion. High hardness can lead to scale formation.
Chloride	High concentration of chloride can increase conductivity of water, accelerate migration rate of ions and electrons in the water and accelerate corrosion. More specifically, high concentration of chloride can cause pitting corrosion, especially for stainless steel.
Sulfate	High concentration of sulfate can increase conductivity of water, accelerate migration rate of ions and electrons in the water and accelerate corrosion. Sulfate can easily cause scale formation when calcium ions exist.
Nitrate	Nitrate can greatly accelerate the general corrosion of iron in acidic solutions but has slight influence on the general corrosion in neutral solutions.[3]
DO	When DO acts on the inner wall of pipeline networks, it can accelerate corrosion. When DO acts on the surface of formed corrosion products, it can promote passivation films formation and prevent further corrosion.
Carbon dioxide	High contents of carbon dioxide can decrease pH value and corrode metals.
Silicon dioxide	Excessive silicon dioxide can form hard scales, especially for heat exchangers.
Iron	Iron can form red iron hydroxide precipitation, causing scale formation. Water containing iron bicarbonate can also cause corrosion.
pH	The increase of pH within specific limits (pH 7,5 to pH 9,5) can reduce the release of iron. Higher pH can increase the oxidation rate of Fe(II) and formed Fe(III) can intensify the physical structure of tubercles, thus inhibiting the release of internal iron.
TSS	TSS are easily disturbed by water flow and can acceleratively scour off corrosion surface layer, thus aggravating erosion of water flow on the inner wall of pipelines. Suspended solids are nuclei of salt crystals. Excessive suspended solids will also promote the formation of scales.

Table 3 — Examples of related influencing factors on biological stability

Influencing factors		Notes of significance
AOC		AOC can provide carbon and energy for heterotrophic bacteria and is generally considered a major limiting factor for the growth of heterotrophic bacteria.
BDOC		BDOC is considered as the hydrolysable pool of carbon available for bacterial growth and biofilm formation in the distribution system. The BDOC can be used to evaluate the reduction in chlorine demand or disinfection by-product (DBP) formation potential through a biological process.
Inorganic nutrients	Nitrogen	Due to bacterial elemental composition (e.g. molar ratio C:N:P is 100:20:1,7), nitrogen is also required for heterotrophic growth, though in considerably smaller amounts than organic carbon. The lack of nitrogen will limit the growth of heterotrophic bacteria. Ammonia can be oxidized to nitrous acid by ammonia-oxidizing bacteria, which simultaneously leads to pH decrease. Under low pH value, pipelines of carbon steel, copper, aluminium and other metals are prone to corrode. Nitrate-reducing bacteria can utilize nitrate and generate nitrogen gas which is not corrosive, which prevents corrosion through competition with sulfate reduction by sulfate-reducing bacteria.
	Phosphorus	Phosphorus is an important limiting factor for bacterial growth, among which phosphate can provide nutrient source for bacteria. Compared with carbon content, phosphorus content required by bacteria is lower. The content of phosphorus in the effluent water depends on the removal efficiency of the treatment process.
	Sulfur	Sulfur-oxidizing bacteria can oxidize elemental sulfur and sulfide, and produce sulfate and corrosive sulfuric acid, which can increase acidity, hydrogen penetration and corrosion rates. The presence of sulfur-oxidizing bacteria can promote the growth of sulfate-reducing bacteria by producing the products necessary for their growth (e.g. sulfate).[4] Sulfate-reducing bacteria can use the oxygen component of sulfate for respiration and generate hydrogen sulfide in the absence of DO or in biofilm. The sulfide will come out of solution at various pH ranges and then convert to sulfuric acid by sulfur-oxidizing bacteria, which will easily lead to corrosion in concrete sewers. Just like sulfate-reducing bacteria, thermophilic sulfate-reducing archaea can also cause corrosion in a similar way.
	Iron	Iron-oxidizing bacteria can oxidize divalent iron Fe(II) to trivalent ion Fe(III) by using DO and produce large amounts of iron oxide precipitates, which can alter the acidity and promote corrosion. In biofilm, aerobic or facultative iron-oxidizing bacteria can provide an oxygen-free local environment for sulfate-reducing bacteria growth, which can lead to more severe corrosion.[4] Iron-reducing bacteria can promote corrosion by altering minerals adhering to alloyed steel, removing passivating layers and increasing the concentration of Fe(II) and ferrous sulfide formed by mixed communities.[4]
DO		The absence of DO can provide suitable conditions for anaerobic bacteria growth, such as sulfate-reducing bacteria and iron-reducing bacteria. Low DO levels can provide suitable conditions for facultative bacteria growth, such as nitrate-reducing bacteria and sulfate-reducing bacteria. High DO levels can provide suitable conditions for aerobic bacteria growth, such as ammonia-oxidizing bacteria, sulfur-oxidizing bacteria and iron-oxidizing bacteria. High pressure and low temperature can increase DO solubility in water and prevent anaerobic conditions in pipelines; high temperature can decrease DO levels. The metabolism of microorganisms in biofilm can lead to concentration gradients of DO and affect microbial community compositions.

Table 3 *(continued)*

Influencing factors		Notes of significance
AOC		AOC can provide carbon and energy for heterotrophic bacteria and is generally considered a major limiting factor for the growth of heterotrophic bacteria.
BDOC		BDOC is considered as the hydrolysable pool of carbon available for bacterial growth and biofilm formation in the distribution system. The BDOC can be used to evaluate the reduction in chlorine demand or disinfection by-product (DBP) formation potential through a biological process.
Operating conditions	Temperature	Increasing temperature can promote bacterial growth.
		Temperature can also affect bacterial community composition by providing competitive advantages to specific bacterial species in specified temperature ranges.
	Hydraulic conditions	Low flow can lead to low flow velocities and long retention time, providing favourable conditions for bacterial growth.
		High flow can lead to increasing biofilm detachment and bacterial dispersal.
	Pressure	Operating modes of sewers include gravity modes and pressure modes.
		Under gravity modes, DO level in sewers is high and dominant microorganisms are aerobic and facultative bacteria.
		Under pressure modes, sewers are in anaerobic conditions and dominant microorganisms are anaerobic bacteria.
Disinfectants		Dissolved nutrients, extra-cellular polymeric substances, organic and inorganic nutrients adsorbed on biofilm can react with disinfectants, resulting in consumption of disinfectants and promoting bacterial regrowth.
Pipeline materials		The composition of pipeline materials can affect biofilm development, including growth rates, bacterial densities and community compositions.
		The corrosion of pipes can lead to release of particles and the formation of rough sinks on the pipe surfaces, on which organic and inorganic compounds and bacteria can be adsorbed, and which also protect bacteria from disinfectant residuals. The corrosion of iron pipes is easier than that of plastic pipes as higher bacterial abundance is found on iron pipes than on plastic pipes.

5.2 Evaluation principles of water quality stability

The evaluation of water quality stability should consider the utilization of reclaimed water. Accordingly, evaluation parameters for water quality stability of reclaimed water should be selected based on equipment materials. Evaluation processes should follow the principles of accuracy, comprehensiveness and independence (listed in Table 4).

Table 4 — Evaluation principles of water quality stability of reclaimed water

Principle	Notes
Accuracy	Accurate and objective parameters should be recommended according to utilization, equipment materials and characteristics of reclaimed water.
Comprehensiveness	An appropriate number of evaluation parameters should be selected. The evaluation with multiple parameters is beneficial for accuracy of results. Excessive selection of parameters should be avoided due to the complexity and cost of the evaluation process.
Independence	Independent parameters should be selected. If several parameters describe similar characteristics, one of them should be recommended.

6 Evaluation system of water quality stability

The evaluation of water quality stability can be performed according to the framework depicted in Figure 1. The following points show considerations for establishing a framework for water quality stability evaluation of reclaimed water.

a) Reclaimed water use is a complex process. The evaluation of water quality stability should be based on the specific reuse conditions. Reuse conditions can vary based on applications, equipment and component materials and operating conditions. For example, when characteristics of reclaimed water change, different ionic components can react and form scales. The changes of thermodynamic conditions can lead to reclaimed water instability (e.g. temperature decrease can reduce the solubility of ionic components, thus leading to scaling; increasing temperature can promote bacterial growth). Besides, the extent of fouling is affected by, for example, hydraulic conditions and roughness of the contact surfaces. Water quality stability parameters for reclaimed water are respectively proposed according to chemical stability and biological stability. It is also necessary to supplement or omit some parameters according to the actual situation of different regions. Every parameter has its own characteristics, scopes and limits, and will be discussed in detail in Clause 7. Annex B describes chemical stability evaluation parameters in urban water supply systems of some countries. Annex C and D describe evaluation parameters in water quality standards for boiler water and industrial water, respectively.

b) The tendency of water quality stability for reclaimed water can be evaluated by comparing the determined or calculated values of selected parameters with critical values. The critical values determination usually needs to consider many factors, including social and economic levels and comprehensive utilization benefits of water reuse. It is recommended that generally accepted values are selected as critical values. Moreover, critical values need to be updated with the development of technology.

c) Stability evaluation results for reclaimed water include corrosion, scale formation (including scaling and fouling) and relatively stable. They can be divided into five grades: severe corrosion, slight corrosion, relatively stable, slight scaling or fouling and severe scaling or fouling. Evaluation results should be accurate and comprehensive. The contingency and uncertainty in the evaluation process should be minimized or avoided if possible. Final stability evaluation conclusions for reclaimed water should be drawn based on evaluation results. Suggestions and improvement measures should be proposed.

The framework includes five steps (Figure 1). Specifically, the first step is to determine equipment and pipe materials and to collect given parameters of water quality characteristics for reclaimed water and operating conditions of a specific application. The second step is to select corresponding parameters based on the available information. The third step is to measure or calculate parameters for stability evaluation of reclaimed water. The fourth step is to compare calculated values with critical values. The last step is to analyse evaluation results and draw a conclusion.
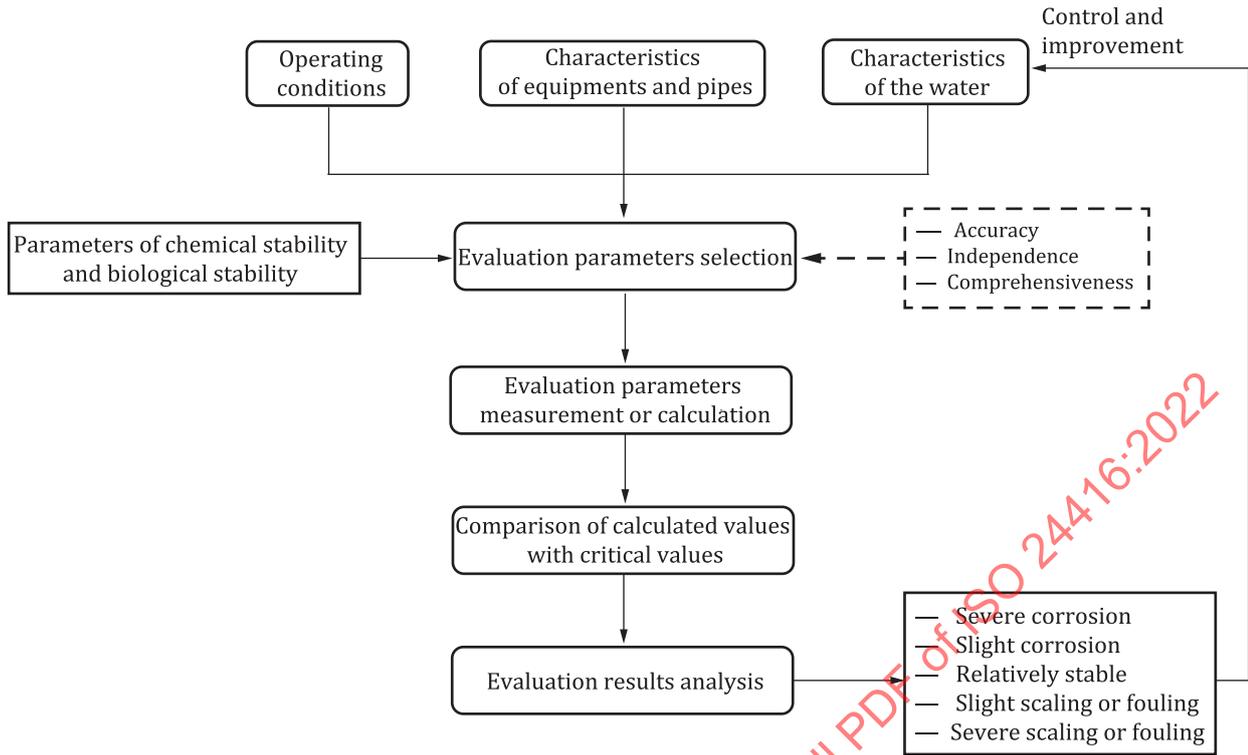
Figure 1 — Framework of water quality stability evaluation

7 Evaluation parameters of water quality stability

7.1 General

There are two kinds of stability parameters: single parameters and composite parameters. Single parameters such as pH, hardness and alkalinity are common parameters in water quality standards. The data of single parameters are easy to obtain. The data of composite parameters are usually calculated from single parameters. Calculation formulas of most composite parameters also consider multiple influencing factors, which is beneficial for comprehensively evaluating water quality stability. Those parameters with independent and complementary information should be selected to characterize the water quality stability.

7.2 Single parameters

A set of single parameters for stability evaluation of reclaimed water are proposed in Table 5. The selection of evaluation parameters depends on water characteristics, characteristics of equipment and pipelines and operating conditions.

Table 5 — Single parameters for stability evaluation of reclaimed water

Single parameters	Units	Determination method	Notes of significance
pH	–	ISO 3696	The changes of pH can break many dynamic equilibrium reactions and affect ion concentration related to water quality stability.
Total hardness	mg/l calculated as $CaCO_3$	ISO 6059	High hardness can easily lead to scale formation; low hardness can easily lead to corrosion. The World Health Organization (WHO) recommends an appropriate range of hardness in its *Guidelines for drinking-water quality*. If hardness is less than 100 mg $CaCO_3$/l or exceeds 200 mg $CaCO_3$/l, corrosion or scaling will respectively occur in the pipelines of drinking water.[7]
Total alkalinity	mg/l calculated as $CaCO_3$	ISO 9963-1	Taking iron pipeline as an example, increasing alkalinity can promote the formation of ferrous carbonate ($FeCO_3$), which is an intermediate corrosion product. Ferrous intermediate can then be oxidized to stable trivalent iron oxide (e.g. Fe_3O_4, FeOOH). These products deposit on the pipelines and form passivation films, which can prevent further corrosion. Changes of alkalinity can lead to changes of pH, which can affect the growth of certain types of bacteria.
DO	mg/l	ISO 5814 and ISO 17289	When DO acts on the surface of the inner wall of metal pipelines, corrosion can be accelerated. When DO acts on the surface of formed corrosion products, it can accelerate the formation of passivation films, which can delay or prevent further corrosion. High DO levels can provide suitable conditions for aerobic bacteria growth, so that sulfates are not degraded by anaerobic sulfate-reducing bacteria generating corrosion and odours. Low DO levels can provide suitable conditions for facultative bacteria growth, such as nitrate-reducing bacteria. The absence of DO can provide suitable conditions for anaerobic bacteria growth, such as sulfate-reducing bacteria and iron-reducing bacteria. DO levels can affect the structure of biofilms. Under aerobic conditions, biofilms can show a hollow and seeding dispersal structure. Under anaerobic conditions, biofilm can show a round and densely-packed structure.[11]

NOTE 1   Annex E lists some limits of pH, DO and TSS for different purposes of reclaimed water.

NOTE 2   Annex F lists some modified measurement methods based on the original AOC method.

NOTE 3   Annex G describes the biological stability guideline values for AOC.

NOTE 4   Annex H compares measurement methods for evaluation parameters of biological stability.

NOTE 5   In ISO 20468-1, the monitoring parameters for non-potable water reuse projects can include biochemical oxygen demand (BOD), turbidity or TSS, *E. coli* and chlorine residual.

Key

CFU   colony-forming unit

NTU   nephelometric turbidity unit

Table 5 *(continued)*

Single parameters	Units	Determination method	Notes of significance
TDS	mg/l	ISO 7888	Among TDS, chloride has the highest influence on the corrosion of the carbon steel, followed by sulfate, nitrate and ammonium.[12] High concentration of sulfate and chloride ions will increase conductivity of water, accelerate the migration rate of ions and electrons and promote corrosion; release of irons (sulfate and chloride ions) can promote the release of aluminium and manganese ions, but have little effect on the release of copper, chromium, zinc, nickel and arsenic ions.[14] Nitrate can greatly accelerate the general corrosion of iron in acidic solutions but has only a slight influence on the general corrosion in neutral solutions.[3] Nitrate can be easily degraded by bacteria so that sulfate is not degraded in the sewer, generating corrosion and odours.
TSS	mg/l	ISO 11923	TSS are easily disturbed by water flow and can aggravate erosion of water flow on the inner wall of pipelines. Then, the corrosion surface layer can be scoured off in an accelerated manner, leading to aggravation of corrosion. TSS can also promote scale formation. Suspended solids are nuclei of salt crystals. Excessive suspended solids promote the formation of scales.
Turbidity	NTU	ISO 7027-1	The particle size of TSS is over 1 μm, while that of turbidity is between 1 nm and 1 μm, which is commonly called colloidal substances.[17] Because colloidal substances play an essential role in scaling, it is more accurate to select turbidity instead of TSS to describe water quality stability.
AOC	μg/l calculated as acetate carbon	Specific method is described in Reference [18]	AOC serve as carbon source and energy source for heterotrophic bacteria and can be converted to biomass by heterotrophic bacteria. It is generally recognized that the AOC level to keep biological stability is below 100 μg/l.[19,20]
BGP	CFU/ml	The maximum bacterial count after inoculation of indigenous bacteria and incubation Specific method is described in Reference [21]	The maximum bacterial count that can be achieved owing to diverse compounds available in water and complex interactions among indigenous bacterial population. Suitable application field: direct evaluation of what really happens in the water sample.

NOTE 1   Annex E lists some limits of pH, DO and TSS for different purposes of reclaimed water.

NOTE 2   Annex F lists some modified measurement methods based on the original AOC method.

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Key

CFU   colony-forming unit

NTU   nephelometric turbidity unit

Table 5 *(continued)*

Single parameters	Units	Determination method	Notes of significance
BFR	pg ATP/cm²·d	The flux of substrate through column or monitor Specific method is described in Reference [22]	The rate and extent of biofilm formation as a function of time. Suitable application field: determination of the ability of water to promote biomass accumulation.
BDOC	mg/l	The difference between initial DOC and final DOC during incubation Specific method is described in Reference [23]	The consumption of DOC to catabolize organic carbon to carbon dioxide and/or new biomass. Suitable application field: evaluation of the reduction in chlorine demand or DBP formation potential through a biological process.
MAP	µg PO$_4$-P/l	The linear relationship between MAP value and the concentration of phosphorus Specific method is described in Reference [24]	The bacterial maximum growth from inoculation until steady-state with phosphorus as the standard substrate. Suitable application field: regions where microbial growth in water is restricted by phosphorus content rather than organic carbon content.
ATP	ng ATP/cell	The chemical and/or enzymatic extraction of ATP from bacterial cells, followed by the measurement of light emission derived when the dissolved ATP reacts with the luciferin/luciferase reagent Specific method is described in Reference [25]	ATP is present in all living cells and it helps to estimate the total live biomass in a sample. Suitable application field: ATP can be complementary to conventional parameters to account for bacterial dynamics in storage and distribution.

NOTE 1   Annex E lists some limits of pH, DO and TSS for different purposes of reclaimed water.

NOTE 2   Annex F lists some modified measurement methods based on the original AOC method.

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Key

CFU   colony-forming unit

NTU   nephelometric turbidity unit

7.3   Composite parameters

7.3.1   General

Composite parameters are mainly divided into two kinds: the first based on calcium carbonate dissolution equilibrium and the second based on multi-parameter analysis. Annex I illustrates water quality stability evaluation conclusions for different composite parameters.

7.3.2 Langelier saturation index (LSI)

LSI is proposed on the basis of the solubility equilibrium of calcium carbonate. LSI is suitable to qualitatively evaluate the tendency of corrosion or scaling. LSI can be used to evaluate water chemical stability of metal pipelines without additives and internal corrosion protection, such as steel pipelines, cast iron pipelines and galvanized steel pipelines. But LSI also has its limits. The first is that two identical LSI values cannot be compared for chemical stability. The second is that when LSI value is near zero, it is easy to draw a contrary conclusion. See Formula (1).

$$I_{LSI} = pH - pH_S \tag{1}$$

where

I_{LSI} is Langelier saturation index;

pH   is the actual pH of water;

pH_S is the pH at which calcium carbonate is at equilibrium.

[SOURCE: ISO 23446:2021, Annex B]

pH_s can be calculated by many methods, including the calculation method, the table method and the image method. Besides being related to bicarbonate alkalinity, calcium ions concentration and water temperature in water, pH_s is also influenced by many factors such as salt content, calcium association ions and other components that can form alkalinity. Generally, from the perspective of simplified calculation, it is recommended that pH_s is calculated using Formulae (2) to (6):[28]

$$pH_S = (9,3 + A + B) - (C + D) \tag{2}$$

$$A = \frac{[Log_{10}(I_{TDS}) - 1]}{10} \tag{3}$$

$$B = \text{-}13,12 \times Log_{10}(°C + 273) + 34,55 \tag{4}$$

$$C = Log_{10}(Ca^{2+} \text{ as } CaCO_3) - 0,4 \tag{5}$$

$$D = Log_{10}(\text{alkalinity as } CaCO_3) \tag{6}$$

where

A is the dissolved solids coefficient of water quality;

B is the temperature coefficient;

C is the hardness coefficient;

D is total alkalinity coefficient.

7.3.3 Ryznar stability index (RSI)

RSI is a parameter substantially modified from LSI. RSI is suitable for intercooled open-type recirculating cooling water system and is more accurate at pH 6,5 to pH 8. The US Environmental Protection Agency (USEPA) has recommended the use of LSI and RSI by utilities to monitor the corrosion potential of water.[29]

$$I_{RSI} = 2pH_S - pH = pH_S - I_{LSI} \tag{7}$$

where

I_{RSI} is Ryznar stability index;

pH   is the actual pH of water;

pH_S is the pH at which calcium carbonate is at equilibrium;

I_{LSI} is Langelier saturation index.

[SOURCE: ISO 22449-1: 2020, 3.1.10]

7.3.4   Calcium carbonate precipitation potential (CCPP)

CCPP can quantitatively reflect the precipitation or dissolution amount of calcium carbonate. When corrosive ions such as chloride ions are introduced into water, chemical stability cannot be accurately evaluated by CCPP alone. The CCPP can be calculated by alkalinity, see Formula (8).[28]

$$I_{CCPP} = 50\ 000(I_{alki} - I_{alkeq}) \tag{8}$$

where

I_{CCPP} is calcium carbonate precipitation potential index;

I_{alki} is original alkalinity of water (mg/l calculated as $CaCO_3$);

I_{alkeq} is the alkalinity after calcium carbonate is balancing (mg/l calculated as $CaCO_3$).

A higher CCPP value means more calcium carbonate precipitating on the inner wall of pipelines. Deposited films can prevent the dissolution and release of corrosion products from pipelines.

7.3.5   Aggressive index (AI)

AI is suitable for evaluating chemical stability of water quality in the cement pipelines. AI considers the effects of all ions in raw water on alkalinity, hardness and pH, see Formula (9).[28]

$$I_{AI} = pH + Log(I_{alk} \cdot I_{hardness}) \tag{9}$$

where

I_{AI} is the aggressive index;

pH   is the actual pH of water;

I_{alk} is the water alkalinity (mg/l calculated as $CaCO_3$);

$I_{hardness}$ is the water hardness (mg/l calculated as $CaCO_3$).

7.3.6   Larson corrosion index (LR)

LR is suitable to evaluate water chemical stability of iron pipelines, see Formula (10).[28]

$$I_{LR} = \frac{\left[Cl^-\right] + \left[SO_4^{2-}\right]}{\left[HCO_3^-\right]} \tag{10}$$

where

I_{LR} is Larson corrosion index;

[Cl⁻]   is the concentration of chloride (mol/l);

[SO_4^{2-}]   is the concentration of sulfate (mol/l);

[HCO_3^-]   is the concentration of bicarbonate (mg/l).

When water quality parameters such as pH, alkalinity and hardness have their own obvious change trends, water chemical stability cannot be evaluated by LR alone.[31] Considering the effects of various factors, such as water temperature, hydraulic residence time and DO, improved LR (ILR) was proposed on the basis of LR, see Formula (11).[28]

$$\text{Log}(I_{ILR}) = -1,922 + 0,3\text{Log}(I_{LR}) + 9,968\text{Log}(\frac{I_{hardness}}{100}) - 0,277\text{Log}(\frac{I_{DO}}{8}) - 2,417\text{Log}(\frac{T}{25}) - 0,088\text{Log}(\frac{I_{HRT}}{6})$$

(11)

where

I_{ILR} is the improved LR index;

I_{LR} is the Larson corrosion index;

$I_{hardness}$ is the hardness of water (mg/l calculated as $CaCO_3$);

I_{DO} is the concentration of dissolved oxygen (mg/l);

T is the temperature of water (°C);

I_{HRT} is the hydraulic retention time (h).

7.3.7   Riddick corrosion index (RI)

RI is suitable for evaluating water chemical stability with low hardness. Besides introducing conventional parameters related to corrosion, this parameter also considers the effect of hardness, alkalinity, nitrate, chloride, DO and silicon dioxide, see Formula (12).[28]

$$I_{RI} = \frac{75}{I_{alk}}\left[I_{CO_2} + \frac{1}{2}(I_{hardness} - I_{alk}) + \left[Cl^-\right] + 2\left[NO_3^-\right]\right](\frac{10}{I_{SiO_2}})(\frac{I_{DO}+2}{I_{DO_s}})$$

(12)

where

I_{RI} is Riddick corrosion index;

I_{DO} is the concentration of dissolved oxygen (mg/l);

I_{DOs} is the concentration of dissolved oxygen at saturation (mg/l).

When there is no corresponding data of silica, DO or both, product term of silica and DO can be deleted.

Table 6 lists the determination methods of necessary parameters in the formula.

Table 6 — The determination methods of necessary parameters

Parameter	Determination methods
Ca^{2+}	ISO 6058
Cl⁻	ISO 9297 and ISO 10304-1

Table 6 *(continued)*

Parameter	Determination methods
SO_4^{2-}	ISO 10304-1
HCO_3^-	ISO 9963
NO_3^-	ISO 7890-3 and ISO 10304-1
CO_2	ASTM D513-02
SiO_2	GB/T 12149
DO	ISO 5814 and ISO 17289

7.4 Selection principles of evaluation parameters

The following points indicate considerations for selecting evaluation parameters for water quality stability of reclaimed water.

a) Water quality characteristics: The selection of evaluation parameters should consider water quality characteristics of reclaimed water. More specifically, among six composite parameters, only AI can be used to evaluate the chemical stability of different water quality characteristics. LSI is suitable for qualitative evaluation of chemical stability of water not containing additives. RSI is more accurate at pH 6,5 to pH 8. If corrosive ions such as chloride ions are introduced into water, chemical stability cannot be accurately evaluated by CCPP alone. When water quality parameters such as pH, alkalinity and hardness have their own obvious change trends, chemical stability cannot be evaluated by LR alone. RI is suitable for evaluating water chemical stability with low hardness. Among the six parameters presented for biological stability, AOC can evaluate microbial regrowth in various water qualities.

b) Utilization and equipment materials: Considering reclaimed water has various utilizations, the selection of evaluation parameters should consider equipment materials related to reclaimed water. For example, LSI and RSI are suitable for metal pipelines. AI is suitable for cement pipelines. LR is suitable for iron pipelines. CCPP and RI are suitable for various materials (listed in Table 7). Six parameters for biological stability are suitable for various equipment materials.

c) Evaluation parameter characteristics: Among the six composite parameters presented for chemical stability, LSI, RSI and CCPP are suitable for evaluating the tendency of corrosion or scaling or for being stable, and AI, LR and RI are suitable for evaluating the tendency of corrosion or being stable. Among the six single parameters presented for biological stability, AOC and BDOC are suitable for situations when microbial growth in water is restricted by organic carbon content, and MAP is suitable for situations that microbial growth in water is restricted by phosphorus content. BGP and BFR can evaluate the ability of water to promote biomass accumulation, including the effects of various nutrients on bacterial growth. ATP is complementary to the other five conventional parameters for estimating the total living biomass in samples.

d) Combination of various parameters: In order to comprehensively evaluate stability of reclaimed water, it is recommended that various kinds of parameters, including single and composite parameters, are selected. Among the composite parameters, the parameters of both calcium carbonate dissolution equilibrium and multi-parameter analysis are suggested. More specifically, LSI, RSI and CCPP are parameters based on the calcium carbonate dissolution equilibrium, which can be used to evaluate the scaling of calcium carbonate. AI, LR, RI are parameters based on multi-parameter analysis, which can be used to evaluate the scaling of other minerals.

Table 7 — Optional stability evaluation parameters for different pipelines

Parameter	Pipeline material				
	Steel and galva-nized steel	Concrete and cement, and cement-mor-tar-lined metal	Plastic	Cast iron and ductile cast iron	Non-ferrous metal
LSI	•			•	•
RSI	•			•	•
CCPP	•	•	•	•	•
AI		•			
LR				•	
ILR				•	
RI	•	•	•	•	•
NOTE The dot "•" indicates that attention should be paid to this category.					

7.5   Case study of evaluation parameters selection

The selection of evaluation parameters is the most difficult step during the entire evaluation process, which affects the accuracy of the evaluation results. Combined with the selection principles of evaluation parameters, one case is illustrated to clearly show how to select indicators for water stability evaluation. The corresponding information of reclaimed water is listed in Table 8.

Table 8 — Information of reclaimed water for water stability evaluation

Pipe-line mate-rial	pH	T (°C)	PO_4^{3-}-P (mg/l)	Ca^{2+} (mg/l as $CaCO_3$)	TN (mg/l)	NH_4^+-N (mg/l)	NO_3^--N (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	TDS (mg/l)	Total hard-ness (mg/l)	Total alkalin-ity (mg/l)
Steel	6,98	25	0,27	240	9,58	0,18	8,36	62,9	56,8	142,9	181	97,8

In terms of chemical stability, optional parameters for steel pipelines include LSI, RSI, CCPP and RI. Among them, LSI, RSI and CCPP are parameters based on the calcium carbonate dissolution equilibrium, and RI is a parameter based on multi-parameter analysis. It is recommended that one parameter is selected for each class of two classes (parameters of calcium carbonate dissolution equilibrium and parameters of multi-parameter analysis). Considering the characteristics of reclaimed water, RI is firstly excluded because water hardness is relatively high. CCPP cannot accurately describe chemical stability alone when corrosive ions (chloride and sulfate ions) exist in the water. Between LSI and RSI, RSI is more accurate at pH 6,5 to pH 8. Therefore, RSI is selected as the composite parameter for chemical stability evaluation. The formula of RSI considers the effect of pH value, so pH is not selected as a single parameter again. The remaining single parameters, including hardness, alkalinity, DO, TDS and turbidity, are selected. Among them, TDS is especially important, for it reflects the effects of chloride and sulfate ions. The evaluation parameters for chemical stability are determined as hardness, alkalinity, DO, TDS, turbidity and RSI. According to the formula of RSI, the calculated value of RSI is 8,09 > critical value 6, therefore the evaluation conclusion for chemical stability evaluated by RSI is corrosive.

In terms of biological stability, the ratio of C:P under this condition needs to be calculated and compared with the ratio favourable for bacterial growth (e.g. the ratio of 100:1), and then it can be determined whether phosphorous acts as a limiting factor for bacterial growth. If the answer is yes, MAP is selected as the evaluation parameter for biological stability. If the answer is no, AOC is selected. Besides, it is obvious that the contents of nitrogen (NH_4^+-N and NO_3^--N) are high, which can promote bacterial growth and activity (ammonia-oxidizing bacteria and nitrate-reducing bacteria) and further affect biological stability, so BGP is selected to evaluate what really happens in the water sample. The evaluation parameters for biological stability are determined as AOC (or MAP) and BGP.

8 Evaluation parameters of water quality stability for pipeline networks

Pipeline networks are important parts for transportation and distribution of reclaimed water. Water quality stability for reclaimed water is affected by many factors, such as hydraulic conditions and pipeline materials. The influence of pipeline materials is mainly embodied in the surface condition, such as roughness coefficient and chemical composition of pipelines. There are many kinds of water supply pipeline networks. Common pipeline materials include metal, non-metal and composite types. Metal pipelines include cast-iron pipelines, steel pipelines and copper pipelines. Non-metal pipelines include plastic pipelines and concrete pipelines. It is recommended that stability evaluation parameters are selected based on pipeline materials. Table 9 lists optional recommended stability evaluation parameters for pipeline networks.

Table 9 — Evaluation parameters of water quality stability for pipeline networks

Parameter		Pipeline network				
		Steel and galvanized steel	Concrete and cement pipelines, and cement-mortar-lined metal	Plastic	Cast iron and ductile cast iron	Non-ferrous metal
Single parameter	pH	•	•	•	•	•
	Hardness	•	•		•	•
	Alkalinity	•	•		•	•
	DO	•	•		•	•
	TDS	•	•		•	•
	Turbidity	•	•	•	•	•
	AOC	•	•	•	•	•
	MAP	•	•	•	•	•
	BGP	•	•	•	•	•
Composite parameter	LSI				•	
	RSI	•				
	CCPP			•		•
	AI		•			
	ILR				•	
	RI	•				•
NOTE The dot "•" indicates that attention should be paid to this category.						

9 Evaluation parameters of water quality stability for equipment

Reclaimed water is widely used in many fields with various modes, and the types of related equipment are quite different. Cooling water is the highest utilization for industrial applications of reclaimed water. In addition, reclaimed water is usually used as toilet flushing water and landscape water. Annex J and Annex K, respectively, provide guideline values for reclaimed water used in toilet and urinal flushing and recreational purposes. Table 10 lists optional recommended stability evaluation parameters for common equipment.

Table 10 — Evaluation parameters of water quality stability for equipment

Parameter		Boiler and heat exchanger	Air conditioning	Toilet-flushing device[a]	Irrigation equipment
Single parameter	pH	•	•	•	•
	Hardness	•	•		•
	Alkalinity	•	•		•
	DO	•	•		•
	TDS	•	•		•
	Turbidity	•	•	•	•
	AOC	•	•	•	•
	MAP	•	•	•	•
	BGP	•	•	•	•
Composite parameter	LSI				•
	RSI	•			
	CCPP		•		
	ILR	•			
	RI		•		•
NOTE The dot "•" indicates that attention should be paid to this category.					
[a] Some countries and regions regulate that reclaimed water used for toilet and urinal flushing should be disinfected.					

The selection of evaluation parameters is affected by a variety of factors, and the selection of evaluation indicators still needs to be combined with specific situations of different regions. Appropriate modifications are needed under certain circumstances.

Annex A
(informative)

Information on corrosion types

Table A.1 describes common corrosion types of metals and alloys.

Table A.1 — Corrosion types of metals and alloys

Corrosion type	Notes
Electrochemical corrosion	Corrosion involving at least one anodic reaction and one cathodic reaction
Chemical corrosion	Corrosion not involving electrochemical reaction
General corrosion	Corrosion proceeding over whole surface of the metal exposed to the corrosive environment
Localized corrosion	Corrosion preferentially concentrated on discrete sites of the metal surface exposed to corrosive environment
Uniform corrosion	General corrosion proceeding at almost the same rate over whole surface
Pitting corrosion	Localized corrosion resulting in pits, i.e. cavities extending from the surface into the metal
Layer corrosion	Corrosion of internal layers of wrought metal, occasionally resulting in exfoliation, i.e. detachment of unattacked layers
Deposit corrosion	Localized corrosion associated with, and taking place under or immediately around, a deposit of corrosion products or other substance
Microbiologically influenced corrosion	Accelerated deterioration of metals owing to the presence of biofilms on their surfaces
High-temperature corrosion	Corrosion by gases or deposits or both gases and deposits occurring at elevated temperatures under conditions where aqueous electrolytes no longer exist

Annex B
(informative)

Chemical stability guidelines for water quality in urban water supply systems of some countries

Table B.1 describes chemical stability guidelines for water quality in urban water supply systems of some countries.

Table B.1 — Chemical stability parameters in urban water supply systems

Parameter	Norway	Denmark	UK	USA	Canada	Germany
pH	7,5 to 8,5	8	5,5 to 9,5	6,5 to 8,5	6,5 to 6,8	6,5 to 9,5
Alkalinity (mg/l)	60 to 100	> 160	> 50	–	–	–
Hardness (mg/l)	15 to 25	20 to 200	–	–	–	–
Chloride (mg/l)	< 100	< 50	–	< 250	< 250	< 250
Sulfate (mg/l)	< 100	< 50	–	< 250	< 250	< 240
Iron (mg/l)	< 0,1	0,05	–	< 0,3	< 0,3	≤ 0,2
Manganese (mg/l)	0,05	0,02	–	0,05	0,05	≤ 0,05
Aluminium (mg/l)	0,1	0,05	–	0,1	0,1	≤ 0,2
Langelier saturation index	–	–	–	0	–	0
$([SO_4^{2-}]+[Cl^-])/[HCO_3^-]$	–	–	–	–	–	< 1
NOTE The values for chemical stability parameters in urban water supply systems are based on Reference [38].						

Annex C
(informative)

Guidelines for water conditioning of boiler water in Japan

Table C.1 describes guidelines for water conditioning of boiler water in Japan.

Table C.1 — Guidelines for water conditioning of boiler water

Parameter	Cylindrical boiler		Multitubular special circulation boiler				Water tube boiler	
Normal operating pressure (MPa)	≤ 1	> 1, ≤ 2	≤ 1	> 1, ≤ 3	≤ 2	> 2, ≤ 3	≤ 1	> 1, ≤ 2
pH	11,0 to 11,8		11,0 to 11,8		10,5 to 11,5	10,0 to 11,0	11,0 to 11,8	
Acid consumption (pH 4,8, mg/l $CaCO_3$)	100 to 800	600 max.	100 to 800	600 max.	250 max.	150 max.	100 to 800	600 max.
Acid consumption (pH 8,3, mg/l $CaCO_3$)	80 to 600	500 max.	80 to 600	500 max.	200 max.	120 max.	80 to 600	500 max.
Conductivity (mS/m)	400 to 600 max.	350 max.	400 max.	300 max.	150 max.	100 max.	400 max.	300 max.
Chloride (mg/l)	400 to 600 max.	350 max.	400 max.	300 max.	150 max.	100 max.	400 max.	300 max.
Phosphate (mg/l)	20 to 40		20 to 40		10 to 30	5 to 15	20 to 40	
Sulfite (mg/l)	10 min.		10 min.	10 to 20	10 to 20	5 to 10	10 min.	10 to 20
NOTE The parameter values for water conditioning of boiler water in Japan are based on Reference [39].								

Annex D
(informative)

Reuse of urban recycling water — Water quality standard for industrial use in China

Table D.1 details the water quality standard for industrial uses of urban recycling water in China.

Table D.1 — Water quality standard for industrial uses of urban recycling water in China

Parameter	Cooling water		Washing water	Boiler make-up water	Process and product water
	Once-through cooling water	Open-type recirculating cooling water			
pH	6,5 to 9,0	6,5 to 8,5	6,5 to 9,0	6,5 to 8,5	6,5 to 8,5
TSS ≤ (mg/l)	30	–	30	–	–
Turbidity ≤ (NTU)	–	5	–	5	5
Colour ≤ (Hazen)	30	30	30	30	30
BOD_5 ≤ (mg/l)	30	10	30	10	10
COD_{Cr} ≤ (mg/l)	–	60	–	60	60
Fe ≤ (mg/l)	–	0,3	0,3	0,3	0,3
Mn ≤ (mg/l)	–	0,1	0,1	0,1	0,1
Chloride ≤ (mg/l)	250	250	250	250	250
Silica ≤ (mg/l)	50	50	–	30	30
Total hardness ≤ (mg/l $CaCO_3$)	450	450	450	450	450
Total alkalinity ≤ (mg/l $CaCO_3$)	350	350	350	350	350
Sulfate ≤ (mg/l)	600	250	250	250	250
NOTE The parameter values for industrial water are based on Reference [40].					
Key					
BOD_5 five-day biochemical oxygen demand					
CFU colony-forming unit					
NTU nephelometric turbidity unit					

Table D.1 *(continued)*

Parameter	Cooling water		Washing water	Boiler make-up water	Process and product water
	Once-through cooling water	Open-type recir-culating cooling water			
NH$_3$-N ≤ (mg/l)	–	10	–	10	10
Total phosphorus ≤ (mg/l)	–	1	–	1	1
TDS ≤ (mg/l)	1 000	1 000	1 000	1 000	1 000
Petroleum ≤ (mg/l)	–	1	–	1	1
Anionic surfactant ≤ (mg/l)	–	0,5	–	0,5	0,5
Residual chlorine ≥ (mg/l)	0,05	0,05	0,05	0,05	0,05
Faecal coliforms ≤ (CFU/1 000 ml)	2 000	2 000	2 000	2 000	2 000
NOTE The parameter values for industrial water are based on Reference [40].					
Key					
BOD$_5$ five-day biochemical oxygen demand					
CFU colony-forming unit					
NTU nephelometric turbidity unit					

Annex E
(informative)

Water quality parameter limits of reclaimed water depending on specific use

Table E.1 lists some water quality parameter limits of reclaimed water depending on specific use.

Table E.1 — Water quality parameter limits of reclaimed water depending on specific use

Parameters	Private, urban and irrigation	Environmental and aquaculture	Indirect aquifer recharge	Industrial cooling
pH	6,0 to 9,5	6,0 to 9,5	7 to 9	7,0 to 8,5
DO (mg/l)	> 0,5	> 3	> 8	> 3
TSS (mg/l)	10 to 20	10 to 20	–	10 to 20

Annex F
(informative)

Modification methods based on the original AOC method

Table F.1 lists some modified measurement methods based on the original AOC method.

Table F.1 — Modified measurement methods based on the original AOC method

References	Modification	Notes
[41], [42]	Standardized AOC method based on stepwise inoculation with Pseudomonas fluorescens P-17 and Spirillum NOX	Original method
[43]	Incorporation of four species in the inoculum	Increased speed
[44]	A single fast growing Acinetobacter used for the inoculum	
[45]	Increased inoculation density	
[19]	Increased incubation temperature	
[46]	Rapid macroscopic technique	
[47]	Rapid technique based on flow cytometry	
[48]	40-ml vials batched instead of 1-l flask	Reduction of contamination potential
[49]	Natural microbial consortium used for inoculum	Greater sensitivity
[50]	Samples heated to 72 °C then cooled on ice instead of pasteurization	Greater biostability
[51]	Use of membranes to sterilize the water instead of pasteurization	

Annex G
(informative)

Biological stability guideline values for AOC

Table G.1 describes the biological stability guideline values for AOC.

Table G.1 — Biological stability guideline values for AOC

References	Parameters	Units	Reported values
[50]	AOC (without chlorine)	μg/l	2 to 301
[51]			4 to 130
[52], [53]			< 10
[54]	AOC (with chlorine)		92 to 482
[55]			36 to 446
[19], [20]			50 to 100
[56]			< 200

Annex H
(informative)

Comparison of measurement methods for evaluation parameters of biological stability

Table H.1 compares the measurement methods for evaluation parameters of biological stability.

Table H.1 — Comparison of measurement methods for evaluation parameters of biological stability

Method	AOC	BGP	BFR	BDOC	MAP	ATP
Inoculation	Pure bacteria	Indigenous bacteria	Indigenous bacteria	Indigenous bacteria	Pure bacteria	Indigenous bacteria
Incubation temperature	20 °C	20 °C	> 10 °C	22–25 °C	22 °C	30 °C
Incubation time	3 d to 5 d	5 d to 7 d	Weeks to months	28 d	3 d	1 d to 5 d
Results	Total microbial count	Total microbial count	Adenosine-triphosphate (ATP)	Difference between initial DOC and final DOC	Amount of phosphorus	ATP
Expression	Acetate carbon	Cells per millilitre	pg ATP/cm²·d	Organic carbon	µg PO$_4$-P/L	ng ATP/cell
NOTE The comparison is based on References [22], [57] and [58].						