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Guidelines for treatment and reuse of leachate from municipal solid waste (MSW) incineration plants

Lignes directrices pour le traitement et la réutilisation du lixiviat provenant des installations d'incinération des déchets ménagers

Reference number
ISO 24297:2022(E)

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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).

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

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

Introduction

Commonly used methods for disposal of municipal solid waste (MSW) include landfilling, incineration and composting (Annex D), and each of these methods generates leachate. Leachate is a kind of wastewater containing highly concentrated organic contaminants that can pose a high risk to the environment. It is necessary for leachate to have proper treatment before being discharged or reused to avoid adverse impacts on the environment. Due to the differences in duration of waste stacking and fermenting, leachate from different MSW disposal methods varies significantly in the concentration and biodegradability of organic matter, which requires tailored treatment processes. Leachate generated from MSW incineration plants has a higher concentration of biodegradable organic pollutants, and thus degrades more easily than leachate from landfills and composting plants. Due to higher quality requirements for water reuse in MSW incineration plants, this document focuses on leachate treatment and reuse in MSW incineration plants.

In MSW incineration plants the MSW first enters the unloading platform and then goes to the MSW pit, where stacking and fermentation occurs. The stacking and fermenting process aims to reduce moisture content of the MSW before incineration. The MSW leachate has a strong odour and high concentrations of organic and inorganic compounds; it includes stacking and fermenting wastewater and unloading platform flushing water. Many kinds of wastewater, such as municipal wastewater, industrial wastewater and stormwater, are used as sources of reclaimed water to address worldwide water shortages caused by economic growth, increasing populations, climate change and other factors.

The quality and quantity of MSW leachate can vary based on climate, residents' living habits, composition of waste and waste collection and separation systems. Therefore, leachate treatment can be more challenging than other kinds of wastewater treatment. Due to the complex composition of leachate and the high concentrations of pollutants, a combined treatment process is usually necessary for leachate treatment to meet environmental requirements and intended reuse applications. The essential components of the leachate treatment and reuse system include pretreatment, biological treatment and advanced treatment.

In consideration of the problems in the treatment of MSW leachate and the absence of relevant International Standards, an integrated standard is needed to guide the treatment and reuse of MSW leachate.

This document aims to provide design and operation principles and advice for MSW leachate treatment and reuse in MSW incineration plants. It considers and addresses the critical issues and factors in the design and operation of treatment and reuse systems and is intended to assist engineers, authorities, decision-makers and stakeholders in providing a clear structure and feasible approach for safe and reliable treatment and reuse of MSW leachate.

Guidelines for treatment and reuse of leachate from municipal solid waste (MSW) incineration plants

1 Scope

This document provides guidelines for the treatment and reuse of MSW leachate.

It is applicable to personnel involved in the design, management, operation and supervision of the treatment and reuse of MSW leachate and environmental authorities engaged in regulation.

2 Normative references

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

ISO 20670, *Water reuse — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20670 and the following apply.

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

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

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

3.1
municipal solid waste
MSW
waste stream consisting of end-of-life-materials

[SOURCE: ISO 16559:2022, 3.135, modified — Notes to entry removed.]

3.2
MSW leachate
mixture of flushing water from the waste unloading platform and wastewater generated during the *stacking and fermenting* (3.3) process

3.3
stacking and fermenting
process to reduce moisture content of MSW and to degrade the organic materials in a MSW pit, during which leachate is generated

3.4
leachate treatment system
treatment units that receive and treat municipal solid waste leachate

Note 1 to entry: Leachate treatment systems include those for preliminary treatment, biological treatment, advanced treatment, disposal of sludge and concentrate and odour control.

3.5
aerobic biological treatment
biological treatment in the presence of oxygen

[SOURCE: ISO 11074:2015, 6.4.1]

3.6
anoxic biological treatment
biological treatment process in which nitrate and/or nitrite are reduced by microbes in the absence of, or with minimal, dissolved oxygen concentration with molecular nitrogen (N_2) ultimately produced

3.7
membrane bioreactor
MBR
integrated wastewater treatment process combining a suspended growth biological treatment and a membrane filtration system (UF/MF membrane) replacing conventional secondary clarifier

Note 1 to entry: The MF or UF membrane is submerged in the biological reactor (submerged MBR). Another configuration has pressurized membrane modules externally coupled to the bioreactor, with the biomass recirculated between the membrane modules and the bioreactor by pumping (side-stream MBR).

[SOURCE: ISO 20468-5:2021, 3.1.12]

3.8
filtrate
liquid by-product from a filter press or other sludge dewatering devices

4 Abbreviated terms

A/O anoxic or aerobic biological treatment

BOD_5 five-day biochemical oxygen demand

CAPEX capital expenditure

COD_{Cr} chemical oxygen demand

DO dissolved oxygen

DTRO disc-tube reverse osmosis

HRT hydraulic retention time

IC internal circulation anaerobic reactor

MBR membrane bioreactor

MF microfiltration

MLSS mixed liquor suspended solids

MVR mechanical vapour recompression

NF nanofiltration

NH_4^+-N ammonium nitrogen as N

OLR organic loading rate

OPEX operating expenditure

ORP oxidation-reduction potential

RO reverse osmosis

SBR sequencing batch reactor

SCE submerged combustion evaporation

SDI silt density index

SS suspended solids

STRO spiral-tube reverse osmosis

TDS total dissolved solids

TN total nitrogen

TP total phosphorus

UASB upflow anaerobic sludge blanket reactor

UBF upflow anaerobic sludge bed-filter reactor

UF ultrafiltration

VFA volatile fatty acids

5 General principles

5.1 General

The principles of safety, reliability, stability and economic viability and sustainability should be incorporated in the design of the treatment and reuse system for the MSW leachate. The quality of treated leachate should meet requirements for water reuse applications, be appropriate and safe for end users and protect human health and the environment from the adverse impacts of pathogens, toxic chemical contaminants and nutrients contained in the leachate.

5.2 Safety

The MSW leachate can contain highly concentrated salts, refractory organics, ammonium nitrogen, pathogens and heavy metals, which can impact human health, the environment and equipment. For example, highly concentrated salts can cause soil salinization, scaling and corrosion of equipment. Organics and ammonium nitrogen can pollute water. Heavy metals and pathogens can impact human health. It is important to take into consideration the quality of treated leachate in terms of physical, chemical and microbiological indicators to ensure safe reuse.

Mature and reliable technologies should be applied to attaining required effluent and reuse quality, as well as minimizing adverse environmental impacts. Validated and verified new technologies, processes, materials and equipment can also be adopted to improve treatment efficiency and effectiveness, optimize operation and management, save energy and reduce capital expenditure (CAPEX) and operating expenditure (OPEX). In addition, the quantity and quality of the leachate, the objectives of treatment, the intended purpose for water reuse, technological performance of the treatment facilities, location of the treatment facilities and land availability should be considered in the selection of technology and design of the process.

5.3 Reliability

The characteristics of the MSW leachate should be considered to ensure that the treatment and reuse system can perform its prescribed function without failure and the effluent quality can meet the demand of intended reuse purposes. The following aspects should be considered to ensure the reliability of the treatment and reuse system:

a) the peak leachate quality and quantity;

b) the demand for water reuse applications;

c) redundancy of systems and/or equipment;

d) effectiveness and efficiency of treatment technologies and processes;

e) monitoring programme, including operational monitoring, water quality monitoring, alarm systems and response plans for critical aspects to detect the performance of treatment processes and effluent quality;

f) operations, control and proactive maintenance.

5.4 Stability

When designing the treatment system, the operational stability and effluent quality stability should be assessed to ensure that the requirements of intended reuse applications are met. In view of the complexities of the leachate quality, a combined process approach and online monitoring system should be adopted to reduce the risks of effluent non-compliance. Redundant systems can also be considered, which involves the addition of measures beyond the minimum needs to ensure performance targets are consistently achieved.

The stability of treated leachate quality should also be considered by assessing parameters, such as pH, alkalinity, temperature, hardness, anions such as sulfate and chloride and cations such as calcium and magnesium.

5.5 Economic sustainability

Economic evaluations should consider both CAPEX and OPEX. CAPEX includes acquiring property, plants, buildings, technology or equipment. OPEX includes operation, maintenance and repair. An economic and technological comparison between different technologies should be conducted, taking into account, for example, quality and quantity of the leachate, demand of water reuse applications and energy cost, before designing a proper leachate treatment system.

5.6 Environment

The reuse of treated leachate should consider the environmental impacts of contaminants in leachate. Water sampling should be at the main outlet of the reclaimed water system.

Preventive measures should be implemented to avoid adverse impacts caused by residual sludge, odour, concentrate and noise generated during the operation of the leachate treatment and reuse system on the ambient ecosystem (soil, air quality, noise levels and surface and groundwater).

6 Quantity and quality of the MSW leachate

6.1 Quantity

MSW leachate is generated principally by flushing the unloading platform and waste stacking and fermenting, as shown in Figure 1. The determination of the quantity of leachate produced is of critical concern for the design and operation of the treatment and reuse system. In general, the quantity of the leachate generated from waste stacking and fermenting can be estimated based on the available data from local MSW incineration plants or those in other similar regions. In the absence of reference information, the quantity of the leachate can be estimated according to the MSW moisture content and duration of waste stacking and fermenting. The quantity of flushing water can be estimated based on the water consumption in a single flushing and the frequency of flushing. Cases of leachate quantity data are given in Annex B.

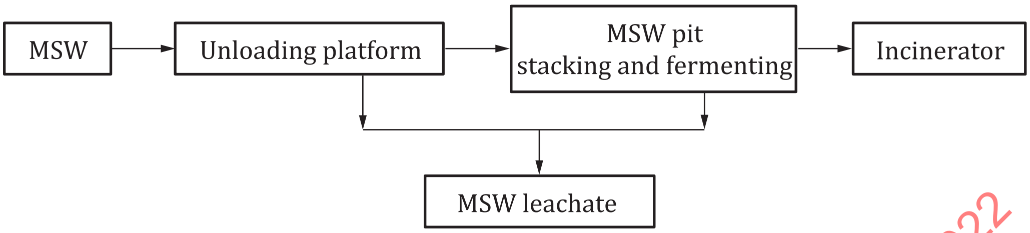


Figure 1 — Flow chart of a typical MSW incineration plant

6.2 Quality

The MSW leachate varies in composition depending on the type of waste, and it can contain high concentrations of organic matters, ammonium nitrogen and salts. Concentration of COD_{Cr} can reach tens of thousands of milligrams per litre. Concentration of ammonium nitrogen and salts can also reach several thousand milligrams per litre. The high concentrations of contaminants bring challenges to the treatment process and if not treated properly can pose a potential risk to the environment. The quality characteristics of the leachate affect the design and operation of the treatment process. The readily biodegradable organic matter contained in MSW leachate makes biological processes practicable for treatment. However, the high concentrations of ammonium nitrogen and high salinity in the MSW leachate should be noted, as they can inhibit the microbial activity and thus affect the effectiveness and efficiency of the biological treatment process or overwhelm the biological treatment.

The typical ranges of quality characteristics of the MSW leachate are given in Table 1. When data on the leachate quality are unavailable, the value ranges given in Table 1 can serve as a reference for MSW incineration power plants.

Table 1 — Characteristics of the leachate quality[9]–[17]

Parameter	Units	Values
COD_{Cr}	mg/l	20 000 to 75 000
BOD_5	mg/l	10 000 to 50 000
NH_4^+-N	mg/l	500 to 2 500
TP	mg/l	50 to 150
TN	mg/l	1 500 to 3 000
SS	mg/l	1 000 to 15 000
pH	—	5 to 7
SO_4^{2-}	mg/l	50 to 3 000
S^{2-}	mg/l	0 to 50
TDS	mg/l	10 000 to 25 000
Cl^-	mg/l	500 to 5 000
Na	mg/l	1 000 to 4 000
Mg	mg/l	300 to 1 500
Ca	mg/l	500 to 6 000
Fe	mg/l	0 to 1 000
Mn	mg/l	0 to 50

Table 1 *(continued)*

Parameter	Units	Values
Zn	mg/l	0 to 50
Pb	mg/l	0 to 8
Ni	mg/l	0,05 to 5
As	µg/l	40 to 120
Pd	mg/l	0,05 to 0,2
Cr	mg/l	0,05 to 1,5

6.3 Influencing factors and considerations

The quantity and quality of the MSW leachate are affected by factors such as waste classification, waste collection and transportation system, composition of domestic waste, separation of organics and plastics, moisture content, duration of stacking and fermenting, seasonal changes, local climate and residents' living habits (Annex D). The varying waste classification systems from different areas can change the composition and moisture content of MSW and can impact the quantity and quality of leachate. In the rainy season or in rainy areas, the entry of rainwater during waste collection and transportation can increase the quantity of leachate and at the same time lower the concentration of the pollutants. Therefore, the factors mentioned should be fully considered when estimating the quantity and quality of the leachate.

In determining the quantity and quality of leachate, data comparisons with local MSW incineration plants and/or those in similar areas should also be considered in estimating ranges of the quality and quantity of the MSW leachate. To ensure that the MSW leachate can be treated in a timely manner, fluctuations of the quality and quantity of the leachate, and required operating time, should be considered in determining the capacity of the treatment system.

7 Treatment system design for the MSW leachate

7.1 Treatment process

MSW leachate has a high concentration of pollutants with complex constituents. Treatment process combinations with several different technologies are required to ensure the reliability and stability of the treatment system. The leachate treatment system (Figure 2) normally comprises preliminary treatment, biological treatment and advanced treatment. In some cases, the combined processes of preliminary treatment + advanced treatment or biological treatment + advanced treatment can also be adopted, depending on the quantity and quality of the leachate to be treated and the requirements for reclaimed water quality and use.

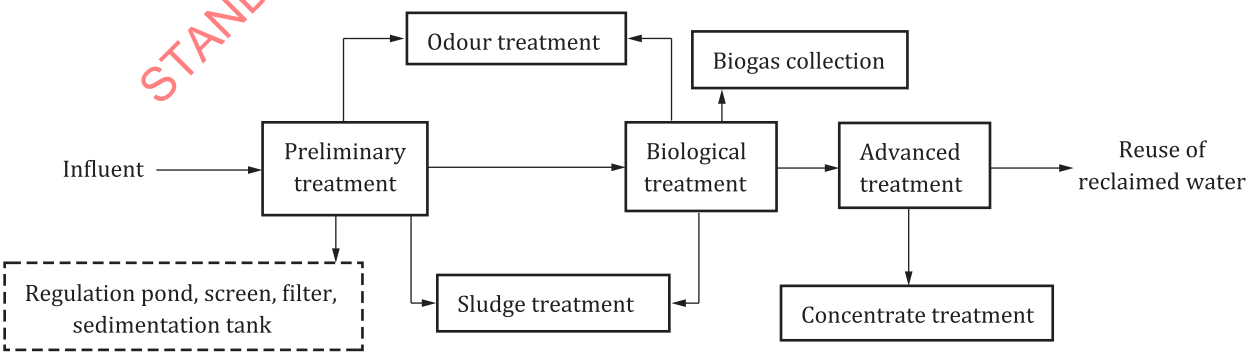


Figure 2 — Process flow chart of the leachate treatment system

To increase safety and address reliability concerns, if temporary interruptions are not allowed or alternative water resources are not available, equipment redundancy is required to ensure performance targets are consistently achieved without interruption during maintenance and overhaul of the treatment system. The treatment and reuse system should be designed in two or more trains so that the total treatment capacity of all trains is sufficient for treating all MSW leachate. If the design treatment capacity is relatively low, a single system design can also be considered.

The main objectives of preliminary treatment are to remove suspended solids (SS), gravel and other solid granules from the leachate to reduce the risks of abrasion, blockage and damage to pipelines and equipment. The technologies commonly used for the leachate preliminary treatment include screening, regulating, filtering and sedimentation. Adjustment and control of leachate quantity and quality entering the biological treatment process is required to ensure the stable performance of subsequent treatment units.

Biological treatment is considered as a better alternative for the complex water quality of the leachate due to its reliability, environmental friendliness and cost-effectiveness, and thus should be selected as the main treatment process. Biological treatment can include an anaerobic process followed by an aerobic process consisting of an anoxic unit and an aerobic unit. The anaerobic process is to remove the majority of the organic contaminants from the leachate, produce biogas and convert the organic nitrogen to ammonium nitrogen. The anoxic-aerobic units are used mainly to remove total nitrogen (TN) from the anaerobic digestion process effluent via reactions of nitrification and denitrification and further remove the remaining organics from the leachate. The resilience of biological treatment systems should accommodate to the potential impact of variable contaminant loadings in order to address the dramatic fluctuations in quality and quantity of leachate caused by seasonal variations and climate change.

For reference, operational parameters for the biological treatment process are provided in Annex A.

Advanced treatment is adopted in reuse system to remove total dissolved solids (TDS) and/or trace constituents (e.g. heavy metals), and especially salinity, from the effluent of the upstream unit, to ensure water quality meets the requirements for reclaimed water. Membrane filtration processes, including nanofiltration (NF) and reverse osmosis (RO), are generally used to remove TDS, salts and heavy metals. For reference, operational parameters for NF and RO are provided in Annex A.

7.2 Treatment system

7.2.1 Preliminary treatment

7.2.1.1 Sedimentation tank

In the sedimentation tank, high concentrations of SS or solid granules can be settled from the leachate through gravity to prevent deposition in the regulating pond. Based on the quantity of the leachate, vertical flow sedimentation tanks are usually installed.

7.2.1.2 Regulating pond

The regulating pond is used to equalize both the quality and quantity of the leachate to minimize variations to the subsequent biological treatment processes.

The regulating pond generally follows the sedimentation tank. A mixing device(s) should be included in the regulating pond to avoid settling anaerobic conditions to ensure a homogenized leachate. As leachate can generate unpleasant smells, odour-control measures should be taken in the regulating pond. Dredging can be needed depending on leachate SS. The hydraulic retention time (HRT) of the regulating pond should not be less than 7 days. Regulating ponds can also be used as emergency ponds.

7.2.1.3 Screen and filtering

Screen and filtering devices can be used to remove SS from the leachate before it flows into the subsequent treatment system, to reduce the pollutant load and protect piping and equipment (e.g. pumps) from being plugged or damaged.

7.2.2 Biological treatment

7.2.2.1 Anaerobic digestion system

Anaerobic digestion is mainly used to remove the organic pollutants in leachate. In general, the organics removal rate for the anaerobic digestion process should be controlled in order to obtain the objectives that the bulk of contaminants be biodegraded from the system effectively and efficiently and organics remain for the subsequent biological process, especially for denitrification.

The anaerobic digestion system consists of an anaerobic digester, heating and insulation, biogas collection and residual sludge disposal. Commonly used anaerobic digesters include upflow anaerobic sludge blanket reactors (UASBs), upflow blanket filter reactors (UBFs) and internal circulation reactors (ICs). Anaerobic digesters modified with the latest and validated technologies can also be considered.

The anaerobic digester can be constructed from reinforced concrete or steel. The inner wall of the reinforced concrete structure requires anti-corrosion treatment and both the inner and outer walls of the steel structure require anti-corrosion treatment. When the biogas produced by the anaerobic process is burned with a flare, multiple protective measures, such as flame arresters and water seals, should be included to prevent an explosion caused by flashback. The steel structure tanks should be equipped with breather valves, explosion-proof membranes and positive or negative pressure protection devices to maintain biogas pressure in the anaerobic digester within a normal range to avoid pressure fluctuations under abnormal conditions and damage to the structure of the anaerobic digester.

Explosion-proof equipment and other safety measures should be implemented to prevent explosions and fires in areas where generation and accumulation of flammable or explosive gases can occur, such as anaerobic digesters, regulating ponds and biogas collectors.

7.2.2.2 Anoxic or aerobic biological treatment process

The anoxic or aerobic biological treatment (A/O) process is mainly used to remove nitrogen and the remaining organic matter from the anaerobic digestion process effluent. The aeration system for the aerobic processes can use equipment such as jet aerators, aeration blowers and membrane aerators. Commonly used aerobic processes include oxidation ditches, pure oxygen aeration reactors, membrane bioreactors (MBRs), sequencing batch bioreactors (SBRs), biological aerated filters, contact oxidation tanks and rotating biological disks. An MBR system is widely used to ensure the effluent quality meets the requirements of influent quality to the subsequent advanced treatment systems (e.g. high-pressure membrane filtration by NF or RO) or discharge requirements. An MBR system normally consists of a bioreactor (aerobic unit) and UF/MF module in series. Membrane material with strong mechanical properties is recommended to avoid membrane damage to prevent SS and other contaminants from fouling the membrane. The types of MBR system generally include sidestream MBR (Figure 3) and submerged MBR (Figure 4).

A typical A/O process for when sidestream MBR is adopted is given in Figure 3.

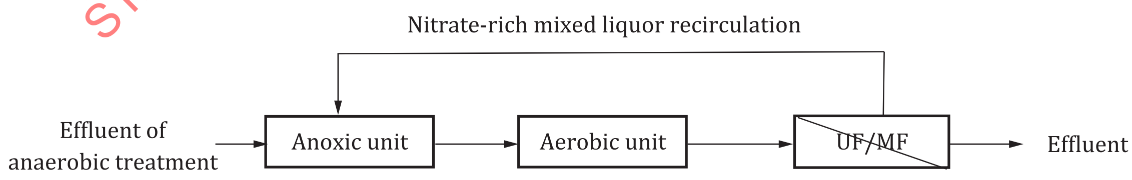


Figure 3 — Flow chart of a typical A/O process with sidestream MBR

A typical A/O process for when submerged MBR is adopted is given in Figure 4.

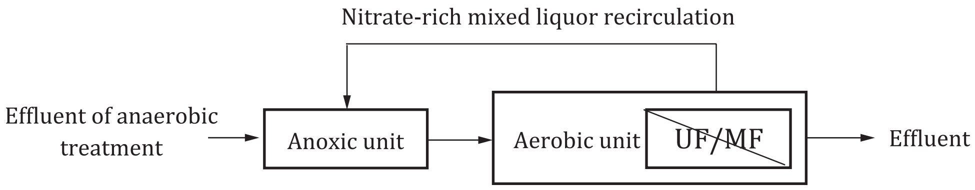


Figure 4 — Flow chart of a typical A/O process with submerged MBR

In some cases, the multiple-stage A/O process is selected to improve the effluent quality of the treatment system; a typical process flow chart is shown in Figure 5. An additional carbon source will possibly be required for the second stage A/O.

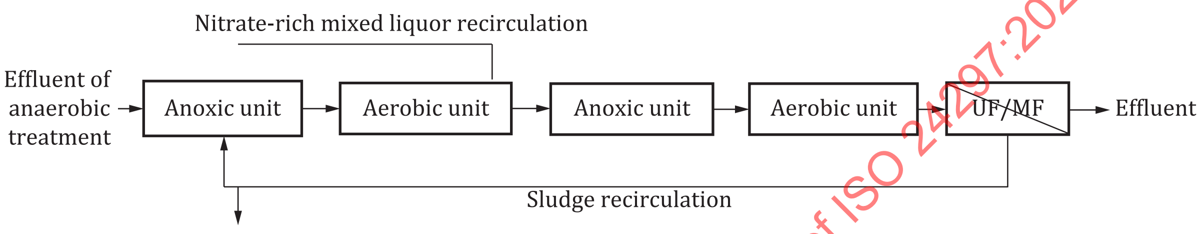


Figure 5 — Flow chart of a typical two-stage A/O process with sidestream MBR

Nitrate-rich mixed liquor from the aerobic MBR unit (Figures 3 and 4) is returned to the anoxic unit with the purpose of nitrate reduction and sludge recirculation. As a result, TN is removed from the system and the biomass concentration is able to be maintained at the desired level to ensure performance of the biological units.

In the multiple-stage A/O process (Figure 5), nitrate-rich mixed liquor is internally recirculated in the first-stage A/O process. As the SS concentration of mixed liquor recirculation is relatively low, the separated sludge from the UF/MF module in the second stage A/O process is returned to the first anoxic unit in order to avoid a decrease in biomass and ensure the performance of the multiple-stage biological process.

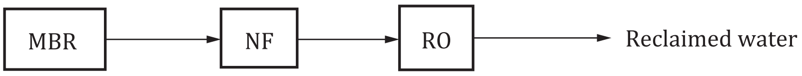
Based on local economic and technical conditions, SBR or other approximate processes can also be adopted to treat the effluent of anaerobic processes for nitrogen removal. In this case, a pilot study should be carried out before process selection.

Due to the high organic contaminant concentrations of leachate, a higher biomass concentration and longer HRT are required to ensure the performance of the A/O system. The biochemical reactions in the aerobic unit can produce heat, thus a cooling system for the aerobic unit should be provided in summer or in hot areas to prevent overheating in the unit. Bulking and foaming in activated sludge processes, caused by poor sedimentation performance of activated sludge, should be carefully controlled by adopting preventive and corrective measures (e.g. defoaming agents) in order to prevent the wash-out of biomass.

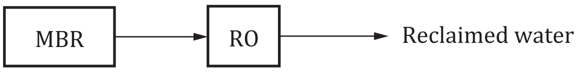
7.2.3 Advanced treatment for reuse

The selection of advanced treatment processes should be dependent on the effluent quality from the preceding biological treatment process(es), the requirements of the water reuse applications and the economic viability of reclaimed water system(s) for the processes. High-pressure membrane filtration systems, including nanofiltration (NF) and reverse osmosis (RO), are widely used as major components for advanced treatment.

Usually, the effluent of biological treatment processes (e.g. MBR) can directly enter the high-pressure membrane filtration system for advanced treatment. Effluent from non-MBR-type aerobic biological treatment processes should undergo UF treatment before entering the advanced treatment system (e.g. NF, RO). When the MBR process is implemented for the biological treatment process, the examples of combined processes for advanced treatment given in Figure 6 can be considered after taking into consideration the effluent quality of MBR and economics considerations.



a) Example I



b) Example II

Figure 6 — Typical examples of combined process for advanced treatment

DTRO and STRO can be considered in the reuse system.

To prevent or mitigate membrane fouling, substances (e.g. hardness, colloids, SiO_2) that can cause membrane fouling should be monitored and treated, if necessary, before feeding MBR effluent into the advanced treatment system.

Some other processes and technologies of wastewater treatment (Annex C) can be potential options for MSW leachate treatment.

7.3 Monitoring system

A sound monitoring programme, including operational monitoring and water-quality monitoring, should be carried out in real time or on a regular basis in order to ensure that the performance of treatment processes and effluent water quality are in compliance with target objectives and operation failures can be detected and solved in a timely manner. Online monitoring facilities should be equipped for providing monitoring data on system performance and water quality indicators. As part of the online monitoring system, alarm measures should also be implemented to ensure the emergency and performance deterioration can be identified in a timely manner. For parameters that cannot be measured online, an offline monitoring scheme should be established.

The key performance indicators and operating parameters should be monitored to provide timely information to indicate the potential operational non-compliance of the system. Special attention should be paid to the quality of the influent and operating parameters that can affect microbial activity and further affect the performance and stability of the leachate treatment system. The focus should be on key performance indicators such as COD_{Cr}, BOD_5, ammonium nitrogen, TN and total phosphorus. In addition, the monitoring of operating parameters for the anaerobic digestion process should include temperature, pH, VFA, biogas flow rate and pressure, alkalinity and ORP. The monitoring of operating parameters for anoxic units should include temperature, pH, ORP and MLSS. The monitoring of operating parameters for aerobic units should include temperature, DO and MLSS. The monitoring of operating parameters for NF and RO should include temperature, pH, pressure, COD_{Cr}, ammonium nitrogen, ORP, SDI, membrane flux, flow rate, salinity of the influent, permeate and concentrate streams.

To ensure normal operation of each treatment process and unit, an inspection plan and preventive maintenance measures should be developed to minimize the occurrence of system failures or malfunctions (e.g. equipment, instruments, buildings and structures of the treatment and reuse system) and improve process compliance of treatment and reuse systems.

7.4 Auxiliary treatment

7.4.1 General

The by-products, including excess sludge, concentrate, biogas, odour and noise created during the processes of the treatment and reuse of the leachate, should be controlled by auxiliary treatment systems in order to prevent adverse environmental impacts.

7.4.2 Sludge

The sludge is mainly generated in the processes of biological treatment and sedimentation. As the amount of sludge is relatively low, it can be dewatered to improve its heat value and incinerated together with MSW for power generation or be treated together with municipal sludge by a sustainable system. The filtrate from sludge dewatering can be treated together with or separately from the leachate.

7.4.3 Concentrate

7.4.3.1 General

Concentrate is generated in the high-pressure membrane treatment process and contains refractory organics, salinity and other contaminants. It is difficult to treat concentrate with a biological process.[18] The concentrate can be treated by processes such as incineration, evaporation crystallization, chemical oxidation or other capable processes. In some circumstances, the concentrate can also be reused for slag cooling or lime slurry preparation, which can be used for the treatment of flue gas from MSW incineration.

7.4.3.2 Incineration

Incineration is an economically efficient method that can be used to treat concentrate in MSW incineration plants. The injection of concentrate into incinerators should have no negative impact on MSW incineration.

Incineration of concentrate can lead to the accumulation of salinity in ash, and this issue should be considered in the disposal of ash.

7.4.3.3 Evaporation crystallization

Evaporation crystallization processes, including MVR and SCE, can be used to reduce the volume of concentrate.

In the MVR process, steam is compressed and then sent into an evaporator, where the heat is transferred to concentrate and used to vaporize the concentrate. In the SCE process, biogas produced in anaerobic digestion after purification is burned to heat the concentrate. The vapour produced from concentrate during evaporation crystallization is cooled and condensed. The condensed water can be reused in the plant if the water quality meets the requirements or discharged, with the evaporation residual sent to a landfill.

Thermal energy is needed in evaporation crystallization processes, and the vapour produced from concentrate heating can contain trace contaminants such as ammonia nitrogen and volatile organic compounds. Therefore, energy consumption, scaling of equipment and adverse environmental impacts of vapour emissions should be taken into consideration in the application of these processes.

7.4.3.4 Chemical oxidation

The chemical oxidation process is a potential treatment option for the removal of complex organic and inorganic pollutants from concentrate. Oxidation reactions are often pH-dependent and control of pH-values is an important consideration.

In concentrate treatment, the amount of chemical oxidant required can be greater than the theoretical value by calculation because the chemical oxidants can be consumed by other chemical reactions. Factors such as the rate of reaction, the oxidants available, the risk of adverse environmental impacts, the storage and handling of potentially hazardous chemicals and the removal efficiency of the pollutants should be evaluated because they can restrict the application of chemical oxidation. In addition, the cost of chemical oxidation should be taken into consideration.

For treatment of concentrate, ozone or hydrogen peroxide should be used as other oxidants can generate by-products. There is a potential for some chemical oxidation processes, such as wet air oxidation, and electrochemical systems, which are novel but have not been adopted to leachate treatment so far, to be developed and become alternatives for concentrate treatment in the future.

7.4.4 Biogas

The anaerobic reactor should be sealed and equipped with a gas collector. The biogas can be purified for safe and sustainable resource utilization and excess biogas can be combusted in a flare for safety and environmental impacts.

7.4.5 Odour

Odour-generating areas should be enclosed to minimize odours. The odour generated from the treatment of the leachate should be collected and treated centrally. The odorous gasses generated can be piped to the incinerator or to a separate treatment system.

7.4.6 Foam

The foam produced from the biological treatment process should be disposed of by means of chemical-physical treatment processes. The selected chemical reagents should not inhibit the activity of microbes in the biological treatment process or affect the performance of the subsequent membrane system.

7.4.7 Noise

Low-noise equipment is recommended and noise-control measures should be implemented at all the noise-generating sites.

8 Reuse of treated leachate

8.1 Reuse application considerations

To increase utilization of water recycling, especially in areas facing water scarcity, it is important to consider leachate as a water source. Water requirements in MSW incineration plants are high, and the main usage is for make-up water in cooling systems and production water. Reuse applications for treated leachate, such as irrigation of suitable plants, street cleaning and firefighting, should be considered in the plant. Reuse of treated leachate within the plant can reduce the environmental risk caused by the discharge of leachate and also effectively reduce freshwater consumption, providing environmental and economic benefits.

The collection of rainwater in the treatment facility is another source of reuse water.

8.2 Reclaimed water quality considerations

The quality of reclaimed water not only has a bearing on the safety of the surrounding environment, but is also a crucial consideration in the operation, maintenance and management of the reuse system. Due to the high concentrations of contaminants (e.g. organics, ammonium nitrogen, SS, metals and salinity) contained in leachate, consideration of the impact on environmental safety, occupational health and, stability and service life of the reuse system is necessary. In addition, as the leachate is coloured (brownish or dark brownish) and extremely odorous, aesthetic parameters, including colour, odour and appearance, should also be considered. When the reclaimed water is used as make-up water for cooling systems, see ISO 22449-1. When it is used for plant irrigation, see ISO 16075-2 and ISO 20419. For other purposes, see ISO 20761.

9 Environmental and occupational health and safety

9.1 Identification of health and safety risks

Leachate treatment and reuse involves a variety of equipment and chemicals. The variety of risks to which the operators are exposed in the use of the equipment and chemicals should be identified and managed. Proactive risk-identification methods should be established, including recognizing risks, defining their characteristics and evaluating adverse consequences, including potential loss and injury. Well-run risk-management facilitates successful health and safety programmes and minimize accidents.

Examples of methods that can be adopted to identify health and safety hazards to minimize incidents include:

— conducting hazard (or risk) surveys and job safety analyses;

— carrying out regular safety inspections of the workplace and periodic reviews of work procedures;

— encouraging workers to recognize and highlight hazards while performing work;

— analysing proposed new or modified plants, materials, processes or structures;

— reviewing past incidents and near-miss reports;

— ranking hazards based on severity and likelihood.

Examples of health and safety risks that can occur in the workplace of leachate treatment and reuse plants include:

— poisoning due to inadequate O_2 content or high toxic gas content when working in or near confined spaces;

— electric shock or fire hazards due to electrical hazards;

— falling, slipping and potential drowning when working at height or around tanks;

— potential physical injuries when working around exposed rotating equipment parts;

— exposure to corrosive material.

9.2 Establishment of health and safety programmes

Health and safety programmes for the leachate treatment and reuse systems should be established, covering occupational health and safety management systems, occupational disease control actions, preventive measures, safe work practices and operational procedures for various equipment.

When working in a confined space, such as a covered regulating pond, special attention should be paid to toxic and harmful gases. The operational specification for confined spaces should be strictly followed to avoid any accidents caused by toxic gases, such as hydrogen sulphide. Consider both minimizing confined space in the design of the plant, if possible, and the use of alternative options if available.

9.3 Safety considerations in system design

Treatment and reuse systems consist of a variety of processes and equipment, and thus reasonable system design and equipment configuration are indispensable to ensure safe operation.

Examples of safety considerations in system design and equipment configuration include the following:

— Guardrails or fences should be designed and installed surrounding the waste pit as well as on the top of buildings and constructions (e.g. anaerobic reactors, anoxic tanks, aerobic tanks).

— Pipelines, valves, outlets and appurtenances associated with water reuse systems can be painted a suitable colour, such as purple, to distinguish them from freshwater distribution systems. The sewage pipe network should be properly labelled to indicate the reclaimed water system in service. The pipelines should be properly labelled with the flow direction.

— Anaerobic tanks should be equipped with breather valves, explosion-proof membranes and positive or negative pressure protection devices to maintain the biogas pressure within a normal range so as to avoid pressure fluctuations under abnormal conditions and damage to the tank.

— Warning signs should be displayed in hazardous areas as a safety precaution to avoid accidents. For example, 'no smoking' and 'no flames' signs near the anaerobic tank.

9.4 Implementation of health and safety equipment

Occupational health and safety risks can be controlled and minimized by the reasonable implementation of health and safety equipment, such as life-saving appliances, personal protective equipment, firefighting devices and biogas alarm systems. Equipment for monitoring the work environment should also be implemented to protect staff from health hazards. All health and safety equipment should be provided at appropriate on-site locations (e.g. anaerobic reactor, anoxic tank, aerobic tank, biogas collector, chemical dosing systems of membrane treatment systems), available at all times and regularly checked and replaced when needed.

9.5 Training

Increasing the safety awareness and professional skills of the employees on safe work practices is extremely important to minimize health and safety risks. Proper training applicable to occupational health and safety should be provided to all staff and staff should have a good knowledge of safety risks, emergency measures, instructions and warnings for equipment and operating procedures (e.g. how to read signs and labels, what to do in an emergency) to avoid the occurrence of health and safety issues caused by misuse.

9.6 Management of incidents and emergencies

An incident and emergency response plan to ensure timely and effective action to protect life and safety, stabilize incidents or accidents and minimize potential damage should be developed and updated periodically.

The emergency response plan should contain warnings of all risks, protective measures for the risks, procedures for communication with responders and a rescue, recovery or retrieval plan.

Annex A
(informative)

Process parameters for leachate treatment system design

A.1 General

Due to the high concentrations and a wide variety of pollutants in the MSW leachate, the operating parameters for the treatment system should be given proper consideration in the design to ensure operational efficiency and stability.

A.2 Operation parameters

A.2.1 General

Parameters for MSW leachate treatment systems are shown in Tables A.1 to A.4.

A.2.2 Regulating pond

The HRT of a regulating pond should be 7 days to 10 days.

A.2.3 Anaerobic digestion process

Table A.1 — Parameters for anaerobic digestion treatment processes

Parameter	Units	Value
Temperature	°C	33 to 38 or 20 to 30
HRT	d	4 to 10
pH	—	6,5 to 7,8
OLR	$kgCOD_{Cr}/(m^3.d)$	4 to 10
Up-flow velocity	m/h	0,5 to 3,0

The removal rate of organics by anaerobic digestion should be regulated depending on the water quality of the leachate.

The biogas production rate is 0,35 $m^3/kg\ COD_{Cr}$ to 0,60 $m^3/kg\ COD_{Cr}$ and the methane content of the biogas is 55 % to 65 %. The biogas collecting system should be designed on the basis of gas production.

A.2.4 MBR

Table A.2 — Parameters for MBR

Parameter	Units	Value
Temperature	°C	20 to 35
Sludge loading	$kgCOD_{Cr}/kgMLVSS{\cdot}d$	0,05 to 0,3
Influent COD_{Cr}	mg/l	≤ 20 000
Influent $NH_4^+ - N$	mg/l	≤ 3 500
MLSS	mg/l	8 000 to 15 000
Membrane flux of submerged MBR	$l/(h{\cdot}m^2)$	8 to 20

Table A.2 *(continued)*

Parameter	Units	Value
Membrane flux of recirculated MBR	$l/(h·m^2)$	60 to 70

Taking into account the high concentration of ammonium in the leachate, a rather high concentration of sludge is required for the stable operation of an MBR. The concentration of sludge should be set within the range of 8 000 mg/l to 15 000 mg/l or the sludge loading should be kept within 0,05 $kgCOD_{Cr}$/(kgMLSS·d) to 0,3 $kgCOD_{Cr}$/(kgMLSS·d), depending on the influent quality.

A cooling system should be considered for anoxic-aerobic treatment systems in hot areas or during the summer.

A.2.5 NF and RO

Table A.3 — Parameters for NF

Parameter	Units	Value
Temperature	°C	8 to 30
pH	—	5 to 7
Pressure	MPa	0,5 to 2,5
Influent COD_{Cr}	mg/l	≤ 1 200
Influent NH_4^+-N	mg/l	≤ 30
ORP	mV	≤ 200
Membrane flux	$l/(h·m^2)$	10 to 20

Table A.4 — Parameters for RO

Parameter	Units	Value	
		DTRO	STRO
Temperature	°C	8 to 30	8 to 30
pH	—	5 to 7	5 to 7
Pressure	MPa	5,0 to 7,0	1,5 to 4,0
Influent COD_{Cr}	mg/l	≤ 10 000	≤ 1 000
Influent NH_4^+-N	mg/l	800	50
SDI	—	6,5	5
ORP	mV	≤ 200	—
Membrane flux	$l/(h·m^2)$	10 to 20	

Annex B
(informative)

Quantity generation of MSW leachate

Examples of leachate quantity data from some MSW incineration plants are shown in Table B.1.

Table B.1 — Cases of leachate quantity data

Plant location	Plant scale t/d	Leachate quantity m^3/d	
		Wastewater from stacking and fermenting	Unloading flushing water
Ethiopia	1 000	180	10
Viet Nam	300	80	
Thailand	650	250	
Maldives	500	150	
China	800	300	
Viet Nam	300	100	
Sri Lanka	500	180	

Annex C
(informative)

Potential treatment options for MSW leachate

Potentially, some processes and technologies used in wastewater treatment can also be used for treating MSW leachate, in spite of a lack of commercial reference and experience.

One example is evaporation processes, which can be used for concentrate treatment to reduce the volume of concentrate and recover water resource and can also serve as a potential process that can probably be used to treat raw leachate.

When used for treating MSW leachate, the evaporation process has an advantage in that organic matters in the leachate can be recovered for energy. It is recommended that the balance of energy consumption and recovery be assessed when evaporation is adopted.

It should be noted that some volatile components in the leachate can evaporate along with water, and further treatment of these components should be addressed and considered.

The design and choice of evaporator is critical to the treatment efficiency. Scaling and clogging caused by inorganic and organic matter in leachate is a potential problem that needs to be considered.

Ion exchange is another potential option to treat MSW leachate. As a type of ion exchange process, electrodialysis has been used in advanced treatment of landfill leachate recently, but its application for the treatment of MSW leachate is restrained by high concentrations of ions and complex composition present in the leachate.

That is not to say that ion exchange processes will not be used when further development is made in future. If suitable systems can be developed and validated, application of ion exchange can be an efficient and economical option for the treatment of MSW leachate.

Other potential technologies, such as air stripping, sand filtration, dissolved air flotation and activated carbon adsorption, have been used in treatment of different kinds of wastewater. However, these processes and technologies have not yet been successfully applied to the treatment of MSW leachate. The complexity and variability in quality and quantity of MSW leachate can inhibit their performance and pose pollution risk if these processes and technologies are applied without verification. In the future, these processes and technologies can be developed and verified in pilot-scale tests; only then should they be considered seriously.

Annex D
(informative)

Overview of MSW composition and treatment

D.1 MSW composition

MSW composition varies significantly between different countries and regions. These variations are mainly caused by differences in living habits, climate, economics and waste management systems.

The compositions of MSW generated in some countries and regions are shown in Tables D.1 to D.8.

Table D.1 — MSW composition data by per cent – Canada[19]

Composition		Value %
Food		23
Paper		11
Wood		10
Diapers and pet waste		6
Yard and garden		4
Textiles (degradable)		1
Rubber and leather		1
Other organics		7
Non-degradable	Plastics	13
	Building material	9
	Metals	3
	Glass	2
	Total other (including electronics, household, hazardous and bulky objects)	9

Table D.2 — MSW composition data by per cent – China[20]

Composition	Value %
Organic fraction	53,7
Paper	16,9
Plastic and rubber	13,6
Textile	2,3
Ash and stone	8,3
Wood	2,2
Metal	0,6
Glass	1,5
Others	1

Table D.3 — MSW composition data by per cent – United States of America[21]

Composition	Value %
Paper	31
Metals	8,4
Plastics	12
Glass	4,9
Organics	25,9
Textiles	7,9
Wood	6,6
Miscellaneous	3,3

Table D.4 — MSW composition data by per cent – Sultanate of Oman[22]

Composition	Value %
Food	33,6
Inert matter	5,6
Paper and cardboard	25,2
Textile and burlap sacks	5,2
Wood	1,6
Construction waste	0,2
Glass	8
Leather	0,4
Metal-ferrous	2,4
Metal-non-ferrous	0,4
Plastics	16,4
Thermocole	1

Table D.5 — MSW composition data by per cent – Mexico[23]

Composition	Value %
Plastics	13,16
Textiles	3,64
Organics	49,5
Sanitary waste	10,77
Paper	5,89
Cardboard	4,03
Construction material	1,88
Ferrous material	1,16
Wood	0,45
Fines	0,8
Aluminium	0,29
Glass	2,65
Special waste	1,41
Hazardous waste	0,18
Others	4,19

Table D.6 — MSW composition data by per cent – India[24]

Year	Biodegradable	Paper	Plastics or rubber	Metal	Glass	Rags	Others	Inerts
1996	42,21	3,63	0,6	0,49	0,6	Nil	Nil	45,13
2005	47,43	8,13	9,22	0,5	1,01	4,49	4,016	25,16
2011	52,32	13,8	7,89	1,49	0,93	1	—	22,57

Table D.7 — MSW composition data by per cent – Nigeria[25]

Composition	Region						
	Nsukkz	Lagos	Makurdi	Kano	Onitsha	Ibadan	Maiduguri
Putrescible	56	56	52,2	43	30,7	76	25,8
Plastics	8,4	4	8,2	4	9,2	4	18,1
Paper	13,8	14	12,3	17	23,1	6,6	7,5
Textile	3,1	—	2,5	7	6,2	1,4	3,9
Metal	6,8	4	7,1	5	6,2	2,5	9,1
Glass	2,5	3	3,6	2	9,2	0,6	4,3
Others	9,4	19	14	22	15,4	8,9	31,3

Data of MSW composition in different regions are shown in Table D.7. These data are based on the weight of wet waste. Data on garden and park waste and nappies are not shown in this table.

Table D.8 — MSW composition data by per cent – regional default[26]

Region	Food waste	Paper or cardboard	Wood	Textiles	Rubber or leather	Plastic	Metal	Glass	Other
Asia									
Eastern Asia	26,2	18,8	3,5	3,5	1	14,3	2,7	3,1	7,4
South-central Asia	40,3	11,3	7,9	2,5	0,8	6,4	3,8	3,5	21,9
South-eastern Asia	43,5	12,9	9,9	2,7	0,9	7,2	3,3	4	16,3
Western Asia and Middle East	41,1	18	9,8	2,9	0,6	6,3	1,3	2,2	5,4
Africa									
Eastern Africa	53,9	7,7	7	1,7	1,1	5,5	1,8	2,3	11,6
Middle Africa	43,4	16,8	6,5	2,5	4,5	3,5	2	1,5	
Northern Africa	51,1	16,5	2	2,5	4,5	3,5	2	1,5	
Southern Africa	23	25	15						
Western Africa	40,4	9,8	4,4	1	3	1			
Europe									
Eastern Europe	30,1	21,8	7,5	4,7	1,4	6,2	3,6	10	14,6
Northern Europe	23,8	30,6	10	2	13	7	8		
Southern Europe	36,9	17	10,6						
Western Europe	24,2	27,5	11						
Oceania									
Australia and New Zealand	36	30	24						
Rest of Oceania	67,5	6	2,5						
America									
North America	33,9	23,2	6,2	3,9	1,4	8,5	4,6	6,5	9,8
Central America	43,8	13,7	13,5	2,6	1,8	6,7	2,6	3,7	12,3
South America	44,9	17,1	4,7	2,6	0,7	10,8	2,9	3,3	13
Caribbean	46,9	17	2,4	5,1	1,9	9,9	5	5,7	3,5

NOTE 1 Data are based on the weight of wet waste of MSW without industrial waste at generation around the year 2000.

NOTE 2 The region-specific values are calculated from national, partly incomplete composition data. The percentages given will therefore possibly not add up to 100 %. Some regions will possibly not have data for some waste types. Blanks in the table represent missing data.