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Guidelines for softening and desalination of industrial wastewater for reuse

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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).

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

This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 4, *Industrial water reuse*.

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

Introduction

With the development of society and economy, the contradiction between water shortage and industrial growth is becoming increasingly acute. Industrial wastewater reclamation and reuse could be an effective way to alleviate this contradiction by improving the water utilization efficiency[4]. Industrial processes such as oil extraction, chemicals production, printing and dyeing, pharmaceuticals manufacturing and food processing[5] produce the wastewater containing total dissolved solids. In order to reuse these wastewater, total dissolved solids need to be removed by using water softening and desalination technologies[6].

Currently, wastewater softening and desalination processes are based on chemical precipitation, ion exchange, nanofiltration (NF), evaporation, reverse osmosis (RO), electrodeionization (EDI), electrodialysis (ED), membrane distillation (MD), and so on, see References [7] to [10]. Each technology has different applicable conditions and operational costs. The absence of an international standard to provide guidance on the selection of wastewater softening and desalination processes makes it difficult to determine the most appropriate softening or desalination technology for industrial enterprises. Therefore, it hinders industrial wastewater reclamation and reuse. Six technologies have been selected for consideration under this document, including chemical precipitation, ion exchange, nanofiltration (NF), reverse osmosis (RO), electrodialysis (ED), electrodeionization (EDI), and there are other technologies that could be similarly considered for future updates. It should be noted that mechanical vapour recompression (MVR) and multi-effect evaporation (MEE) are mainly used for evaporation and crystallization to acquire salts, not for the purpose of water reuse.

Based on the specific inorganic ion species and their concentration in influent, appropriate effluent quality can be obtained using the recommended technologies that meets the requirement for hardness, alkalinity and salinity for potential reuse applications.

This document is an innovative standard in the field of industrial wastewater reclamation and reuse. It can help enterprises, engineers, operators and other stakeholders, who engage in designing or operating in industrial saline wastewater reclamation and reuse, choose the technologies applying in the process, and evaluate the treatment effects. As a result, the reuse of industrial saline wastewater can be promoted and utilization of water can be improved.

Guidelines for softening and desalination of industrial wastewater for reuse

1 Scope

This document provides guidance on, the evaluation and comparison of wastewater softening and desalination processes for industrial wastewater reclamation and reuse with specific consideration for the following six: 1) chemical precipitation; 2) ion exchange; 3) nanofiltration (NF); 4) reverse osmosis (RO); 5) electrodialysis (ED) and 6) electrodeionization (EDI). This document provides guidance on the characterisation of both influent and effluent quality (e.g. hardness, alkalinity, etc.) and the effects of these processes on those constituents. The purpose of softening and desalination is only for the reuse usages that have requirements for hardness and salinity, such as cooling circulating water, boiler water, production process water, and cleaning water.

This document includes the following sub-processes of wastewater softening and desalination processes:

a) wastewater softening processes based on chemical precipitation, ion exchange and NF, which aim to remove hardness ions, such as Mg^{2+} and Ca^{2+};

b) desalination processes based on ion exchange, RO, ED, EDI and NF, which aim to remove the most of total dissolved solids (TDS).

This document is applicable to:

a) industrial saline wastewater, which has been pre-treated to remove most of the organic matters if necessary;

b) the selection or design of wastewater softening and desalination processes for reuse of wastewater from industries.

2 Normative references

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

ISO 20670, *Water reuse — Vocabulary*

3 Terms, definitions and abbreviated terms

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 http://www.iso.org/obp

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

3.1 Terms and definitions

3.1.1
regeneration
process of restoring an ion-exchange resin after use to its operationally effective state

Note 1 to entry: Two types of generation can occur: co-current regeneration and counter-current regeneration. Co-current regeneration is original downflow process where both input water and regeneration chemicals flow in the same direction, while counter-current regeneration is upflow process where input water and regeneration chemicals flow in different directions.

3.1.2
electrodeionization
method for removing ions by combination of mixed bed ion exchange and electrodialysis in an electrodialyser, where the fresh water chamber is filled with mixed bed ion exchange resin, and the ion exchange resin can be electrochemically regenerated by polarization during the electrodialysis process

Note 1 to entry: Generally, it is a polishing process for production of ultrapure reclaimed water and used after reverse osmosis.

3.1.3
electrodialysis
process used for the deionization of water in which ions are removed, under the influence of an electric field, from one body of water and transferred to another across an ion-exchange membrane

[SOURCE: ISO 6107-1:2004, 32]

3.1.4
industrial saline wastewater
industrial wastewater that contains high concentration of inorganic ions

3.1.5
ion exchange
process by which certain anions or cations in water are replaced by other ions by passage through a bed of ion-exchange material

[SOURCE: ISO 6107-1:2004, 46]

3.1.6
mechanical vapour recompression
use of the heat of the secondary steam as a heat source instead of fresh steam by raising its temperature, with a part of the compressor working to achieve cyclic evaporation

3.1.7
membrane distillation
separation process where a micro-porous hydrophobic membrane separates two aqueous solutions at different temperatures

3.1.8
microfiltration
type of physical filtration process by pressure driven where a contaminated liquid is passed through a special pore-sized membrane (0,1-1 µm) to separate microorganisms and suspended particles from process liquid

3.1.9
multi-effect evaporation
use of microporous membranes with a filtration accuracy of 0,01-0,1 µm for the separation of microorganisms, large molecules or very finely divided suspended matter from water by filtration, often by means of applied differential pressure

3.1.10
nanofiltration
membrane separation technology with a filtration accuracy of 0,001-0,01 µm to separate proteins and low molecular organic compounds

3.1.11
precipitation
chemical reaction in solution resulting in the formation of a solid product

[SOURCE: ISO 11074:2015, 6.4.30]

3.1.12
pre-treatment
treatment process or processes carried out before the softening and desalination processes

3.1.13
reverse osmosis
flow of water through a membrane with a filtration accuracy of 0,000 1-0,001 µm, from a more concentrated to a less concentrated solution, as a result of applying pressure to the more concentrated solution in excess of the normal osmotic pressure

Note 1 to entry: The filtration accuracy of membrane is added.

[SOURCE: ISO 6107-1:2004, 61]

3.1.14
softening
partial or complete removal from water of calcium and magnesium ions which are responsible for hardness

Note 1 to entry: In this context, not only calcium and magnesium ions are removed, other inorganic ions and cations are also included.

[SOURCE: ISO 6107-1:2004, 68]

3.1.15
ultrafiltration
use of microporous membranes with a filtration accuracy of 0,01-0,1 µm for the separation of large molecules or very finely divided suspended matter from water by filtration, often by means of applied differential pressure

Note 1 to entry: The filtration accuracy of microporous membranes is added.

[SOURCE: ISO 6107-6:2004, 100]

3.2 Abbreviated terms

BOD_5 biochemical oxygen demand after 5 days

COD chemical oxygen demand

DO dissolved oxygen

ED electrodialysis

EDI electrodeionization

MF microfiltration

NF nanofiltration

RO reverse osmosis

TDS total dissolved solids

TOC total organic carbon

TSS total suspended solids

UF ultrafiltration

MD membrane distillation

MEE multi-effect evaporation

MVR mechanical vapor recompression

4 General

Water quality indicators should include TSS, TOC, COD, pH, temperature, TDS, the species and concentrations of ions.

The product water from wastewater softening and desalination processes is recommended to be reused for urban non-potable water, environmental water, and as pure or ultrapure water for cooling water, boiler feed water, process water, rinse water, and so on[4].

The process selection of wastewater softening and desalination processes should be determined after technical and economic comparison based on factors such as influent quality, product quality, quantity requirements, site conditions and environmental protection requirements.

The wastewater needs to be pre-treated if necessary, before being fed into softening and desalination devices.

The selection of pre-treatment process should consider the quality of wastewater, influent quality requirements for softening and desalination processes, water treatment volume and test data. Besides, the operational experience of similar projects should be referred, combined with local conditions. Finally, users can determine which technology to adopt through technical and economic comparison.

Minimizing the discharge quantity of waste acid, waste alkali, waste residue and other harmful substances are important in the selection of softening and desalination processes or device. Measures for treating and disposing these wastes should be taken to meet the relevant environmental protection requirements.

Waste liquid (e.g., regeneration liquid of ion exchange resin process, concentrate of reverse osmosis process, etc.) disposed from the softening and desalination processes should be collected separately according to the characteristics of wastewater quality.

Process flow diagram of industrial saline wastewater treatment for reuse is shown in Figure 1.

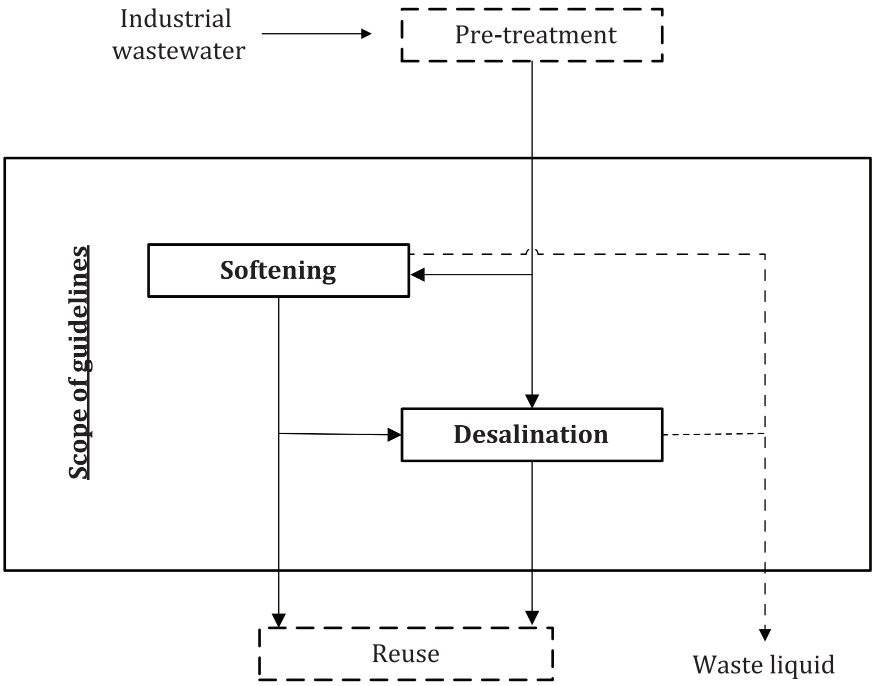

Figure 1 — Process flow diagram of industrial saline wastewater treatment for reuse

5 Requirements for influent quality

Influent quality requirements for softening and desalination device are shown in Table 1. It is noted that data provided in this table is all in advisory typical ranges, which is suggested to be applied according to specific conditions, as well as the manufacturer's specifications. The parameters listed in Table 1 are also illustrated as follows to show its effect on softening and desalination devices.

a) Silt density index (SDI) reflects the content of particles, colloids, and other objects in influent that can block softening and desalination devices. SDI values higher than the limit can easily block the membrane which will lead to fouling, thereby shortening the operating life of the membrane.

b) Turbidity represents the concentration of undissolved matters in influent that reduce transparency. These undissolved matters can adhere to surface of ion exchange resin, and then block the exchange channel or pollute resin. It can also cause membrane fouling.

c) Water temperature can affect ion exchange rate and ion absorption ability of resin. It also can affect membrane flux and TDS removal ability of membrane.

d) pH can affect TDS removal ability of membrane and shorten its operating life if exceed typical range.

e) Chemical oxygen demand refers to organic matters which can easily pollute anion exchange resin, because it is difficult to precipitate after the reaction with the anion exchange resin.

f) Appropriate residual chlorine can ensure the sterilization ability for water quality. However, resin is combined with macromolecular organic compounds those can be easily oxidized by high concentration of chloride to break the chemical structure, and then ion exchange ability of resin would be weakened. High residual chlorine can also oxide membrane element and make an irreparable damage[11].

g) Iron and manganese can be intercepted by resin to form adsorbent that is not easy to wash off. The resin would lose function as the reaction is not reversible. In addition, both iron and manganese can accelerate the oxidation of the membrane and cause irreversible damage to the membrane element.

