INTERNATIONAL STANDARD

ISO 31800

First edition
2020-08

Faecal sludge treatment units — Energy independent, prefabricated, community-scale, resource recovery units — Safety and performance requirements

Unités de traitement des boues de vidange — Unités préfabriquées et autonomes en énergie de récupération de ressources à l'échelle locale — Exigences de sécurité et de performance

Reference number
ISO 31800:2020(E)

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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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).

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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.

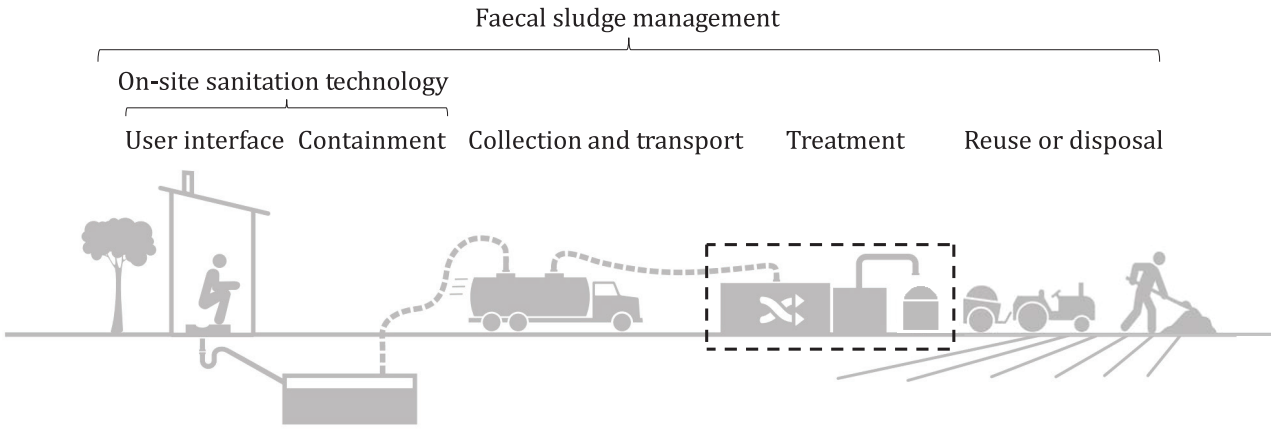
This document was prepared by Project Committee ISO/PC 318, *Community scale resource-oriented sanitation treatment systems*.

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

Hygienic sanitation systems are crucial for public health, yet 61 % of the global population do not have access to safely managed sanitation services; that is, excreta safely treated in situ or treated off-site.

Safe and sustainably managed sanitation improves health and welfare and is fundamental to human development. Integrated business models and technologies throughout the sanitation value chain (see Figure 1) can ensure the economic viability of processes that turn waste into valuable resources, such as renewable energy by-products (e.g. electricity, biofuels, or briquettes) or agriculture products. Safely managed sanitation systems can also prevent contamination of water sources, thus leading to livelihood improvements.



NOTE Treatment is the focus of this document (depicted in the dashed box).

Figure 1 — Sanitation value chain

As shown in Figure 1, this document focuses on non-sewered faecal sludge treatment units with the purpose to specify performance and safety requirements of community-scale resource recovery faecal sludge treatment units serving approximately, but not limited to, 1 000 to 100 000 people. It aims to specify technical requirements and recommendations for such treatment units in terms of performance, safety, operability and maintainability.

This document is intended to ensure the performance, safety, and sustainability of community-scale resource recovery faecal sludge treatment units as well as technical robustness and safety in terms of human health and the environment.

It further aims to promote trust among the different stakeholders involved in faecal sludge management, such as investors, technology developers, government officials, regulatory bodies, local service providers, and users, increasing their willingness to implement innovative new technologies. Manufacturers and technology developers can use this document to gain consumer confidence in the reliability and safety of treatment units. Stakeholders can use this document as a benchmark to compare performance capabilities of different treatment unit options and identify which option is most suitable for their needs.

Faecal sludge treatment units — Energy independent, prefabricated, community-scale, resource recovery units — Safety and performance requirements

1 Scope

This document specifies requirements and test methods to ensure performance, safety, operability and maintainability of community-scale resource recovery faecal sludge treatment units (herein addressed as treatment units) that serve approximately, but not limited to, 1 000 to 100 000 people. This document applies to treatment units that:

a) primarily treat faecal sludge,

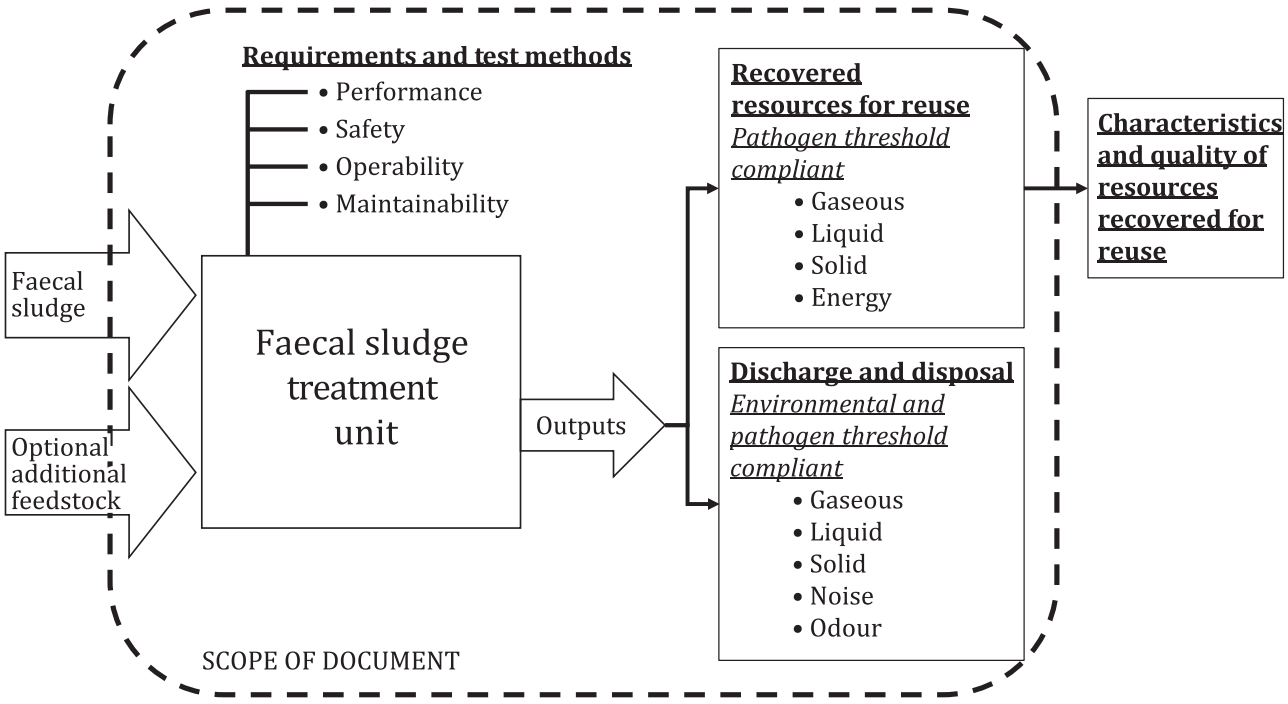
b) are able to operate in non-sewered and off-grid environments,

c) are prefabricated,

d) exhibit resource recovery capability (e.g. recovering energy, reusable water, soil amendment products), and are capable of being energy neutral or energy net positive.

This document does not apply to treatment units requiring major sewer infrastructure.

Figure 2 illustrates the scope of this document with respect to treatment unit inputs and outputs.



Key

--- boundary of the scope of this document

Figure 2 — Scope of this document

Inputs are primarily faecal sludge derived from human excreta and can include additional substances at the discretion of the manufacturer. This document does not specify the characteristics of the faecal

sludge (e.g. COD, BOD, moisture content, etc.) and which forms of the additional inputs (e.g. food waste) are treated within the unit. These inputs are defined by the manufacturer as well as the input characteristics which meet the requirements specified in this document.

This document addresses:

— the performance, safety, operability, and maintainability of the treatment unit,

— the protection of human health and the environment,

— safety aspects of the treatment unit's solid, liquid, and gaseous outputs,

— noise and odour outputs of the treatment unit.

This document specifies minimum requirements of all types of outputs from the treatment unit. It does not specify or mandate the quality of resources recovered as these are highly dependent on the local (e.g. economic, social) context.

Any resources produced and consumed internally to the process itself are outside the scope of this document. Similarly, with the exception of pathogen requirements, the quality and value of any resource recovery and reuse products derived from the treatment unit are outside the scope of this document. Apart from the requirement for energy independence under manufacturer specified input conditions during steady-state operation, this document does not set performance targets with respect to the amount or type of energy or resources to recover and/or use locally.

This document does not address transportation and any intermediary processes required to supply the treatment unit with the defined inputs. Provisions of this document apply to the treatment unit according to its unit boundaries, i.e. within the process chain beginning with its specified inputs and ending with its outputs. Some of the considerations on sustainability of the treatment unit are highlighted in Annex B.

2 Normative references

The following documents are referred to in the text in such a way that some or all of the 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 4126 (all parts), *Safety devices for protection against excessive pressure*

ISO 5667-1, *Water quality — Sampling — Part 1: Guidance on the design of sampling programmes and sampling techniques*

ISO 5667-3, *Water quality — Sampling — Part 3: Preservation and handling of water samples*

ISO 5667-13, *Water quality — Sampling — Part 13: Guidance on sampling of sludges*

ISO 7250 (all parts), *Basic human body measurements for technological design*

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 14159, *Safety of machinery — Hygiene requirements for the design of machinery*

ISO/IEC 17065:2012, *Conformity assessment — Requirements for bodies certifying products, processes and services*

ISO 19458, *Water quality — Sampling for microbiological analysis*

ISO 20816-1, *Mechanical vibration — Measurement and evaluation of machine vibration — Part 1: General guidelines*

ISO 55000, *Asset management — Overview, principles and terminology*

ISO 80000 (all parts) and IEC 80000 (all parts), *— Quantities and units*

IEC 31010, *Risk management — Risk assessment techniques*

IEC 60050-192, *International Electrotechnical Vocabulary (IEV) — Part 192: Dependability*

IEC 60204 (all parts), *Safety of machinery*

IEC 60309-1, *Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements*

IEC 60364 (all parts), *Low voltage electrical installations*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems — Part 1: Principles, requirements and tests*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 60947 (all parts), *Low voltage switchgear and control gear*

IEC 61000-6, *Electromagnetic compatibility — Part 6: Generic standards*

IEC 61069, *Industrial process measurement, control and evaluation — Evaluation of system properties for the purpose of system assessment*

IEC 61140, *Protection against electric shock — Common aspects for installation and equipment*

IEC 61260-1, *Octave-band and fractional-octave-band filters — Part 1: Specifications*

IEC 61511 (all parts), *Functional safety — Safety instrumented systems for the process industry sector*

IEC 61558 (all parts), *Safety of transformers, reactors, power supply units and combinations thereof*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 61882, *Hazard and operability studies (HAZOP studies)*

IEC 61984, *Connectors — Safety requirements and tests*

IEC 62305 (all parts), *Protection against lightning*

IEC/IEEE 82079-1, *Preparation of information for use (instructions for use) of products — Part 1: Principles and general requirements*

EN 547 (all parts), *Safety of machinery — Human body measurements*

EN 1127-1, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

EN 1837, *Safety of machinery — Integral lighting of machines*

EN 1839, *Determination of the explosion limits and the limiting oxygen concentration (LOC) for flammable gases and vapours*

EN 10216 (all parts), *Seamless steel tubes for pressure purposes — Technical delivery conditions*

EN 10217 (all parts), *Welded steel tubes for pressure purposes — Technical delivery conditions*

EN 13480 (all parts), *Metallic industrial piping*

EN 13725:2003, *Air quality — Determination of odour concentration by dynamic olfactometry*

EN 15259, *Air quality — Measurement of stationary source emissions — Requirements for measurement sections and sites and for the measurement objective, plan and report*

ASTM E681, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)*

API 520, *Sizing, selection, and installation of pressure-relieving devices*

API 521, *Pressure-relieving and depressuring systems*

API 650, *Welded steel tanks for oil*

ASME B31.1, *Power piping*

ASME BPVC *Boiler and pressure vessel code*

SW-846 Test Method 1311, *Toxicity Characteristic Leaching Procedure*

Confidence Grading System, International Infrastructure Management Manual (IIMM), 2015

NFPA 30, *Flammable and Combustible Liquids Code*

UL 58, *Standard for steel underground tanks for flammable and combustible liquids*

UL 142, *Standard for steel aboveground tanks for flammable and combustible liquids*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 http://www.electropedia.org/

3.1 General

3.1.1
human excreta
waste products of human metabolism, in solid or liquid form, generally urine and/or faeces

[SOURCE: ISO 24521:2016, 3.3]

3.1.2
faecal sludge
sludge generated from the storage of *human excreta* (3.1.1) in pit latrines, septic tanks or other onsite sanitation systems that may be mixed with flush water, domestic waste, anal cleansing material and other liquids

3.1.3
input
substances fed to the treatment unit; primarily *faecal sludge* (3.1.2), which may include other substances such as liquid and solid *domestic waste* (3.2.1) and may include different forms of *biomass* (3.2.2)

3.1.4
prefabricated
factory produced either as a fully assembled unit or as a set of components that assemble to form the unit

3.1.5
design requirement
requirement that specifies or constrains the design of a system or system component; *cf.* functional requirement, implementation requirement, interface requirement, performance requirement, and physical requirement

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.1146]

3.1.6
risk assessment
overall process comprising a risk analysis and a risk evaluation

[SOURCE: ISO/IEC Guide 51:2014, 3.11]

3.1.7
safety assessment
review of the aspects of design and operation of the treatment unit which are relevant to the protection of persons or the safety of the treatment unit, including the analysis of the safety and protection provisions established in the design and operation of the treatment unit and the analysis of risks associated with normal conditions and accident situations

3.1.8
design process
process of converting the requirements of the functional specification into the technical specification

[SOURCE: ISO 13880:1999, 3.3]

3.2 Input, energy balance, and resource recovery

3.2.1
domestic waste
waste that arises from domestic use of a private dwelling

3.2.2
biomass
material of biological origin excluding material embedded in geological formations and/or fossilized

Note 1 to entry: This definition includes crop waste, food waste, wood chips, etc. that can increase the calorific content of input beyond the content in faecal sludge.

[SOURCE: ISO 16620-1:2015, 3.1.2, modified — The Note has been added.]

3.2.3
steady state
condition in which all relevant operational parameters are not significantly changing with time

3.2.4
energy balance
accounting of *input* (3.1.3) and/or interconversion of different forms of energy outputs, and energy usage within a defined boundary

3.2.5
energy independent
able to perform the intended functions of the treatment unit relying exclusively on energy from *faecal sludge* (3.1.2) as defined by the manufacturer during steady state operation

3.2.6
energy positive
able to convert the treatment unit's defined *input* (3.1.3) into energy and/or output materials that can be converted into energy that can be reused in applications beyond the treatment unit

3.2.7
thermal treatment
treatment process that uses heat to convert *inputs* (3.1.3) into outputs

3.2.8
calorific value
quantity of heat produced by the combustion, at a constant pressure equal to 0,101 325 MPa, of unit volume or mass, the constituents of the combustible mixture being taken at reference conditions and the products of combustion being brought back to the same conditions

Note 1 to entry: A distinction is made between:

a) the superior calorific value (Hs)/ gross calorific value/ upper heating value (UHV) in which the water produced by combustion is assumed to be condensed, and

b) the inferior calorific value (Hi)/ net calorific value/ lower heating value (LHV) in which the water produced by combustion is assumed to be in the vapour state.

The units used for calorific value are either:

c) megajoules per cubic metre (MJ/m^3) on dry basis at the reference conditions, or

d) megajoules per kilogram (MJ/kg) on dry basis.

Note 2 to entry: This document does not mandate the use of the superior or inferior heating value as long as the one used is most relevant to the technology and clearly noted.

[SOURCE: ISO 22967:2010, 3.2.2, modified — The Note 2 to entry has been added, to remove “gas”, to include “/gross calorific value/upper heating value (UHV)” and “/net calorific value/lower heating value (LHV)”.]

3.2.9
biochemical oxygen demand
BOD
mass concentration of dissolved oxygen consumed under specified conditions by the aerobic biological oxidation of a chemical compound or organic matter

Note 1 to entry: It is typically expressed in mg/l.

[SOURCE: ISO 14592-2:2002, 3.1.3, modified — “in water” has been deleted, Note 1 to entry has been modified.]

3.2.10
chemical oxygen demand
COD
mass concentration of oxygen equivalent to the amount of a specified oxidant consumed by a chemical compound or organic matter

Note 1 to entry: It is typically expressed in mg/l.

[SOURCE: ISO 9408:1999, 2.6, modified — "when a water sample is treated with the oxidant under defined conditions" has been deleted, Note 1 to entry has been modified.]

3.2.11
total suspended solids
TSS
mass of particulates, both organic and inorganic, suspended, but not dissolved, per unit of water

[SOURCE: ISO 16345:2014, 2.58, modified — “weight” has been replaced with “mass’, Note 1 to entry has been deleted.]

3.2.12
total nitrogen
TN
sum of total Kjeldahl nitrogen (ammonia, organic and reduced nitrogen), nitrite-N and nitrate-N

3.2.13
total phosphorus
TP
sum of organically bound and inorganically bound phosphorus measured under specified conditions

3.2.14
volatile organic compound
VOC
any organic liquid and/or solid that evaporates spontaneously at the prevailing temperature and pressure of the atmosphere with which it is in contact

[SOURCE: ISO 4618:2014, 2.270, modified — Notes to entry have been deleted.]

3.2.15
resource recovery
using *input* (3.1.3) to generate valuable outputs

3.3 Performance

3.3.1
utilization time
period during which the treatment unit is in operation or is being maintained calculated as the sum of the *mean time between failure* (3.3.6), *technical downtime* (3.3.5), and all other downtimes including *preventive maintenance* (3.3.3) but not including downtime owing to factors external to the system (e.g. supply, labour, weather)

3.3.2
technical availability
ratio of the *mean time between failure* (3.3.6) and the sum of the meantime between failure and *meantime to repair* (3.3.7) under ideal conditions:

$$A = \frac{T_{BF}}{T_{BF} + T_{TR}}$$

where

A is the technical availability;

T_{BF} is the mean time between failure;

T_{TR} is the mean time to repair

3.3.3
preventive maintenance time
T_{pm}
part of the maintenance time taken to perform preventive maintenance, including technical delays and logistic delays inherent in preventive maintenance

Note 1 to entry: Preventive maintenance activities aim to minimize the technical downtime by precluding failure or damage.

[SOURCE: IEC 60050-192:2015, 192-07-05, modified — Note 1 to entry has been replaced.]

3.3.4
downtime
time interval for which the item is in a down state

[SOURCE: IEC 60050-192:2015, 192-02-21, modified — Spelling has been changed from “down time” to “downtime”, Note to entry has been deleted.]

3.3.5
technical downtime
unscheduled *downtime* (3.3.4) during which the treatment unit's processes are not conforming to the expectations in terms of performance, safety, operability, and maintainability as specified by the manufacturer

Note 1 to entry: This may be due to shortcomings in the design, material defects, process interruptions due to design deficits, or shortcomings in the product literature provided by the manufacturer.

Note 2 to entry: There are various methods to determine the PFD-value, e.g. Markov models, Bayesian models, quantitative fault tree analysis.

3.3.6
mean time between failure
MTBF
expectation of the duration of the operating time between failures

[SOURCE: IEC 60050-192:2015, 192-05-13, modified — "mean operating time between failures" has been changed to "mean time between failure", Note to entry has been deleted.]

3.3.7
mean time to repair
MTTR
expectation of the time to restoration under the control of the designer

Note 1 to entry: MTTR generally does not reflect lead time for parts or administrative or logistical downtime.

Note 2 to entry: MTTR refers to reactive maintenance, i.e. maintenance activities triggered only after failure or damage has already occurred.

[SOURCE: IEC 60050-192:2015, 192-07-23, modified — "mean time to restoration" has been changed to "mean time to repair", "under the control of the designer" has been added, original Note to entry has been deleted and two new Notes to entry have been added.]

3.3.8
failure on demand
failure of the treatment unit to respond as intended to operator signals

EXAMPLE 1 Failure to resume stable operations after starting or re-starting the treatment process.

EXAMPLE 2 Failure to enter a safe state following shutoff.

3.3.9
interlock
mechanical, electrical or other type of devices, the purpose of which is to prevent the operation of machine elements under specified conditions by an inhibit command from the interlocking device that (a) directly interrupts the energy supply or directly disconnects parts from the equipment or (b) is introduced into the control system so that interruption of the energy or disconnection of parts from the equipment is triggered by the control system, or (c) provides safety protection for personnel and equipment

[SOURCE: ISO 21789:2009, 3.6, modified — "(c) provides safety protection for personnel and equipment" has been added.]

3.3.10
redundancy
existence of more than one means for performing a required function

[SOURCE: ISO 20815:2018, 3.1.49, modified — "of an item" has been deleted, all Notes to entry have been deleted.]

3.4 Operability

3.4.1
process stability
process condition exhibiting consistent means and variances throughout the *utilization time* (3.3.1)

3.4.2
water tightness
ability of the closed faecal sludge treatment unit to resist water penetration and leakage

[SOURCE: ISO 15821:2007, 3.6, modified — "test specimen" has been replaced with "faecal sludge treatment unit", "and leakage" has been added.]

3.4.3
technical tightness
inherent characteristics of a faecal sludge treatment unit that prevents hazardous fluids, gases, or suspended particulate matter from passing through the external environment to the processing/ treatment internal environment, or from the processing/treatment internal environment to the external environment, or both

Note 1 to entry: The sanitation system or components thereof are considered technically tight if the leakage rate does not exceed 0,000 01 mbar l/s.

3.5 Outputs

3.5.1
effluent
liquid discharged from any item of equipment after fulfilment of its function or after having itself been treated

[SOURCE: ISO 1213-1:1993, 6.1.9, modified — "water" has been replaced with "liquid", "(e.g. for clarification)" has been deleted.]

3.5.2
pathogen
organism capable of producing disease in a susceptible plant or animal, including humans

[SOURCE: ISO 6107-5:2004, 39, modified — "man" has been replaced with "humans".]

3.5.3
protozoa
phylum of unicellular eukaryotic animals varying from simple uninucleate organisms to cell colonies or highly organized structures and with a considerable diversity of forms and nutrition

[SOURCE: ISO 6107-5:2004, 47]

3.5.4
environmental correction
correction applied to the mean (energy average) of the time-averaged sound pressure levels over all the microphone positions on the measurement surface, to account for the influence of reflected or absorbed sound

Note 1 to entry: Environmental correction is expressed in decibels.

Note 2 to entry: The environmental correction is frequency dependent; the correction in the case of a frequency band is denoted K2f, where f denotes the relevant mid-band frequency, and that in the case of A-weighting is denoted K2A.

[SOURCE: ISO 3744:2010, 3.17, modified — Note 3 has been deleted.]

3.5.5
total dust
particles, of any shape, structure or density, dispersed in the gas phase at the sampling point which may be collected by filtration under specified conditions after representative sampling of the gas to be analysed, and which remain upstream of the filter and on the filter after drying under specified conditions

3.6 Abbreviated terms

APHA American Public Health Association

API American Petroleum Institute

ASME American Society of Mechanical Engineers

ASSE American Society of Safety Engineers

ASTM American Society for Testing and Materials

BMUB German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

BOD biochemical oxygen demand

CAPEX capital expenditure

CFU colony-forming units

COD chemical oxygen demand

EPA U.S. Environmental Protection Agency

GHG greenhouse gas emissions

HAZOP hazard and operability study

LEL lower explosive limit

NFPA National Fire Protection Association

NIOSH US National Institute for Occupational Safety and Health

OPEX operational expenditures

OU_e odour unit (European)

PFD probability of failure on demand

PFU plaque-forming units

TSS total suspended solids

TCLP toxic characteristic leaching procedure

STLC soluble threshold limit concentration

UEL upper explosive limit

UL Underwriters Limited

UN United Nations

VDI Association of German Engineers

VOC volatile organic compound

4 General requirements

4.1 Industrial design and manufacture

Treatment units shall be designed and manufactured in accordance with industrial best practices. For the purposes of this document, industrial design and manufacture comprise the following requirements:

a) Design and manufacture of the treatment unit shall be specified and realized in accordance with the International System of units (SI) defined in ISO 80000 (all parts) and IEC 80000 (all parts).

b) Design and manufacture shall be systematically planned, realized, and tested along a defined product safety lifecycle that ensures testability, quality, and conformity of the treatment unit.

c) Design and manufacture of the treatment unit shall be based on a clearly specified design basis and uniform manufacturing process. The design basis shall cover electrical, mechanical, structural, and process engineering, including the basis for calculating the declared capacity, availability, and performance of the treatment unit.

d) Design and manufacture of the treatment unit shall be documented in a systematic technical file.

4.2 Hazard and operability study and risk assessment

The manufacturer shall carry out a hazard and operability study (HAZOP) following IEC 61882, and a risk assessment following either ISO 12100 or IEC 31010.

The hazard and operability study and risk assessment shall:

a) determine the health and safety requirements that apply to the treatment unit;

b) determine risk-mitigating measures to be taken;

c) demonstrate the safety of the product by documenting the results of a safety assessment;

d) be completed before field testing commences;

e) cover the relevant life cycle of the treatment unit, considering its expected use and use in a way not intended by the designer, but which can result from readily predictable human behaviour.

This assessment should be carried out during the design process.

NOTE Operational issues over which the operator (rather than the manufacturer) has control are outside the scope of this document and therefore excluded from this assessment.

4.3 Ambient operation conditions

The treatment unit shall operate within the ambient temperature range, air humidity, and pressures specified by the manufacturer (see 12.1).

4.4 Expected technical lifetime

Treatment units shall be designed for a serviceable life of not less than 20 years, assuming operation and maintenance are conducted according to the manufacturer's specifications. The expected technical lifetime requirement relates to the design of the treatment unit and does not impose any requirement on spare parts (see 9.4) of the treatment unit.

4.5 Treatment unit input

4.5.1 Input types

Treatment units shall primarily treat faecal sludge derived from human excreta.

Other inputs in addition to faecal sludge (e.g. biomass) may be treated.

4.5.2 Specification of input parameters and ranges

Manufacturers shall specify the necessary range of values for performance-based input parameters required to achieve energy independence (5.2.1) or energy positive status (5.2.2).

If the treatment unit can operate with an extended range of input parameter values while remaining in compliance with the exception of the energy independence requirement, then the manufacturer shall specify the extended range of defined inputs for which the treatment unit does not meet the energy independence requirement. Table 1 provides an example of how to specify the input specifications.

EXAMPLE Calorific value, moisture content, and ash content of input can require specification for a combustion system.

Table 1 — Example of treatment unit input specifications

Input type	Input parameter	Units	Range of values of parameter (compliant operation, energy independence not required)	Range of values of parameter (energy independent and/or energy positive for testing)
Faecal sludge	Throughput (dry basis)	kg/h	≤37,5	20,0 to 37,5
	Calorific value	MJ/kg	≥9,0	≥15,0
	Solids content	% solids	≥10,0	≥15,0
	Inorganic content	% mass, dry basis	≤25,0	≤15,0
Other inputs	Throughput (dry basis)	kg/h	≤20,0	
	Calorific value	MJ/kg	≥12,0	
	Solids content	% solids	≥15,0	
NOTE 1 Parameters and values in Table 1 are for illustration purposes only.				
NOTE 2 Not all possible combination of these parameter values may be viable simultaneously.				
NOTE 3 Other formats for presenting the extended range of input parameters, such as graphs may be used; choice of format is at the discretion of the manufacturer.				

Examples of input specifications templates are provided in Annex A.

4.6 Requirements for handling of faecal sludge as a fuel

4.6.1 Reception of faecal sludge

The treatment unit shall be designed so as to take all necessary precautions concerning the reception of faecal sludge to prevent negative effects on the environment, such as the pollution of air, soil, surface water, and groundwater and the potential for odours, noise, and direct risks to human health, e.g. through contact with faecal sludge.

4.6.2 Storage of faecal sludge

If the treatment unit includes a component for storage of faecal sludge, the treatment unit shall be designed so as to take all necessary precautions concerning the storage of faecal sludge to prevent

negative effects on the environment, such as the pollution of air, soil, surface water and groundwater and the potential for odours, noise, and direct risks to human health.

4.6.3 Feeding system

The faecal sludge feeding system including other inputs shall be closed and automatically operated to minimize direct risks to human health and safety.

4.6.4 Drying facilities

If the treatment unit includes drying facilities, the treatment unit shall be designed so as to take all necessary precautions to prevent exposure from the drying process and direct risks to human health.

5 Energy balance and resource recovery

5.1 General

This clause specifies requirements and recommendations for performance with respect to energy balance and resource recovery. Energy and resource recovery performance requirements as well as test methods for verification may vary across treatment units. Performance verification for energy balance and resource recovery specifications are given in 12.5.

5.2 Energy balance

5.2.1 Energy independence

Treatment units shall be able to operate in an off-grid environment at steady state without relying on external energy sources apart from exclusively faecal sludge as defined in 4.5.2. Manufacturers shall define the properties of exclusively faecal sludge input and specify the duration of time under which the treatment unit can operate in energy independent mode.

Alternatively, energy independence may be demonstrated by using an auxiliary system. The auxiliary system need not be part of the treatment unit and may only be used for the purpose of testing for energy independence. The auxiliary system shall not have any integration with the treatment unit, beyond that of recovering energy and without relying on external energy apart from exclusively faecal sludge as defined in 4.5.2.

This requirement does not apply to start-up, shutdown, and maintenance periods. Energy from an electrical grid or fuel from external sources for onsite electricity generation may be used only when necessary for safe process start-up, shutdown, and unscheduled maintenance.

EXAMPLE 1 A treatment unit produces methane as a resource recovered output. During testing, an auxiliary system e.g. a generator able to utilize the methane to produce electricity is used to show that the treatment unit is energy independent.

EXAMPLE 2 Use of a generator (e.g. diesel generator) utilizing non-renewable sources or use of renewable energy sources (e.g. photovoltaic/solar, wind, hydropower) to generate heat and/or electricity to power the treatment unit during testing for energy independence would exclude the unit from the scope of this document.

NOTE 1 The intent of these provisions is to ensure that the primary source of energy for the treatment unit is the treatment unit's defined input. These provisions allow comparisons of technologies.

NOTE 2 These provisions do not restrict treatment units that meet the requirements of this document from adapting to the local context and/or utilizing resources that render the unit most viable from an economic or technical standpoint.

5.2.2 Energy positive

In addition to achieving energy independence (see 5.2.1), treatment units may be energy positive, i.e. generate excess energy from the defined inputs (e.g. as biocrude or biogas) that can be used in applications beyond the treatment unit. Energy positive status fulfils the resource recovery requirement articulated in 5.3.

5.3 Resource recovery

The treatment unit shall recover resources from the specified input. This requirement may be met through positive energy balance (see 5.2.2) and/or through recovery of additional resources. Examples of such additional resources include, but are not limited to, biosolids, biochar, fertilizer (pellets or concentrated solutions), soil amendments, metal salts, biogas, biofuels, carbon dioxide and carbonates, chemical intermediates (alcohols, acids, biopolymers), biomass (plant and algal), and reclaimed water. The type of resource recovery shall be specified in the product literature [see 12.3 a) 1)].

6 Performance requirements

6.1 Technical process availability

6.1.1 Mean time between failure (MTBF)

The manufacturer shall specify the technical availability of the treatment unit based on MTBF (3.3.6) calculations. The technical availability shall allow the treatment unit to conform to the expectations in terms of performance, safety, operability, and maintainability as specified by the manufacturer for greater than or equal to 85 % of the sum of the MTBF and MTTR.

MTBF calculations shall be made in accordance with IEC 60050-192, as shown in Figure 3.

Development of availability targets, and the expected reduction of the statistical variance and confidence interval of the MTBF values, shall be calculated in accordance with the Confidence Grading System of the International Infrastructure Management Manual (IIMM), and ISO 55000 approaches on asset management planning.

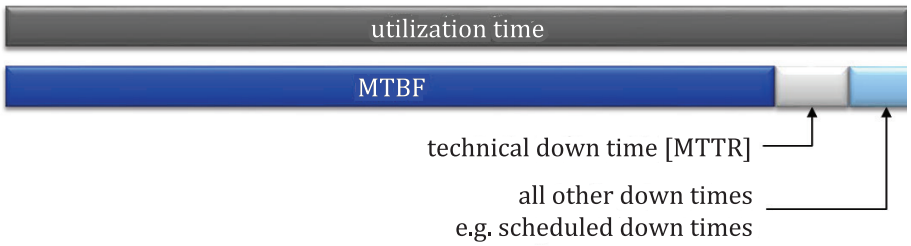


Figure 3 — MTBF as a component of utilization time

6.1.2 Mean time to repair (MTTR)

The manufacturer shall specify the expected technical downtime of the treatment unit based on MTTR calculations.

6.1.3 Preventive maintenance time (T_{pm})

The manufacturer shall specify the expected preventive maintenance time (T_{pm}) required for the treatment unit in hours/annum. Preventive maintenance includes any work to be done according to the maintenance schedule provided by the manufacturer. The maximum preventive maintenance time requiring shutdown shall be less than 5 % of the utilization time.

6.2 Process reliability

6.2.1 Process stability

Treatment units shall realize process stability and the manufacturer shall specify all measures and activities necessary to ensure the treatment process conforms to the expectations in terms of performance, safety, operability, and maintainability (see 12.3).

6.2.2 Start reliability and start time

The manufacturer shall specify the probability of failure on demand (PFD) when starting or re-starting the treatment process, which shall be calculated independently from the expected technical downtime of the process. All activities and measures necessary for the operator to reliably achieve the PFD shall be specified (see 12.3). The manufacturer shall specify the treatment process ramp-up time necessary to reach process stability.

6.2.3 Shut-off reliability and shut-off time

The manufacturer shall specify the probability of failure on demand (PFD) when stopping or shutting off the treatment process. All activities and measures necessary for the operator to reliably achieve the PFD shall be specified (see 12.3). The manufacturer shall specify the treatment process shut-off time necessary to reach a safe state.

NOTE There are various methods to determine the PFD-value, e.g. Markov models, Bayesian models, quantitative fault tree analysis.

7 Safety and functional requirements

7.1 Applicability

Some of the provisions in this clause may not be applicable to certain treatment units, depending on treatment unit technologies. To identify which of the requirements of this clause are relevant to a specific treatment unit, a hazard and operability (HAZOP) study and risk assessment shall be conducted as specified in 4.2.

7.2 Process control

7.2.1 General

Treatment units shall be equipped with a control system. The control system shall provide all control functions necessary for the treatment unit to conform to the expectations in terms of performance, safety, operability, and maintainability as specified by the manufacturer. Any malfunction of the control system shall transition the treatment unit to a safe state. In the event that a control system is required to achieve a safe state, it shall be equipped with an uninterrupted power supply or emergency back-up power. Design and performance of the control system shall be in accordance with IEC 61069.

7.2.2 Degree of automation

The control system should enable automated operation of the treatment unit. The treatment unit shall not require continuous action on the part of the operator.

7.2.3 Intentional starting of operation

Starting and restarting of the treatment unit through deliberate actuation, including restarting after a stoppage, shall be enabled exclusively through a start-up sequence of control actions that trip the treatment unit's ready-state condition interlocks. The start-up sequence and related interlocks shall be clearly indicated by the manufacturer (see 12.3).

Restarting of the treatment process after a stoppage shall not be possible without deliberately resetting the treatment process into default mode for an intentional starting.

7.2.4 Intentional stopping of operation

The control system shall be capable of transitioning the treatment unit safely to a complete stop and safe state through a shutdown sequence of control actions that trip the shutdown condition interlocks. The shutdown sequence and related interlocks shall be clearly indicated by the manufacturer (see 12.3).

If a safe state cannot be immediately achieved upon the shutdown sequence and a transition period follows initiation of the stop command, the control system shall clearly indicate transition mode status and the duration of this transition period. The safety of the system during this transition period shall be ensured. If necessary, a safety-related function shall be available for use until the shutdown interlocks are fully applied. The stop control shall retain priority over the start and operational controls.

7.2.5 Emergency stop

The treatment unit shall be equipped with one or more emergency stop devices that safely halt all treatment processes and operations (e.g. mechanical and electrical) and cut off energy supply. Additional emergency stops may be installed that only affect relevant individual subsystems, if the results of a risk assessment prove the entire treatment unit remains safe when those subsystems are halted. The subsystem affected through a subsystem-level emergency stop shall be clearly indicated. It is recommended to refer to ISO 13850 for additional guidance concerning emergency stop functions.

7.2.6 Continuous monitoring

Treatment units shall continuously monitor critical unit process parameters during the utilization time. Unit process parameters shall be regarded as critical if they interfere with and/or determine either the process performance or the process safety (e.g. boiler temperature, vessel pressure, output). The critical process parameters shall be determined through a HAZOP and risk assessment (see 4.2). Continuous monitoring shall be automatic and may be remote and/or capable of online reporting.

7.2.7 Feedback of process failures

The treatment unit shall incorporate a control system that serves to acquire and process data and information regarding the safe, reliable, and efficient operation of the treatment unit. The control system shall provide continuous control and monitoring of all critical process parameters. The control system shall be capable of:

a) generating system alarms that provide feedback of any process failures, where possible preventively (before the process failure occurs);

b) prioritizing generated alarms according to their criticality for the treatment process performance and safety;

c) maintaining the treatment unit in a safe state or initiating the transition of the treatment unit into a safe state;

d) providing error codes to aid system corrections on the operational level which the manufacturer expects to be managed by the operator; the related corrective actions shall be described in the operation manual; and

e) creating an onsite and offsite digital record of process failures.

7.2.8 Safety-related functions of the control system

If the HAZOP and risk assessment (see 4.2) reveal the need for further risk reduction additional to the operational functions of the electric, electronic, or programmable electronic system for the treatment process control, then this necessary risk reduction should be realized through safety functions of

the control system, introducing an additional layer of protection. Safety functions shall be specified, designed, verified, and validated in accordance with IEC 61511 (all parts).

Safety functions shall be prevented from being unintentionally interlocked, overruled, or shut down. If the risk assessment results indicate that it is safe to do so, the manufacturer may allow exceptions for maintenance activities.

NOTE Typical safety functions include overpressure control, fire prevention, and explosion prevention.

7.2.9 Input overload protection monitoring

The control system shall provide overload protection monitoring in order to prevent overloading of the treatment unit. The overload protection monitoring system shall indicate when the treatment unit is nearing maximum capacity and indicate to the operator to perform the required actions to prevent the overload. Should overload occur, the treatment process shall be transitioned into a safe state that prevents any hazards due to overload.

The overload protection requirement may also be realized through an equivalent solution (e.g. a mechanical solution preventing overload).

7.2.10 Overpressure protection

The control system shall provide overpressure protection monitoring if the maximum operation pressure exceeds 50 kPa and other means of overpressure control are not sufficient (e.g. safety valves). The overpressure protection monitoring system shall prevent the treatment process from operating in excess of the specified maximum operation pressure. The overpressure protection monitoring system shall indicate when the treatment unit is nearing maximum operation pressure and indicate to the operator that the treatment process exceeds the maximum operation pressure and therefore is not operable. Should overpressure occur, the treatment process shall be transitioned into a safe state that prevents any hazards due to overpressure. As required by the risk assessment (see 4.2), similar requirements would apply to systems under vacuum.

7.2.11 Fire and overheating prevention

Treatment units shall be designed in such a way as to prevent any risk of uncontrolled fire or overheating caused by operation or malfunctions of the treatment unit itself, or by gases, liquids, dust, vapours, or other substances. If the HAZOP and risk assessment (see 4.2) identify fire or overheating of the treatment as a significant hazard that cannot be controlled sufficiently through other means, then the control system shall realize an additional independent fire and overheating prevention system through which the required risk reduction is achieved. The overheating prevention system shall prevent the treatment process from catching fire or operating in excess of the specified maximum operation temperature. The overheating protection monitoring system shall indicate when the treatment process is nearing maximum operation temperature and indicate to the operator that the treatment process exceeds the maximum operation temperature and therefore is not operable. Should fire or overheating occur, the treatment process shall be transitioned into a safe state.

7.2.12 Explosion prevention

Treatment units shall be designed in such a way as to avoid any risk of explosion caused by explosive atmospheres or substances including gases, liquids, dust, vapours, or other substances. Hazardous accumulations of potentially explosive gases, liquids, dust, vapours or other substances shall be automatically monitored and recorded through the control system reliably, and appropriate mitigation measures shall be taken by the manufacturer, accounting for, at a minimum, the lower explosive limit (LEL), the upper explosive limit (UEL) in accordance with EN 1839 or ASTM E681, and the evaluation of the potential sources of ignition in accordance with EN 1127-1. Hazardous accumulations of potentially explosive gases, liquids, dust, vapours or other substances shall be prevented through flares or safe ventilation in accordance with API 520 or API 521.

7.3 Process redundancy

To achieve the performance parameters defined in 6.1 and 6.2, and to maintain the safety of the treatment unit, the unit or relevant sections thereof shall be designed and realized with sufficient redundancy.

The redundancy approach shall ensure:

a) uninterrupted continuous system operation according to the intended use for safety related functions and minimal loss of operation time within MTTR for operational functions if one redundancy option fails;

b) uninterrupted continuous system operation according to the intended use for safety related functions and minimal loss of operation time within MTTR for operational functions in case maintenance activities are performed on one redundancy option;

c) consideration and mitigation of all common cause failures that have the potential to induce all redundancy options to fail simultaneously; and

d) a non-volatile record in the case of a total loss of all redundancy.

The control system shall notify the operator of the loss of any redundancy option through a high-priority alarm.

7.4 Material fire resistance

Based on the outcome of the HAZOP (see 4.2), treatment units shall achieve acceptable fire resistance for all parts and surfaces for which a fire hazard exposure is relevant. Relevant materials and surfaces shall not ignite, progressively glow, smoulder, or show evidence of being functionally impaired when exposed to a source of ignition. Materials should conform to ISO 10295 (all parts).

7.5 Security of electrical energy supply

The following provisions apply to any electrical energy supply, internal or external (e.g. for start-up).

7.5.1 Safety and security

In the event of total power failure, independent emergency exit lighting shall be provided as identified through the HAZOP study and risk assessment conducted as specified in 4.2.

7.5.2 Security of external electrical energy supply

Failure of the external electrical energy supply (e.g. grid, battery, photovoltaic, generator) shall not trigger hazardous system conditions. The necessary hazard prevention shall be realized through automatic system transition to a safe state.

7.5.3 Security of internal electrical energy supply

Failure of the internal electrical energy supply shall not trigger hazardous system conditions. This hazard prevention shall be realized through automatic system transition to a safe state or through the provision of an appropriate redundant source of energy. The amount of energy supplied by the redundant source shall be indicated to the operator.

7.6 Safety requirements for electrical energy supply

7.6.1 Separation and isolation

Any electrical energy supply, internal or external, shall be separable and isolatable from the other parts and subsystems of the treatment unit through proven safety devices such as circuit power switches,

fuses, or other proven interlock devices. Isolators shall be made clearly noticeable by marking and arrangement and shall be capable of being locked if reconnection could endanger humans (e.g. during configuration, adjustment, and maintenance).

If components or devices of the treatment unit are plugged into an electrical outlet, removal of the plug may be sufficient to satisfy these requirements for separation and isolation of the energy source, if the operator can verify from any of the points to which he or she has access that the plug remains removed.

7.6.2 Electrical energy discharge

The treatment unit shall be equipped with a means of discharging any internal and external electrical energy remaining or stored in the system following isolation from the source of electrical energy supply to achieve a safe state and prevent hazards. Subsystems of the treatment unit that supply or store electrical energy need not be discharged if these subsystems can be separated from the system (e.g. through separation switches) in such a way as to ensure that the safe state of the system is not affected and hazards do not emerge from the subsystem.

NOTE Typical subsystems include batteries and capacitors.

7.6.3 Overvoltage protection

The treatment unit shall be equipped with a means of overvoltage protection to prevent hazards to safe system operation. The procedure to determine the necessity of a surge protective device (SPD) shall be in accordance with IEC 62305-2. Overvoltage protection shall include lightning protection measures in accordance with IEC 62305 (all parts).

7.7 Structures and supporting elements

7.7.1 Structural integrity

Materials, equipment, components, connections, and joining elements within the treatment unit shall be capable of withstanding both static and dynamic stresses of expected operation and reasonably expected interferences.

Where a hazard of fracture or disintegration remains despite countermeasures, the structures and parts concerned shall be mounted, positioned, and/or guarded in such a way as to contain any hazards.

Installations and pipes, whether rigid or flexible, that carry fluids and/or gases shall be capable of withstanding the relevant maximum internal and external stresses expected from the treatment unit design, and shall be firmly attached and/or protected to minimize the risk posed by a rupture.

7.7.2 Integrity against external impacts

Treatment units and their installations, components, and fittings shall be stable to prevent tilting, overturning, falling, or uncontrolled movements.

If the shape or structure of the installations and components do not offer both sufficient tilting stability and sufficient stability under mechanical load, then appropriate means of fixation or anchorage shall be incorporated in the manufactured product and their use shall be specified in the product literature (see 12.7).

The treatment process shall reliably resist reasonably expected external mechanical impacts incurred during installation, normal operation, and maintenance.

7.8 Sanitary requirements

7.8.1 Hygienic design

Treatment units shall be designed in such a way as to mitigate any risk of infection due to potential pathogens from human urine or faeces or other manufacturer defined inputs (as identified through the HAZOP study and risk assessment conducted as specified in 4.2) or the intermediate and residual products of the treatment unit. This requirement includes the prevention or suitable minimization of human exposure to aerosols or dust (e.g. at feed hoppers).

Treatment units shall be designed in such a way as to allow for cleaning.

Treatment units shall be closed systems designed in accordance with the requirements of ISO 14159. Treatment units shall prevent the entry as well as the exit of insects and vermin to and from the subsystems and components.

7.8.2 Materials

All materials and their respective coatings, if present, used for the treatment unit shall be suitable for their specific use and shall resist degradation. If suitability and durability cannot be verified through respective data sheets, then it shall be proven through adequate tests.

7.8.3 System tightness

All installations of the treatment unit that contain, transport, or store liquids shall achieve water tightness. In cases in which the results of the HAZOP and risk assessment (see 4.2) indicate hazards that require mitigation through a higher degree of system tightness (e.g. for potentially dangerous gases), technical tightness shall be achieved.

7.8.4 Leakage protection

Where the HAZOP and risk assessment (see 4.2) indicate that it is necessary, suitable passive protection measures to prevent leakage shall be implemented in the design of the treatment process (e.g. double walled pipes) or realized through loss prevention systems (e.g. retention basins, secondary containment).

7.9 Mechanical requirements

7.9.1 Pressurized equipment

Vacuum and pressurized equipment with a nominal operation gauge pressure exceeding the range of −50 kPa to +50 kPa, respectively, shall be designed so as to withstand the mechanical loading vacuum/pressure to which the equipment is subjected, including appropriate structural strength safety factors. Equipment exceeding the range shall be controlled by appropriate and proven safety relief valves in accordance with the relevant parts of ISO 4126 or by additional safety-related functions (see 7.2.8) where necessary. Pressurized equipment shall comply with ASME B31.1 and all parts of standards such as ASME BPVC, EN 13480, EN 10216, or EN 10217.

7.9.2 Pipes, hoses and fittings

7.9.2.1 Design and dimension

Design and dimensions of pipes, hoses, and fittings shall conform to the operational requirements of the treatment unit process with respect to pressure-temperature ratings and volume flows. If two or more different materials are connected within the treatment unit, detrimental galvanic corrosion shall be prevented. The requirements in 7.7 and 7.8 apply to pipes, hoses, and fittings. Design and dimensions of pipes, hoses, and fittings shall comply with all parts of EN 13480.

7.9.2.2 Positioning

Pipes, hoses, and fittings shall be positioned for proposed function during all operational phases, under all defined environmental conditions and, if necessary, restrained to minimize deterioration resulting from contact with other elements of the treatment unit (e.g. hot surfaces, sharp edges, vibrations). Pipes, hoses, and fittings shall be safely accessible for visual inspection.

7.9.3 Tanks and vessels

Tanks and other storage vessels shall be capable of withstanding the stresses of prolonged containment of the relevant substances without exhibiting breakage, cracks, or other structural damage or deformation. Tanks and vessels shall be equipped with means of determining their fluid levels (e.g. fluid level indicators).

7.9.3.1 Flammable liquid tanks and vessels

Buried flammable liquid storage tanks shall meet the requirements of UL 58 and NFPA 30. Above-ground flammable liquid storage tanks shall meet the requirements of UL 142. Liquid fuel storage shall meet API 650.

7.9.4 Moving and rotating parts

Hazards associated with moving and rotating parts of the treatment unit shall be minimized either through design that prevents human contact with such parts or through the application of appropriate guards or protective devices. Treatment units shall be designed to prevent accidental blockage of moving parts.

7.9.5 Vibration

Vibrations produced by the treatment unit shall not result in hazards to the treatment unit's integrity. When tested in accordance with ISO 20816-1, the vibration level on the XYZ-axis at the defined personnel working stations within treatment units shall not exceed 0,5 m/s^2.

7.10 Radiation

7.10.1 High temperatures of parts and surfaces

Accessible parts or surfaces of the treatment unit that exceed the temperature of 60 °C shall be equipped with protection measures or fixed guards sufficient to prevent burn injuries.

7.10.2 Low temperatures of parts and surfaces

Accessible parts or surfaces of the treatment unit that fall below the temperature of –20 °C shall be equipped with protection measures or fixed guards sufficient to prevent injuries due to low temperatures.

7.10.3 Electromagnetic compatibility

Undesirable electromagnetic effects from the treatment unit shall be eliminated or reduced to safe levels. The treatment unit shall be sufficiently protected against relevant, undesirable electromagnetic effects introduced from other devices and installations outside of the treatment unit that can be reasonably expected to interact with the treatment unit. The requirements of IEC 61000-6 shall be met.

7.10.4 Other radiation emissions

All relevant undesirable radiation emissions from the treatment unit shall be eliminated or reduced to safe levels.

7.11 Electronic and electrical components

Electronic and electrical components shall meet the requirements of IEC 61140 and IEC 60529, and the relevant parts of IEC 60204 and IEC 60364.

Electronic and electrical components shall comply with the corresponding standards in Table 2.

Table 2 — Standards for electronic and electrical components

Component	Standard
Switchgears	IEC 60947 (all parts)
Control gears	IEC 60947 (all parts)
Power transformers	IEC 61558 (all parts)
Plugs, socket-outlets and couplers	IEC 60309-1
Connectors	IEC 61984

The insulation coordination shall meet the requirements of IEC 60664-1.

8 Operability

8.1 Safe loading

The treatment unit shall be designed in such a way as to allow safe loading of the unit when following the loading procedure recommended by the manufacturer (see 12.7.3). The design of the unit shall permit the operator to perform loading duties without coming into contact with the treatment unit inputs, and without causing non-negligible amounts of the treatment unit input to reach beyond the boundaries of the treatment unit.

8.2 Anthropometric design

8.2.1 General

Anthropometric data shall be used in the design of the treatment unit. Anthropometric data of the target operator groups shall be calculated in accordance with ISO 7250 (all parts).

8.2.2 Forces to be applied

Control elements for which forces are to be applied shall be designed in such a way that they can be operated comfortably by the intended personnel. Comfortable operation should be evaluated using EN 1005-1, EN 1005-2, EN 1005-3, EN 1005-4 requirements or NIOSH lifting risk calculations[100].

8.2.3 Accesses and stairs

Accesses (e.g. for maintenance purposes) and stairs within and surrounding the treatment unit shall meet design requirements (see 4.1) and fulfil any necessary ergonomic requirements with regard to their dimensions and accessibility. Treatment units shall comply with the requirements of the EN 547 series. Design of accesses and stairs shall minimize hazards related to slipping, tripping, or falling.

8.2.4 Aisles and platforms

Aisles and platforms within and surrounding the treatment unit shall meet design requirements (see 4.1) and fulfil any necessary ergonomic requirements with regard to their dimensions and accessibility. Design of aisles and platforms shall minimize hazards related to slipping, tripping, or falling.

8.3 Lighting

The treatment unit shall be equipped with lighting capable of fully illuminating all areas within the treatment unit which personnel can be expected to interact during treatment unit operation and maintenance. Treatment units shall comply with the requirements of EN 1837.

NOTE A typical minimum illumination level is between 150 lx and 300 lx and a typical minimum colour rendering index R_a value is between 40 and 80.

8.4 Operator system ergonomic design

The treatment unit shall be designed to be operable by persons with the level of expertise and capability indicated within the product literature (see 12.7.4).

The control elements and indicators shall be chosen, designed, realized, and arranged so that they are easy to access and locate according to expectations, neutral positions of the control elements are automatically reset after triggering, and the movement of the control elements correspond to the intended effect.

8.5 Operator personal protection

Personal protective equipment (PPE) for the prevention of direct risks to human health and safety shall be specified by the manufacturer, in accordance with the risk mitigating measures determined in the risk assessment (see 4.2).

9 Maintainability

9.1 Adjustability and maintainability

9.1.1 Identification of adjustment and maintenance needs

The manufacturer shall clearly define in the product literature which adjustment and maintenance activities are needed to ensure system function (see 12.7.4). Both preventive and reactive activities shall be described in detail. For preventive maintenance activities, their frequency shall be defined. For reactive maintenance activities, comprehensive instructions for responding to potential alarms and failures and for repair and/or replacement of parts and components shall be specified.

9.1.2 Ease of maintenance of devices, components and subassemblies

The design of the treatment unit shall allow personnel to perform the required adjustment and maintenance as described by the manufacturer (see 9.1.1).

9.2 Access to adjustment, and maintenance points

For adjustment and maintenance points that need to be accessed by personnel (e.g. through ladders, manways, hatches or doors), a hazard and operability (HAZOP) study and risk assessment as specified in 4.2 shall be conducted prior to commencement of activities described in 9.1.1. Essential suitable safety control measures to be implemented in accordance with the HAZOP shall meet design and ergonomic requirements with regard to their dimensions, accessibility, and prevention of slipping, tripping or falling.

9.3 Requirements for adjustment and maintenance activities

9.3.1 Discharge and cleaning, testability, adjustment, and maintenance on the running unit

The treatment unit shall allow safe adjustment and maintenance activities. This requirement includes safe:

a) discharge and cleaning of sections that need to be maintained;

b) testing of these sections following adjustment and maintenance; and

c) adjustment and maintenance of these sections while the treatment unit is in operation.

NOTE Not all maintenance tasks can be done while the treatment unit is in operation. The requirements in this clause only address maintenance tasks that can be done while the treatment unit is in operation.

9.3.2 Safe handling of electrical equipment

To ensure safe handling of electrical equipment during adjustment and maintenance, treatment units shall be designed in accordance with the requirements of IEC 60204-1.

9.4 Spare parts

The manufacturer shall provide a list of all critical spare parts. All parts and components that need to be exchanged prior to the end of the treatment unit's expected technical lifetime (see 4.4) shall be interchangeable.

9.5 Tools and devices

Tools and devices required for adjustment and routine maintenance shall be either mass-produced, widely available tools (such as screwdrivers and wrenches) or, if unit-specific tools are needed, then they shall be provided together with the treatment unit.

10 Outputs

10.1 General

The purpose of this clause is to specify required solid, liquid, gas, odour, and noise output parameters and thresholds. Outputs specified as recovered resources shall comply with pathogen requirements in 10.2.1 for solids, and 10.3.1 for effluent. In addition, manufacturers shall specify needs for monitoring, storage, transportation, and handling of recovered resources as per 5.3.

Outputs specified for discharge and disposal shall comply with pathogen requirements in 10.2.1 for solids, and 10.3.1 for effluent, and requirements in 10.2.2 for solids, 10.3.2 and 10.3.3 for effluent.

For small amounts of outputs that are produced during regular maintenance activities these outputs need not adhere to the requirements in Clause 10, provided that they are disposed of in a safe manner without causing harm to the environment or human health. Discharge of these outputs shall not be a substitute for treatment by the treatment unit.

10.2 Solid

10.2.1 Pathogens and indicator organisms

The presence of pathogens and indicator organisms in solid outputs from treatment units shall not exceed the thresholds specified in Table 3.

Table 3 — Solid output validation thresholds for human health protection

Parameter (Pathogen class)	Human enteric bacterial pathogens	Human enteric viruses	Human enteric Helminths	Human enteric Protozoa
Indicator organism	using *E. coli* as surrogate, measured in CFU	using Somatic Coliphage as surrogate, measured in PFU	using all human enteric helminths viable ova	using *Cryptosporidium parvum*[a] as surrogate, measured in oocyst
Max concentration in solids [#/g (dry solids)]	100	10	<1	<1

Source: ISO 30500:2018, Table 4.

[a] Cryptosporidium parvum is not taken from ISO 30500.

10.2.2 Requirements for trace elements in solid outputs

The presence of trace elements in solid outputs from treatment units shall not exceed the thresholds specified in Table 4 or alternatively shall meet the requirements of 10.2.3 for the disposal of solids. See A.3 for additional information.

Table 4 — Solid output trace elements thresholds

Metal	Maximum concentration in solids (mg/kg dry mass basis)
Arsenic, As	75[a]
Cadmium, Cd	20[b]
Chromium, Cr	3 000[a]
Copper, Cu	1 000[b]
Lead, Pb	750[b]
Mercury, Hg	16[b]
Molybdenum, Mo	75[a]
Nickel, Ni	300[b]
Selenium, Se	100[a]
Zinc, Zn	2 500[b]

[a] From Reference [94], see Table 2-1 Ceiling Concentration Limits for All Biosolids Applied to Land (milligrams per kilogram).

[b] From Reference [61].

10.2.3 Alternative requirements for solids for disposal

Solid outputs for disposal that do not meet the thresholds in Table 4 shall pass a toxic characteristic leaching procedure (TCLP) and soluble threshold limit concentration (STLC) following SW-846, test method 1311 to determine their leachate properties using the thresholds in Table 5.

Table 5 — Maximum concentration in extract for TCLP and STLC

Contaminant	TCLP[a] max. mg/l
Arsenic, As	5,0[a]
Cadmium, Cd	1,0[a]
Chromium, Cr	5,0[a]
Lead, Pb	5,0[a]
Mercury, Hg	0,2[a]
Selenium, Se	1,0[a]
	STLC[b] max. mg/l
Copper, Cu	25[b]
Molybdenum, Mo	350[b]
Nickel, Ni	20[b]
Zinc, Zn	250[b]

[a] From Reference [95].

[b] From Reference [96].

10.3 Effluent

10.3.1 Pathogens and indicator organisms

The presence of pathogens and indicator organisms in effluent output from the treatment unit shall not exceed the thresholds specified in Table 6.

Table 6 — Liquid effluent validation threshold for human health protection

Parameter (Pathogen class)	Human enteric bacterial pathogens	Human enteric viruses	Human enteric helminths	Human enteric protozoa
Indicator organism	using *E. coli* as surrogate, measured in CFU	using Somatic Coliphage as surrogate, measured in PFU	using all human enteric helminths viable ova	using viable *Clostridium perfringens spores* as surrogate, or *Cryptosporidium parvum*, measured in CFU or oocyst, respectively
Max. concentration in liquids (number/l)	100	10	<1	<1
Source: ISO 30500:2018, Table 5.				

10.3.2 Environmental parameters

Effluent from the treatment unit shall not exceed the water quality thresholds specified in Table 7.

Table 7 — Effluent performance thresholds for environmental parameters

Parameter	Threshold
BOD (mg/l)	≤25[a]
COD (mg/l)	≤100
pH	6 to 9[b]
Temperature (°C)	≤45
Total nitrogen (mg/l)	≤15[a,c]
Total phosphorous (mg/l)	≤2[c]
TSS (mg/l)	≤30[b]

[a] From Reference [60], Tables 1 and 2.

[b] From Reference [77], Tables 4–7.

[c] Total nitrogen means: the sum of total Kjeldahl nitrogen (organic N + NH_3), nitrate (NO_3-), nitrogen and nitrite (NO_2-) nitrogen.

10.3.3 Requirements for trace elements in effluent outputs

Effluent from the treatment unit shall not exceed the concentrations of the pollutants listed in Table 8.

Table 8 — Threshold levels of trace elements in effluent

Polluting substance	Threshold value for unfiltered sample (mg/l unless otherwise specified)
Aluminium, Al	5
Arsenic, As	0,1
Beryllium, Be	0,1
Cadmium, Cd	0,01
Chromium, Cr	0,1
Cobalt, Co	0,05
Copper, Cu	0,2
Fluoride	1
Iron, Fe	5
Lead, Pb	5
Lithium, Li	2,5
Manganese, Mn	0,2
Molybdenum, Mo	0,01
Nickel, Ni	0,2
Selenium, Se	0,02
Vanadium, V	0,1
Zinc, Zn	2

Source: Reference [113], Table A1.2.

10.4 Air emissions

Treatment units utilizing a thermal treatment process or processes that include combustion shall meet all emissions thresholds given in Table 9. Non-thermal units shall only meet the requirement for total dust.

Table 9 — Air emission parameter requirements

Emission threshold values (mg/m³ normalized) for thermal systems using faecal sludge as a fuel, 7 % O_2, 0 °C, dry		
Pollutant	**Thermal load up to 1 MW**	**Thermal load 1 MW up to 5 MW**
CO, mg/Nm³	440[a]	140
NO_x, mg/Nm³ [e]	880[a]	466[b]
SO_2, mg/Nm³	—	2 000[d]
Total dust, mg/Nm³	47[a]	47[b]
Dioxins and furans, ng/m³	**Average emission threshold value (ng/Nm³) for dioxins and furans, combined, over a sampling period of minimum 6 h and maximum 8 h**	
	0,18[a]	0,18[a]
	Average emission threshold values (mg/Nm³) for the trace elements at left, combined, over a sampling period of a minimum of 30 min and maximum of 8 h[a]	
Arsenic, As, mg/m³	0,7[c]	0,7[c]
Cadmium, Cd, mg/m³	0,07[c]	0,07[c]
Mercury, Hg, mg/m³	0,07[c]	0,07[c]

[a] From Reference [76].

[b] From Reference [58].

[c] From Reference [57].

[d] From Reference [64].

[e] $NO_x = NO_2 + NO$

Thermal load shall be calculated in accordance with Formula (1):

$$Q_F = B \times H_S \times \frac{1}{3\,600} \quad (1)$$

where

Q_F is the thermal load [MW];

B is the mass flow fuel (dry basis) [kg/h];

H_S is the superior calorific value [MJ/kg dry].

10.5 Odour

Odour emitted from the treatment unit shall not exceed 15 OU_E/m^3 at 15 m distance and beyond from the unit boundary for heights between 0 m and 6 m. Meeting the threshold shall be achieved by measurement to determine the odour emission inventory in accordance with EN 13725 followed by odour dispersion calculation based on the inventory results following the methodology in 11.7.

10.6 Noise

Ambient noise from the treatment unit shall not exceed 55 dB(A) at 15 m from the unit boundary. If measurements at 15 m are not possible, measurements at shorter distances may be conducted, and then normalized to 15 m equivalent as specified in 11.8.3.

11 Testing

11.1 General

Where testing is performed as part of the product certification process, the certification body shall meet the requirements of ISO/IEC 17065.

NOTE ISO/IEC 17065 requires that when testing is conducted as part of the certification process, the testing laboratory shall meet the applicable requirements of ISO/IEC 17025 (see ISO/IEC 17065:2012, 6.2.1 and 6.2.2).

11.2 Type tests

To demonstrate conformity with this document, type tests shall be performed according to Table 10. Type tests shall be conducted for a period that provides the best representation of performance. Tests shall be repeated following any modification likely to alter safety-related, functional, performance, or capacity-related properties of the treatment unit.

Table 10 — Means of obtaining type test results

Clause/Subclause	**Results/to be obtained through:** **— Document check** **— Inspection** **— Testing**
4.1 Industrial design and manufacture	Document check and inspection
4.2 Hazard and operability study and risk assessment	Document check and inspection
4.3 Ambient operation conditions	Document check and inspection
4.4 Expected technical lifetime	Document check and inspection
4.5.1 Input types	Document check
4.5.2 Specification of input parameters and ranges	Document check and testing
4.6.1 Reception of faecal sludge	Document check and inspection
4.6.2 Storage of faecal sludge	Document check and inspection
4.6.3 Feeding system	Document check and inspection
4.6.4 Drying facilities	Document check and inspection
5.2.1 Energy independence	Document check and testing according to 12.5
5.2.2 Energy positive	Document check and testing according to 12.5
5.3 Resource recovery	Document check and testing
6.1.1 Mean time between failure (MTBF)	Document check
6.1.2 Mean time to repair (MTTR)	Document check
6.1.3 Preventive maintenance time (Tpm)	Document check
6.2.1 Process stability	Document check and testing
6.2.2 Start reliability and start time	Document check and testing
6.2.3 Shut-off reliability and shut-off time	Document check and testing
7.1 Applicability	Document check
7.2.1 General	Document check
7.2.2 Degree of automation	Document check, inspection and testing
7.2.3 Intentional starting of operation	Document check, inspection and testing
7.2.4 Intentional stopping of operation	Document check, inspection and testing
7.2.5 Emergency stop	Document check, inspection and testing
7.2.6 Continuous monitoring	Document check, inspection and testing

Table 10 *(continued)*

Clause/Subclause	Results/to be obtained through: — Document check — Inspection — Testing
7.2.7 Feedback of process failures	Document check, inspection and testing
7.2.8 Safety-related functions of the control system	Document check, inspection and testing
7.2.9 Input overload protection monitoring	Document check, inspection and testing
7.2.10 Overpressure protection	Document check, inspection and testing
7.2.11 Fire and overheating prevention	Document check, inspection and testing
7.2.12 Explosion prevention	Document check, inspection and testing
7.3 Process redundancy	Document check and inspection
7.4 Material fire resistance	Document check and inspection
7.5.1 Safety and security	Document check and inspection
7.5.2 Security of external electrical energy supply	Document check, inspection and testing
7.5.3 Security of internal electrical energy supply	Document check, inspection and testing
7.6.1 Separation and isolation	Document check and inspection
7.6.2 Electrical energy discharge	Document check and inspection
7.6.3 Overvoltage protection	Document check and inspection
7.7.1 Structural integrity	Inspection
7.7.2 Integrity against external impacts	Document check and inspection
7.8.1 Hygienic design	Document check and inspection
7.8.2 Materials	Document check and inspection
7.8.3 System tightness	Document check and inspection
7.8.4 Leakage protection	Document check and inspection
7.9.1 Pressurized equipment	Document check and inspection
7.9.2.1 Design and dimension	Document check and inspection
7.9.2.2 Positioning	Document check and inspection
7.9.3 Tanks and vessels	Document check
7.9.4 Moving and rotating parts	Document check and inspection
7.9.5 Vibration	Document check and testing according to ISO 20816-1
7.10.1 High temperatures of parts and surfaces	Document check and inspection
7.10.2 Low temperatures of parts and surfaces	Document check and inspection
7.10.3 Electromagnetic compatibility	Document check and inspection
7.10.4 Other radiation emissions	Document check and inspection
7.11 Electronic and electrical components	Document check
8.1 Safe loading	Document check and inspection
8.2.2 Forces to be applied	Document check and testing
8.2.3 Accesses and stairs	Document check and inspection
8.2.4 Aisles and platforms	Document check and inspection
8.3 Lighting	Document check and inspection
8.4 Operator system ergonomic design	Document check and testing
8.5 Operator personal protection	Document check
9.1.1 Identification of adjustment and maintenance needs	Document check and inspection

Table 10 *(continued)*

Clause/Subclause	Results/to be obtained through: — Document check — Inspection — Testing
9.1.2 Ease of maintenance of devices, components and subassemblies	Document check and inspection
9.2 Access to adjustment, and maintenance points	Document check and inspection
9.3.1 Discharge and cleaning, testability, adjustment, and maintenance on the running unit	Document check and inspection
9.3.2 Safe handling of electrical equipment	Inspection
9.4 Spare parts	Document check and inspection
9.5 Tools and devices	Document check and inspection
10.2.1 Solid — Pathogens & Indicator Organisms	Testing according to 11.5.1
10.2.2 Requirements for trace elements in solid outputs	Testing according to 11.5.2
10.2.3 Alternative requirements for solids for disposal	Document check and testing according to 10.2.3
10.3.1 Effluent — pathogens & indicator organisms	Testing according to 11.5.1
10.3.2 Effluent — environmental parameters	Testing according to 11.5.3
10.3.3 Effluent — requirements for trace elements in effluent outputs	Testing according to 11.5.4
10.4 Air emissions	Testing according to 11.6
10.5 Odour	Document check and testing according to 11.7
10.6 Noise	Document check and testing according to 11.8
12 Product literature	Document check

11.3 Performance testing

Subclauses 11.3.1 to 11.3.2 describe the test conditions, durations, and sampling principles that treatment units shall adhere to while conducting testing. All testing shall be conducted in a field environment.

11.3.1 Test conditions

For tests which require the treatment unit to be in operation, the corresponding operating conditions are based on the input parameter and range specifications of the unit (see 4.5.2), and the treatment unit is required to operate in energy independent mode (see 5.2.1) throughout the duration of the test.

The following two test conditions shall be tested:

— upper throughput limit of defined input range, operating in energy independent mode;

— lower throughput limit of defined input range, operating in energy independent mode.

Other test conditions may also be tested, if deemed necessary.

While operating in the upper and lower limits of operation, the defined input shall not deviate by ±5 % of throughput.

During this test period, any preventive maintenance activities (and their associated durations) shall be accounted for and specified by the manufacturer. If this maintenance results in downtime of the unit, this duration shall not be part of the entire test duration.

11.3.2 Test duration

The test duration depends on the technology and shall cover the most regular operating conditions (i.e. undisturbed continuous operation and deviating operating states), corresponding to the test conditions (see 11.3.1) specified.

For each operating condition, the test duration shall be no less than listed in Table 11. Test duration may be extended depending on the technology and field circumstances.

Start-up and shutdown periods are not included in the test duration, but shall be accounted for, and specified by the manufacturer.

Table 11 provides a recommended sequence of testing. The sequence shall be repeated for every test condition (see 11.3.1).

Table 11 — Recommended test sequence

No	Test(s)	Test duration[c]	Remarks
0	Start-up: Follow start-up procedure according to the manufacturer's instructions	Not applicable	The timeframe depends on the duration of the start-up period required to achieve system operability and stability. This duration shall be specified by the manufacturer.
1	Solid and effluent	1 day, for 8 h[a]	Refer to 11.5 for details of sampling planning
2	Air emissions (except dioxins and furans) Odour measurement	1 day, for 8 h[a]	Refer to 11.6 for air emissions, and 11.7 for odour for details of sampling planning
3	Air emissions — Dioxins and furans	At least 3 days, for 8 h/day[a,d]	One sample per day. A total of three are required.
4	Noise measurements	1 day, for 8 h[a]	Refer to 11.8 for details of sampling planning Test shall be conducted on a day without other testing activities[b]

[a] 8 h excludes time for setting up of equipment, adjustment, calibration, etc.

[b] This is done to have the least disturbance.

[c] If not specified, test may be carried out in parallel with other test(s).

[d] As concentrations to be measured are very low (>0,18 ng/m^3). An accumulation for at least 6 h on the adsorbent is necessary to reach the detection threshold. With the preparation and follow-up time, only one measurement per day is possible.

11.4 Input characterisation and sampling

Characterisation of input critical control parameters as specified in defined input (see 4.5), pathogens and indicator organisms, and trace elements shall be carried out in accordance with corresponding test methods in Table 12 and Table 13.

For every day of performance testing, one grab sample shall be taken every hour, with three grab samples forming one composite sample, forming a total of three composite samples per designated day of testing.

Sampling shall be conducted at the input location(s) of the faecal sludge treatment unit. The output concentration shall be reported with the input concentration for each performance test.

Wherever possible, the tests should be performed with input material that shows average contamination with respect to pathogens and indicator organisms, and trace elements that can be expected in the country of application.

11.5 Solid and effluent

11.5.1 Pathogens and indicator organisms in solid outputs and effluent

Table 12 provides recommended test methods for pathogens and indicator organisms in solid output and effluent (see 10.2.1 and 10.3.1 for requirements).

Table 12 — Recommended test methods for measuring pathogens and indicator organisms in solid output and effluent

Parameter	Test methods
Human enteric bacterial pathogen (using *E. coli* as surrogate, measured in CFU)	APHA 9221[73], APHA 9222[74], and APHA 9223[75]
Human enteric helminths (using all human enteric helminths viable ova)	— Methods for microbiological analysis of sewage sludges, EPA[93] — Standard operating procedure Helminth Test[102] — EPA 600/1-87-014[92]
Human enteric viruses (using Somatic Coliphage as surrogate, measured in PFU)	EPA 1601[90] or ISO 10705-2
Human enteric protozoa (using *Clostridium perfringens* spores as surrogate or *Cryptosporidium parvum* as surrogate, measured in CFU or oocyst)	Solids: ISO 7937 Liquid: ISO 14189 EPA 1623[91]

11.5.2 Trace elements in solid outputs

Table 13 presents recommended test methods for trace elements in solid outputs (see 10.2.2 for requirements).

Table 13 — Recommended test methods for trace elements testing of solid outputs

Trace element	Recommended test methods	
Arsenic, As	ISO 11885	EN 16171[56]
Cadmium, Cd	ISO 11885	EN 16171[56]
Chromium, Cr	ISO 11885	EN 16171[56]
Copper, Cu	ISO 11885	EN 16171[56]
Lead, Pb	ISO 11885	EN 16171[56]
Mercury, Hg	ISO 17852	EN 16171[56]
Molybdenum, Mo	ISO 11885	EN 16171[56]
Nickel, Ni	ISO 11885	EN 16171[56]
Selenium, Se	ISO 11885	EN 16171[56]
Zinc, Zn	ISO 11885	EN 16171[56]

11.5.3 Environmental parameters for effluent

Table 14 presents recommended test methods for effluent discharge testing (see 10.3.2 for requirements).

Table 14 — Recommended test methods for environmental parameters for effluent

General parameter	Test method
BOD	APHA 5210 B[71]
COD	APHA 5220 B, D[72]
Fluoride, F	ISO/TS 17951-2
pH	APHA 4500-H+[68]
Total nitrogen	APHA 4500-N C[69], APHA 4120[66], APHA 4130[67]
Total phosphorus	APHA 4500-P[70], ISO 6878
Total suspended solids (TSS)	APHA 2540 D[65], EN 872[47]

11.5.4 Trace elements in effluent outputs

Table 15 presents recommended test methods for effluent discharge testing (see 10.3.3 for requirements).

Table 15 — Recommended test methods for trace elements for effluent

General parameter	Test method
Aluminium, Al	ISO 11885
Arsenic, As	ISO 11885
Beryllium, Be	ISO 11885
Cadmium, Cd	ISO 11885
Chromium, Cr	ISO 11885
Cobalt, Co	ISO 11885
Copper, Cu	ISO 11885
Iron, Fe	ISO 11885
Lead, Pb	ISO 11885
Lithium, Li	ISO 11885
Manganese, Mn	ISO11885
Molybdenum, Mo	ISO 11885
Nickel, Ni	ISO 11885
Selenium, Se	ISO 11885
Vanadium, V	ISO 11885
Zinc, Zn	ISO 11885
Probe taking (sampling of effluent)	ISO 5667-1

11.5.5 Sample planning

Before performing recurrent individual measurements, a detailed sample plan shall be developed in accordance with the requirements of:

— ISO 5667-1;

— ISO 5667-3;

— ISO 19458; and

— ISO 5667-13.

11.5.6 Measurement principles

The measurement scope and type shall be derived from the specified operating conditions, and the conditions at the sampling location. Based on the information gathered during the site review, the following criteria shall be defined:

a) time, number and duration of measurements;

b) operating conditions during the measurements; and

c) number of samples to be collected, to ensure that the receiving stream is properly quantified.

11.5.7 Sampling location

A sampling point from which to draw solid output and effluent samples shall be chosen so that it ensures that a representative sample is obtained at the point in the system of the treated output.

Guidance for sample planning can be found in 11.5.5.

11.5.8 Output sampling type and frequency

Samples shall be taken according to the sample types and sampling frequency described in Table 16.

Sampling equipment and procedures shall comply with relevant national and international standards, and the equipment, procedures, and standards used shall be documented in the test report. Samples shall be preserved using proven, parameter-specific preservation methods.

Table 16 — Sampling type and frequency for solid and effluent

Parameters	Sample type — grab/composite	Minimum sampling frequency
Pathogens (Indicator organisms)		
Bacteria	grab	One grab sample every hour. 9 grab samples per designated day of sampling.
Helminths	composite	One grab sample every hour, 3 grab samples form one composite sample. 3 composite samples per designated day of sampling.
Protozoa	composite	
Viruses	composite	
Environmental		
BOD	composite	One grab sample every hour, 3 grab samples form one composite sample. 3 composite samples per designated day of sampling.
COD	composite	
Fluoride, F	composite	Three one-hour composite samples per designated day of sampling.
pH	composite	One grab sample every hour, 3 grab samples form one composite sample. 3 composite samples per designated day of sampling.
Total nitrogen	composite	
Total phosphorus	composite	
TSS	composite	

Table 16 *(continued)*

Parameters	Sample type — grab/composite	Minimum sampling frequency
Trace elements		
Aluminium, Al	composite	Three one-hour composite samples per designated day of sampling.
Arsenic, As	composite	
Beryllium, Be	composite	
Cadmium, Cd	composite	
Chromium, Cr	composite	
Cobalt, Co	composite	
Copper, Cu	composite	
Iron, Fe	composite	
Lead, Pb	composite	
Lithium, Li	composite	
Manganese, Mn	composite	
Mercury, Hg	composite	
Molybdenum, Mo	composite	
Nickel, Ni	composite	
Selenium, Se	composite	
Vanadium, V	composite	
Zinc, Zn	composite	

11.5.9 Sample size

Table 17 and Table 18 give minimum sample sizes for each sample for analysis.

Table 17 — Minimum sample size for solids

Parameter	Sample size
Pathogen (indicator organisms)	
Bacteria	≥40 g[a]
Helminths	
Protozoa	
Viruses	

[a] Based on Reference [116]. There is a general assumption that 100 ml = 4 g dry solids. As the requirement is on a per litre basis for effluent, it can be assumed that for a 1 l sample equivalent, 40 g would be required.

[b] Reference [101] (see TMECC 02.01-4 and TMECC 02.01-5).

Table 17 *(continued)*

Parameter	Sample size
Trace elements	
Arsenic, As	≥10 g[b]
Cadmium, Cd	
Chromium, Cr	
Copper, Cu	
Lead, Pb	
Mercury, Hg	
Molybdenum, Mo	
Nickel, Ni	
Selenium, Se	
Zinc, Zn	

[a] Based on Reference [116]. There is a general assumption that 100 ml = 4 g dry solids. As the requirement is on a per litre basis for effluent, it can be assumed that for a 1 l sample equivalent, 40 g would be required.

[b] Reference [101] (see TMECC 02.01-4 and TMECC 02.01-5).

Table 18 — Minimum sample size for effluent

Parameter	Sample size
Pathogen (indicator organisms)	
Bacteria	≥1 l[a]
Helminths	
Protozoa	
Viruses	
Environmental	
BOD	≥100 ml
COD	≥100 ml
Fluoride, F	≥50 ml[b]
pH	≥50 ml or water sample must be deep enough to cover the tip of the electrode
Total nitrogen	≥50 ml[c]
Total phosphorus	≥50 ml[d]
TSS	≥1 l if dried residue is between 2,5 mg and 200 mg[e]

[a] For consistency with units in Table 5. Based on ISO 19458.

[b] Reference [101] (see TMECC 02.01-4 and TMECC 02.01-5).

[c] HACH Method 10071 (low range)[98].

[d] HACH Method 8190 (low range)[99].

[e] APHA 5220 A,[72]; HACH Method 8000[97].

Table 18 *(continued)*

Parameter	Sample size
Trace elements	
Aluminium, Al	≥50 ml[b]
Arsenic, As	
Beryllium, Be	
Cadmium, Cd	
Chromium, Cr	
Cobalt, Co	
Copper, Cu	
Iron, Fe	
Lead, Pb	
Lithium, Li	
Manganese, Mn	
Molybdenum, Mo	
Nickel, Ni	
Selenium, Se	
Vanadium, V	
Zinc, Zn	

[a] For consistency with units in Table 5. Based on ISO 19458.

[b] Reference [101] (see TMECC 02.01-4 and TMECC 02.01-5).

[c] HACH Method 10071 (low range)[98].

[d] HACH Method 8190 (low range)[99].

[e] APHA 5220 A,[72]; HACH Method 8000[97].

11.5.10 Sampling method

The general principles set out in ISO 5667-1 apply to the design of sampling programs for the purposes of quality control, quality characterization, and identification of sources of pollution of water, including bottom deposits and sludges. Detailed information is given in ISO 5667-13.

Sampling for microbiological analysis is described in ISO 19458. ISO 5667-4 provides information about sampling equipment, sampling procedure, frequency and timing, transport, stabilisation, sample identification and reporting.

11.5.11 Sample storage

Sampling containers should be chosen, as far as possible, which do not give rise to any interaction between the sample and the materials.

Sampling for microbiological analysis requires special measures regarding the sterilization of the sampling containers and should conform to ISO 19458.

11.6 Air emissions

Recommended test methods for flue gas emissions are indicated in Table 19. Either the ISO/EN/VDI guideline or the EPA method may be used.

Table 19 — Recommended test methods for air emissions

Parameter	ISO/EN/VDI guideline	EPA test method	Sample test duration (hours)
Carbon monoxide, CO	EN 15058[55]	Method 10[86]	0,5
Nitrogen oxides, NO_x	EN 14792[54]	Method 7E[85]	0,5
Sulphur dioxide, SO_2	EN 14791[53]	Method 6C[84]	0,5
Total dust	EN 13284-1[50]	Method 5[82] Method 5I[83]	2
Dioxins and furans	EN 1948[48]	Method 23A[87]	6
Arsenic, As	VDI 3874[103]	Method 29[88]	2
Cadmium, Cd	VDI 3874[103]	Method 29[88]	2
Mercury, Hg	EN 13211[49]	Method 101A[89]	0,5
Moisture content	EN 14790[52]	Method 4[81]	0,5
Oxygen, O_2	EN14789[51]	Method 3A[80]	0,5
Volume flow	ISO 16911-1	Method 2[79]	0,5
Requirements for measuring sections	EN 15259	Method 1[78]	Not applicable

11.6.1 Measurement planning

Before performing recurrent individual measurements, a detailed measurement plan shall be developed in accordance with the requirements of EN 15259.

11.6.2 Measurement principles

The measurement scope and type shall derive from specified operating conditions and conditions at the sampling location. Based on the information gathered during the site review and as required by measurement planning (see 11.6.1), the following criteria shall be defined:

a) Time, number, and duration of measurements:

   1) For dioxins and furans: a sampling period of 6 h to 8 h shall be observed. Measurements shall be taken once per day for 3 days.

   2) CO, NO_x and O_2 shall be measured for the duration specified in Table 19. The test period will be agreed upon prior to testing.

   3) The sampling period for all other air emission measurements shall be 0,5 h to 2 h. Measurements shall be taken three times within a 10-hour period.

b) Selection of sampling location:

   1) The sampling location shall present a sufficiently high flue gas flow velocity and a homogeneous velocity profile in the measurement cross section as defined in EN 15259.

   2) In selecting the measurement section, vertical ducts should be given preference over horizontal ducts.

c) Operating conditions during the measurements:

   1) Measurements shall be performed during steady state operating conditions leading to peak emissions.

      NOTE Maximum emission mass flow does not necessarily coincide with the maximum emission concentration. Consequently, the measurement objective can relate to the concentration, the mass flow, or both. The treatment unit operating mode, the input materials, and the flue gas cleaning system can influence the emissions.

2) Operating conditions shall be documented in detail in the measurement report.

11.6.3 Equipment specification

Analysers used for the air emissions tests shall be proven capable of measuring the emissions of interest with appropriate detection sensitivity. Equipment shall be operated according to the manufacturer's instructions. Testers shall ensure their familiarity with the characteristics of their analyser for their particular application.

Instrumental analysers shall be validated prior to use with respect to the following performance characteristics:

a) response time;

b) zero and span drift;

c) detection limit;

d) effect of interfering substances;

e) effect of temperature, relative humidity and pressure on instrument; and

f) stability.

11.6.4 Equipment calibration

For semi-continuous emission monitors, a zero and span check on the entire sampling system shall be performed immediately prior to the on-site test (within 2 h of analyser stabilization). A final zero and span check shall be performed after site measurements have been completed.

The calibrations frequency shall follow the instruments manufacturer's recommendations.

11.6.5 Sampling location

To ensure a representative measurement of the spatial and temporal distribution of the measured component in the flue gas duct, the sampling location for recurrent individual measurements and continuous measurements shall meet the minimum requirements specified in EN 15259. The following criteria shall be satisfied:

a) straight, possibly vertical duct section of uniform geometry and cross-sectional area, free from internal installations;

b) free inlet section with a length greater than 5 times the hydraulic diameter;

c) free outlet section with a length greater than twice the hydraulic diameter;

d) sufficient working space and ease of access; and

e) weather protection.

Measurements should be performed as grid measurements. Ports for the sampling probes within the flue gas duct shall be sized to allow the simultaneous sampling of several emission components without mutual interference.

To ensure the correct design of the measurement sections and sampling locations for new treatment units, sampling location should be determined early in the design phase.

11.6.6 Normalizing of measured pollutants

Air emission measurements shall be normalized as referenced in Table 9, by converting the raw values indicated on the instrument to the standard conditions prevalent in the test location.

In systems in which combustion processes are applied, the conversion formula is given in Formula (2).

$$C_N = C \times \frac{1}{1-H_2O} \times \frac{21-7}{21-O_{2,measured}} \times \frac{101,3}{P} \times \frac{273,15+T}{273,15} \quad (2)$$

NOTE Formula (2) has a reference O_2 concentration of 7 % by volume. All limits in Table 9 have been corrected from their respective sources to a common 7 % O_2 reference condition.

In systems in which non-combustion processes are applied, the conversion formula is given in Formula (3).

$$C_N = C \times \frac{1}{1-H_2O} \times \frac{1013}{P} \times \frac{273,15+T}{273,15} \quad (3)$$

where

C_N is the normalized concentration, in mg/m^3;

C is the measured concentration, in the same units as C_N;

H_2O is the humidity measured in volume fraction of water vapour $\frac{m^3 H_2O}{m^3 gas}$;

$O_{2,measured}$ is the O_2 concentration of the exhaust gas, measured in $\frac{m^3 O_2}{m^3 exhaust\ gas} \times 100$;

P is the pressure of the exhaust gas, measured in kPa;

T is the temperature of the exhaust gas, measured in °C.

11.6.7 Reference conditions

Before comparing the measured emission concentrations with the prescribed limit values, the measured values shall be corrected to the following reference conditions:

a) flue gas pressure: 101,3 kPa;

b) flue gas temperature: 273,15 K; and

c) flue gas moisture: dry basis.

11.7 Odour

11.7.1 Test methods for odour output

Odour measurement shall be carried out in accordance with EN 13725. EN 13725 specifies a validated interlaboratory comparison of olfactometry (ICO) method for the objective of determining the odour concentration of a gaseous sample using dynamic olfactometry with a panel of human assessors being the sensors and the emission rate of odours emanating from point sources, area sources with outward flow and areas without outward flow. The unit of measurements is the European odour unit per cubic metre: OU_E/m^3.

For additional guidance, the following standards may be used:

— EN 13725

— VDI 3882-1[104]

— VDI 3882-2[105]

— VDI 3884-1[106]

— EN 15259

— ISO 16911-1

— German Odour Emission Policy — GIRL[62]

— Software: Austal 2000

— VDI 3783[107]

— VDI 3880[108]

— VDI 3883[109]

— VDI 3945 part 1[110]

— VDI 3945 part 3[111]

11.7.2 Measurement planning

Before performing individual measurements, a detailed sampling plan shall be developed, taking into account the requirements of EN 15259. The measurement planning shall include the following aspects:

a) all relevant odour producing processes to be identified;

b) assessment of the toxicity and potential risk to the panel members of any emissions;

c) likely fluctuations in odour emission over time;

d) odour sampling point location(s);

e) conditions affecting the odour emission, including uncontrolled conditions such as weather and controlled or controllable conditions; and

f) time frame to bring the air samples to the laboratory.

11.7.3 Measurement principles

The extent and type of sampling for the olfactometric measurement shall be derived from the operating conditions specified by the supplier of the installation and the conditions at the place of sampling. Based on the information gathered during the measurement planning (see 11.7.2), the following criteria shall be defined:

a) time, number and duration of measurements (a recommended sampling period for individual measurements on point sources is 0,5 h, 3 times per day); for sampling surface sources and fugitive emissions, the number of measuring points shall be determined depending on the emitting surfaces. For surfaces, generally one measuring point per 10 m^2 is sufficient;

b) operating conditions during the measurements; and

c) number of samples to be collected, to ensure that the inventory of odourous gases is properly quantified.

11.7.4 Sampling location requirements

11.7.4.1 Point source emissions

The requirements in 11.6.5 for the sampling location of air emissions shall apply for the point measurement of odour. See also ISO 10396.

11.7.4.2 Surface and fugitive emissions

When using a canopy to measure surface and fugitive emissions, it is important to carefully select sampling location to ensure results are accurate and representative.

11.7.5 Measurement process

11.7.5.1 Sampling train

Sampling of a point source (e.g. ventilation outlet) can be performed using a sampling train consisting of a probe, a delivery pipe, and an optional particulate filter preceding the sampling system.

11.7.5.2 Materials selection

Appropriate materials shall be used for those parts of the sampling equipment that are in contact with the odourant sample. The following materials are appropriate:

— PTFE (polytetrafluorethylene);

— FEP (tetrafluoroethylene hexafluoropropylene copolymer);

— PET (polyethylene terephthalate);

— stainless steel;

— glass.

11.7.6 Additional equipment considerations

Sampling probes and tubes that are exposed to odourant samples during a sampling session shall not be re-used unless they are cleaned and odourless before re-use.

11.7.7 Sample collection

11.7.7.1 Sample collection on non-ventilated, odour-emitting solid or liquid area sources, and fugitive emissions

The odour sample collection process shall use a canopy or a buoyant chamber (also known as a convective flux chamber) and shall be carried out as follows:

a) Cover the liquid or solid surface with a rigid canopy of known volume and area.

b) Ventilate the canopy with odour-free air at a known volumetric flow rate. Ensure the air passes over the whole surface and ensure sufficient time for steady concentration before sampling.

c) Register the air flow velocity.

d) Collect representative odour samples at the canopy outlet using a sampling train as described in 11.7.5.1.

11.7.7.2 Sample collection on a solid or liquid surface with very low discharge rates

The odour sample collection process shall be carried out as follows:

a) Cover the liquid or solid surface with a non-ventilated sampling hood (a surface of 1 m^2 is recommended).

b) Use a wind collar to keep the flow conditions in the hood constant.

c) Carry out the measurements in the exhaust gas tube of the hood.

d) Record the air flow velocity in the exhaust gas tube.

e) Collect representative odour samples at the hood outlet using a sampling train as described in 11.7.5.1.

11.7.7.3 Sample collection on point sources, odour-emitting stacks, ducts, vents and alike

The odour sample collection process shall be carried out as follows:

a) Carry out the measurements in the stack, duct or vent as a grid measurement according to EN 15259.

b) Record the air flow velocity.

c) Collect representative odour samples at the exhaust gas outlet using a sampling train as described in 11.7.5.1.

11.7.8 Minimum requirements for reporting

The following information shall be reported with results of odour sampling.

11.7.8.1 Treatment unit information

a) Information about the treatment unit technology, such as a flow chart;

b) location of treatment unit;

c) outer boundaries;

d) location of buildings;

e) location of odour sources;

f) locations of odour sampling points.

11.7.8.2 Odour source information

The following information shall be provided for each odour source.

a) Description of the odour source;

b) height of discharge of the odour;

c) dimensions (e.g. area) of the odour source;

d) measurement location in accordance with 11.7.4;

e) sample collection process used: 11.7.7.1, 11.7.7.2, or 11.7.7.3.

11.7.8.3 Flow conditions

The following information shall be provided for each odour source.

a) Air flow rate or air velocity and cross section area of emission to calculate flow rate;

b) temperature;

c) pressure;

d) humidity;

e) volume flow normalized, wet conditions.

11.7.8.4 Odour measurement results

The following information shall be provided for each odour source.

a) Odour concentration results for each measurement in OU_E/m^3;

b) odour concentration results geometric average for each source in OU_E/m^3;

c) odour flow rate for each source in OU_E/s;

11.7.8.5 Quality assurance

a) Certificate of last olfactometer calibration;

b) certificates for reference gases;

c) calibration results for the panellists according to EN 13725.

11.7.9 Determination of the odour concentration in the laboratory

11.7.9.1 Selection of panellists

The following requirements and recommendations (modified from EN 13725) apply to the selection of panellists.

a) In order to obtain a reliable panel, assessors with specific qualities shall be selected from the general population to serve as panellists.

b) In order to ensure repeatability of panellists' observations, their olfactory responses should be as constant as possible from day to day, and within a day.

c) In order to ensure repeatability, the olfactory sensitivity of the panellists shall be within a defined bandwidth. To achieve this aim, candidates for the panel shall be screened to ensure a specific range of sensitivity to the reference odourant.

d) To familiarize panellists with the olfactometric procedures, they shall first be trained by performing an assessment. These results shall be discarded.

Panellists shall be selected from among those whose screening assessment results comply with the criteria given in EN 13725.

11.7.9.2 Dilution apparatus

Dynamic olfactometry uses a panel of human assessors for sensory assessment. The olfactometer is an apparatus in which a sample of odourous gas is diluted with odourless air in a defined ratio and presented to the panelists. The odour concentration is measured by determining the dilution factor required to reach the detection threshold. The odour concentration at the detection threshold is by definition 1 OU_E/m^3.

The quality criteria and technical requirements for olfactometer are described in EN 13725:2003, 5.4.

11.7.9.3 Reference odourant

The calibration of the sensor of the sensory measurement, in this case the odour panel, shall be done on the basis of a reference odourant. Neutral gas shall be safe for breathing and perceived as odourless. A certified reference material with an uncertainty of ±5 % or less of n-butanol (CAS-Nr. 71-36-3) in nitrogen shall be used.

11.7.10 Dispersion modelling

The methodology for the evaluation of odour emissions is designed to provide a location-independent result. Therefore, it relies on the odour emissions inventory as determined for the unit undergoing testing and an odour dispersion calculation carried out for standardized conditions.

For this purpose, the following inputs and assumptions shall be used:

— odour emissions rate from the experimentally determined odour emission inventory;

— specific characteristics of emission sources (diameter, area, height, etc.);

— assumption of an open and flat terrain;

— absence of topographical structures or obstacles such as buildings or trees, etc.;

— constant wind speed in a specified direction of 1 m/s.

NOTE The odour emissions inventory can be used by the manufacturer, potential users, or regulators to calculate site-specific odour dispersion for any given site.

11.7.10.1 Dispersion model

To determine the odour concentration map around the system and demonstrate meeting the requirement of 10.5, a dispersion model shall be used. Two suitable atmospheric dispersion models exist:

— Gaussian puff model;

— Lagrangian particle model.

Since generally, more than one source of odour needs to be considered, the Lagrangian particle model shall be used.

11.7.10.2 Lagrangian particle model

The Lagrangian particle model tracks point-like particles on their path through the atmosphere, in this case odourous airborne molecules. The particles travel with the mean wind and are additionally subjected to the influence of turbulence. The effect of the turbulence is modelled by adding an additional random velocity to the mean motion for each particle.

A detailed description of the calculations behind this model can be found in VDI 3945-3[111].

11.7.10.3 Computational grid

The main factors governing the selection of the form of the computational grid structure are whether terrain irregularities, obstructing buildings and/or vegetation canopies which are to be considered in the dispersion simulation. Here, to provide location-independent results, a flat terrain configuration without any obstructing buildings or vegetation is assumed. The size of the grid should be chosen so that all particle trajectories between the investigated sources and receptors are adequately modelled. The evaluation relates to the odour concentration at a distance of 15 m outside the system boundary. This should be taken into account when defining the grid.

11.7.10.4 Physical and chemical data

To simulate the deposition, sedimentation and interception of trace species and their transformation by chemical reactions, physical and chemical data about the trace species are required as model input. Odour is considered as a gas in the dispersion model. The calculation is done without considering a deposition. Usually, dispersion modeling software have built in substance databases.

11.7.10.5 Source data

Odour emission sources shall be represented by specifying the source geometry, the source emission rate and data defining the inertial and buoyancy effects after release (see 11.7.8.2 to 11.7.8.3).

11.7.10.6 Evaluation grid

Lagrangian dispersion models calculate the spatial distribution of trace species concentrations as mean values over defined discrete space volumes and time intervals. The length of the time intervals and the location and dimensions of the sampling volumes (receptor cells) shall be defined. The selection of the sampling grid therefore requires a trade-off between averaging error and sample error.

NOTE For a detailed discussion about the accuracy, see Section 5 in VDI 3945-3[111].

11.7.11 Real measured values, treatment unit data and design data as input

11.7.11.1 Source data

The input data for odour dispersion calculation are described in 11.7.8.2 to 11.7.8.3. The report on the measurements shall contain all the information essential for the subsequent calculations.

11.7.11.2 Treatment unit data

A map of the layout is needed from which the location of the emissions sources can be identified. The layout shall have the system boundaries and the 15 m line for odour compliance clearly marked (with exact dimensions).

11.7.11.3 Design data

11.7.11.3.1 Mean wind velocity

The wind speed shall be fixed to 1 m/s.

11.7.11.3.2 Surface roughness

In the near-field observations of the plant, the roughness of the surface has a considerable influence on the turbulence.

The surface roughness is defined by the average roughness length, Z_0, and often presented by the Corine classes. A Z_0 value of 1,0 m shall be used in the calculations. This value is typical for industrial or commercial facilities, and construction sites.

11.8 Noise

11.8.1 Test methods

11.8.1.1 Noise output

Recommended test methods for noise emission are indicated in the following list.

— DIN 45645-1[63];

— ISO 3744;

— ISO 9613-2;

— IEC 61672-1;

— IEC 61672-2;

— IEC 61672-3;

— ISO 1996-1;

— ISO 1996-2.

11.8.2 Measurement planning

A noise assessment involves the examination of the nature and characteristic of noise. The following information shall be obtained:

a) the type of noise occurring;

b) the time the noise occurs (noise may be a nuisance at any time of day or night);

c) a subjective assessment of the source noise (i.e. at what distance is the noise audible; is the noise at a level that would preclude sleep or prevent others from enjoying the confines of their own environments);

d) the duration of the noise; and

e) the frequency of the noise (both the tone/pitch and how often it occurs).

Environmental conditions having an adverse effect on the microphones used for the measurements (e.g. strong electric or magnetic fields, wind, impingement of air discharge from the noise source being tested, high or low temperatures) shall be avoided as far as possible. If such conditions are unavoidable, the manufacturer's instructions regarding adverse environmental conditions shall be followed for all measuring instrumentation.

In an outdoor area, care shall be taken to minimize the effects of adverse meteorological conditions (e.g. temperature, humidity, wind, precipitation) on the sound propagation and on sound generation over the frequency range of interest or on the background noise during the measurements.

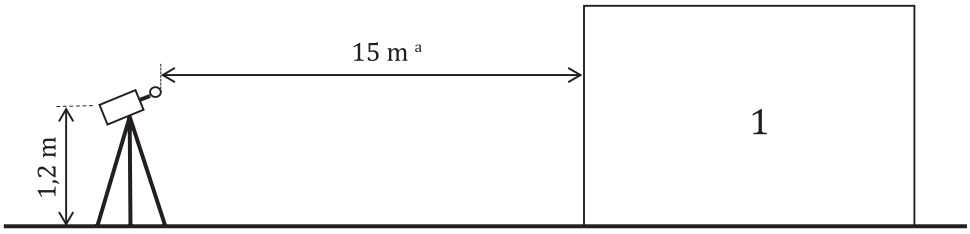
When a reflecting surface is not a ground plane or is not an integral part of a test room surface, particular care should be exercised to ensure that the plane does not radiate any appreciable sound due to vibrations.

11.8.3 Requirements for the sampling location

Noise is propagated to the environment by a sound source. Measurement shall be made at locations around the perimeter of the treatment unit or adjacent to the residential area or at receiver location.

Measurement shall be conducted at least 15 m from reflective surface other than the ground. If conditions do not permit, then a measurement at a defined distance shall be conducted, and the reading taken shall be normalized to 15 m equivalent using Formula (4).

The microphone shall be located 1,2 m above the ground level. See Figure 4 and Figure 5 for guidance.



Key

1 treatment unit

a Ideal.

Figure 4 — Ideal scenario — Noise measurement taken without any fence or hedge

$$L_2 = L_1 + 10\log\left(\frac{r_1}{r_2}\right)^2 - K1 - K2 \quad (4)$$

where

L_1 is the measured sound level in dB (A);

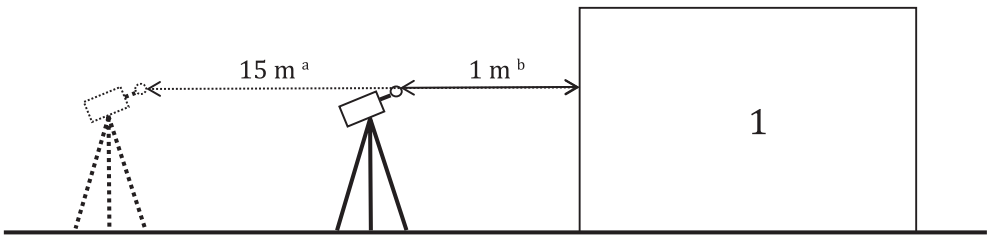
L_2 is the normalized sound level in dB (A);

r_1 is the distance the measured sound reading, in meters;

r_2 is the normalized sound reading, in meters;

$K1$ is the correction to account for background noise (see 11.8.10);

$K2$ is the correction to account for the environmental corrections in the test site (see 11.8.10).



Key

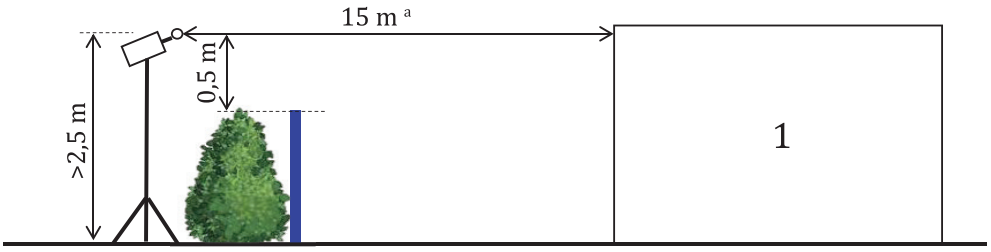
1 treatment unit

a Normalised distance.

b Non ideal.

Figure 5 — Non-ideal scenario case of measurement r_1, normalized to r_2 = 15 m

If the site is surrounded by fence, wall or dense hedge, the microphone shall be located 0,5 m above the fence, wall or dense hedge up to a maximum height of 2,5 m above the ground. See Figure 6 for guidance.



Key

1 treatment unit

a Ideal.

Figure 6 — Measurement with fencing or hedge

The microphones shall be positioned between 5 m to 10 m between each measuring point along the unit boundary.

11.8.4 Measurement methods and parameters

Measurements shall be conducted continuously through sampling of instantaneous sound pressure level for 24 h, using the A-weighted equivalent continuous sound level in decibels within 24 h (LAeq, 24 h).

If measurements cannot be conducted continuously, sampling may be conducted on an hourly basis and repeated continuously over the hours to obtain LAeq, 1 h, computed for LAeq, 24 h noise levels time profile.

This procedure can be used with a permanent monitoring station or measured manually.

11.8.5 Measurement equipment

The instrumentation system, including the microphones, cables, and windscreen, if used, shall meet the requirements of IEC 61672-1, class 1, and the filters shall meet the requirements of IEC 61260-1, class 1.

11.8.6 Calibration

Before and after each series of measurements is taken, a sound calibrator meeting the requirements of IEC 60942, class 1 shall be applied to each microphone to verify the calibration of the entire measuring system at one or more frequencies within the frequency range of interest. Without any adjustment, the difference between the readings made before and after each series of measurements shall be less than or equal to 0,5 dB. If this value is exceeded, the results of the series of measurements shall be discarded.

11.8.7 Operation of treatment unit during test

The noise level of the treatment unit shall be tested under conditions that are reproducible, and representative of the loudest operations involved in typical usage.

11.8.8 Sound level meter setting

The sound level meter shall be set to A-weighting with slow time weighting and shall record the average and level for each measuring event.

11.8.9 Microphone orientation

The microphone shall be oriented to achieve maximum sensitivity to the incident sound from the noise source, to the exclusion of other noises. The microphone shall be oriented so that the reference direction of the microphone is normal to the measurement surface. The instrument manufacturer's

recommendations shall be followed in using the meter and in determining the correct microphone orientation for the flattest frequency response.

11.8.10 Correction for background noise and reflecting surfaces in test environment

Two possible corrections can be applied to improve the measurement uncertainty of noise levels:

a) the correction, $K1$, in dB, to account for background noise; and

b) the correction, $K2$, in dB, to account for the environmental corrections in the test site.

12 Product literature

This clause specifies the information that shall be provided with the treatment unit.

12.1 General

The following general information shall be provided with the treatment unit:

a) information about the manufacturer:

   1) company name; and

   2) address;

b) description of the technology, including its unique identifier (e.g. commercial/trade name, unit identification number, or version number);

c) designated ambient operating conditions:

   1) ambient temperature range (minimum and maximum ambient temperature between which the unit functions as intended);

   2) ambient air humidity (minimum and maximum ambient air humidity between which the treatment unit functions as intended); and

   3) atmospheric pressure range (minimum and maximum atmospheric pressure between which the treatment unit functions as intended; this specification may also be expressed in units of meters above sea level).

12.2 Input

The following information shall be provided regarding inputs to the treatment unit:

a) type of input(s) for which the technology is intended, in addition to primarily treating faecal sludge derived from human excreta (see 4.5.1);

b) critical input parameters and the range of input values at which the unit meets the requirements of this document (see 4.5.2);

c) if applicable, expanded input parameter ranges within which the treatment unit meets all requirements except the energy independence requirement (see 4.5.2);

d) expected origin of input (e.g. pit latrines, wastewater treatment plant, faecal sludge drying beds);

e) estimated number of people served (including assumptions made); and

f) throughput on wet and dry basis (kg wet/day or kg dry/day or m^3/day).

Additional input specifications for consideration are provided in Annex A.

12.3 Performance claims

The following performance claims information shall be provided with the treatment unit:

a) unit-specific performance parameters and their numerical values to be verified, including:

   1) resource recovery type(s) and amount(s), categorized in accordance with the outputs described in the unit boundaries; and

   2) net positive energy generated (e.g. electricity, heat), if applicable;

b) test data and test methods applied to support the performance claim;

c) expected technical lifetime (see 4.4);

d) preventive maintenance time (see 6.1.3);

e) PFD at start-up or re-start (see 6.2.2);

f) PFD at stoppage or shutdown (see 6.2.3);

g) MTBF (see 6.1.1);

h) MTTR (see 6.1.2).

12.4 Unit boundaries

A process flow diagram (or equivalent) shall be provided containing process data (e.g. mass and energy balance) and indicating the boundaries of the treatment unit in a similar manner as that shown in Figure 7. Process information summarising the entire treatment unit shall include:

a) all known input amount(s);

b) all known output amount(s); and

c) energy balance (thermal or electrical) demonstrating energy neutrality or net positive energy including:

   1) operational power requirements, E_{FSP}, and

   2) power output, E_{OUT}.

NOTE The purpose of drawing the boundary of the treatment unit is to provide a clear demonstration that the treatment unit fulfils the essential criteria specified in the scope of this document.

12.5 Energy independence assessment

Prior to demonstrating energy independence (see 5.2), the treatment unit technology provider shall present assumptions for:

a) energy input, and

b) useful energy output for all major unit operations within the treatment unit technology that produce or utilize energy.

This information shall be presented in a table (or spreadsheet) format.

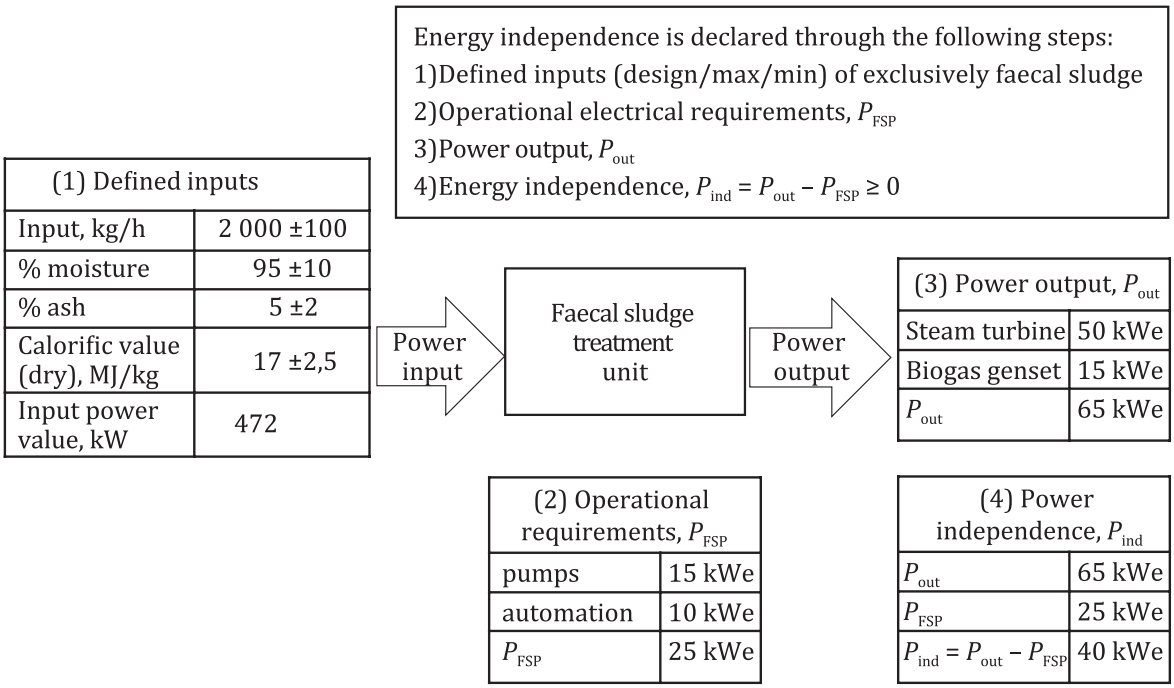
The table shall include assumptions regarding input mass flows (kilograms of water and dry solids per hour), the calorific value of the dry solids, and the net accessible energy value of the input per hour (megajoules per hour) during steady-state operation.

The table shall also list each major energy producing or consuming unit operation (e.g. gasifier, digester, turbine, pumps, compressors) within the treatment unit. Minor electrical or pneumatic

energy consuming components (e.g. lights, analytical instruments, controls, valve operators) may be collectively addressed as a single unit operation labelled 'Miscellaneous energy consumers'.

The table shall summarize assumptions for all major energy outputs produced by, consumed within, and available for export from the treatment unit, indicating the form and amount of energy output in the form of electricity, heat or fuel, all expressed in electricity equivalents (kWe or MWe), the net energy extracted from the input for each form of energy (megajoules per kilogram of input), and the net power production rate for each form of energy (megajoules per hour).

Figure 7 provides a recommended template for energy independence assessment or energy positive capabilities.



NOTE 1 Parameters in blocks (2) and (3) are for illustration purpose.

NOTE 2 Electricity is used as an example to illustrate power independence.

Figure 7 — Recommended template for energy independence assessment

Analysis of critical control parameters in input and output shall be demonstrated by 11.4, or sampling as per 11.5.8. Continuous monitoring of these critical control parameters, if available, may also be used to demonstrate conformity.

12.6 Environmental sustainability

This subclause specifies information to be provided by the manufacturer relevant to environmental sustainability, and complements other aspects of this document concerned with environmental sustainability, including energy balance and resource recovery requirements (see Clause 5 and 12.5) and environmental health parameters for effluent (see 10.3.2).

12.6.1 Consumables

To facilitate comparison between different systems, consumption of chemicals, and other additives, during the operational phase shall be calculated and indicated in appropriate SI units (e.g. l or mg per volume or mass of treated input). The manufacturer shall specify the assumed factors for these calculations. The manufacturer shall also provide the list of essential consumables and the expected total annual quantity of consumables to operate the treatment unit.

12.6.2 Greenhouse gas (GHG) emissions

The manufacturer shall indicate the amount of GHG emissions from treatment unit operation in appropriate units (e.g. kg per treated volume or mass of input). These emission measurements shall include, but are not limited to, CO_2, N_2O and CH_4. BECCS (bioenergy with carbon capture and storage) concepts suitable for the treatment unit may be outlined.

12.6.3 Characteristics of resource recovered products

The manufacturer of the treatment unit shall specify the type, subtypes, concentration, and amount of any valuable substances as generated during testing to be contained in each output product (in units such as mg/l or mg/kg dry mass and mg per volume of treated input). The manufacturer shall specify the assumptions used for these calculations. In addition, any products for which no quality specifications are given in this document shall be evaluated through a detailed risk assessment (see 4.2) that the manufacturer shall provide with the product literature, demonstrating that no unacceptable environmental or health risks will be caused by foreseeable use of the output product.

NOTE 1 The substances of interest are those that will provide an economic value for the product.

NOTE 2 This information can be used to determine the potential economic value of the product for a given location.

12.7 Maintenance and operator documentation

12.7.1 Language requirements

All manuals provided with the treatment unit shall be composed at the reading level of the intended operators. Information shall be provided:

a) in the official local language(s) of the country or region of use and, additionally;

b) in the English language.

12.7.2 Provision of manual

The operator of the treatment unit shall be provided with the user manual prior to operation of the treatment unit. Manuals shall be in accordance with IEC/IEEE 82079-1.

12.7.3 Information to be provided

The required information may be provided in one manual or divided among several manuals.

User manuals shall include, at a minimum:

a) product information, including:

   1) model number;

   2) serial number;

   3) date of manufacture;

   4) tare weight of the unit;

   5) treatment capacity;

   6) recommended pre-treatment if required;

   7) list of critical spare parts;

   8) product certification references, if applicable; and

9) operability conditions for the treatment unit such as temperature, humidity and pressure;

b) general description of the treatment unit;

c) drawings, including any required offsets, and diagrams that illustrate basic system design and include basic piping and instrumentation diagrams (P&ID) and circuit diagrams;

d) contact details (name, address, phone number, email) of the manufacturer, supplier, and service personnel to be contacted in case a problem with the system occurs;

e) comprehensive instructions for assembly and installation of the unit;

f) recommended operating team required, depending on the mode of operation (e.g. start-up, maintenance, etc.) and level of initial training and qualifications needed;

g) comprehensive instructions on how to load the unit safely, including instructions or appropriate references for how to conduct regular sampling of the specific input quality;

h) general safety instructions for the operator that include all warnings with respect to relevant residual risks during expected operation, considering reasonable foreseeable misuse;

i) comprehensive operating instructions including, for example, usage of an appropriate fire alarm system and fire suppression equipment and regular calibration of devices;

j) comprehensive instructions for responding to potential alarms and failures and for repair and/or replacement of parts and components, including required steps to re-establish safe and reliable operation and indication of when the operator should contact service personnel, in addition to:

   1) clear indication of the type of failure and/or defect to which alarm corresponds;

   2) clear indication of possible failures and/or defects, and instructions on identifying those failures and defects;

   3) clear indication of which repair actions are expected from the operator and which should be reserved for service personnel (e.g. for safety reasons);

   4) clear indication of which parts and components are expected to be replaced by the operator, including the expected replacement schedule and detailed replacement instructions; and

   5) clear instructions for the operator to only use parts and components that are recommended by the manufacturer;

k) comprehensive instructions for cleaning;

l) comprehensive instructions for personal protective equipment required for operation and maintenance of the treatment unit;

m) comprehensive maintenance instructions, including, at a minimum:

   1) clear distinction between activities to be conducted by the operator and activities to be conducted by service personnel;

   2) step-by-step description of procedures and activities to be conducted by the operator;

   3) frequency of procedures and activities to be conducted by the operator;

   4) frequency of procedures and activities to be conducted by the service personnel; and

   5) description of specialized maintenance tools, if required.

12.7.4 Recurring operation and maintenance

The manufacturer shall provide along with the product the relevant information specified below for the treatment unit, considering the treatment capacity of the system as declared under 12.7.3.

a) Recommended configuration, adjustment, and maintenance activities, including the estimated time required to perform each activity, identification of parts and components expected to require periodic replacement, and the estimated frequency with which such parts and components will be replaced. This information shall be provided in a summary table. See Table 20 as an example.

b) Estimated energy generation (in units such as kWh/year) including assumptions made.

c) Estimated annual consumption (amount/number) of other resources such as chemical and biological additives and specialized cleaning and maintenance tools.

d) Estimated energy consumption (in kWh) to bring the unit from shutdown to steady state operation.

e) Duration of the unit's ability to operate in energy independence mode (refer to 5.2.1)

Table 20 — Manufacturer's recommended configuration, adjustment, and maintenance activities

Who is to perform activity (Operator/professional service personnel)	Type of activity	Complexity of task (as per Table 21)	Frequency	Expected duration per activity (person hours)	Required parts, components or consumables

This information can enable the user to quantify the likely operational expenditures for the treatment unit. Further information and explanations related to these estimates can be found in B.2.3.

12.7.5 Complexity of configuration, adjustment, and maintenance activities

The manufacturer shall clearly indicate the type of training, technical skills, and experience expected of personnel adjusting and maintaining the treatment unit. The manufacturer shall indicate the complexity of the required activities regarding the technical competence needed to perform them. The manufacturer shall refer to activities to evaluate the complexity of each configuration, adjustment, and maintenance activity.

NOTE Technical competence refers to the individual's capability gained from experience, training, and education and can be understood as cognitive comprehension and behavioural performance. The degree of technical competence of the user or service person determines how effectively and efficiently he or she interacts with the treatment unit to achieve the intended system functionality. A complex system requires high technical competence, whereas a system of low complexity requires no or low technical competence.

Table 21 — Complexity of configuration, adjustment, and maintenance activities

Complexity	Technical competence
Very low	No skills (background education, experience)
Low	Basic skills and less than 1 h training required
Medium	Requires certain skills that can be acquired by training lasting no more than 1 day
High	Requires high technical skills (e.g. technical education in the field related to the activity), more than 1 day of training, and at least 6 months of work experience
Very high	Requires very high and specialized technical skills (e.g. advanced technical education in the field related to the activity), extensive training, and at least 1 year of work experience

12.7.6 Labelling and marking

The treatment unit shall be labelled and marked with the vital information regarding the points stated in 12.7.3 about the treatment unit specifications and certification mark, if applicable, and which shall be easily visible and permanently affixed on the body of the treatment unit.

Annex A
(informative)

Input specification templates

A.1 Thermal processes

Table A.1 details the recommended input parameters for specification of treatment units utilizing thermal processes. Recommended International Standards for parameter measurement are provided. If alternative methods are used, this should be reported and documented.

Separate tables should be completed for each type of feedstock.

Table A.1 — Sample table specifying input parameters for thermal processes

Parameter		Comments
Input type: e.g. faecal sludge, urine, biomass		
Origin: e.g. faecal sludge received from non-sewered sanitation service provider; sludge left exposed to air on drying beds for an average of 5 days		[Provide as much detail as possible e.g. recommended types of pre-processing required.]
Throughput (kg/day)		[Provide maximum, minimum, and design values]
Particle size (mm)		[If diameter and length are not suitable forms of measure, other formats may be used and clearly indicated.]
D_x =	x = maximum diameter	
L_y =	y = maximum length	
Moisture content, *M* (*M*%, as received) — ISO 18134-1 or ISO 18134-2		[Prepare report based on the total mass of the test sample (wet basis).]
M% =		
Ash content, *A* (mass %, dry basis) — ISO 18122		[Provide maximum, minimum, and design throughput]
A% =		
Calorific value, *Q* MJ/kg or kWh/kg dry basis, or **Energy density, *E*** MJ/m^3 or kWh/m^3 bulk volume, — ISO 18125		[Provide maximum, minimum, and design throughput]
Bulk density, *BD* kg/m^3 as received — ISO 17828		
BD =		
Nitrogen, N (mass %, water free basis) — ISO 16948		[Maximum value should be specified.]
N% =		
Arsenic, As (mg/kg, dry mass basis)		[Maximum value should be specified.]
As =		
Cadmium, Cd (mg/kg, dry mass basis)		[Maximum value should be specified.]
Cd =		
Chromium, Cr (mg/kg, dry mass basis)		[Maximum value should be specified.]
Cr =		

Table A.1 *(continued)*

Parameter	Comments
Copper, Cu (mg/kg, dry mass basis)	[Maximum value should be specified.]
Cu =	
Mercury, Hg (mg/kg, dry mass basis)	[Maximum value should be specified.]
Hg =	
Lead, Pb (mg/kg, dry mass basis)	[Maximum value should be specified.]
Pb =	
Molybdenum, Mo (mg/kg, dry mass basis)	[Maximum value should be specified.]
Mo =	
Nickel, Ni (mg/kg, dry mass basis)	[Maximum value should be specified.]
Ni =	
Selenium, Se (mg/kg, dry mass basis)	[Maximum value should be specified.]
Se =	
Zinc, Zn (mg/kg, dry mass basis)	[Maximum value should be specified.]
Zn =	
Sulphur, S (mass %, water free basis) — ISO 16994	[Maximum value should be specified.]
S% =	
Chloride, Cl (mass %, water free basis) — ISO 16994	[Maximum value should be specified.]
Cl% =	
Other: Rheology	

A.2 Biological processes

Table A.2 details the recommended input parameters for specification for treatment units utilizing biological processes. These may vary according to the utilized treatment process. Recommended International Standards for parameter measurements are provided in the table. If alternative test methods are used, this should be reported and documented.

Table A.2 — Sample table specifying input parameters for biological processes

Parameter	Comments
Input type: e.g. faecal sludge, urine, biomass	
Origin: e.g. faecal sludge received from pit latrines and other human waste repositories, delivered to the treatment location	[Provide as much detail as possible.]
Throughput (kg/day)	
Waste characteristics (mg/l) e.g. Average and maximum concentration (mg/l) for BOD, COD, VOC, nitrogen, phosphorous, suspended solids, salinity	
Moisture content, *M* (*M*%, as received) — ISO 18134-1 or ISO 18134-2	[Prepare report based on the total mass of the test sample (wet basis).]
M% =	
Ash content, A (mass %, water free basis) — ISO 18122	[Maximum value should be specified.]
A% =	
Nitrogen, N (mass %, water free basis) — ISO 16948	[Maximum value should be specified.]
N% =	
Phosphorous, P (mass %, water free basis) — ISO 6878	[Maximum value should be specified.]
P% =	

Table A.2 *(continued)*

Parameter	Comments
Sulphur, S (mass %, water free basis) — ISO 16994	[Maximum value should be specified.]
S% =	
Other	

A.3 Trace elements

Mass (composition and amount) of trace elements in the output are directly related to the mass (composition and amount) of trace elements in the inputs. It is understood that the treatment unit is not necessarily able to remove trace elements.

Annex B
(informative)

Sustainability

B.1 General

This annex provides guidance intended for, but not limited to, the purchaser, operator, planner, and/or user, and relates to collecting and analysing information that can be used to determine the suitability of a treatment unit for a given location, focusing upon the sustainability of faecal waste recycling services over time.

The challenges normally associated with all three aspects of sustainability — environment, people, and economics — are the underlying drivers of the development of faecal sludge treatment units described in this document. The critical aspects of people and economics, which are not included in the scope of this document, are discussed in this annex, focusing on the sustainability of faecal waste recycling services over time.

Regarding environmental sustainability, the key purpose of the treatment unit (i.e. reuse and recycling of human wastes) is a key component of sustainability in the context of an ever-increasing global population. Aspects of environmental sustainability are addressed in the provisions of this document.

In this annex, aspects of economic sustainability are considered, focusing upon ongoing financial viability of faecal sludge recycling services and people-oriented sustainability, considering the three dimensions of individual needs, organizational needs, and community issues.

Context-specific non-technical aspects are at least as important as technical considerations for achieving long-term sustainability of sanitation infrastructure projects, and hence should be considered in project implementation of treatment units. This annex is based on ISO Guide 82, which recommends identifying sustainability issues that are considered relevant and significant for the subject area.

Clauses B.2 to B.4 cover economic and financial aspects, B.5 and B.6 focus on institutional aspects, and B.7 highlights socio-economic aspects of sustainability.

B.2 Estimated cost of use calculations

B.2.1 General

To determine the costs of the treatment unit for the intended users, the estimated expenditures for the unit should be based on a calculation of the life cycle costs encompassing CAPEX (see B.2.2) and recurring cost (see B.2.3). To aggregate present costs and future running costs, the annualized net present value should be calculated. Net present value calculations involve the specification of a discount rate and a timespan for planning, which should be the expected design lifetime of the treatment unit. Further guidance on performing life cycle costing can be found in ISO 15686-5.

Net present value calculations can be used to compare different treatment unit choices. To facilitate sustainability, such calculations should also be presented as ‘Equivalent Annual Costs — Recurrent’, focusing upon recurrent costs of capital maintenance expenditure, without the inclusion of CAPEX. This calculation will give purchasers the understanding of the funding levels necessary, and therefore the budgeting considerations necessary, to ensure ongoing functioning and serviceability of the treatment unit.

B.2.2 CAPEX

Capital expenditure (CAPEX) comprises all initial investment costs required for implementation of a treatment unit. For a given location and users, at a minimum, costs to acquire the system and costs for transport, assembly, installation, and space required for the system (e.g. land use/property costs) should be considered.

B.2.3 Recurring costs

Recurring costs also commonly referred to as operational expenditure (OPEX) comprises all recurrent costs to keep the system in continuous working order. Recurrent costs include administrative, regular operation and minor maintenance costs as well as less regular capital maintenance costs, relating to replacement and renewal costs of components and/or subsystems over the life of the treatment unit.

When an installation location is identified, prices such as hourly rates for professional service personnel can be obtained and OPEX can be calculated. The information provided by the manufacturer in accordance with 12.7.4 and 12.7.5 can assist in these calculations.

For a given location and users, it should be ascertained that all parts, components, tools, and additives required and recommended for system operation and minor maintenance are available locally, including chemical and biological additives and specialized cleaning and maintenance tools. Price lists for these items should be made available to the user.

Regarding longer-term-but-occasional capital maintenance expenditure, the information provided by the manufacturer in accordance with 6.1.1 regarding confidence grades can be used to assess the anticipated life of components and/or subsystems that are likely to require renewal and replacement over the planned life of the treatment unit. Service providers will need to budget for such capital maintenance to ensure ongoing serviceability, understanding that renewal costs for treatment units can vary significantly due to context.

B.3 Financing

B.3.1 General

The actual costs to the purchaser may be adjusted by appropriate financing models for cost recovery. Cost recovery for faecal sludge treatment may be in the form of tariffs, taxes, revenues (e.g. from sale of output products), or some combination thereof. Financing models are further interlinked with the applied organizational models, such as public-private-partnership models. Hence, the envisaged financing and organizational model should be considered when assessing the actual cost of the treatment unit for a given location. Indirect benefits related to the treatment unit (e.g. value of avoided pollution or health costs) may be considered when evaluating financing mechanisms.

B.3.2 Financing in the context of the sanitation value chain

The treatment unit functions within the overall sanitation value chain (see Figure 1). The financial sustainability of the treatment unit can therefore be understood only in the context of the sustainability of the entire sanitation value chain (i.e. pit/tank emptying, waste transfer, pre-treatment where required, treatment unit operations, and final disposal and/or sale of resulting outputs).

It is envisaged that the treatment unit could be managed through private and/or public entities, and/or community business models that rely less on direct user charges and more on direct and indirect public taxes and transfers. This expectation is due to the treatment unit's function as a 'public good' (i.e. providing for the protection of public and environmental health). The treatment unit provides a service for which there is a clear societal need but for which in certain contexts there is limited private householder willingness or ability to pay. Evidence suggests there is similarly limited public/societal willingness to pay as 'globally, over 80 % of all wastewater is discharged without treatment'.

Funding flows to support the sanitation value chain will likely be accessed from a range of direct charges, such as household pit/tank emptying charges and conveyance emptying license fees, in

addition to indirect sources, such as transfers from water tariff sanitation surcharges, municipal (sanitation) taxes, national taxes, and municipal land allocation transfers, as well as revenues earned from sale of recovered resources. The combination of any of these funding flows will vary significantly between contexts. It is anticipated therefore that household willingness to pay or affordability may be one of several factors that could define the characteristic of financial sustainability of treatment units. The most significant defining characteristic may be the public sector's willingness to administer relevant tariffs and taxes, coupled with a clear understanding of the real ongoing costs of running a treatment unit.

Depending on the pre-treatment needs of the technology, the aspect of "Cost of Faecal Sludge Management (FSM) Treatment Plant" may need to be assessed for both a pre-treatment unit and a treatment unit. There are other financial models available. Within this assessment, it is noted that different organizational models will likely lead to differing financing approaches and therefore costs of capital.

The input parameter specifications provided by the manufacturer in accordance with 4.5 and 12.2 will indicate the extent of pre-treatment required before the input enters the treatment unit. If pre-treatment is required, close attention is to be paid to the residues of the pre-treatment. This pre-treatment is likely to comprise faecal sludge screening (and safe disposal of screenings) and faecal sludge dewatering.

A community-scaled treatment unit situated near the community to minimize transport costs, would ideally be managed by a community-based organization (CBO), ensuring acceptance by the local community. However, such an organization is unlikely to have sufficient financial capacity to address both the capital expenditure and capital maintenance expenditure requirements of a treatment unit, as well as any pre-treatment processes, and will require significant inputs to assure ongoing technical staffing capability.

A private operator is likely more able to access the necessary technical skills, commitment to efficient operations, and financing. However, that financing comes at a significant cost, which also requires assurance of ongoing funding flows. Direct user charges are likely to be insufficient.

The public sector has a responsibility to ensure public health, access to initial financing through taxes, grants and transfers (donations), and appropriate staffing skills, but often finds it difficult to sustain efficient operations and timely capital maintenance. There is evidence that well-established public-private-community partnerships are an appropriate organizational solution to such community-scale operations.

B.4 Suitability

Prior to the installation, a suitability assessment should be conducted (e.g. via survey) for individual projects to determine whether the inherent complexity of a treatment unit is reasonable for the intended setting given the expertise and experience of local service personnel. Relevant information for this assessment will be provided by the manufacturer in accordance with 12.7.4 and 12.7.5.

B.5 Planning, stakeholder participation and integration of the treatment unit

Planning and stakeholder participation are major factors in the long-term success of treatment units. Moreover, fragmented planning of infrastructure is a major problem in many developing countries. Before implementing a treatment unit, a well-structured planning process that allows for participation of relevant stakeholders and considers the integration of the planned treatment unit with other existing and planned infrastructure projects (e.g. water supply, solid waste, collection and transport services) should be conducted. The planning process should allow for appropriate consideration and balancing of various interests of stakeholders. In addition, the planning process should be based as far as possible on a comprehensive evaluation of needs and alternatives for solutions. Tools such as scenario analysis can support the planning process. The evaluation of all options should include technical, economic, environmental, institutional, and social aspects.

B.6 Environmental compliance monitoring and enforcement

Environmental compliance monitoring and enforcement is crucial for the long-term sustainability of the treatment unit. Therefore, before installing a treatment unit, a well-functioning process for environmental compliance monitoring and enforcement should be in place. Compliance monitoring should cover all parameters that can affect environmental and human health. The frequency of sampling should be adjusted to the risk potential of the monitored parameters. If no relevant guidelines are available for that purpose, a risk assessment should be conducted, considering the location-specific risk factors.

B.7 Acceptance and affordability

User acceptance has been identified as a major factor in the long-term success of sanitation systems, and a prerequisite for achieving user acceptance is satisfying users' cultural preferences, educating them on the advantages of using this system and accommodating existing practices. It is recommended that projects for a given location and users assess cultural preferences that may affect the sustainability of the faecal sludge treatment unit; in particular, acceptance related to the reuse of products stemming from the faecal sludge treatment unit.

In addition, user acceptance is interlinked with affordability. Affordability of water and sanitation services is internationally defined as the ratio between the household income (or household expenditures) of the user and expenditures of the user for water and sanitation services (in this case, the annualized net present value of the CAPEX and OPEX of the entire sanitation value chain for a defined timeframe). A threshold of 3 % to 5 % of household income (or household expenditures) for water and sanitation services is often recommended, of which just one third is likely to be claimable by a sanitation value chain. For a given location and users, more detailed affordability studies should be conducted for individual projects considering socioeconomic and social-cultural local contexts, including users' willingness to pay.

NOTE Household expenditure is offered as an alternative to household income because expenditure data is often more readily available than income data in many of the settings for which treatment units are designed.

In practice, household willingness to pay may be significantly less than the affordability calculation indicates. Globally, the resulting funding gap is typically addressed through indirect means, such as through municipal and general taxation, but the economic benefits of healthier people and a cleaner environment can significantly boost the overall economic potential of a community.

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