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Water reuse in urban areas — Guidelines for water reuse safety evaluation — Assessment parameters and methods

Réutilisation de l'eau en milieu urbain — Lignes directrices concernant l'évaluation de la sécurité de la réutilisation de l'eau — Paramètres et méthodes d'évaluation

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Contents

Page

Foreword

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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 on 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 the following URL: www.iso.org/iso/foreword.html.

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

Introduction

With economic development, climate change, increases in population and rapid urbanization, water has become a strategic resource especially in arid and semi-arid regions. Water shortages are considered as one of the most serious threats to the sustainable development of society. To address these shortages, reclaimed water resources are increasingly being used to satisfy water demands. In addition, some communities are expanding water supply by employing potable reuse. These strategies have proven useful in increasing the reliability of long-term water supplies in many water-scarce areas.

The role of water reuse is growing for urban areas in many countries including: landscape irrigation; industrial uses; municipal non-potable uses such as toilet and urinal flushing; fire-fighting and fire suppression; environmental and recreational uses (ornamental water features, water bodies' replenishment); and vehicle washing. These non-potable water reuse systems have been developed to the degree that they are considered as an effective component of urban water management and are widely used in many cities and countries.

However, there are several types of pollutants in wastewaters, including dissolved organic matter, nutrients, salts, toxic and harmful chemicals, and pathogens. Therefore, safety evaluation and public acceptance of water quality are important issues which are of high concern during water reuse in urban areas. Water reuse safety includes health safety, environmental safety and facilities safety. For different types of reclaimed water uses, exposure pathways and potential hazards are very different. The diversity of reclaimed water applications and related hazards can result in significant differences in water quality parameters for such applications.

This document provides assessment parameters and methods for safety evaluation of non-potable water reuse in urban areas. They are intended to assist water engineers, authorities, decision makers and stakeholders in determining the safety of reclaimed water for end uses.

Water reuse in urban areas — Guidelines for water reuse safety evaluation — Assessment parameters and methods

1 Scope

This document provides water reuse safety evaluation and public acceptance parameters and methods for users who design, manage, and/or oversee the non-potable water reuse schemes or activities in urban areas from the viewpoint of water quality. The document can be used in various stages of non-potable water reuse projects such as design, operation, and post assessment.

The document is applicable to non-potable water reuse in urban areas with reclaimed water from municipal wastewater sources. The wastewater sources can also include a limited contribution of industrial wastewater input. While some communities are turning to potable reuse to meet water supply needs, discussion of safety evaluation of potable reuse is outside the scope of this document.

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:—[1)], *Water reuse — Terminology*

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 terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
environmental safety
freedom from the occurrence of a risk which is not tolerable and that is related to environmental change (especially scarcity and degradation) which can arise when water reuse service is prepared and/or provided according to its intended use. It includes the impact of the reclaimed water on the receiving environment — soil; groundwater and surface water; air; aquatic and terrestrial biota

4 Abbreviated terms

BOD_5	biochemical oxygen demand after 5 days
COD	chemical oxygen demand
CFU	Colony forming unit
DBPs	disinfection byproducts
DO	dissolved oxygen

1) Under preparation. Stage at the time of publication: ISO/DIS 20670:2017.

E. coli	*Escherichia coli*
EECRW	estimation of environmental concentration at a site induced by water reuse
HPC	heterotrophic plate counts
LC_{50}	estimated concentration that is expected to be lethal to 50 % of a group of organisms
MPN	most probable number
NOEC	no observed effect concentration
NTU	nephelometric turbidity unit
TSS	total suspended solids
TDS	total dissolved solids
TN	total nitrogen
TOC	total organic carbon
UV	ultraviolet light

5 Water reuse safety

Water reuse safety generally includes health safety, environmental safety, and facilities safety. Consideration for safety and public acceptance of water reuse in urban areas are shown in Table 1. The premise of water reuse safety is to satisfy relevant water quality standards and limit risk of water degradation through implementation of good practices. When using reclaimed water, it is essential to protect human health and the environment and to prevent the degradation of the materials and assets of the distribution system, storage system and end uses. Public acceptance is also a criterion to consider when assessing water quality aesthetic parameters such as colour and odour.

Table 1 — Considerations for safety and public acceptance of water reuse in urban areas

Targets	Considerations
Health safety	Health risks to public and workers handling the reclaimed water
Environmental safety	Effects on aquatic and terrestrial biota Effects on receiving soil, groundwater, surface water and air
Facilities safety (such as equipment and pipes)	Scaling, fouling and corrosion of facilities Harmful effects on property of users' belongings, e.g. clothes and vehicles Adverse effects associated with the operation (exclude failures in manual operations) of processes and equipment
Public acceptance	Colour and odour

6 Water reuse safety parameters

A set of relevant water quality parameters and their interest to characterize the water reuse safety and public acceptance are proposed in Table 2. The selection of the relevant and suitable parameters for safety evaluation and public acceptance depends on local water quality standards, on reclaimed water source characteristics, on the context (climatic, environmental, occupational) and use. Selected water quality parameters can possibly include routine physical and chemical parameters, aesthetic parameters, microbial parameters, stability parameters, and toxic and harmful chemicals.

Indicators and surrogates can be selected for monitoring (instead of specific water quality parameters, for instance) when studies have shown their representativeness. In routine analysis, turbidity, disinfectant residuals and bacterial indicators such as *Escherichia coli* (*E. coli*) and heterotrophic plate counts (HPC) can be used to verify microbial safety in storage and distribution systems.

Table 2 — Relevant water quality parameters[a] and their interest to characterize water reuse safety and public acceptance

Types	Water quality parameters	Notes of significance
Routine physical and chemical parameters	pH	Affects disinfection efficiency, coagulation, metal solubility, toxicity of pollutants
	Biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), or total organic carbon (TOC)	Indicates organic pollution and also the potential of microbial growth and biofilm formation
	Ammonia	Exhibits toxicity to aquatic life and plants, causes stress corrosion in copper-based alloys
	Total nitrogen (TN), nitrate, or nitrite	Stimulates algae and bacterial growth, induces groundwater contamination
	Phosphorus	Stimulates algae and bacterial growth
	Dissolved oxygen (DO)	Can be associated with odour, corrosion, scaling, and maintenance of aquatic life
	Total dissolved solids (TDS), electrical conductivity	Can be associated with corrosion and scaling of pipes and equipment and affect plants water availability and crops yield
	Alkalinity, hardness	Can be associated with corrosion and scaling of pipes and equipment
	Turbidity or total suspended solids (TSS)	Affects disinfection efficiency and reuse equipment (e.g. clogging, fouling, odour generation) and public acceptance
	Chlorine demand	Prevents/minimizes DBP formation by adjusting chlorine disinfection levels according to chlorine demand
	Residual disinfectants (residual chlorine, etc.)	Prevents microbial growth and exhibits toxicity to aquatic life and plants
Aesthetic parameters	Colour	Affects public acceptance
	Odour	Affects public acceptance
Microbial parameters	Indicator bacteria (thermo-tolerant coliforms, *E. coli*, or total coliform, etc.)	Indicates likelihood of microbial health risk and affects public acceptance
	Environmental pathogens[b]	Can cause potential health risk, for example, *Legionella pneumophila* survives in cooling water environments
Stability parameters	Chemical stability: Specific ions (such as Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}), etc.[c]	Can be associated with corrosion and scaling of pipes and equipment
	Biological stability: heterotrophic plate counts (HPC), algae, etc.[d]	Can favour microbial growth, affect filtration and disinfection efficiency, induce biological fouling of facilities, and create aesthetic and nuisance problems
Toxic and harmful chemicals	Specific metal (such as Pb, Hg, Cd) [c]	Exhibits toxicity to flora and fauna
	Oil and grease	Results in toxicity to aquatic life
	Surfactants	Results in foaming and toxicity to aquatic life

[a] Recommended for consideration in water reuse safety evaluation.

[b] Considered for selection depending on reclaimed water source characteristics and uses.

[c] Specific metals and ions are considered for selection depending on reclaimed water source characteristics (such as ion contribution from industrial wastewater input) and use.

[d] Evaluation of changes in biological stability parameters during distribution, storage and use with long hydraulic retention time is recommended. For details concerning the chemical and biological stability, see References [9] and [10].

The optional water quality parameters in terms of microbial, stability, harmful chemicals and toxicity can be considered for risk assessment on a case-by-case basis in response to a specific water quality issue, depending on the local context (e.g. uses with high risk of exposure and sensitive population, epidemiological evidence, equipment or facility degradation). Investigation studies can be carried out to support the risk assessment.

Examples of optional parameters are listed as follows and are informative.

a) Microbial organisms such as the protozoa (*Giardia* and *Cryptosporidium*) and helminths are widely detected in raw wastewater. The relevant parameters or indicator microorganisms can be introduced depending on the specific water quality application and monitoring capability.

b) Assimilable organic carbon in reclaimed water can favour microbial regrowth, induce biological fouling of facilities and distribution pipes such as in cooling water and chilled water systems. The relevant biological stability parameters or surrogates can be introduced.

c) Toxic and harmful chemicals such as disinfection byproducts (DBPs) can be detected in reclaimed water which can affect human health. The relevant parameters can be selected according to local water quality and technological conditions.

d) Aquatic toxicity can be considered for environmental uses such as habitat enhancement and stream augmentation.

The above mentioned optional parameters can be addressed due to increasing concerns on their potential risks. Under each type of parameter, there can be multiple kinds of indicators. Further investigation studies can be carried out to assist the optimal selection and evaluation of appropriate indicators according to local cases.

7 Framework for safety evaluation of water reuse in urban areas

Water reuse safety evaluation can be performed according to the framework depicted in Figure 1. Water quality should be fit for purpose and safety evaluation should accordingly depend on specific corresponding conditions. Further, the need for the water reuse safety evaluation should be addressed for the intended purpose in order to ensure that the evaluation is suitable and useful for informed decisions. The following points indicate the considerations for establishing a framework for safety evaluation of water reuse.

a) The framework for safety evaluation is mainly based on comparison with water quality standards and best practices/feedback of experience and inspection. Safety evaluation relies on adherence with water quality standards and effectiveness of preventive measures to prevent water quality degradation.

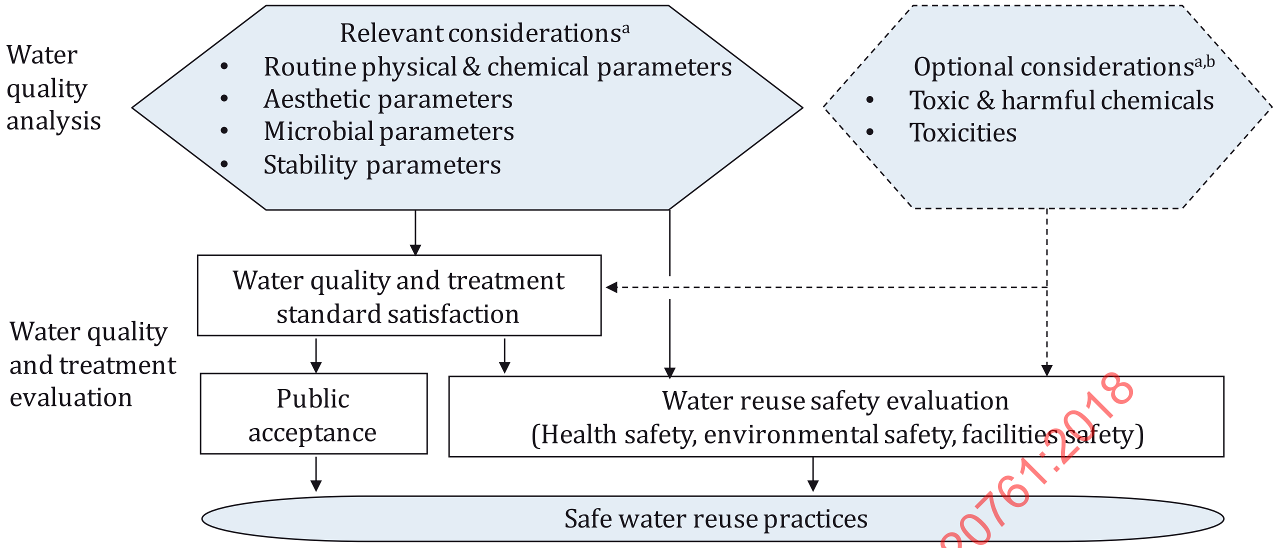
b) Water quality parameters for safety evaluation in urban areas should be selected considering various issues such as water quality characteristics of reclaimed water sources, water reuse applications as well as different exposure routes and pathways for users/populations.

c) For safety evaluation, susceptible population and those with high exposure to reclaimed water, such as children, workers who were handling the reclaimed water (such as fire-fighters, street cleaning and vehicle washing workers, operators at water reclamation facilities) should be considered.

d) Water quality parameters can be set to reduce the risk of acute and chronic health effects to a tolerable level for exposure to reclaimed water via ingestion, inhalation and/or contact.

e) Safety evaluation for protection of health, environment and facilities are performed according to water quality standard and risk assessment guidelines, see ISO 20426, References [11] and [12].

f) Long-term evaluation of water reuse safety can be performed if pollutants are present at detectable levels that can bioaccumulate, persist in the environment or tend to undergo bio-magnification in food chains or pose chronic toxicity to humans and sensitive species.



a Relevant water quality parameters are recommended for consideration in water reuse safety evaluation. Optional water quality parameters can be considered for risk assessment on a case-by-case basis in response to specific water quality issue(s).

b Research studies can be conducted to select and optimize parameters such as toxic and harmful chemicals and toxicities.

Figure 1 — Framework of water reuse safety evaluation

8 Water quality parameters selection for water reuse in urban areas

8.1 General

The selection of appropriate water quality parameters for consideration to ensure safety and public acceptances should be tailored to reclaimed water sources and fit for purpose needs.

a) Tailoring to source. Reclaimed water is obtained after proper treatment of municipal wastewater effluent or raw wastewater. For details concerning centralized water reuse system, see ISO 20760-1 and ISO 20760-2. Thus, the selection of appropriate water quality parameters involves the consideration of different influent types (e.g. municipal wastewater, small amount of industrial wastewater or stormwater, etc.) and different types of treatment technologies.

b) Fit for purpose. Different reclaimed water use approaches have different protection targets and exposure pathways which should be defined on a case-by-case basis. Protection targets and exposure pathways of water reuse should be determined. Afterwards, water quality parameters can be chosen based on various protection targets, including human health safety, environmental safety, facilities safety, plus public acceptance. Routine parameters and specific parameters associated with potential risks are monitored to ensure compliance with water quality standards. Optional parameters can be applied on a case-by-case basis if site-specific risks are identified. Research studies can be developed to deal with health and environmental safety (such as long-term chemical risks).

It is important to determine the appropriate site for monitoring the water quality parameters. For environmental and recreational uses, municipal non-potable uses (irrigation, high-pressure street maintenance, toilet flushing, fire-fighting and construction), the monitoring sites are normally located at outlets of water reclamation plants for treatment control or point of use if necessary. For some specific water reuse applications, some water quality parameters, such as microbial parameters and residual chlorine, can be considered at the distribution system outlet, at the point of delivery to end-user, additional treatment outlet, or at end-user sites. For vehicle washing, cooling and other reuse purposes which consider additional treatment, the monitoring sites are commonly situated at the outlet of the additional treatment system.

8.2 Parameter considerations for environmental and recreational uses in urban areas

8.2.1 General

Environmental reuse primarily includes the use of reclaimed water to replenish and support wetlands and supplement stream, river and lake flows, without contact with the human body. Recreational uses include impoundments involving incidental contact (bird watching, fishing and boating), public water features (fountains, waterfalls and snowmaking plants) and full body contact (swimming, bathing and wading).

8.2.2 Important aspects for safety and public acceptance considerations

Considerations for safety and public acceptance of environmental and recreational uses are shown in Table 3. Compared with environmental use, recreational purposes should pay greater attention for public health protection because of greater exposure. The hazards of exposure to aerosols and windblown spray produced from reclaimed water via inhalation should always be considered for some applications such as fountains and waterfalls.

Table 3 — Considerations of water reuse safety and public acceptance for environmental and recreational uses

Targets	Considerations	Environmental use	Recreational use
Health safety	Exposure via inhalation		•[a]
	Exposure via ingestion		•[b]
	Exposure via dermal routes		•
Environmental safety	Toxicity to aquatic life	•	•
	Eutrophication and algal bloom	•	•
	Sediment and soil pollution	•	•
	Receiving water pollution	•	•
Public acceptance	Colour and odour	•	•

NOTE The dot "•" indicates that attention should be paid to this category.

[a] This can refer to the aerosols and windblown spray produced from fountains and waterfalls.

[b] Accidental ingestion can be possible in some recreational uses.

8.2.3 Water quality parameters of interest

Examples of water quality parameters of interest for safety evaluation and public acceptance of environmental and recreational uses are shown in Table 4. The following water quality parameters should be selected based on the use, the type of water body to which reclaimed water is supplied and the likelihood of human exposure.

a) Routine physical and chemical parameters are recommended to be monitored to ensure water quality of impoundments meets the environmental and recreational water standards.

b) Aesthetic parameters including turbidity, colour, and odour are considered to facilitate public acceptance of reclaimed water. The odour of the receiving water bodies can be largely influenced by the growth of algae and bacteria (related to biological stability), organic content in sediments and dissolved oxygen.

c) Monitoring of microbial parameters such as indicator bacteria should be considered to reduce potential health risks, especially for recreational uses. Besides, the prior determination of chlorine demand can be used to adjust disinfectant dose to prevent or minimize the DBP formation. In routine analysis, residual disinfectants and indicator bacteria at the outlet of the plant can be proposed to verify water reuse safety for recreational uses.

d) Nutrients including phosphorus and nitrogen can be addressed to ensure an appropriate nutrient level, because an excess of nutrients can cause eutrophication or algal blooms in receiving waters.

e) Biological stability parameters (e.g. algae) can be recommended for consideration, to prevent algal growth in receiving water and reduce potential health and environmental risks.

f) Parameters such as residual disinfectants (e.g. residual chlorine) and ammonia should be considered because of ecosystem protection concerns.

Table 4 — Examples of water quality parameters of interest for safety evaluation and public acceptance of environmental and recreational uses in urban areas[a,b,c]

Reclaimed water for environmental and recreational use
— pH
— BOD_5, COD or TOC
— Ammonia
— TN, or nitrate
— Phosphorus
— Turbidity or TSS
— Indicator bacteria, such as *E. coli*, thermo-tolerant coliforms
— Residual disinfectants [d]
NOTE This table is based on References [13], [14], [15] and [16].
[a] Monitoring sites are located at the point of reclaimed water treatment outlets if there is no specific requirement.
[b] Parameters, such as DO, colour, odour, biological stability-algae in receiving water, specific metals, surfactants, can be considered on a case-by-case basis if specific risks are identified. For the biological stability parameters, monitoring sites are located at the point of receiving reclaimed water.
[c] For reclaimed water for recreational uses, specific microorganisms (viruses, protozoa, etc.) can be introduced in the case of identified risk or epidemiological evidence.
[d] To control biological stability and contamination from water environment, particular from fecal sources, residual chlorine is important in long hydraulic retention time distribution systems and recreational uses. For environmental uses, dechlorination can be considered for ecosystem protection.

In some sensitive areas, additional monitoring can be considered for aquatic toxicity, toxic and harmful chemicals (such as metals and adsorbable organic halides) and pathogens.

8.3 Parameter considerations for municipal non-potable uses in urban areas

8.3.1 General

Common water reuse applications in urban areas include landscape irrigation (e.g. golf course irrigation), street maintenance, toilet flushing, fire-fighting, construction, etc. Water reuse for irrigation should be carried out in accordance with ISO 16075-1, ISO 16075-2, ISO 16075-3 and ISO 16075-4. Water reuse in street care and maintenance includes street cleaning and snow melting. Water reuse in construction projects includes soil compaction, dust control, concrete washing, and concrete mixing.

8.3.2 Important aspects for safety and public acceptance considerations

Considerations for safety and public acceptance of municipal non-potable uses in urban areas are shown in Table 5. For these purposes, the following aspects can be addressed:

a) Potential for human exposure via direct contact or inhalation (e.g. aerosols and windblown spray produced from reclaimed water) should be taken into consideration. Exposure pathways and doses depend on human behaviour and water reuse modes and access. The risk can be reduced when using low pressure street maintenance compared to high pressure street maintenance. In addition, potential risks induced by cross-connection contamination should be prevented through proper management.

Particularly, for landscape irrigation, sprinklers can lead to higher human exposure to reclaimed water via inhalation compared to localized irrigation systems (e.g. micro-sprinklers and drip irrigation).

b) Environmental safety can be addressed depending on water quality and water reuse project context (the capacity of water reuse and receiving water bodies), and if there is potential discharge to storm sewers and then to creeks, ponds and rivers. Nevertheless, the ecological risks associated with reclaimed water are significantly lower when compared to risk from non-point source discharge of detergents, salts, defrosting agents and other chemicals used in some urban applications.

c) Scaling, fouling and corrosion of the pipelines and facilities, such as flushing devices, that are used for water reuse applications should be considered.

Table 5 — Considerations for water reuse safety and public acceptance of high pressure street maintenance, toilet and urinal flushing, fire-fighting by outdoor fire hydrants, and construction projects

Targets	Considerations	High pressure street maintenance	Toilet and urinal flushing	Fire-fighting by outdoor fire hydrants	Construction projects
Health safety[a]	Exposure via inhalation	•	•	•	•
	Exposure via dermal routes			•	
Environmental safety	Discharge to storm sewers and receiving water	•[b]		•	•[b]
Facilities safety	Scaling, fouling and corrosion of devices and pipelines		•	•	•
Public acceptance	Aesthetic issues (colour, odour, etc.)	•	•	•	•

NOTE The dot "•" indicates that attention should be paid to this category.

[a] Appropriate health protection measures should be implemented for workers, such as protection clothes, gloves, masks, etc. to prevent contact.

[b] Not from reclaimed water but from added chemicals for snow melting and construction projects.

8.3.3 Water quality parameters of interest

Examples of water quality parameters of interest for safety evaluation and public acceptance of municipal non-potable water reuses in urban areas are given in Table 6. Suitable and relevant water quality parameters should be chosen depending on reclaimed water sources, water reuse facilities and equipment, water reuse characteristics, site-specific conditions, end-users and the likelihood of human exposure (i.e. exposure pathway and dose) to reclaimed water as suggested below.

a) Microbial parameters should be addressed and protection measures are recommended to protect human health, especially regarding microbial impacts on users, workers and the public that are associated with water reuse activities. Turbidity/TSS and microbial parameters, including indicator bacteria such as *E. coli*, should be considered for public health concerns and acceptance. Some biological stability parameters, including HPC, can be considered to prevent bacterial growth, depending on water quality and retention time of distribution systems. Residual chlorine is recommended to verify reclaimed water microbial safety and to achieve a balance between microbial control and ecosystem protection. The prior determination of chlorine demand can be used to adjust disinfectant dose to prevent or minimize the DBP formation.

For some special cases, optional microbial parameters can be taken into consideration according to demonstrated high health risk for contact by susceptible users, such as infants, the elderly and those with compromised immune systems.

b) Aesthetic parameters such as colour and odour are recommended to achieve public acceptance of the practice. No odour nuisance should be associated or induced by reclaimed water (usually with high quality for urban reuse). In some cases, odour can be caused by lack of maintenance of distribution systems. Measures should be taken for these issues. In addition, for some applications, e.g. toilet flushing, intentional addition of dye into reclaimed water is done to mask remaining colour of reclaimed water and help distinguish reclaimed water from drinking water.

c) Facility safety parameters that are associated with scaling, fouling and corrosion issues, including turbidity, specific anions, and certain metals such as Fe and Mn are recommended to be addressed for safety evaluation.

In water reuse practice, the following methods can be taken to control the risks:

a) For irrigation, a multi-barrier approach is recommended in ISO 16075-1 and ISO 16075-2.

b) For high pressure street maintenance, street cleaning during periods without public presence and automatic equipment are recommended to reduce risks during street cleaning.

c) For toilet flushing, disinfection, maintenance of circulation with residual chlorine and avoidance of dead ends in distribution systems, plus periodic flushing with disinfectants, can be considered to reduce risks.

d) For fire-fighting, maintenance of circulation with residual chlorine, avoidance of accidental use of reclaimed water hydrants, colour-coding, water signs and labels of distribution pipes, prevention of backflow and cross-connections, prevention of system leakage and corrosion, and periodic flushing with reclaimed water are also recommended to reduce risks of reclaimed water for fire hydrants.

Table 6 — Examples of water quality parameters of interest for safety evaluation and public acceptance of irrigation, high pressure street maintenance, toilet and urinal flushing, fire-fighting by outdoor fire hydrants, and construction projects[a]

Irrigation[b]	High pressure street maintenance[c]	Toilet and urinal flushing[d]	Fire-fighting by outdoor fire hydrants[e]	Construction projects[f]
— pH — BOD_5 — TDS or electrical conductivity — Turbidity or TSS — Residual chlorine[g] — Indicator bacteria, such as *E. coli* or thermo-tolerant coliforms — Odour	— pH — Turbidity or TSS — Indicator bacteria, such as *E. coli* or thermo-tolerant coliforms (can be considered in some cases)	— pH — Turbidity or TSS — Colour — Odour — Residual chlorine[g] — Indicator bacteria, such as *E. coli* or thermo-tolerant coliforms	— pH — Turbidity or TSS — Odour — Indicator bacteria, such as *E. coli* or thermo-tolerant coliforms — Residual chlorine[g]	— Indicator bacteria, such as *E. coli* or thermo-tolerant coliforms (can be considered in some cases)

NOTE This table is based on References [13],[16],[17],[18],[19] and[20].

[a] Monitoring sites are commonly located at the point of reclaimed water treatment outlets.

[b] The evaluation of the parameters for irrigation in urban areas can be performed according to ISO 16075.

[c] For high pressure street maintenance, parameters such as colour, odour and residual chlorine can be considered on a case-by-case basis.

[d] For toilet and urinal flushing, parameters such as HPC that indicate the changes of biological stability during distribution, storage and use with long hydraulic retention time can be considered on a case-by-case basis.

[e] For fire-fighting by outdoor fire hydrants, parameters such as colour and specific microorganisms can be considered on a case-by-case basis.

[f] For construction projects, other parameters can be considered on a case-by-case basis .

[g] Residual chlorine can also be considered at the distribution system outlet at the point of delivery to end-users.

8.4 Parameter considerations for other uses in urban areas

8.4.1 Important aspects for safety and public acceptance considerations

In urban areas, reclaimed water is widely used for some industrial and commercial applications. Additional treatment after reclaimed water treatment outlet is usually conducted by users for cooling and chilled water make-up for recirculating cooling tower system and vehicle washing. Considerations for safety and public acceptance of cooling water, chilled water (air conditioning) and vehicle washing are listed in Table 7. Safety issues including health and facilities safety should be tackled. Public acceptance is also important for vehicle washing.

a) Health risks to population at risk, such as cooling/chilled water system user, and vehicle washing workers should be considered. Potential exposure of individuals to aerosols emitted from cooling towers should be considered and controlled. Extra caution should be taken to prevent biological growth, especially *Legionella* spp. Maintenance of cooling towers on a regular basis, including the cleaning of demisters, is also important. Compared with automatic vehicle washing, more attention should be paid to manual vehicle washing because of higher risk of human exposure to reclaimed water.

b) In cooling water and chilled water systems, including pipes and facilities, scaling and corrosion problems induced by salinity and silica should be addressed. Biofouling in cooling water and chilled water systems induced by biological growth is also an important issue. During vehicle washing, formation of dirty spots on vehicles due to use of reclaimed water should be also a concern.

In some cases, reclaimed water can be used for other potential applications, such as boiler water make-up and fire-fighting by indoor sprinkler systems after additional treatment. A safety issues analysis of boiler water make-up and fire-fighting by indoor sprinkler systems should be site-specific and varied according to multiple factors.

Table 7 — Considerations for water reuse safety and public acceptance of vehicle washing and cooling water/chilled water make-up

Targets	Considerations	Vehicle washing	Cooling and chilled water make-up
Health safety	Exposure via inhalation	• [a]	•
	Exposure via dermal routes	•	
Facilities safety	Scaling, fouling and corrosion		• (pipes and equipment)
	Spots on vehicles	•	
Public acceptance	Aesthetic issues (colour, odour, etc.)	•	
NOTE The dot "•" indicates that attention should be paid to this category.			
[a] If washing area is not well isolated or in the case of high-pressure manual washing.			

8.4.2 Water quality parameters of interest

Examples of water quality parameters and considerations for safety evaluation and public acceptance of water reuse for vehicle washing and cooling water/chilled water make-up are listed in Table 8. Suitable and relevant water quality parameters for vehicle washing and cooling water/chilled water make-up should be chosen depending on reclaimed water sources, cooling and air conditioning system pipes and equipment, vehicle washing equipment, and human exposure to reclaimed water as suggested below.

a) Microbial parameters should be considered for public health concerns. Disinfection is a proactive way to deal with microbial risks. Residual disinfectant and indicator bacteria, such as *E. coli* can be considered to verify water reuse safety. It is important to note that the concentration of residual disinfectant should be at tolerable level to avoid harmfulness to health and the environment. In cooling and chilled water systems, biological stability parameters, such as HPC, are also advised to be considered for biofilm control.

b) For vehicle washing, protection measures, such as gloves and masks, are recommended to protect health of workers, especially regarding microbial impacts on vehicle washing workers. Automatic equipment is recommended to reduce risks during vehicle washing.

c) For cooling and chilled water, *Legionella* spp. or related parameters, such as biocides, should be of concern. The need to maintain and clean the tower and demisters such as the addition of biocides should be addressed. Measures to prevent the risk of proliferation and dissemination of *Legionella* spp. are recommended to be performed according to relevant guidelines, see Reference [21].

d) Parameters associated with scaling, fouling and corrosion issues, including turbidity, TDS, as well as chemical stability parameters (such as anions, cations and metals), are recommended for consideration depending on water quality, vehicle washing frequency and concentration cycles of the cooling and chilled water system. For cooling and chilled water, ammonia should be addressed because it can result in biological growth and can cause corrosion by forming complexes with metals, especially copper or copper alloys.

Table 8 — Examples of water quality parameters of interest for safety evaluation and public acceptance of vehicle washing and cooling water/chilled water make-up

Reclaimed water for vehicle washing[a,b]	Reclaimed water for cooling water/chilled water make-up[a,c]
— pH — Turbidity or TSS — Indicator bacteria, such as *E. coli*, coliform bacteria, etc. — Residual disinfectant[d] — Colour and odour (can be considered in some cases)	— pH — BOD_5, COD or TOC — Turbidity or TSS — Ammonia — TDS or electrical conductivity — Indicator bacteria, such as *E. coli*, coliform bacteria, etc. — Environmental pathogens[c] (such as *Legionella* spp.) — Residual disinfectant[d] — Hardness

NOTE This table is based on References [13], [16], [18] and [20].

a Parameters such as chemical stability (e.g. Fe, Mn, Cl^-, SO_4^{2-}, alkalinity, silica) and biological stability (e.g. HPC) can be considered on a case-by-case basis if specific risks are identified. Specific metals and anions are considered for selection depending on final use. Monitoring sites of biological stability can be considered at distribution and storage system outlets and point-of-use with long hydraulic retention time.

b Specific microorganisms (in the case of high-pressure manual washing) such as viruses, protozoa, etc. can be considered in the case of identified risk or epidemiological evidence.

c *Legionella* spp. and its indicators can be monitored at circulating cooling tower at point-of-use or circulating cooling water pipelines.

d Residual disinfectant can also be considered at point-of-use. Some biocides are used for the onsite uses of cooling or chilled water systems with copper piping.

For cooling and chilled water, additional satellite treatment for control of inorganic substances, organics, and bacteria is usually provided to prevent scaling, corrosion, biological growth, fouling and foaming. In industrial area, windblown spray should not reach areas accessible to workers or the public. Moreover, limiting the cycles of concentration and addition of antifouling agents and biocides are important to achieve facility safety. Closed cooling and chilling systems to limit offsite vapour drift and regular cleaning are also recommended to ensure health and facility safety.

9 Water reuse safety evaluation

9.1 General

Water reuse safety evaluation should follow three steps, namely, water quality parameters and criteria selection, monitoring, and safety evaluation. Treatment technologies and processes should be optimized to improve their reliability and ensure the continuous compliance of water quality, see ISO 20468-1[2]. The use of proven technologies, good operation practices and reduction of exposure during utilization activities are recognized as effective measures to ensure the water reuse safety.

9.2 Water quality parameters and criteria selection

Water quality parameters should be selected based on the specific use of reclaimed water. Workers handling reclaimed water, the related public concerns and facilities, and environmental factors should be determined. Then, key safety issues should be chosen from Tables 1, 3, 5 or 7 on a case-by-case basis. Suitable water quality parameters can be selected from those listed in Tables 2, 4, 6 or 8 according to the specific conditions of water reuse.

After water quality parameter selection, for criteria or reference values of water quality parameters, practitioners can refer to their country's national, state, provincial, or local water quality guidelines,

2) Under preparation. Stage at the time of publication: ISO/DIS 20468-1:2018.

critical limits or associated guidelines relative to specific end-use applications. For example, when reclaimed water is used for cooling water purposes, its water quality should meet criteria for cooling water.

For some important parameters, reference value selection is recommended according to risk assessment, public acceptance and current practices.

a) A qualitative risk assessment can be performed according to standard methods, see ISO 20426, in order to determine relevant parameters in the case of identified specific chemical or microbiological health risks. Quantitative microbial risk assessment can only be applied if high risk and direct exposure occur and if sufficient data is available for modelling.

b) Characteristics of microbial growth under different organic matter levels, as well as related corrosion and scaling levels, can be investigated to determine the acceptable biological stability level for risk control. For facility safety, analytical results should be compared to operational practices.

9.3 Water quality monitoring

Monitoring of water quality can refer to ISO standard methods (such as those in ISO 16075-4) or national or local standard monitoring methods. During analysis, caution should be taken regarding reclaimed water characteristics, such as complexity of the water constituents and low pollutant concentrations.

The monitoring frequencies should be determined depending on the use, the likelihood of exposure and the potential adverse impact on health and environment. Frequencies should be higher when the risks are higher. Daily or weekly monitoring can be recommended for operational parameters as it enables corrective actions in a timely manner. For nonconventional water quality parameters, annual or semi-annual monitoring can be adequate to control potential adverse impacts.

The compliance of water quality is, as a rule, monitored at the outlet of the water reclamation facility. In some cases of urban reuse, it can be considered to include additional points for water quality monitoring, high risk of exposure or risk of changes in water quality (i.e. distribution system outlet at the point of delivery to end-user, additional treatment outlet, and end-user sites depending on the site-specific conditions). For end-user sites, those with the greatest distance and longest hydraulic retention time would be most of concern. More attention should be given to sensitive end-users that are susceptible to infection and/or under high exposure situations, such as susceptible population (e.g. children, the elderly and immunocompromised individuals), sensitive organisms (e.g. waterlogged plants and threatened species), workers and important facilities (e.g. cooling towers). For end-user sites with high exposure, public education and communication should be considered as an important part of the water reuse projects. Quality control and assurance are essential components of all phases of the monitoring program, to ensure that data collected are reliable and of good quality.

For daily monitoring and management, surrogates and indicators of water quality parameters are recommended. A system failure can be indicated by poor removal of the surrogates and/or indicators, while normal operating conditions can be indicated by partial or complete removal of the surrogates and/or indicators. Organic bulk parameters can be used as surrogates for water quality control. For example, decrease of UV absorbance and fluorescence intensity is used as a surrogate of removal efficiency of toxic and harmful chemicals (including endocrine disrupting chemicals) during treatment. Turbidity, residual chlorine and alternative microbial parameters, such as coliphages, can be considered as surrogates for evaluation of water quality. By measuring a number of surrogates (both physical and biological) in reclaimed water, it is reasonable to indicate that a specified level of water quality is being achieved [22].

9.4 Safety evaluation in water reuse in urban areas

9.4.1 General

Safety evaluation in water reuse in urban areas comprises health, environmental and facilities safety.

For some water quality parameters, including routine water quality monitoring, chemical stability and aesthetic ones, monitoring data should be recorded and compared with target criteria and reference average and maximum values specified in standard guidelines. Annex A illustrates water quality limit values specified in some countries for informative reference. Corrective measures and additional monitoring should be applied to ensure correct operation of the reclamation system. The monitoring results should be reported and reviewed periodically.

9.4.2 Health safety evaluation

Health safety evaluation is based on the comparison with water quality standards and implementation of good operation practices. A qualitative health risk assessment can be performed depending on the context, see ISO 20426, or health risk assessment guidelines of individual countries. Potential risks via exposure pathways, including ingestion, inhalation and dermal routes, can be addressed.

9.4.3 Environmental safety evaluation

Environmental safety evaluation of water reuse in urban areas includes evaluation of effects on the receiving environments (soil, groundwater and surface water), air; aquatic and terrestrial biota.

Environmental safety evaluation for receiving waters and soil can be performed depending on water reuse project context. A qualitative risk assessment can be carried out for soil, groundwater and surface water to deal with the risk of the soil and water bodies being contaminated by the use of treated wastewaters, linked with the characteristics and vulnerabilities of the groundwater and of the surface waters. The simplified assessment methods for evaluating irrigation impacts on groundwater and surface water can refer to Annex C of ISO 16075-1:2015.

Environmental safety evaluation of relevant parameters listed in Table 2 to aquatic and terrestrial biota during water reuse in urban areas for specific risk assessment are recommended for some extreme situations. Qualitative ecological risk assessment can be considered as simplified approach according to the specific situations of each reclaimed water use application. See Annex B for the information of quantitative risk assessment.

Annex A
(informative)

Information of water quality criteria and guidelines for water reuse applications in some countries

For reference, Table A.1 to A.5 illustrate water quality criteria and guidelines for different water reuse applications (e.g. environmental and recreational uses, landscape irrigation, toilet flushing, street maintenance and fire-fighting) which are currently implemented in several countries. For successful water reuse case studies in different countries, see References [13] and [23].

Table A.1 — Water quality criteria and guidelines for environmental uses in several countries

Parameters	China[a]	Spain[b]	U.S.[c]
pH	6,0–9,0	Minimum quality needs will be set on a case-by-case basis	—
BOD_5 (mg O_2/L)	≤10 (6)		≤30
TSS (mg/L)	≤20 (10)		≤30
Colour (colour or Hazen units)	≤30		—
TN (mg N/L)	≤15		—
NH_3-N (mg N/L)	≤5		—
TP (mg P/L)	≤1 (0,5)		—
Faecal coliforms (colony-forming unit, CFU/100 mL or most probable number, MPN/100 mL)	1 000 (200)		≤200 (7 d median) ≤800 (maximum)
Chlorine residual (mg/L)	≥0,05		≥1,0 (90 min)

[a] China: The limit values are for water reuse in rivers and lakes, the limit values inside bracket are for water reuse in waterscapes, see Reference [14] which also lists some values for bulk parameters and gives specific values for some metals and toxic chemicals.

[b] Spain: Maintenance of wetlands, minimum stream flows and similar, see Reference [24].

[c] U.S.: Residual chlorine ≥1,0 mg/L (a minimum actual modal contact time of at least 90 min unless a lesser contact time has been demonstrated to provide indicator organism and pathogen reduction equivalent to those suggested in these guidelines. In no case should the actual contact time be less than 30 min), see Reference [16]. In the U.S., each state sets its own criteria for water reuse. The values in the table are guidelines put forward as recommendations by the U.S. EPA for the states to consider.

Table A.2 — Water quality criteria and guidelines for recreational uses in several countries

Parameters	China[a]	Israel[b]	Japan[c] (Unrestricted area)	U.S.[d] (Restricted area)	U.S.[d] (Unrestricted area)
pH	6,0–9,0	6,5–8,5	5,8–8,6	—	6,0–9,0
BOD_5 (mg O_2/L)	≤6	<10	—	≤30	≤10
TSS (mg/L)	—	—	—	≤30	—
Colour (colour or Hazen units)	≤30	—	≤10	—	—
Turbidity (nephelometric turbidity unit, NTU or mg-kaolin/L)	≤5 NTU	≤2 NTU (median), <5 NTU (maximum)	<2 mg-kaolin/L	—	≤2 NTU
NH_3-N (mg N/L)	≤5	—	—	—	—
TN (mg N/L)	≤15	—	—	—	—
TP (mg P/L)	≤1 (0,5)	—	—	—	—
Faecal coliforms (CFU/100 mL or MPN/100 mL)	≤50 (Not detected)	<0 (median), <14 (maximum)	—	≤200 (7 d median) ≤800 (maximum)	Not detected (7 d median) ≤14 (maximum)
E. coli (CFU/100 mL or MPN/100 mL)	—	—	Not detected	—	—
Chlorine residual (mg/L)	≥0,05	>1,0 (30 min)	free residual chlorine >0,1 or combined residual chlorine >0,4	≥1,0 (90 min)	≥1,0 (90 min)

[a] China: The limit values are for water reuse in rivers and lakes, the limit values inside bracket are for water reuse in waterscapes, see Reference [14], which also lists some values for bulk parameters and gives specific values for some metals and toxic chemicals.

[b] Israel: Fountains and water falls, see Reference [25].

[c] Japan: Reference [26].

[d] U.S.: Residual chlorine ≥ 1.0 mg/L (a minimum actual modal contact time of at least 90 min unless a lesser contact time has been demonstrated to provide indicator organism and pathogen reduction equivalent to those suggested in these guidelines. In no case should the actual contact time be less than 30 min), see Reference [16]. In the U.S., each state sets its own criteria for water reuse. The values in the table are guidelines put forward as recommendations by the U.S.. EPA for the states to consider.

Table A.3 — Water quality criteria and guidelines for landscape irrigation uses in several countries

Parameters	Australia[a] (Unrestricted area)	China[b]	Israel[c] (Unrestricted area)	Israel[c] (Restricted area)	Japan[d]	Portugal[e] (Restricted area)	U.S.[f] (Restricted area)
pH	Minimum quality needs will be set on a fit-for-purpose basis	6,0–9,0	6,5–8,5	6,5–8,5	5,8–8,6	—	6,0–9,0
BOD_5 (mg O_2/L)		≤20	≤10	≤10	—	—	≤30
TSS (mg/L)		—	—	—	—	—	≤30
Colour (colour or Hazen units)		≤30	—	—	≤40	—	—
Turbidity (NTU or mg-kaolin/L)		≤10 NTU	≤2 NTU (median) ≤5 NTU (maximum)	≤5 NTU (medium) ≤10 NTU (single)	≤2 mg-kaolin/L	—	—
NH_3-N (mg N/L)		≤20	—	—	—	—	—
Faecal coliforms (CFU/100 mL or MPN/100 mL)		≤200	≤0 (median) ≤14 (maximum)	≤10 (median) ≤40 (maximum)	—		—
E. coli (CFU/100 mL or MPN/100 mL)		—	—	—	—	≤200 (30 m ≤ d < 60 m) 200 < *E. coli* ≤ 1 000 (60 m ≤ d < 80 m) >1 000 (d ≥ 80 m)[g]	≤200 (7 d median) ≤800 (maximum)
Total coliforms (CFU/100 mL or MPN/100 mL)		—	—	—	≤1 000 (temporary)	—	—
TDS (mg/L)		≤1 000	—	—	—	—	—
Chlorine residual (mg/L)		—	>1,0 (30 min)	>1,0 (30 min)	—	—	≥1,0 (90 min)

a Australia: References [11] and [27].

b China: Reference [28] which also lists some values for bulk parameters.

c Israel: Reference [25].

d Japan: Reference [26].

e Portugal: Reference [29].

f U.S.: Residual chlorine ≥1,0 mg/L (a minimum actual modal contact time of at least 90 min unless a lesser contact time has been demonstrated to provide indicator organism and pathogen reduction equivalent to those suggested in these guidelines. In no case should the actual contact time be less than 30 min), see Reference [16]. In the U.S., each state sets its own criteria for water reuse. The values in the table are guidelines put forward as recommendations by the U.S. EPA for the states to consider.

g "d" refers to the minimum distance between houses and the limit of the irrigated area.

Table A.4 — Water quality criteria and guidelines for toilet flushing in several countries

Parameters	Australia[a]	Canada[b]	China[c]	Israel[d]	Japan[e]	Spain[f]	U.S.[g]
pH	Minimum quality needs will be set on a fit-for-purpose basis	—	6,0–9,0	6,5–8,5	5,8–8,6	—	6,0–9,0
BOD_5 (mg O_2/L)		≤10 (median) ≤20 (maximum)	≤10	≤10	—	—	≤10
TSS (mg/L)		≤10 (median) ≤20 (maximum)	—	—	—	≤10	—
Colour (colour or Hazen units)		—	≤30	—	—	—	—
Turbidity (NTU or mg-kaolin/L)		≤2 NTU (median) ≤5 NTU (maximum)	≤5 NTU	≤2 NTU (median) ≤5 NTU (maximum)	≤2 mg-kaolin/L	≤2 NTU	≤2 NTU
NH_3-N (mg N/L)		—	≤10	—	—	—	—
Faecal coliforms (CFU/100 mL or MPN/100 mL)		Not detected (median) ≤200 (maximum)	—	≤0 (median), 14 (maximum)	—	—	Not detected (7 d median) ≤14 (maximum)
E. coli (CFU/100 mL or MPN/100 mL)		Not detected (median) ≤200 (maximum)	—	—	Not detected	Not detected	—
Total coliforms (CFU/L)		—	≤3	—	—	—	—
TDS (mg/L)		—	≤1 500	—	—	—	—
Chlorine residual (mg/L)		≥0,5	≥1,0 (30 min), ≥0,2 (at point of use)	>1 (30 min)	free residual chlorine >0,1 or combined residual chlorine >0,4	—	≥1,0 (90 min)

[a] Australia: References [11] and [27].

[b] Canada: Reference [17].

[c] China: Reference [18] which also lists some values for bulk parameters.

[d] Israel: Reference [25].

[e] Japan: Reference [26].

[f] Spain: Reference [24] Authorization will only be given if each section up to the point of use is a marked dual circuit.

[g] U.S.: Residual chlorine ≥1,0 mg/L (a minimum actual modal contact time of at least 90 min unless a lesser contact time has been demonstrated to provide indicator organism and pathogen reduction equivalent to those suggested in these guidelines. In no case should the actual contact time be less than 30 min), see Reference [16]. In the U.S., each state sets its own criteria for water reuse. The values in the table are guidelines put forward as recommendations by the U.S. EPA for the states to consider.