
**Water reuse in urban areas —
Guidelines for centralized water reuse
system —**

Part 1:
**Design principle of a centralized water
reuse system**

*Réutilisation de l'eau en milieu urbain - Lignes directrices concernant
les systèmes centralisés de réutilisation de l'eau —*

*Partie 1: Principe de conception d'un système centralisé de
réutilisation de l'eau*

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Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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*.

A list of all parts in the ISO 20760 series can be found on the ISO website.

Introduction

With economic development, climate change and 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 sustainable development of society. To address these shortages, reclaimed water is increasingly being used to satisfy water demands and this strategy has 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, toilet and urinal flushing, firefighting and fire suppression, street cleaning, environmental and recreational uses (ornamental water features, water bodies' replenishment, etc.) and car washing. These centralized water reuse systems have been developed to the degree that they are now considered as an effective component of urban water management and are used in many cities and countries.

The essential components of a centralized water reuse system include a source water, wastewater collection systems (sewers and pumping stations), a wastewater treatment facility, a reclaimed water distribution system, reclaimed water storage, a water quality monitoring system and operation and maintenance provided by experienced and certified operators. The variable nature and diversity in source water present a challenge to ensuring water safety and reliability in each system component. A further complication to distributing the reclaimed water is that different water reuse applications can have different levels of water quality, which would consider installing satellite treatment.

This document provides design principles for centralized water reuse systems in urban areas. It considers and addresses the critical issues and factors in the design of the different system components and is intended to assist water engineers, authorities, decision makers and stakeholders in considering feasible and cost-effective approaches for safe and reliable fit-for-purpose water reuse. For details on the management of a centralized water reuse system, see ISO 20760-2.

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Water reuse in urban areas — Guidelines for centralized water reuse system —

Part 1: Design principle of a centralized water reuse system

1 Scope

This document provides guidelines for the planning and design of centralized water reuse systems and water reuse applications in urban areas.

This document is applicable to practitioners and authorities who intend to implement principles and decisions on centralized water reuse in a safe, reliable and sustainable manner.

This document addresses centralized water reuse systems in their entirety and is applicable to any water reclamation system component (e.g. source water, treatment, storage, distribution, operation and maintenance and monitoring).

This document provides:

- standard terms and definitions;
- system components and possible models of a centralized water reuse system;
- design principles of a centralized water reuse system;
- common assessment criteria and related examples of water quality indicators, all without setting any target values or thresholds;
- specific aspects for consideration and emergency response.

Design parameters and regulatory values of a centralized water reuse system are out of 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:

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

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

3.1

backflow

movement of the fluid from downstream to upstream within an installation

[SOURCE: EN 1717: 2000, 3.5]

3.2

backflow protection device

device which is intended to prevent contamination of potable water by *backflow* (3.1)

[SOURCE: EN 1717: 2000, 3.6]

3.3

destratification system

use of mechanical devices (e.g. bubble plumes, draft-tube mixers or unconfined mixers) to reduce water column stratification, increase the vertical transfer of dissolved oxygen and heat in a tank/reservoir, in order to improve chemical water quality and to control phytoplankton growth

3.4

reliability assessment

formal determination and review of the reliability of reclaimed water system components and equipment

Note 1 to entry: The assessment reviews and details the operating standards, maintainability, critical operating conditions, spare parts requirements and availability, and any other issues that affect the reliability or the treatment performance of the reclamation facility.

3.5

water reclamation facility

facility for recovering reclaimed water of a quality which is suitable for beneficial use

3.6

water reuse in urban areas

beneficial use of reclaimed water for non-potable and/or indirect potable applications in urban areas

EXAMPLE Landscape uses, street cleaning, firefighting, industrial applications, environmental enhancement, recreational applications, flushing and other domestic uses, etc.

4 Abbreviated terms

AI	alkalinity index
AGP	algal growth potential
AOC	assimilable organic carbon
BDOC	biodegradable dissolved organic carbon
BGP	bacterial growth potential
BOD	biochemical oxygen demand
CAPEX	capital expense
COD	chemical oxygen demand
HPC	heterotrophic plate count
LR	Larson ratio

LSI	Langelier saturation index
OPEX	operating expense
POU	point-of-use
RSI	Ryznar stability index
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
TWW	treated wastewater
WWTP	wastewater treatment plant

5 Planning and design of a centralized water reuse system

5.1 General

Planning is fundamental to ensure the effectiveness of a centralized water reuse system. When a reclaimed water master plan is being developed, the following aspects should be considered and carefully defined:

- planning principles and targets, including human health and environment protection;
- planning scope and project timeline;
- water reclamation facility construction, operation and maintenance and potential operational challenges;
- water reclamation production, storage, transmission and distribution system reliability and redundancy;
- reclaimed water applications and related water quality and quantity;
- the urban area to which reclaimed water will be supplied,
- the scale and layout of the system and links/compliance with local or regional water planning;
- economic feasibility and the availability of funding, including tariff strategies and concession agreements;
- stakeholder consultation, open meetings and dialogues;
- customer surveys to determine industrial and domestic demands, value of the reclaimed water (willingness to pay), economic viability and sustainability;
- environmental conscious design and minimization of environmental impacts;
- public comment and social acceptance.

The reclaimed water master plan should be reviewed periodically (by competent authorities) and updated and refined as new information becomes available. For example, water authorities can work together with internal and external stakeholders, including the potential reclaimed water users and the public, throughout the process to ensure that issues and concerns are understood and considered [10] [11].

5.2 Estimation of water demand

5.2.1 General

In the planning stage, the needs of each water reuse application should be assessed including the reclaimed water quantity and quality. Various methods can be applied to estimate current demands and to analyse use applications. Additionally, when transitioning from standard drinking water or wastewater systems to a water reuse system, the sizing of the potable drinking water infrastructure should be heavily evaluated to ensure water quality/water age factors are still intact (i.e. avoiding oversized servicing, increased water age and decreased disinfectant residuals).

5.2.2 Quantity of reclaimed water

When determining the quantity of reclaimed water that is available for reuse, several factors should be considered, including:

- a) the quantity and quality characteristics of wastewater discharged to sewer from the various sources (e.g. types of industrial, commercial and institutional discharges, number of houses, infiltration/inflow, surface runoff, combined or separate sewers, etc.);
- b) the topography of the service area and location of existing wastewater treatment facilities;
- c) diurnal and seasonal dynamics of collected and treated wastewater quantity;
- d) the volume of reclaimed water that could be available after treatment and storage.

5.2.3 Review of potential reclaimed water end-users and uses

An assessment should be carried out to identify potential users of reclaimed water, their locations and their water quantity and quality considerations, particularly those users with high quantity and/or quality needs and cost-effective applications. Special attention should be paid to potential drivers and benefits for the use of reclaimed water, in particular for the large end-users.

5.3 Site conditions

When selecting the site for the centralized water reuse system, the following criteria should be considered:

- a) location and proximity of current and projected future reclaimed water demands and users;
- b) availability of land, routes and rights of way space for the necessary treatment, storage, transmission and distribution systems and pumping facilities;
- c) scoping assessment of the land area;
- d) land use conflicts and local water reuse policies;
- e) proximity (location and quantity of wastewater sources);
- f) hydraulic and civil construction factors;
- g) opportunities for partnership with other agencies;
- h) environmental framework such as climate, geography and topography;
- i) water resources such as surface water or groundwater;
- j) level of social acceptance of water reuse.

A centralized water reuse system may have two configurations:

- adding advanced treatment to an existing centralized wastewater treatment facility;
- constructing a new centralized reclamation facility for additional wastewater treatment and/or polishing and production of reclaimed water.

It may be difficult to find a site where all site conditions are optimal and adjustments can be considered to compensate for site deficiencies. Planning should consider both the current and future demand for all potential reclaimed water uses and growth in demand may be different for the various water demands being considered. A market assessment should be carried out, particularly in communities with established infrastructure, to determine the needs for reclaimed water. Other issues that should also be considered include the impact of potential land-use zoning changes and the possibility of future land development.

5.4 System components

The following five essential water reclamation components should be considered when planning a centralized water reuse system:

- a) source water (quality and quantity);
- b) treatment;
- c) reclaimed water storage;
- d) reclaimed water distribution;
- e) monitoring.

The storage system(s) can be located before and/or after the main transmission pipeline depending on the distribution system hydraulic design and should equalize reclaimed water quantity and pressures.

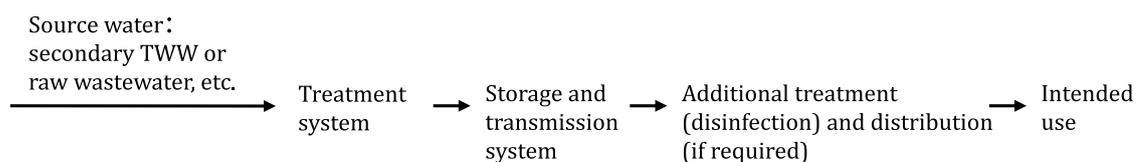
5.5 Possible models of the system

5.5.1 General

There are four generic models of a centralized water reuse system, namely single application, multiple applications, environmental storage and reuse applications and cascading uses, ranging from simple to more complicated water use patterns considered in this document.

5.5.2 Model I – Single application

Model I produces reclaimed water for only one type of water reuse quality application. This model is relatively simple ([Figure 1](#)). Secondary TWW is typically used as source water in a centralized water reuse system. In some cases, when water reclamation is integrated in the wastewater treatment with the intended purpose of water reuse, untreated wastewater from sewer systems is considered as source water (see detailed descriptions in [6.1](#)). A typical example of Model I is given in [Figure 1](#).



NOTE Additional treatment is optional and not compulsory, which depends on the reclaimed water quality and use.

Figure 1 — Typical example of Model I for single application

Model I should be considered when

- a) reclaimed water is being provided to a single user, such as one industrial plant or an individual building, or
- b) reclaimed water is being provided to a single reclaimed water use or standard for a single user or similar users, such as a regional or community-based residential area where the quality of the reclaimed water should meet all the water reuse applications.

Using accepted design principles, the treatment technology or combination of technologies should be selected to achieve the reclaimed water quality targets for the specific uses and the overall reclaimed water system performance, see ISO 20761, ISO 20468-1 and Reference [12].

5.5.3 Model II — Multiple applications

Model II produces multiple reclaimed water streams, each with a different water quality criterion. This model is more complex in design and operation and the treatment is organized into a hierarchical structure. A typical example of Model II is given in Figure 2.

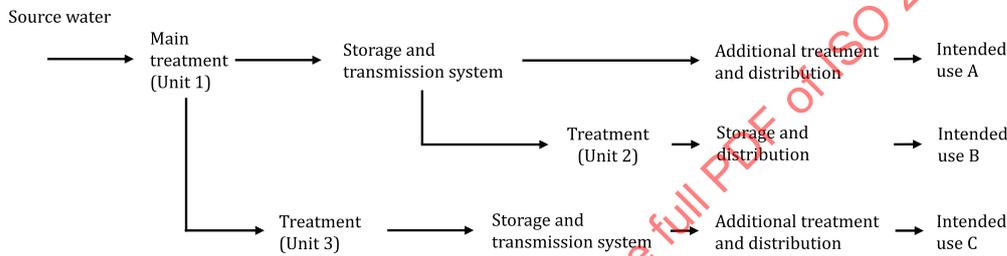


Figure 2 — Typical example of Model II for multiple applications

Model II should be used when reclaimed water is supplied to multiple end uses with different water quality, such as in an industrial park with several industries, or a region with industrial and domestic applications for reclaimed water.

The following issues should be considered when selecting a reclaimed water treatment technology or technology combinations:

- a) treatment Unit 1 is designed to satisfy the water quality and quantity specialities for the large and high priority users;
- b) small users with higher quality demands can connect to the main treatment unit (Unit 1) and either provide an additional treatment unit before distribution or at the point-of-use (POU). The control and responsibility of an end user at the utility site would demand a very detailed contract and access to the site to ensure quality is maintained to their needs. There are two scenarios that could be applied:
 - the reclaimed water utility contracts with the end user for a system with a specified quantity and quality and the utility controls the additional treatment;
 - the small user contracts for the quantity that is being provided and builds the enhanced treatment at its own site where the user has control and responsibility of the system construction and operation;
- c) small users with quality demands that are generally lower than the quality of the produced reclaimed water can connect directly to the main treatment unit (Unit 1) without consideration for further treatment.

The minimum water quality should be guaranteed by the service provider (operator). The water quality demands for specific users could be achieved using additional treatment (e.g. Unit 2 and 3).

5.5.4 Model III — Environmental storage and reuse applications

Model III should be considered when bodies of water such as natural/artificial wetlands, ponds, lakes, rivers and streams are located in close proximity to the treatment system and can be used as storage reservoirs and/or treatment units in which reclaimed water can undergo further purification. Storage aims to provide buffer capacity and/or for environmental enhancement, to achieve high level of environmental benefits and to avoid adverse impacts on users. On-site storage and treatment could be optional as a function of user needs. A typical example of Model III is given in [Figure 3](#).

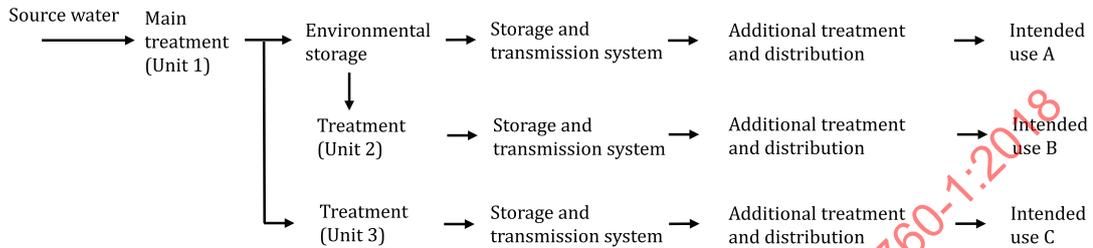


Figure 3 — Typical example of Model III for environmental storage and reuse applications

5.5.5 Model IV — Cascading reclaimed water uses

Model IV provides a cascading system for reclaimed water, with sequential or cascading use of reclaimed water for different reuse applications. For instance, when the reclaimed water is applied for industrial uses, wastewater can be reclaimed from that same industrial process and applied to subsequent reuse applications, such as cleaning, or ornamental landscape irrigation without additional specific water quality needs. If a higher water quality is demanded for the subsequent reuse applications, additional treatment can be provided or the reuse water can be mixed with higher quality water to attain the desired water quality for the reuse application. A typical example of Model IV is given in [Figure 4](#).

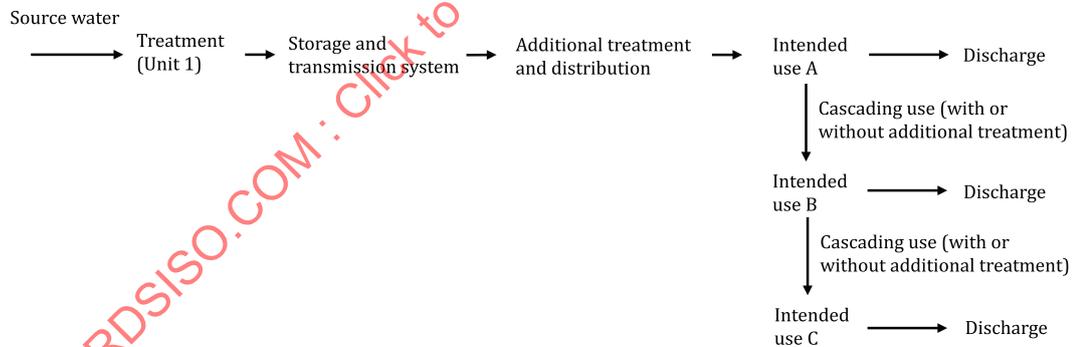


Figure 4 — Typical example of Model IV for cascading use

5.6 Basic principles

Basic principles of safety, reliability, stability and economic viability should be incorporated in all applicable clauses when designing a centralized water reuse system.

6 Source water considerations

6.1 Type of source water

6.1.1 General

The quality of the source water should not have any negative impacts on the subsequent reuse applications as well as on human health and the environment.

Water reclamation facility sources can include either untreated wastewater from sewer systems or treated wastewater (TWW) from wastewater treatment plants (WWTP), with the treatment technology and level of treatment based on the source of water and the reclaimed water quality needs with consideration given to principles of safety, reliability, stability, economic viability and protection of the environment and public health.

In most circumstances, it is expected that secondary TWW will be used as source water in a centralized water reuse system. The quality of the secondary TWW is typically established. Alternatively, water reclamation can be directly integrated into a WWTP with intended purpose for water reuse. In this integrated system, untreated wastewater from sewer systems is the source water as long as treatment and reliability (water quality and quantity) meet water reuse demand.

6.1.2 Treated wastewater from a WWTP

Secondary TWW is commonly used as the source of reclaimed water in areas where centralized wastewater treatment facilities already exist. This typically should consider the existing WWTP to either be expanded or upgraded, or the nearby construction of a new water reclamation facility. For expansion or upgrade of existing WWTPs, compatibility with existing treatment processes is important and several factors should be considered, including the secondary TWW quality, space for new facilities, hydraulic plant profile, piping modifications, operating considerations and ancillary systems. In all cases, future demand, regional planning and land availability should be considered.

6.1.3 Untreated wastewater from sewer systems

Untreated wastewater from sewer systems is typically considered as the source water, such as for

- newly developed areas where centralized wastewater treatment facilities do not yet exist, and
- areas with limited capacity wastewater treatment facilities such as primary treatment plants.

Untreated wastewater from sewer systems is generally available in proportion to the population of the area covered by the collection system.

In general, untreated wastewater from sewer systems has the following characteristics:

- a) higher concentrations of nutrients and organic and inorganic chemical contaminants (including household and industrial chemicals, pharmaceuticals and personal care products and endocrine disruptors) compared to secondary TWW;
- b) high amount of solids (e.g. grit, paper, plastic, wipes, etc.) that could plug pumps, strainers and other equipment;
- c) higher load and broader range of pathogens;
- d) generally collected and available at a lower elevation of the collection system.

The constituents of, and variations in, untreated wastewater quality and quantity are important for the design of subsequent treatment, storage, distribution and application stages and should be accurately assessed.

6.1.4 Other sources

During an emergency, unexpected event, or interruption in the source water supply, backup supplies of water meeting the water quality specification for the reuse applications should be available to meet essential service supply (e.g. toilet flushing). Possible backup water resources include potable water, storm water, river and/or lake sources that are located in close proximity to the centralized water reuse system.

When the available sources of reclaimed water are insufficient to meet the user demand, supplementary sources should be considered where possible. In such cases, these sources may demand additional treatment, storage or mixing with other sources.

If potable water is to be used as a backup source or supplementary source, the potable water distribution system should be protected from potential contamination from the reclaimed water through the use of backflow prevention devices preferably an air gap separation.

6.2 Water quality considerations for source water

6.2.1 General

The quality and quantity of source water should meet the safety considerations for human health and environmental safety of the reclaimed water production and supply process. These two issues should be addressed.

6.2.2 Appropriate source water

Reclaimed water sourced from domestic wastewater with a controlled proportion of industrial wastewater can be considered as an appropriate raw source water for water reuse applications.

6.2.3 Inappropriate source water

Although the sources of municipal wastewater are normally expected to include a mixture of domestic, industrial, commercial and institutional (e.g. hospital) discharges, wastewater from industries and institutions that contains toxic chemicals or pathogens at levels that exceed the specified acceptable levels should be excluded from consideration for reclamation and beneficial reuse, as the high content of contaminants may negatively impact the quality of the reclaimed water. In particular, caution should be taken when considering wastewater with a significant proportion of hospital effluents due to the potential for high pathogen content and presence of disinfectants and pharmaceutical compounds that may negatively impact biological treatment processes.

Good practices should be adopted to detect and minimize adverse impacts. These may include a source control program, permitting system, specific aspects for industries, monitoring and audit procedures. Industrial, commercial and/or institutional wastewater inputs may be appropriate sources of water for reuse when the pollutants are effectively controlled and pre-treated to acceptable levels before being discharged into the sewers.

Radioactive wastewater and industrial wastewaters that contain excessive levels of heavy metals and toxic chemicals cannot be used as source water.

6.3 Reliability considerations

6.3.1 Water quantity

The amount of reclaimed water that is available is determined by the amount of collected untreated wastewater from sewer systems and/or secondary TWW that is available. Pipeline leakage, process water usage and unforeseen water losses should also be taken into account.

The water quantity is subject to hourly and seasonal variations and these variations should be considered in the design.

6.3.2 Water quality

To minimize variations in the water quality of source water, the possible impacts of shock loadings from industrial wastewater sources and storm water infiltration/inflow should be addressed. Once the potential impacts of industrial discharges are understood and key pollutants are identified, the quality of reclaimed water can be controlled by buffer storage, suitable treatment processes, industrial source control and trained process operators.

A fit-for-purpose water reuse safety evaluation should be carried out according to the intended uses, as indicated in ISO 20761. For reference, common parameters for assessing the water quality of source water include indicator microorganisms (e.g. total coliforms, faecal coliforms, or *Escherichia coli*), turbidity, total suspended solids (TSS), biochemical oxygen demand (BOD) (and/or chemical oxygen demand, COD, as a complement), colour, pH, total nitrogen (TN), total phosphorus (TP) and aesthetic indicators. The list of parameters to be monitored should be selected according to fit-for-purpose approach. Optional parameters might be included for some applications. During water quality assessment, stability issues such as bacterial regrowth and potential adverse impacts such as health hazards, soil impacts or other environmental issues may also be taken into account. Relevant information regarding the recommended water quality criteria for water reuse applications in several countries can be found in Annex A of ISO 20761:—²⁾, and References [13], [14], [15] and [16].

6.3.3 Reliability assessment

Each reclaimed water program should conduct a reliability assessment to determine which processes and pieces of equipment are critical, vital and non-critical to the production, distribution and final use of the product water. This assessment determines the level of impact of the loss of critical, vital and noncritical processes and equipment on reclaimed water quality and quality as it affects the ability to produce, distribute and use reclaimed water. The assessment will incorporate these findings into the design of the facilities to ensure adequate redundancy, in-plant storage, environmental buffers and alarms are included. These design factors also determine minimum and critical operator staffing needs.

6.4 Economic considerations

The economic feasibility of water reuse, including capital expense (CAPEX) and operating expense (OPEX), should be evaluated on a case-by-case basis. The cost-effectiveness of adopting source water for water reuse should be compared with other available water resources (e.g. CAPEX, OPEX, water pricing, indirect cost savings, etc.).

7 Reclaimed water treatment system

7.1 General

The following factors should be considered for reclaimed water treatment:

- quality of the source water;
- treatment objectives and target quality of reclaimed water;
- technological performance of the treatment facilities;
- location of the treatment facilities and site constraints;
- energy and economic considerations.

2) Under preparation. Stage at the time of publication: ISO/FDIS 20761:2017.

The treatment technologies and processes should be selected to meet the demands and goals of the end uses.

7.2 Centralized water reuse treatment system design principles

7.2.1 General

The principles of safety, reliability, stability and economic viability should be incorporated in the design of a centralized water reuse treatment system. Avoidance of adverse environmental impacts should also be considered.

7.2.2 Safety

The safety of the reclaimed water should ensure that the quality of the reclaimed water is appropriate for the intended uses, in order to protect human health and the environment from the adverse impacts of pathogens, toxic chemical contaminants or nutrients. For instance, reclaimed water containing high levels of salts (e.g. sodium and boron) can be specifically toxic to some plants. Where a backup or supplementary supply is proposed to ensure reliability and is provided from a potable water system, a backflow protection device is recommended to be provided between the two systems to protect the potable water system from contamination. The selection of the backflow protection device is suggested to be associated to the category of the identified contamination risk.

Water quality should be evaluated taking into consideration a “fit-for-purpose” water reuse safety evaluation according to the end uses.

7.2.3 Reliability

Water quantity needs and availability can be assessed by determining the demand of reclaimed water and ensuring that supply can meet the peak demands. A reliability assessment is used to demonstrate that the treated reclaimed water is of an acceptable quantity and quality when it is delivered to the distribution system. The following aspects should be considered to ensure treatment reliability:

- a) backup water resources and electric power supplies;
- b) standby or alternative equipment;
- c) seasonal or temporary use or buffer storage of reclaimed water (depending on circumstances, e.g. storage in winter, emergency storage, seasonal irrigation or stream augmentation);
- d) effectiveness and efficiency of the treatment and disinfection processes to ensure consistent performance;
- e) monitoring programs, such as online monitoring, alarm systems and automatic controls to detect and control process failures and unregulated discharges in urban wastewater collection systems;
- f) facility operation, maintenance and control.

7.2.4 Stability

Stability assessment may include operational stability and effluent quality stability/compliance.

When designing the treatment system, it is important to conduct performance target checks (e.g. system consistency and resilience) based on water quality approaches to be sure that residual concentrations of chemical and microbial parameters are acceptable. In some cases, for reclaimed water with high risk of direct human contact, a multiple barrier approach or a minimum dual barrier of treatment should be conducted to reduce microbial risks. Equipment redundancy can also be considered which involves the addition of measures beyond the minimum needs to ensure performance targets are consistently achieved. Redundancy includes treatment processes which are capable of independently targeting the same type of contaminants and the provision of standby equipment and power supply.

Chemical stability can be assessed by considering routine parameters, such as pH, alkalinity, temperature, hardness, chloride and sulfate. In some very specific cases, other parameters, such as the Langelier saturation index (LSI), Ryznar stability index (RSI), alkalinity index (AI) and the Larson ratio (LR) could also be monitored, as well as some additional microbial stability indicators such as the heterotrophic plate count (HPC), assimilable organic carbon (AOC), biodegradable dissolved organic carbon (BDOC), algal growth potential (AGP) and bacterial growth potential (BGP).

7.2.5 Economic viability

Economic viability evaluations should consider the initial capital investment for construction and installation and the expenses for operation and maintenance. The treatment costs are influenced by the location, quality of the source water, the effluent quantity and quality for intended uses, energy cost and labour cost. As a rule, specific tariffs are set-up to promote a sustainable water reuse.

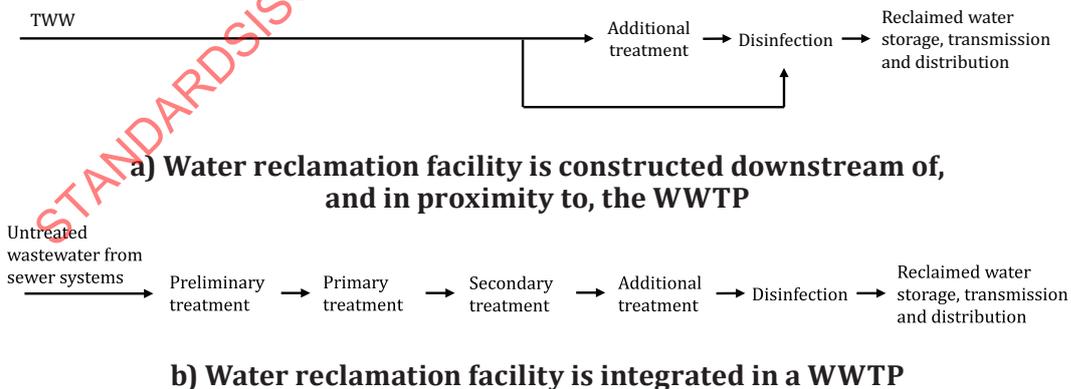
7.2.6 Environment

Protection of the environment and avoidance of adverse environmental impacts are crucial [17] [18] [19]. The following aspects can be considered to ensure the environmental sustainability in water reuse:

- a) land use impacts;
- b) ecosystems, species or biological diversity (e.g. wetlands, threatened species, wildlife and habitats);
- c) floodplain, important farmlands, parklands or preserves;
- d) surface or groundwater quality or quantity;
- e) ambient air quality or noise levels.

7.3 Possible centralized water reuse treatment system configurations

Figure 5 displays the flow chart of a typical reclaimed water treatment system. When the source water is secondary TWW, the system normally comprises additional treatment and disinfection processes [Figure 5 a)]. If the source water is untreated wastewater from sewer systems, the system should include preliminary, primary, secondary and additional treatment and disinfection processes [Figure 5 b)]. Additional treatment and disinfection are major components in reclaimed water treatment. Specific users can implement other complementary treatments if they have special considerations for the quality of reclaimed water (e.g. salt removal).



NOTE Advanced treatment is optional and should be considered depending on the reclaimed water quality and use.

Figure 5 — Flow chart of a typical centralized water reuse treatment system

7.4 Treatment process

In some cases, advanced treatment should be considered. To guarantee the safety and reliability of the treatment system, the adoption of a combined multiple barrier treatment approach and monitoring system are recommended to be considered depending on the applications of reclaimed water, along with minimum technological needs (e.g. disinfection). The multiple barrier approach highlights the use of combined measures as an integrated system.

Common additional treatment includes filtration technologies (rapid sand filtration, cloth/disc filtration or microscreening).

Common disinfection technologies may include chlorination, ultraviolet radiation and ozonation.

Common advanced treatment technologies may include activated carbon adsorption and ion exchange, membrane filtration (e.g. microfiltration, ultrafiltration, nanofiltration and reverse osmosis) and advanced oxidation (e.g. electrochemical oxidation, photochemical catalytic oxidation and radiation)^[20].

8 Reclaimed water storage system

8.1 General

Reclaimed water storage facilities are essential components in a water reuse system. Sufficient storage should be designed and operated to equalize hydraulic flow variations, satisfy water demands, reduce pressure fluctuations and provide reserves for firefighting, power outages and other emergencies. The construction of storage facilities should consider different storage types and specificities. The structural integrity of the system should also be guaranteed and leakage and seepage from the system should be prevented.

8.2 Storage types

8.2.1 General

Storage facilities can be either open (reservoirs or ponds) or closed structures (covered tanks or underground aquifers). The type of storage is influenced by topography, aesthetics, seismic activity, potential of freezing, land availability, capital and operational costs and previous experiences.

8.2.2 Open reservoirs

Open surface reservoirs are commonly used at large facilities. They can be used as a part of the treatment and distribution system (e.g. maturation ponds), or they can be used for storage of the reclaimed water before it is pumped into the distribution system. Onsite storage ponds are often used for urban applications such as golf course and park irrigation.

The size of open storage reservoirs depends on storage objectives. Short-term storage is the predominant option for urban landscape and golf course irrigation. Long-term inter-seasonal storage is mostly used for agricultural irrigation, large urban water reuse projects or for indirect potable reuse. Relevant information regarding water reuse for irrigation can be found in ISO 16075-1, ISO 16075-2, ISO 16075-3 and ISO 16075-4.

NOTE In case of indirect potable reuse, the reclaimed water is released to an environmental buffer before being extracted and treated via a water treatment works for drinking water purposes. The environmental buffer for indirect potable reuse can be an open surface reservoir or lake, or an aquifer. Other relevant standards can be referred to for more specific information on indirect potable reuse ^[21].

8.2.3 Closed reservoirs

Two main types of closed reservoirs, named also storage tanks, are used in water reclamation systems: under-ground and above-ground tanks.

The selection and design of storage tanks depend on topography, land availability and cost consideration. Above-ground tanks are always cheaper than under-ground constructions. They have some advantages, as for example lower unit power costs, because they can be filled during off-peak power demand hours and water can be delivered by gravity during peak-power demand hours.

8.2.4 Aquifer storage and recovery

Reclaimed water for non-potable supplies, such as irrigation and ecosystem restoration, can also be stored in non-potable aquifers when the excess reclaimed water quality meets the considerations of the aquifers. The aquifers for reclaimed water storage cannot be used directly (without additional treatment) as a drinking water source. It is important to make sure that the aquifers do not have connections with drinking water aquifer. As the storage situations and site conditions are complex, hydrogeological issues should be considered and precautions should be taken to prevent groundwater contamination, the potential to cause release of naturally occurring harmful compounds such as arsenic and potential connections with groundwater used for potable supply. In each case, specific circumstances should be taken into account [22] [23] [24] [25].

NOTE For aquifer storage and recovery, it is important that those using water from the aquifer are aware so that either certain quality standards can be agreed before the aquifer recharge or appropriate monitoring/treatment processes can be put in place at the point-of-use.

8.3 Storage considerations

Depending on the objectives, storage considerations can be categorized into operational and seasonal. These aspects should be considered in the storage design and may have a significant impact on the capital cost of the system.

Operational storage should be used to accommodate daily or temporary fluctuations of flows to:

- balance the input and output of the reclaimed water flow through the system,
- provide emergency storage for retention, retreatment, or disposal of unacceptably treated reclaimed water, and
- allow appropriate and controlled discharge to the environment.

Facilities such as reservoirs or ponds, either open or covered, can be used for operational storage. In particular, structural steel or flexible covers are recommended for concrete tanks. Low cost plastic reservoirs are often used for small storage systems.

Seasonal storage is used to

- retain excess reclaimed water during a specific period of low demand or high source water volume, e.g. rain events or rainy seasons,
- ensure that sufficient water is available to meet peak demand,
- maximize the use of available reclaimed water, and
- provide long-term storage.

A large water reuse system can contain more than one seasonal storage facility.

Several factors should be considered when selecting the optimal storage site, including hydraulic and hydrologic conditions, proximity to users, the end use of the water and related water quality, land availability, zoning, topography, site accessibility, soil condition, hazards and construction. Reuse water may also be stored at the utility's facilities, such as the distribution point, or at a location specified by the customer.

Earthen lined ponds are commonly used for long-term seasonal storage.

8.4 Size of the storage facility and turnover considerations

Storage size considerations can generally be estimated from the sum of the average daily use (peak and off-peak demand), firefighting and/or other emergency considerations, capacity to offset maintenance or pipe breaks and additional capacity for future demand. Other factors should also be considered, including the types of users, potential peak demands (daily and seasonal) and fluctuations, potential for concurrent peaks, water delivery pressures, flow velocity, staggered times of end use water consumption, acceptable duration of an interruption in the service and availability of other supplies.

As well as meeting peak demand, the turnover at the storage facilities should be adequate at other times of reduced demand. Unused water can turn stagnant and can develop unwanted tastes and odours due to fermentation of organics and sediments. In cold climates, freezing may occur when turnover is inadequate. A recirculation or mixing system may solve the water turnover issue.

8.5 Control of water quality

Physical, chemical and biological processes (as shown in [Table 1](#)), as well as external contamination may cause deterioration of the quality of stored reclaimed water.

Table 1 — Common water quality problems associated with reuse water storage

Physical issues	Chemical issues	Biological issues
Temperature	pH and alkalinity changes	Algal growth
Turbidity	Chemical contaminants	Microbial regrowth
Suspended solids	Disinfection byproducts formation	Eutrophication
Aesthetic (odour, colour and turbidity)	Taste and odours	Microbial contamination

NOTE Adapted from US EPA (2012).

Water quality issues are interrelated. The water quality control should be based on a water reuse safety evaluation designed fit-for-purpose, according to the end uses. Management strategies should be implemented such as source control and/or hazard reduction through nutrient removal, turbidity management, residual chlorine management, restriction of light sources and hydraulic retention time limitations. Efficient algae control can be achieved through tank destratification, nutrient control, chemical treatment, or installation of fine mesh screens at the reservoir outlet or ultrasonic treatment. If aquifer storage is used, salinity should be controlled. Additional treatment including rechlorination should be performed to maintain the quality of the reclaimed water at the point-of-use.

8.6 Specific considerations for open storage reservoirs

8.6.1 General

There are major concerns about evaporation and water quality related to open storage facilities such as surface reservoirs and ponds.

8.6.2 Evaporation

Significant evaporation can occur from open storage facilities. The larger the surface area per unit of volume of the facility, the greater the evaporation loss. The loss through evaporation should be calculated and included in the estimation of the storage facility size. As well as water loss, long-term evaporation can lead to increased salinity of the reclaimed water. Compensating inflows from direct precipitation or other sources may offset evaporative losses.

8.6.3 Control of water quality

Open storage systems are characterized by high risk of water quality deterioration. The water quality can be influenced by external contaminants, such as excrement from birds and other animals,

microorganisms from windblown dust and debris, organic matter, algal blooms, microalgae growth and uncontrolled surface inflows. Special attention should be given to algal growth and external pathogen contamination (e.g. avian and other virus contamination by birds). For this reason, closed tanks are recommended for all urban uses with high health risk (potential of direct contact with reclaimed water).

Adequate management strategies should be implemented to prevent water quality degradation (e.g. anaerobic conditions may develop in closed tanks) or to ensure additional treatment before distribution.

8.6.4 Post-treatment facilities

If reclaimed water quality deteriorates during open storage, it should be post-treated, depending on the water quality targets and specific considerations. Post-treatment approaches may include one or more of the following options:

- a) filtration facilities such as filters or artificial wetlands to purify reclaimed water;
- b) control of the hydraulic retention time, or other methods and equipment to prevent excessive algal growth (e.g. ultrasonic technology);
- c) destratification systems to maintain the homogeneity of the reclaimed water;
- d) rechlorination to ensure additional disinfection and maintain the residual chlorine in storage and distribution systems.

9 Reclaimed water transmission and distribution system

9.1 General

The design of a reclaimed water transmission and distribution system should consider the system components, supply models, pipe materials, colour and sign identification as well as water quality control [26] [27] [28]. In many ways, the design of a reclaimed water distribution system is similar to a drinking water distribution system, because water quality and quantity should meet high safety and reliability standards. The major differences between the system design of a reclaimed water distribution system and a drinking water distribution system include demand management and specific considerations for cross-connection control.

9.2 Components and models of the distribution system

9.2.1 Components

The main components of a reuse water distribution system should include pumping stations, storage and transmission and distribution pipelines (as shown in Figure 6). The distribution storage is discussed in Clause 9.4.

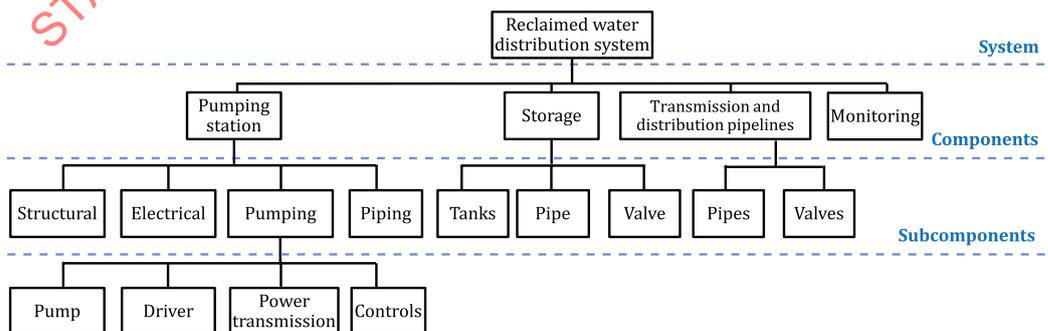


Figure 6 — Example of system components of a reuse water distribution system

9.2.2 Models

In urban areas, a “dual distribution system” is commonly implemented which refers to two separate water piping systems distributing water to users, one carrying drinking water and the other conveying reclaimed water for non-potable purposes. The reuse water distribution system is a separate system from and/or in parallel to the drinking water distribution system.

In developed areas, where there is an existing drinking water distribution system in operation, retrofitting issues should be addressed in further reclaimed water distribution system planning, design and construction.

In newly developed areas, integrated planning, design and construction of drinking water and reclaimed water distribution systems offer advantages in both water resource management and cost savings.

9.2.3 Design principles

The principles of safety, reliability, stability and economic viability should be incorporated in the design of a reuse water distribution system.

For safety concerns, the prevention of cross-connection, improper use of reclaimed water and improper operation of the system are important considerations in the design of any reuse water distribution system. The safeguards can be adjusted to meet the specific aspects of the utility, user and regulator.

The reliability of a reuse water distribution system is usually not as great as that of a drinking water distribution system. In many cases (e.g. when using intermediate storage), the reclaimed water distribution system can tolerate interruptions (e.g. few hours or one day) without undue harm. User service agreements may include provisions relating to the acceptable length of service interruptions.

For stability concerns, reclaimed water in the distribution system should be protected from microbial and/or chemical contamination. Periodic water sampling and analysis from distribution system is recommended.

For economic issues, the cost-effectiveness of the reclaimed water distribution system should be analysed. The initial capital costs for design, construction and system development and the expenses for operation and maintenance (e.g. costs of meters, cross-connection control measures and retrofitting of pipes, plan check and inspection) can be evaluated.

For environmental concerns, the potential impacts of reclaimed water transmission and distribution system on ambient land, ecosystem, air quality, noise levels and surface and groundwater quality and quantity can be taken into account.

9.3 Pumping stations

9.3.1 General

Pumping stations should be designed to ensure that the distribution system is sufficiently reliable to achieve the range of delivery pressures and the flow velocity of the supply. If the system is designed to serve all customers from a central location, a combination of elevated storage, ground storage and booster pumping stations should be used to maintain the system pressure and flow velocity. In addition, the design of a pumping station can consider possible expansion. Therefore, adequate space should be provided for additional pumps and equipment.

9.3.2 Reclaimed water delivery pressure

An adequate system delivery pressure should be maintained to satisfy the customer demands in the service area. Several factors should be considered when determining the minimum and maximum delivery pressures, such as the types of end use, end use demands, peak demands, pipe material limitations and pressure losses between the water mains and the point-of-use.

Peak demands and a large range in the pressure considerations mean that it is difficult to maintain delivery at a constant pressure. Under these conditions, it can be necessary to optimize the water transmission to users and provide onsite storage for large users.

To provide an additional level of safety, it is recommended the reuse distribution network is operated at pressures lower than the potable system, while maintaining usability, to limit the risks of drinking water contamination from unauthorised cross-connections.

9.3.3 Flow velocity of reclaimed water

Minimum and maximum flow velocities and head losses, should be carefully evaluated when designing reclaimed water distribution systems. The flow velocity mainly depends on the quantity of produced reclaimed water, consumption demand and adjustment capacity.

9.4 Reclaimed water distribution systems

9.4.1 Avoiding stagnant conditions

Ideally, where possible, the reclaimed water distribution systems should be looped to minimize the potential for stagnant conditions that might otherwise occur in a branch network. The initial distribution network should distribute reclaimed water safely and reliably to the customers. If possible, dead end pipes should be avoided or minimized (including within buildings) to avoid potential water quality changes due to high hydraulic retention time, bacterial regrowth and pipeline corrosion. In stagnant conditions, chlorine residuals may be difficult to maintain and oxygen can be lost with potential odour generation. Hence, some actions can be adopted to deal with these conditions (e.g. a blow-off can be installed which can be periodically opened to allow draining or flushing of the pipeline for maintenance or inspection). Future demands and costs should be considered when designing an effective distribution system.

9.4.2 Pipeline layout and materials

A distribution network normally consists of one or more major and several minor pipelines that ensure delivery of the reclaimed water to end uses. Knowledge of the location of the major end uses and their spatial distribution within a community are the main criteria for the design of pipeline routes. The main pipe should be constructed in a location that will allow connections to both future pipelines and previously identified large water users. Drinking water mains should be protected and should be above and with an adequate horizontal separation when running parallel to reclaimed or wastewater pipes. In addition, reclaimed water lines should be designed with adequate vertical and horizontal separation with wastewater piping.

Various factors should be considered when choosing the pipeline material, such as the anticipated quality of the reclaimed water, pressure, water flows, geological conditions and technical and economic feasibility. The side effects of some chemicals, such as chlorine, on pipeline materials should be considered. Pipeline materials used in reclaimed water distribution systems include ductile iron, steel, polyvinyl chloride, high-density polyethylene and glass-fibre reinforced polyester.

9.4.3 Water quality in distribution systems

To maintain a high quality of reclaimed water, chlorine is commonly used as a residual disinfectant to control biofilm growth in distribution systems. The residual chlorine level is determined by the residence time of the reclaimed water in the distribution system and the chlorine demands of the reclaimed water. Re-chlorination should be considered at the intermediate storage and booster pumping stations to maintain the desired level of residual chlorine until the point-of-use. If the reclaimed water is discharged to a stream for the purposes of augmenting its flow, it is also important to consider the necessity of dechlorination prior to water release, to protect the aquatic environment or consider alternative disinfection technologies (e.g. ozonation, ultraviolet light, copper sulfate, peracetic acid and pasteurization) to avoid the potential formation of disinfection byproducts and reduce aquatic toxicity.