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

Unités de traitement de matières de vidange — Unités de récupération préfabriquées et autonomes en énergie pour des ressources à l'échelle locale — Sécurité et performances

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Foreword

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

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

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

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

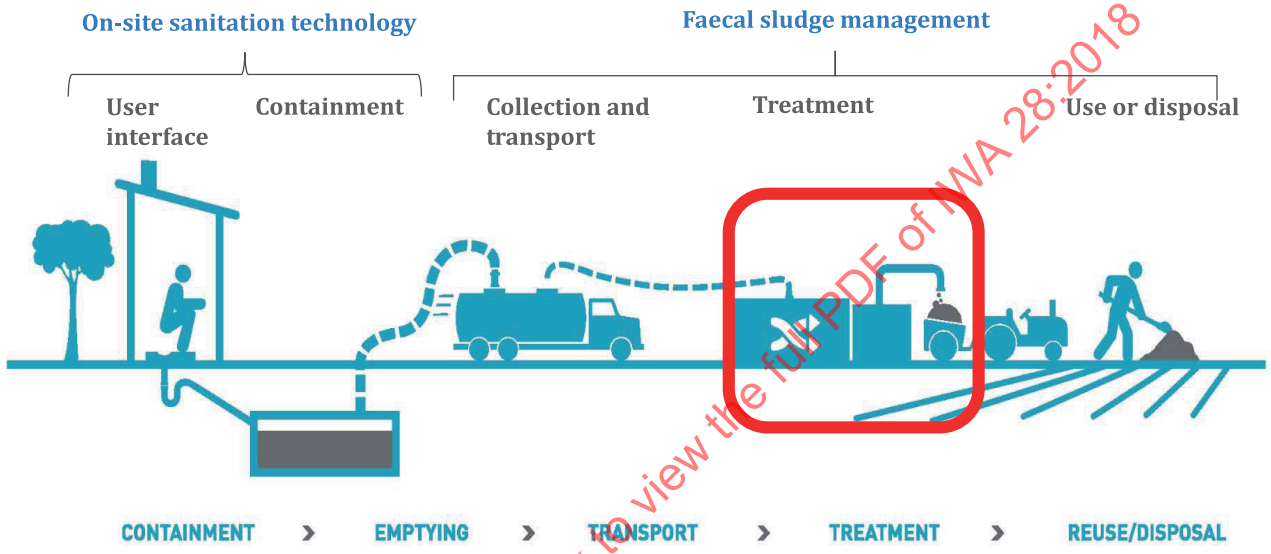
For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

International Workshop Agreement IWA 28 was developed and approved over a series of three workshops hosted by the American National Standards Institute (ANSI) in Durban, South Africa, in June 2017, in Singapore in September 2017 and in Dakar, Senegal, in January 2018.

Introduction

Hygienic sanitation facilities are crucial for public health, yet 61 % of the global population do not use safely managed sanitation services, i.e. excreta safely disposed of in situ or treated off-site (see Reference [186]).

Improved environmental sanitation has a multitude of socio-economic benefits. Functional sanitation systems improve health and welfare and are fundamental to human development. Integrated business models throughout the sanitation value chain can ensure the economic viability of processes that turn waste into valuable resources, such as biofuels or agriculture products. Sanitation systems can also conserve water, thus leading to even broader livelihood improvements. According to the World Health Organization, the estimated economic benefit of the return on a US$1 investment in sanitation is in the range of US$5 to US$28 (see Reference [185]).



NOTE The focus of this document is treatment (as depicted in the red box).

Figure 1 — Sanitation value chain

The focus of this technical document on non-sewered faecal sludge treatment units is represented by the red box along the sanitation value chain in Figure 1, indicating the treatment components of faecal sludge management. The purpose of this document is to specify performance and safety requirements of community-scaled resource-oriented faecal sludge treatment units serving approximately 1 000 to 100 000 people, ensuring technical robustness and safety in terms of human health and the environment. This document aims to facilitate the commercialization and transfer of these treatment units into the market.

This document complements ISO 30500[1)] on-site user-interface non-sewered sanitation systems (depicted at left in Figure 1).

This document aims to specify technical requirements and recommendations for community-scale resource-oriented faecal sludge treatment units in terms of performance, reliability, availability, maintainability and safety. This document further aims to promote trust among the different stakeholders involved in faecal sludge management, such as investors, technology developers, 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.

1) Under preparation. Stage at the time of publication: ISO/DIS 30500:2018.

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

This document is intended to ensure the general performance, safety and sustainability of such units. This document also includes requirements for operability and maintainability to ensure safety and performance of the treatment unit. Figure 2 illustrates the scope of this document with respect to treatment unit inputs and outputs.

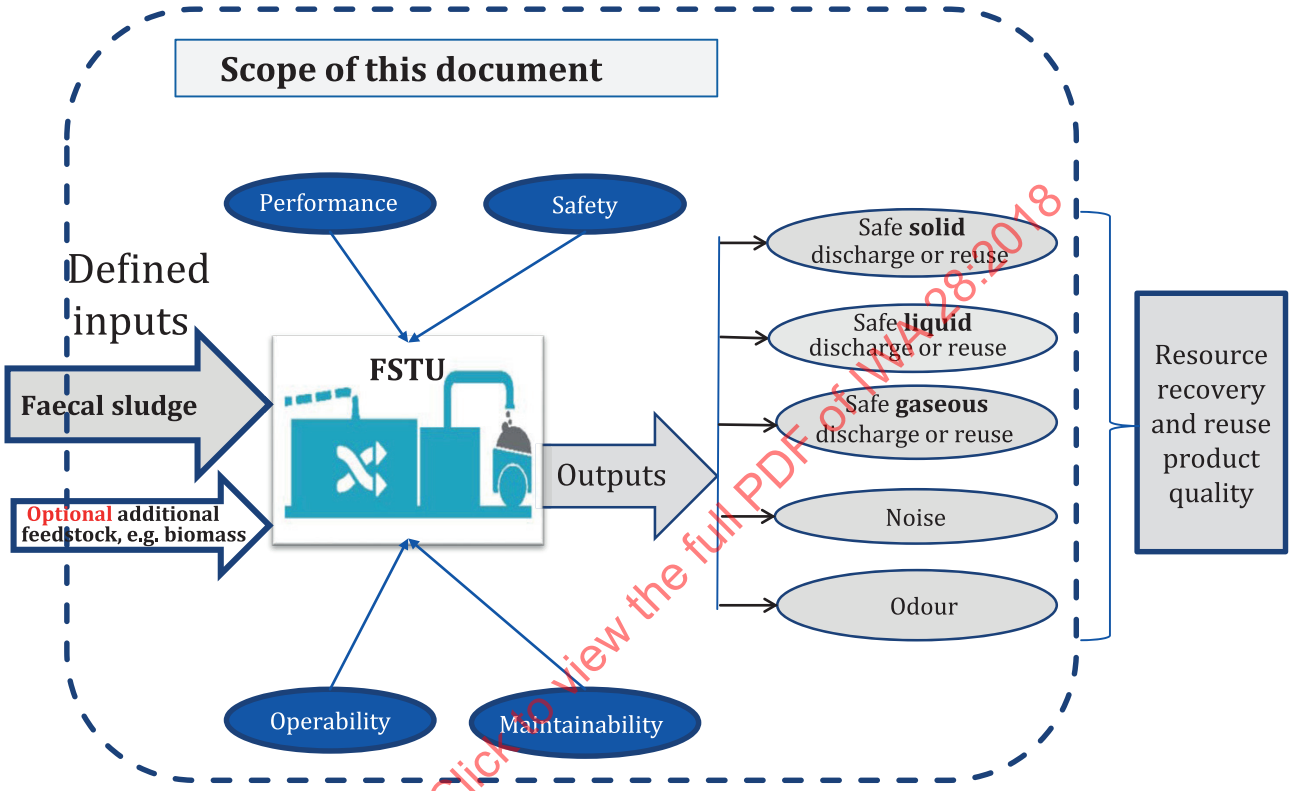


Figure 2 — Scope of this document

The dashed line in Figure 2 shows the boundary of the scope of this document. Inputs are primarily faecal sludge derived from human excreta (likely contaminated with domestic waste) and can include additional inputs at the discretion of the manufacturer. This document does not specify which forms of excreta and additional inputs are treated within the unit (e.g. urine, faeces, greywater); these inputs are defined by the manufacturer.

Inputs are illustrated as partially within and partially outside the document's scope to illustrate that the manufacturer defines the input characteristics which meet the requirements set forth in this document. The performance, safety, operability and maintainability of the treatment unit are addressed in this document, as are human health and safety aspects of the treatment unit's solid, liquid and gaseous outputs. Noise and odour outputs of the treatment unit are also addressed within this document. However, the quality and value of any resource recovery and reuse products derived from treatment unit outputs are outside the scope of this document. Apart from the requirement for energy independence during steady-state operation, this document does not set performance targets with respect to the amount or type of energy or resources that needs to be recovered and/or locally used.

This document excludes 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.

Annex C on sustainability highlights some of these considerations.

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

1 Scope

This document specifies requirements and test methods to ensure safety, performance and sustainability of community-scale resource-oriented faecal sludge treatment units that serve approximately 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.

This document does not apply to sanitation treatment units requiring sewer infrastructure, or to those requiring electric grid access during steady state operation.

Treatment units to which this document applies exhibit resource recovery capability (e.g. recovering energy, reusable water, soil amendment) and are capable of being energy neutral or energy net positive.

2 Normative references

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

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

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

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

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

IEC 60050, *International electrotechnical vocabulary*

IEC 60204-1, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60942, *Electroacoustics — Sound calibrators*

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

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

IEC 82079-1, *Preparation of instructions for use — Structuring, content and presentation — Part 1: General principles and detailed requirements*

API 650, *Welded steel tanks for oil storage*

ASTM D7348-13, *Standard test methods for loss on ignition (LOI) of solid combustion residues*

AWWA D-100, *Welded carbon steel tanks for water storage*

DIN 4109-1, *Sound insulation in buildings*

EN 13137, *Characterization of waste — Determination of total organic carbon (TOC) in waste, sludges and sediments*

EN 13725, *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*

EN 15936, *Sludge, treated biowaste, soil and waste — Determination of total organic carbon (TOC) by dry combustion*

FDBR-RL7, *Acceptance testing of waste incineration plants with grate firing systems*

NFPA 30:2018, *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*

Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)

3 Terms, definitions and abbreviated terms

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
untreated sludge generated from the storage of *human excreta* (3.1.1) that can be mixed with flush water, solid *domestic waste* (3.2.1) and other liquids

3.1.3
input
substances fed to the treatment unit for the purpose of treating those substances

Note 1 to entry: Input to treatment units covered by this document is required to be derived primarily from *faecal sludge* (3.1.2), which can be contaminated by liquid and solid *domestic waste* (3.2.1) and can 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 componentcf. functional requirement, implementation requirement, interface requirement, performance requirement, 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 14971:2007, 2.18]

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 provision 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]

3.1.9
functioning as intended
conforming to all expectations in terms of performance, capacity and safety as specified by the manufacturer

EXAMPLE The treatment process is functioning as intended when the process is stable and the output criteria are met.

3.1.10
reasonably foreseeable misuse
use of a machine in a way not intended by the designer, but which can result from readily predictable human behaviour

[SOURCE: ISO 12100:2010, 3.30]

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 and/or fossilized formations

[SOURCE: ISO 16620-1:2015, 3.1.2]

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 generation of energy supply versus energy outputs based on energy consumption by energy use

[SOURCE: ISO 50002:2014, 3.6, modified — Notes to entry have been deleted.]

3.2.5
energy independent
able to perform the intended functions of the treatment unit relying exclusively on energy from its defined *input* (3.1.3) during *steady state* (3.2.3) operation

3.2.6
energy positive
generating excess energy from the treatment unit's defined *input* (3.1.3) (e.g. as biocrude or biogas) that can be used in applications beyond the treatment unit

3.2.7
thermal treatment
treatment process using heat to convert energy from the treatment unit *input* (3.1.3) into a useful form

3.2.8
calorific value
quantity of heat produced by the combustion, the constituents of the combustible mixture being taken at reference conditions and the products of combustion being brought back to the same conditions

[SOURCE: ISO 22967:2010, 3.2.2, modified — The words "at a constant pressure equal to 0,101 325 MPa, of unit volume or mass of gas" have been deleted from the definition and the Note to entry has been deleted.]

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 in water

[SOURCE: ISO 9408:1999, 2.5, modified — Note to entry has been deleted.]

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 when a water sample is treated with that oxidant under defined conditions

[SOURCE: ISO 9408:1999, 2.6, modified — Note to entry has been deleted.]

3.2.11
volatile organic compound
VOC
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 17895:2005, 3.1, modified — The word "any" has been deleted at the start of the definition and the Notes to entry have been deleted.]

3.3 Performance

3.3.1
utilization time
period in which the treatment unit is in operation

Note 1 to entry: It is calculated as the sum of the *mean time between failure* (3.3.6), *technical downtime* (3.3.5) and all other *downtimes* (3.3.5) including *preventive maintenance* (3.3.3)

3.3.2
technical availability
portion of the treatment unit's uptime within the *utilization time* (3.3.1) compared to the sum of its uptime and *technical downtime* (3.3.5):

Note 1 to entry: It is calculated as the *mean time between failure* (3.3.6) divided by the sum of the mean time between failure and the *mean time to repair* (3.3.7).

Note 2 to entry: See also Figure 3.

3.3.3
preventive maintenance
activities that effectively preclude failure or damage through scheduled maintenance occurring at defined time periods or triggered through defined indicators such as wear and tear of components

3.3.4
downtime
period of time during which an item is not in a condition to perform its required function

Note 1 to entry: See also *functioning as intended* (3.1.9).

[SOURCE: ISO 8107:1993, 3.2]

3.3.5
technical downtime
unscheduled *downtime* (3.3.4) during which the treatment unit's processes are not *functioning as intended* (3.1.9), which can 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 1 to entry: The technical downtime is expressed through the *mean time to repair* (3.3.7).

3.3.6
mean time between failure
MTBF
average operating time between two consecutive failures of a technical system that each initiate a period of *downtime* (3.3.4)

3.3.7
mean time to repair
MTTR
average maintenance repair time for failures resulting in *technical downtime* (3.3.5)

Note 1 to entry: Mean time to repair generally does not reflect lead time for parts or administrative or logistical *downtime* (3.3.4).

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 device, 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

[SOURCE: ISO 21789:2009, 3.6]

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

[SOURCE: ISO 20815:2008, 3.1.40]

3.3.11
atmospheric tank
tank of which the inner vessel is designed to operate at atmospheric pressure

[SOURCE: ISO 5708:1983, 4.3]

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 non-sewered sanitation system to resist water penetration and prevent leakage

[SOURCE: ISO 30500:—[2)], 3.1.3.9]

3.4.3
technical tightness
inherent characteristics of a non-sewered sanitation system that prevent fluids, gases, or dusts from passing from the external through to the internal environment, or from the internal to the external environment, or both; the sanitation system or components thereof are considered technically tight if the leakage rate does not exceed 0,000 01 mbar l/s

[SOURCE: IWA 24:2016, 3.1.3.10]

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 (e.g. for clarification)

[SOURCE: ISO 1213-1:1993, 6.1.09]

3.5.2
odour
property of a substance that activates the human sense of smell

2) Under preparation. Stage at the time of publication: ISO/DIS 30500:2018.

3.5.3
pathogen
organism capable of producing disease in a susceptible plant or animal, including humans

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

3.5.4
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]

3.6 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	US Environmental Protection Agency
HAZOP	hazard and operability study
HSE	UK Health and Safety Executive
IFA	Institute for Occupational Safety and Health of the German Social Accident Insurance
LEL	lower explosive limit
LOI	loss on ignition
NFPA	National Fire Protection Association
NIOSH	US National Institute for Occupational Safety and Health
OPEX	operational expenditures
OSHA	US Occupation Safety and Health Administration
OU_e	odour unit (European)
PAH	polycyclic aromatic hydrocarbon
PFD	probability of failure on demand
PFU	plaque-forming units
$PM_{2.5}$	particulate matter with a diameter less than 2,5 micrometres
R_a	colour rendering value
TOC	total organic carbon
TSS	total suspended solids
UEL	upper explosive limit
UL	Underwriters Limited
UN	United Nations

VDI	Association of German Engineers
VOC	volatile organic compound
WHO	World Health Organization

4 General requirements

4.1 Industrial design and manufacture

Treatment units shall be designed and made in accordance with industrial standards. For the purposes of this document, industrial design and manufacture comprises 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) set forth in ISO 80000, IEC 80000 or an equivalent international or national standard.

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

c) Design and manufacture of the treatment unit shall be based on a clearly specified design base and uniform manufacturing process. The design base shall cover electrical, mechanical and process engineering, including the base for the declared capacity, availability and performance of the treatment unit. International and/or national standards should be used to guide compliance with these design requirements.

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 of a treatment unit shall carry out a hazard and operability study (HAZOP) following EN 61882 or an equivalent standard, and either

a) a risk assessment following ISO 12100 or IEC 31010, or

b) an equivalent standard or an equally effective assessment capable of demonstrating proven safety of treatment units.

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

The safety 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.

This assessment should be carried out during the design process; however, the assessment may be carried out after the design process. The assessment shall cover the relevant life cycle of the treatment unit, considering its expected use and reasonably foreseeable misuse.

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 according to the manufacturer's specifications. Subsystems may have a shorter expected lifetime than the treatment unit as a whole.

NOTE The expected technical lifetime requirement relates exclusively to the design of the treatment unit and does not impose any requirement on spare parts 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 for achieving energy independence (see 5.2.1) or energy positive status (see 5.2.2).

If the treatment unit can operate with an extended range of input parameter values while remaining in compliance with all with the exception of the energy independence requirements, then the manufacturer shall specify this 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 this 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 parameter	Operating input range	Operating input range to fulfil energy independence and/or energy positive
Throughput (kg/h) – wet or dry basis	500 to 1 500	750 to 1 200
Calorific value (MJ/kg)	5 to 15	8 to 15
Moisture content (% solids)	5 to 40	18 to 40
Ash content (%, dry basis)	5 to 20	5 to 15
NOTE 1 Parameters and values in this table are for illustration purposes only. NOTE 2 Not all possible combinations of these parameter values can be viable simultaneously.		

4.5.3 Input specification templates

Example of input specifications templates are provided in Annex A.

4.5.4 Additional input specifications for thermal and biological processes

Additional recommended input specifications for thermal and biological processes are provided in Annex B.

4.6 Requirements for handling of faecal sludge as a fuel

4.6.1 Delivery and reception of faecal sludge

The design of the treatment unit shall take all necessary precautions concerning the delivery and reception of faecal sludge to prevent or to limit as far as practicable 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 through contact with input products.

4.6.2 Storage of faecal sludge

The design of the treatment unit shall take all necessary precautions concerning the storage of faecal sludge to prevent or to limit as far as practicable 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 feeding system shall be closed and automatically operated to avoid direct risks to human health.

4.6.4 Additional requirements for thermal treatment units

4.6.4.1 Drying facilities

If the treatment unit includes drying facilities, the design of the unit shall take all necessary precautions to avoid emissions from the drying process and direct risks to human health. The wet air shall be collected and used as combustion air or directed to the exhaust gas cleaning facilities.

4.6.4.2 Operating conditions for the thermal treatment unit

Thermal treatment unit operating conditions shall be specified and shall ensure sufficient burnout of exhaust gases, slag, fly ash and bottom ash.

5 Energy balance and resource recovery

5.1 General

This clause sets forth requirements and recommendations for specifying performance claims with respect to energy balance and resource recovery. Energy and resource recovery performance claims and test methods for verification may vary across treatment units.

Marking and labelling requirements 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 faecal sludge as defined in 4.5.2.

This requirement does not apply to start-up, shutdown and unscheduled 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.

NOTE 1 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 steady-state operation in an off-grid environment would exclude the unit from coverage of this document.

NOTE 2 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.

NOTE 3 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

To fall within the scope of this document, 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. The type of resource recovery shall be specified in the product literature (see Clause 12).

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 calculations. The technical availability shall allow the treatment unit to function as intended during 85 % to 95 % of the utilization time.

MTBF calculations shall be made in accordance with IEC 60050.

Figure 3 illustrates MTBF as a component of utilization time.

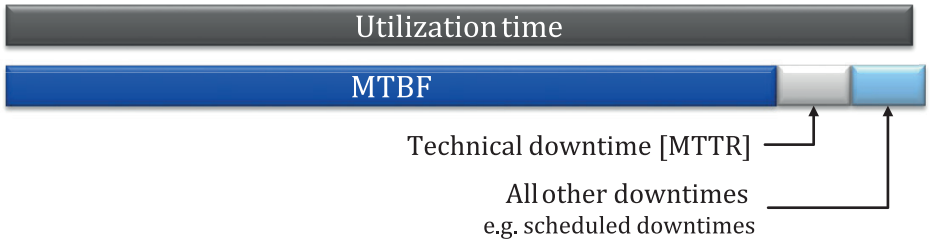


Figure 3 — MTBF as a component of utilization time

Development of availability targets, and the expected reduction of the statistical variance and confidence interval of the MTBF values, shall be calculated according to the Confidence Grading System of the New

Zealand National Asset Management Group (NAMS) International Infrastructure Management Manual (IIMM)[161] or equivalent, taking into account ISO 55000 approaches on Asset Management Planning.

6.1.2 Mean time to repair (MTTR)

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

NOTE MTTR refers to reactive maintenance, i.e. maintenance activities triggered only after failure or damage has already occurred.

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 h/a. Preventive maintenance includes any work to be done according to the maintenance schedule provided by the manufacturer.

NOTE Preventive maintenance activities aim to minimize the technical downtime by precluding failure or damage.

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 functions as intended (see 12.4).

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 12.4). The manufacturer shall specify the treatment process ramp-up time necessary to reach process stability.

NOTE There are various methods to determine the PFD-value, e.g. Markov models, Bayesian models, Quantitative Fault Tree Analysis.

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 12.4). 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

Because treatment unit technologies vary, some of the provisions of Clause 7 are not applicable to certain treatment units. To identify which of the requirements of Clause 7 are relevant to a specific treatment unit, a hazard and operability (HAZOP) study and risk assessment shall be conducted as specified in 4.2, in accordance with the requirements of IEC 61882 and IEC 31010 or equivalent standards.

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 function as intended. Design and performance of the control system shall follow the IEC 61069 series or equivalent standards.

7.2.2 Degree of automation

The control system should enable automated operation of the treatment process, i.e. operation that does not necessitate 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 12.4).

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 bringing 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 12.4).

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. Manufacturers of treatment units should consult 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). Explosive gases shall be included among these critical unit process parameters (see 7.2.12). Continuous monitoring shall be remote and automatic and may be 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 (see 7.2.6). 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 operational level which the manufacturer expects to be managed by the operator. The related correction actions shall be described in the operation manual.

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 according to IEC 61511 or an equivalent standard.

Safety functions shall be prevented from being 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 overload of the treatment unit. The overload protection monitoring system shall indicate when the treatment unit is nearing maximum capacity and indicate to the operator that the unit is overloaded and therefore not operable. If overload occurs, 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. If overpressure occurs, the treatment process shall be transitioned into a safe state that prevents any hazards due to overpressure.

7.2.11 Fire and overheating prevention

Treatment units shall be designed in such a way as to avoid any risk of 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. If fire or overheating occurs, 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 monitored 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) according to EN 1839, ASTM E 681-01 or an equivalent standard; and the evaluation of the potential sources of ignition according to EN 1127-1 or an equivalent standard. Hazardous accumulations of potentially explosive gases, liquids, dust, vapours or other substances shall be prevented through flares or safe ventilation following API 520, API 521 or equivalent standards.

7.3 Process redundancy

To achieve the performance parameters defined according to 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) a suitable level of diversity among redundancy options;

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

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

7.4 Material fire resistance

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.

7.5 Security and safety of electrical energy supply

7.5.1 Security of electrical energy supply

7.5.1.1 Safety and security

For the event of total power failure, independent emergency exit lighting shall be provided where required.

7.5.1.2 Security of external electrical energy supply

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

7.5.1.3 Security of internal electrical energy supply

Failure of the internal electrical energy supply shall not trigger hazardous system conditions. This hazard prevention may 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.

7.5.2 Safety requirements for electrical energy supply

7.5.2.1 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.

7.5.2.2 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, compressed air reservoirs and hydraulic pressure accumulators.

7.5.2.3 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 follow EN 62305-2 or equivalent. Overvoltage protection shall include lightning protection measures that follow IEC 62305 or an equivalent standard.

7.6 Structures and supporting elements

7.6.1 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 fraction 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 ensure that no risk is posed by a rupture.

7.6.2 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 12.4).

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

7.7 Sanitary requirements

7.7.1 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 that follow the design requirements of ISO 14159 or an equivalent standard. Treatment units shall prevent the entry as well as the exit of insects and vermin to and from the subsystems and components.

7.7.2 Materials

All materials used for the treatment process shall be suitable for their specific use and shall resist degeneration. If this suitability and durability cannot be verified through respective data sheets, then it shall be proven through adequate tests.

7.7.3 System tightness

All installations of the treatment unit that contain, transport, or store liquids shall achieve water tightness (see 3.4.2). 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 (see 3.4.3) shall be achieved.

7.7.4 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).

7.8 Mechanical requirements

7.8.1 Pressurized equipment

Pressurized equipment with a nominal operation gauge pressure higher than 50 kPa and vacuum equipment with a nominal operation gauge pressure lower than 50 kPa vacuum shall be designed

so as to withstand the mechanical loading pressure to which the equipment is subjected, including appropriate structural strength safety factors. Overpressures shall be controlled by appropriate and proven safety relief valves according to the relevant parts of ISO 4126 or by additional safety-related functions (see 7.2.8) where necessary. Pressurized equipment shall follow internationally accepted standards such as ASME BPVC, ASME B31.1, EN 13480, EN 10216, or EN 10217.

7.8.2 Pipes, hoses and fittings

7.8.2.1 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. The requirements of 7.6 (structures and supporting elements) and 7.7 (sanitary requirements) apply to pipes, hoses and fittings. Design and dimensions of pipes, hoses and fittings shall follow internationally accepted standards such as EN 13480 or equivalent.

7.8.2.2 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.

7.8.3 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).

7.8.3.1 Atmospheric tanks and vessels

Atmospheric tanks and vessels shall meet the requirements of UL 1746 or equivalent standards. Buried flammable liquid storage tanks shall meet the requirements of UL 58 and NFPA 30:2018, Clause 4. Above-ground flammable liquid storage tanks shall meet the requirements of UL 142. Effluent storage tanks shall meet the requirements of AWWA D-100. Liquid fuel storage shall meet API 650 or equivalent standards.

7.8.3.2 Storage of potable water

Atmospheric storage tanks for potable water shall meet the design requirements of AWWA D-100 or equivalent standards. Atmospheric storage tanks for potable water and related connections such as pipes and hoses shall prevent any cross-contamination of the potable water. Installation methods and devices used, such as air gaps or backflow preventers, shall meet the requirements of ASME A112.1.2, ASSE 1013, ASSE 1052 or equivalent standards. All potable water distribution piping and hoses shall be protected from contaminants and pollutants through backflow devices in accordance with ASSE 1001 through ASSE 1056 or equivalent standards.

7.8.4 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.

7.8.5 Vibration

Vibrations produced by the treatment system shall not provoke sensations of discomfort nor result in hazards to the treatment system's integrity. When tested according to ISO 20816-1, the vibration level on the XYZ-axis at the defined personnel working stations within treatment systems shall not exceed 0,5 m/s^2.

7.9 Radiation

7.9.1 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.

7.9.2 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.

7.9.3 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 undesirable electromagnetic effects introduced from other devices and installations outside of the treatment unit. The requirements of IEC 61000-6 or an equivalent standard shall be met.

7.9.4 Other sources of radiation

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

NOTE Sources of radiation include microwave, laser, ultraviolet, or infrared radiation.

7.10 Electric and electrical components

Electric and electrical components shall meet the requirements of relevant parts of IEC 60204, IEC 61140, IEC 60529 and IEC 60364 or equivalent standards.

Electric and electrical components listed in Table 2 shall meet the requirements of the indicated standards or their equivalents.

Table 2 — Example standards for electric and electrical components

Component	Standard
Switchgears	IEC 60947 or equivalent
Control gears	IEC 60947 or equivalent
Power transformers	IEC 61558 or equivalent
Plugs, socket-outlets and couplers	IEC 60309-1 or equivalent
Connectors	IEC 61984 or equivalent

The insulation coordination shall meet the requirements of IEC 60664-1 or an equivalent standard.

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. 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 according to ISO 7250.

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 in ISO 9241, lifting risk calculations in NIOSH standards, or equivalent ergonomic standards.

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 or equivalent standards. 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.

8.2.5 Enclosed spaces

Enclosed spaces shall allow safe operation. Treatment units shall comply with the requirements of Directive 2009/104/EC or an equivalent standard.

8.3 Lighting

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

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 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.

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.

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. 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

Adjustment and maintenance points that need to be accessed by personnel (e.g. through ladders, manways, hatches or doors) during the activities described in 9.1.1 shall meet design and ergonomic requirements with regard to their dimensions, accessibility and prevention of slipping, tripping or falling. Treatment units shall meet the requirements of Directive 2009/104/EC or an equivalent standard.

9.3 Requirements for adjustment and maintenance activities

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

The treatment system 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;

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

9.3.2 Safe handling of electrical equipment

To ensure safe handling of electrical equipment during adjustment and maintenance, IEC 60204-1 shall be followed when designing the treatment unit.

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 standardized and 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

The purpose of this clause is to specify required solid, liquid, gas, odour and noise output parameters and thresholds to ensure that all outputs from treatment units are safe for the environment and human health.

10.1 Solid

10.1.1 General

The types of solid output specified in 10.1 represent those of the current treatment unit technologies under development. For other types of solid outputs not mentioned in this subclause, a risk assessment (see 4.2) shall be conducted and appropriate thresholds shall be applied.

10.1.2 Pathogens

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 Colony-Forming Units (CFU))	(using Somatic Coliphage as surrogate, measured in Plaque-Forming Units (PFU))	(using all human enteric helminths viable ova)	(using viable *Clostridium perfringens spores* as surrogate, measured in Colony-Forming Units (CFU))
Max concentration in solids (#/g (dry solids))	100	10	<1	<1
NOTE The values in this table have been adapted from ISO 30500. At the time of publication of this document, these values remain under discussion in the corresponding ISO committee.				

10.1.3 Heavy metals

The presence of heavy metals in solid outputs from treatment units shall not exceed the thresholds specified in Table 4.

Table 4 — Solid output heavy metal thresholds

Metal	Max concentration in solids (mg/kg)
Arsenic, As	75
Cadmium, Cd	85
Chromium, Cr	3 000
Copper, Cu	4 300
NOTE 1 Concentrations are on a dry-weight basis. NOTE 2 Adapted from Reference [155] Table 2-1 [Ceiling Concentration Limits for All Biosolids Applied to Land (milligrams per kilogram)].	

Table 4 *(continued)*

Metal	Max concentration in solids (mg/kg)
Mercury, Hg	57
Lead, Pb	840
Molybdenum, Mo	75
Nickel, Ni	420
Selenium, Se	100
Zinc, Zn	7 500
NOTE 1 Concentrations are on a dry-weight basis. NOTE 2 Adapted from Reference [155] Table 2-1 [Ceiling Concentration Limits for All Biosolids Applied to Land (milligrams per kilogram)].	

10.1.4 Additional requirements of solids for disposal

Proper disposal of residuals such as fly ash and other flue gas cleaning residues shall be performed. Solid outputs for disposal shall pass a Toxic Characteristic Leaching Procedure (TCLP) by SW-846, test method 1311, or an equivalent test to determine their leachate properties.

10.2 Effluent

10.2.1 Pathogens

The presence of pathogens and indicator organisms in effluent output from treatment units shall not exceed the thresholds specified in Table 5.

Table 5 — Liquid effluent validation thresholds and 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 Colony-Forming Units (CFU))	(using Somatic Coliphage as surrogate, measured in Plaque-Forming Units (PFU))	(using all human enteric helminths viable ova)	(using viable *Clostridium perfringens spores* as surrogate measured in Colony-Forming Units (CFU))
Max concentration in liquids (#/l)	100	10	<1	<1
NOTE The values in this table have been adapted from ISO 30500. At the time of publication of this document, these values remain under discussion in the corresponding ISO committee.				

10.2.2 Environmental parameters

Effluent from the treatment unit shall not exceed the water quality thresholds specified in Table 6.

Table 6 — Effluent performance thresholds for environmental parameters

	Category A usage: Threshold for unrestricted urban uses [a]	Category B usage: Threshold for discharge into surface water or other restricted urban uses [b]
COD (mg/l)	≤50 [c]	≤150 [d]
TSS (mg/l)	≤10 [c]	≤30 [d]
Total nitrogen (mg/l)	15 [e,f]	
Total phosphorous (mg/l)	2 [e]	
pH	6 to 9 [g]	
Temperature (°C)	15 to 30	

[a] Category A usage refers to unrestricted urban uses that comprise all uses where public access is not restricted (e.g. landscape irrigation, toilet flushing).

[b] Category B usage refers to discharge into surface water and other restricted urban uses that comprise all uses where public access is controlled or restricted by physical or institutional barriers (e.g. fences, temporal access restriction).

[c] EPA Guidelines for Water Reuse (2012) Table 4-7.

[d] EPA Guidelines for Water Reuse (2012) Table 4-4.

[e] EU Urban Wastewater Treatment Directive.

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

[g] EPA Guidelines for Water Reuse (2012).

10.2.3 Requirements for effluent

If the treatment unit produces effluent, then concentrations of the pollutants listed in Table 7 shall not exceed the specified thresholds.

Table 7 — Threshold values for effluent

Polluting substances	Threshold values for unfiltered samples
Mercury and its compounds, expressed as Hg	0,03 mg/l
Cadmium and its compounds, expressed as Cd	0,05 mg/l
Thallium and its compounds, expressed as Tl	0,05 mg/l
Arsenic and its compounds, expressed as	0,15 mg/l
Lead and its compounds, expressed as Pb	0,2 mg/l
Chromium and its compounds, expressed as Cr	0,5 mg/l
Copper and its compounds, expressed as Cu	0,5 mg/l
Nickel and its compounds, expressed as Ni	0,5 mg/l
Zinc and its compounds, expressed as Zn	1,5 mg/l
Dioxins and furans	0,3 ng/l
Source: Directive 2010/75/EU, Annex VI Part 5.	

10.3 Air emissions from thermal treatment units

The requirements in this subclause apply to treatment units utilizing a thermal treatment process.

Treatment units shall meet the emissions thresholds given in Table 8.

Table 8 — Air emission parameter requirements for thermal treatment units

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 to 5 MW**
CO, mg/Nm³	440 [a]	140
NO_2, mg/Nm³	880 [a]	466 [b]
SO_2, mg/Nm³	—	373 [b]
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]
Hg and its compounds, expressed as Hg, mg/m³	**Average emission threshold values (mg/Nm3) for the heavy metals at left, combined, over a sampling period of a minimum of 30 min and maximum of 8 h** [1]	
	0,07 [c]	0,07 [c]
Cd and its compounds, expressed as Cd, mg/m³	0,07 [c]	0,07 [c]
As and its compounds, expressed as, mg/m³	0,7 [c]	0,7 [c]
[a] Source: 1. BImSchV [132].		
[b] Source: Directive 2015/2193/EU.		
[c] Source: Directive 2010/75/EU.		

Thermal load shall be calculated as shown in Formula (1):

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

where

Q_F is the thermal load (kW);

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

H_u is the calorific value (kJ/kg).

10.4 Odour

Odour released shall not exceed 500 OU_E/m^3 from point sources. Emissions from surfaces shall be calculated as an odour rate, i.e. OU_E per unit time

10.5 Noise

Ambient noise from the treatment unit shall not exceed 45 dB(A) at the measured distance according to the test methods provided in 11.6.

11 Testing

11.1 Certification bodies

Where testing is performed for the purposes of certification, certifying bodies shall meet the requirements of ISO/IEC 17065:2012, 6.2.1 and 6.2.2, which state that when testing is conducted as

part of the certification process, the testing laboratory shall meet the applicable requirements in ISO/IEC 17025.

11.2 Input characterization

Characterization of input pathogens and indicator organisms and heavy metals shall be done in accordance with corresponding test methods in Table 9 and Table 10.

NOTE The resulting data are for informational purposes in characterizing the input for identified parameters only and are not intended to be used for determination of performance.

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

Sampling should be conducted at the input location of the faecal sludge treatment unit.

11.3 Solid and effluent

11.3.1 Pathogens in solid outputs and effluent

Table 9 provides recommended test methods for pathogens and indicator organisms in solid output and effluent (see 10.1.2 and 10.2.1 for requirements).

Table 9 — Recommended test methods for measuring pathogens in solid output and effluent

Parameter	Test methods	
Human enteric bacterial pathogen [using E.coli as surrogate, measured in Colony-Forming Units (CFU)]	APHA 922, APHA 9222 and APHA 9223	
Human enteric helminths (using all human enteric helminths viable ova)	— Methods for microbiological analysis of sewage sludges (see Reference [154]) — standard operating procedure Helminth Test, University of Kwazulu-Natal (Reference [176]) — EPA 600/1-87-014	
Human enteric viruses [using Somatic Coliphage as surrogate, measured in Plaque-Forming Unites (PFUs)]	EPA 1601 For large samples use EPA 1601	ISO 10705-1
Human enteric protozoa [using *Clostridium perfringens* spores as surrogate, measured in Colony Forming Units (CFU)]	Solids: ISO 7937 Liquid: ISO 14189	

11.3.2 Heavy metals in solid outputs

Table 10 presents recommended test methods for heavy metals in solid outputs.

Table 10 — Recommended test methods for heavy metal testing of solid outputs

Heavy metal	Recommended test method
Arsenic, As	TMECC:2001
Cadmium, Cd	TMECC:2001
Chromium, Cr	TMECC:2001
Copper, Cu	TMECC:2001
Mercury, Hg	EPA 7471

Table 10 *(continued)*

Heavy metal	Recommended test method
Lead, Pb	TMECC:2001
Molybdenum, Mo	TMECC:2001
Nickel, Ni	TMECC:2001
Selenium, Se	TMECC:2001
Zinc	TMECC:2001
TCLP	SW-846 test method 1311

11.3.3 Environmental parameters for effluent

Table 11 presents recommended test methods for effluent discharge testing (see 10.2.2 for requirements).

Table 11 — Recommended test methods for environmental parameters for effluent

General parameter	Test method
Chemical oxygen demand (COD)	APHA 5220 B
Total suspended solids (TSS)	APHA 2540 D, EN 872
Total nitrogen	APHA 4500-N C, APHA 4120, APHA 4130
Total phosphorus	APHA 4500-P, ISO 6878
pH	APHA 4500-H+

11.4 Air emissions

11.4.1 Loss on ignition and total organic carbon

11.4.1.1 Test methods

Burnout is the key parameter for both disposal and utilization of bottom and fly ash. Testing shall follow Directive 2010/75/EU, EN 13137, EN 15936 and ASTM D7348-13.

11.4.1.2 Sample preparation

The bottom ash and fly ash sampling shall be carried out according to the guideline FDBR-RL7. The guideline may be adapted for other types of technologies.

For the analysis of TOC and LOI in the bottom and fly ash, nine individual samples shall be taken for each parameter over a test period of 8 hours. Larger incombustibles occurring only sporadically shall be removed from the samples and re-fed to the firing system. These substances therefore shall not be reflected in the reported ash balance.

11.4.1.3 Sampling location

Samples shall be taken from a location along the process chain that does not precede ash extractor discharge and does not follow the ash bunker, i.e. the ash extractor discharge and the ash bunker form the outer limits of the potential sampling site.

11.4.1.4 Sample taking and handling

Sample taking and handling shall occur as follows:

a) Weigh each individual sample free from droplets and crush the sample.

b) Remove, weigh and discard metal constituents, stones and other inert material impairing the grind ability. Constituents of the remaining sample shall not exceed an edge length of 3 cm.

c) Combine the following samples to form three average, homogenized samples:

   1) samples 1, 4 and 7;

   2) samples 2, 5 and 8;

   3) samples 3, 6 and 9.

d) Divide each averaged sample into four parts, in accordance with guideline DIN 51701 or an equivalent method (e.g. by means of a riffle sampler) to obtain a reduced sample weight of approximately 5 kg.

e) Using one 5 kg sample from each averaged lot, crush each of the three samples to an edge length of less than 1 cm. Remove, weigh and discard metal constituents, stones and other inert material from the samples.

f) Combine and homogenize the remaining sampled material from the three averaged lots and extract 2 kg for a daily composite sample.

g) Dry the composite sample (max. 40 °C) such that no surface moisture remains.

h) Once water loss is ascertained, store the daily composite sample in a closed, air-tight plastic container.

i) Record each step of the sampling process in a form.

11.4.2 Temperature and residence time

Measurement of the minimum burning temperature and the retention time shall be performed using a suction pyrometer and taking into account the geometrical characteristics of the after burning chamber and their influence on the exhaust gas flow.

The requirements of the BMUB emissions guidelines[131] or an equivalent standard shall be met.

11.4.3 Air pollution emissions

11.4.3.1 Test methods

Recommended internationally accepted and recognized test methods for flue gas emissions are indicated in Table 12. Either the ISO, EN or VDI guideline or the EPA method may be used. Equivalent national standards may be applied.

Table 12 — Recommended test methods for air emissions

Parameter	ISO, EN or VDI guideline	EPA test methods
Total dust	EN 13284-1	EPA Method 5
Sulphur oxides SO_2	EN 14791	EPA Method 6C
Mercury	EN 13211	EPA Method 101A
Nitrogen oxides NO_x	EN 14792	EPA Method 7E
Carbon monoxide CO	EN 15058	EPA Method 10
Heavy metals	VDI 3874	EPA Method 29
PCDDs/PCDFs	EN 1948	EPA Method 23A
Moisture content	EN 14790	EPA Method 4

Table 12 *(continued)*

Parameter	ISO, EN or VDI guideline	EPA test methods
Oxygen O_2	EN 14789	EPA Method 3A
Volume flow	ISO 16911-1	EPA Method 2
Requirements for measuring sections	EN 15259	EPA Method 1

11.4.3.2 Measurement planning

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

11.4.3.3 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, 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 continuously over the full test period. The test period will be agreed upon prior to testing.

   3) The sampling period for all other air emission measurements should 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 should be performed during operating conditions leading to peak emissions characterized by the maximum emission mass flow.

      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 plant 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.

11.4.3.4 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 assessed 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 and pressure on instrument;

f) stability.

11.4.3.5 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.

Additional calibrations should be performed at regular intervals throughout the day.

11.4.3.6 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 defined in EN 15259 or equivalent. 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;

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 plants, sampling location should be determined early in the design phase.

11.4.3.7 Normalizing of measured pollutants

Air emission measurements shall be normalized as referenced in Table 8 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):

$$C_N = C \times \frac{1}{1 - \frac{H_2O[\%]}{100}} \times \frac{21 - x}{21 - O_{2,\text{measured}}} \times \frac{1\,013}{p[\text{hPa}]} \times \frac{273{,}15 + T}{273{,}15} \quad (2)$$

where

C_N is the concentration normalized;

C is the raw value in units of mg/Nm^3;

H_2O is the humidity measured;

x is the O_2 reference concentration:

C_N is the concentration normalized;

i 7% for thermal combustion treatment units;

$O_{2,measured}$ is the O_2 concentration of the exhaust gas;

P is the pressure of the exhaust gas, in hPa;

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

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

$$C_N = C \times \frac{1}{1 - \frac{H_2O[\%]}{100}} \times \frac{1\,013}{p[\text{hPa}]} \times \frac{273{,}15 + T}{273{,}15} \quad (3)$$

where

C_N is the concentration normalized;

C is the raw value in units of mg/Nm^3;

H_2O is the humidity measured;

P is the pressure of the exhaust gas, in hPa;

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

11.4.3.8 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: 1013 hPa;

b) flue gas temperature: 273,15 K;

c) flue gas moisture: dry basis.

11.5 Odour

11.5.1 Test methods for odour output

Odour measurement shall be carried out in accordance with the guideline EN 13725. For additional guidance, the following standards may be used:

— VDI 3882-1

— VDI 3882-2

— VDI 3884-1

— EN 15259

11.5.2 Measurement planning

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

a) relevant odour producing processes to be identified;

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

c) location(s) of odour emission points;

d) likely fluctuations in odour emission over time;

e) odour sampling point location(s);

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

11.5.3 Measurement principles

The measurement scope and type are 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 (a recommended sampling period for individual measurements is 0,5 h, 3 times per day);

b) operating conditions during the measurements;

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

11.5.4 Sampling location requirements

For sampling location requirements, the provisions for air emissions sampling location in 11.4.3.6 apply.

11.5.5 Measurement process

11.5.6 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 (see also ISO 10396).

11.5.7 Materials selection

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

— PTFE (polytetrafluorethylene);

— FEP (tetrafluoroethylene hexafluoropropylene copolymer);

— PET (Nalophan™, polyethyleneterephalate);

— stainless steel;

— glass.

11.5.8 Additional equipment considerations

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

A dynamic olfactometry unit shall be used.

11.5.9 Sample collection on a solid or liquid surface

The odour sample collection process shall be 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 11.5.6.

11.5.10 Selection of panellists

Selection of panellists shall incorporate the following requirements and recommendations (modified from EN 13725):

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 odorant.

d) To familiarize panellists with the olfactometric procedures, they shall first be trained by performing the 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.

11.6 Noise

11.6.1 Test methods for noise output

Recommended internationally accepted and recognized test methods for noise emission are indicated in the following list. Equivalent national and international standards may be applied.

— DIN 45645-1

— ISO 3744

— ISO 9613-2

— IEC 61672-1

— IEC 61672-2

— IEC 61672-3

11.6.2 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 enjoying the confines of their own environments);

d) the duration of the noise;

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 if 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 course of 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.

11.6.3 Measurement objective/scope

The noise under investigation should be measured for a sufficient time to establish that the measured value adequately represents the subject source noise. The source noise is measured over a time interval of at least 15 minutes or, if the noise continues for less than 15 minutes, the duration of the source noise.

11.6.4 Requirements for the sampling location

11.6.4.1 Installed units

If the unit is installed at its final location, the sampling location shall be as follows:

The measuring location for the assessment of the noise emission shall be 0,5 m outside the centre of the open window of the area most affected by the noise according to DIN 4109-1. In the case of differently loaded windows, the most heavily loaded window shall be used. Substitutes may be measured instead of the window of the most vulnerable area in accordance with DIN 4109-1, in particular if the inhabitants are not to be informed or not disturbed. Care shall be taken to ensure sufficient distance from reflecting surfaces.

11.6.4.2 Uninstalled units

For a reference unit that has not been installed in its final location, measuring points around the perimeter of the unit shall be used at a distance of 50 m from the unit boundary.

11.6.5 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.

11.6.6 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.

11.6.7 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.

11.6.8 Sound level meter setting

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

11.6.9 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.

11.6.10 Correction for background noise and reflecting surfaces in test environment

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

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

b) the correction, $K2$, in dB, to account for the reflecting surfaces in the test site.

11.6.11 N_{K1}, Number of uncertain measurements due to background noise

If an A-weighted sound pressure level taken with the test unit operating fails to measure at least 6 dB above background noise levels, then the measurement shall be marked uncertain by the use of an asterisk (*). The number of uncertain measurement points due to background noise is N_{K1}.

11.6.12 Representative A-weighted sound pressure level

The number of valid measurement points shall be calculated by subtracting the uncertain measurement points identified from the total number of measurement points determined. If at least half of the measurement points remain, as validated by Formula (4) then the representative A-weighted sound pressure level (L) shall be calculated using Formula (5):

$$N - N_{K1} - N_{K2} \geq N/2 \tag{4}$$

$$L = 10\mathrm{Log}\left[\sum_{i=1}^{n} 10^{Li/10}\right] - 10\mathrm{Log}10n \tag{5}$$

where

L is the representative or high-limit sound pressure level logarithmic average rounded off to the nearest 0,5 dB for a measuring event;

Li is the sound pressure level at the measured points;

n is the number of points to be averaged = $(N - N_{K1} - N_{K2})$;

N_{K1} measuring points where a background correction is impossible (the background noise is close to or higher than the noise of the source);

N_{K2} measuring points where a reflection correction is impossible (the reflected noise is close to or higher than the noise of the source).

NOTE The intention of Formula (3) is to check the quality of noise measurement. At least 50 % of the measuring points are needed to build an average.

The daily system noise levels, $L_{EX,\ 24h}$ are equivalent to the highest representative A-weighted sound pressure level among all measuring events. The maximum A-weighted sound pressure level, $L_{pA,max}$, is equivalent to the highest A-weighted sound pressure level measured from all measuring events.

12 Product literature

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

12.1 General

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

a) information about the manufacturer:

   1) company name;

   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 operation 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);

   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 standard (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);

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

NOTE Additional input specifications for consideration are provided in Annex B.

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;

   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) expected utilization time (see 6.1.1);

e) preventive maintenance time (see 6.1.2);

f) expected technical downtime (see 6.1.3);

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

h) PFD at stoppage or shutdown (see 6.2.3).

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 4. Process information summarising the entire treatment unit shall include:

a) all known input amount(s);

b) all known output amount(s);

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

   1) operational power requirements (E_{FSP});

   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 set forth in the scope of this document.

12.5 Energy independence assessment

To demonstrate compliance with the energy independence requirement (see 5.2) and provide an estimate of energy conversion efficiency, the treatment unit technology provider shall present its assumptions for:

a) energy input;

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

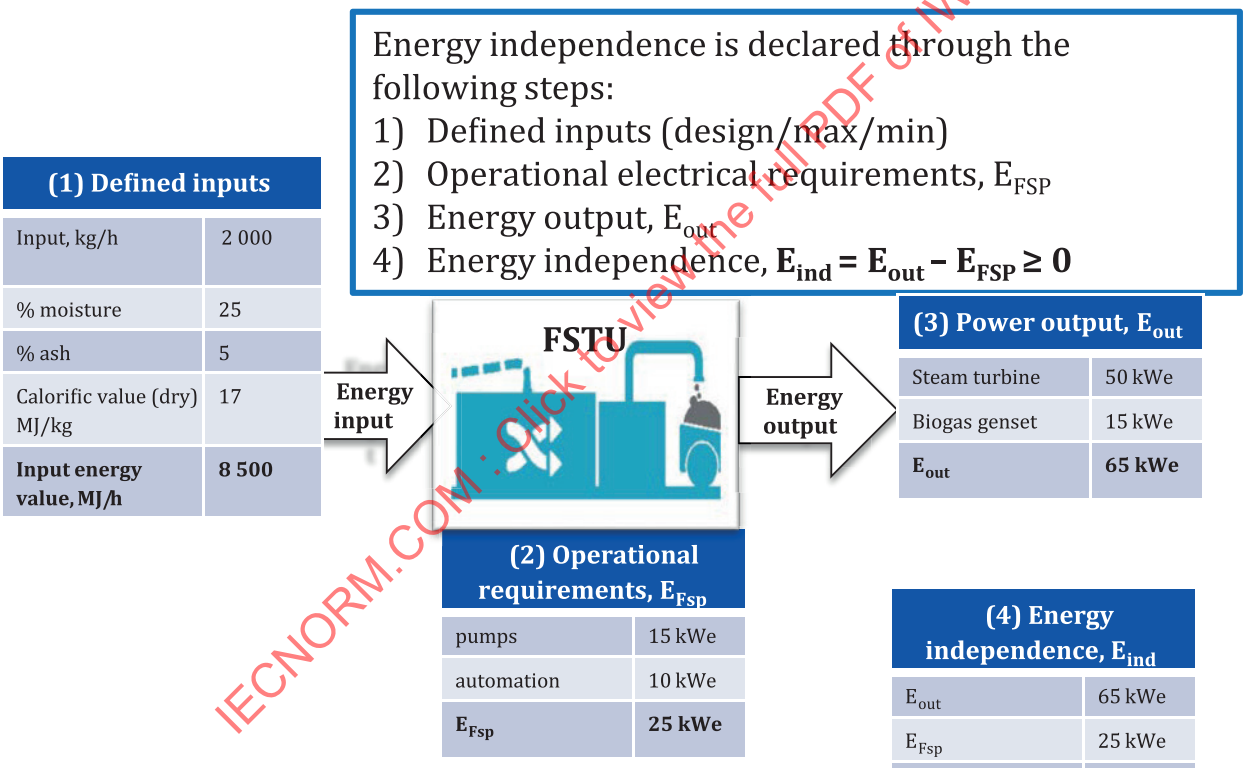
This information shall be presented in a table (or spreadsheet) format.

The table shall include assumptions regarding input mass flows (kilograms of water and dry solids per hour), the calorific or energy 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) in the sequence that energy is produced or consumed within the treatment unit. Minor electrical or pneumatic energy consuming components (lights, analytical instruments, controls, valve operators, etc.) 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 produced for each form of energy (electricity in kilowatts; heat and/or fuel energy in kilograms per hour and megajoules per hour), the net energy extracted from the input for each form of energy (megajoules per kilogram of input) and the net energy production rate for each form of energy (megajoules per hour).

Figure 4 provides a recommended template to demonstrate energy independence or energy positive capabilities.



NOTE Parameters in blocks (2) and (3) are for illustrative purposes. Electricity is used as an example to illustrate energy independence.

Figure 4 — Recommended template for energy independence assessment

12.6 Environmental sustainability

This subclause specifies information to be provided by the manufacturer relevant to environmental sustainability and complements other aspects of this standard concerned with environmental sustainability, including energy balance and resource recovery requirements (see Clause 5 and 12.5) and environmental health parameters for effluent (see 10.2.2).

12.6.1 Consumable consumption

To facilitate comparison across systems as well as determination of suitability for a given location, treatment unit consumable consumption. For example, the use 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.

12.6.2 Greenhouse gas emissions (GHG)

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 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 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. Further, 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 of use;

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 82079-1.

12.7.3 Number of documents

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

Information to be provided

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;

b) general description of the treatment unit;

c) drawings and diagrams that illustrate basic system design and include 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) comprehensive instructions on how to load the unit safely, including how to conduct regular sampling of the specific input quality;

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

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

i) 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;

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

j) comprehensive instructions for cleaning;

k) 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) 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 12.2.

a) Recommended configuration, adjustment and maintenance activities, including the estimated time required to perform each activity, and 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. An example for such a table is given in Table 13).

b) Estimated annual net energy consumption (in units such as kWh/year).

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

Table 13 — Manufacturer's recommended configuration, adjustment and maintenance activities

Who is to perform activity (user/ professional service personnel)	Type of activity	Complexity of task (as per Table 14)	Frequency	Expected duration per activity (man 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 Annex C and Clause D.1.

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 Table 14 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 14 — Complexity of configuration, adjustment and maintenance activities

Complexity	Technical competence
Very low	No skills (background education, experience),
Low	Basic skills and less than 1 hour 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

Annex A
(informative)

Input specification templates

A.1 Thermal processes

Table A.1 details the required and recommended input parameters for specification for treatment units utilizing thermal processes. Recommended International Standards for parameter measurement are provided in the table. If alternative standards are used, this use shall be explained and justified.

Separate tables should be filled 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 wastewater treatment plant biosolids; 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, ISO 18134-2 or equivalent		Prepare report based on the total mass of the test sample (wet basis).
M% =		
Ash content, A (mass%, dry basis) – ISO 18122 or equivalent		Provide maximum, minimum and design throughput.
A% =		
Calorific value, Q MJ / kg or kWh/kg dry basis, or **Energy density, E** MJ/m³ or kWh/m³ bulk volume, – ISO 18125 or equivalent		Provide maximum, minimum and design throughput.
Bulk density, BD kg/m³ as received – ISO 17828 or equivalent		
BD =		
Nitrogen, N (mass %, water free basis) – ISO 16948 or equivalent		Maximum value should be specified.
N% =		
Sulphur, S (mass %, water free basis) – ISO 16994 or equivalent		Maximum value should be specified.
S% =		
Chloride, Cl^- (mass %, water free basis) – ISO 16994 or equivalent		Maximum value should be specified.
Cl% =		
Other		

A.2 Biological processes

Table A.2 details the required and recommended input parameters for specification for treatment units utilizing biological processes. Recommended International Standards for parameter measurement are provided in the table. If alternative standards are used, this use shall be explained and justified.

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, volatiles, nitrogen, phosphorous, suspended solids, salinity	
Moisture content, M (M%, as received) – ISO 18134-1, ISO 18134-2 or equivalent	Prepare report based on the total mass of the test sample (wet basis).
M% =	
Ash content, A (mass%, water free basis) – ISO 18122 or equivalent	Maximum value should be specified.
A% =	
Nitrogen, N (mass %, water free basis) – ISO 16948 or equivalent	Maximum value should be specified.
N% =	
Sulphur, S (mass %, water free basis) – ISO 16994 or equivalent	Maximum value should be specified.
S% =	
Other	

Annex B
(informative)

Additional input specifications

B.1 Input specifications for thermal processes

This subclause outlines additional input specification recommendations for treatment units utilizing thermal processes.

Table A.1 provides a sample template for fulfilling the input specification recommendations for units utilizing thermal processes. Separate tables should be completed for each type of input.

In addition to the general input specifications (see 12.1 b)), thermal treatment input specifications may include, but are not limited to:

a) particle size;

b) moisture content, measured according to ISO 18134-1, ISO 18134-2 or an equivalent national standard;

c) ash content, measured according to ISO 18122 or an equivalent national standard;

a) calorific value or energy density measured according to ISO 18125 or an equivalent national standard;

e) rheology;

f) bulk density, measured according to ISO 17828 or an equivalent national standard;

g) nitrogen, measured according to ISO 16948 or an equivalent national standard;

h) sulphur, measured according to ISO 16994 or an equivalent national standard;

i) chloride, measured according to ISO 16994 or an equivalent national standard.

If alternative standards are used, this use should be explained and justified.

B.2 Input specification for biological processes

This subclause provides additional input specification recommendations for treatment units utilizing biological processes.

Table A.2 provides a sample template for fulfilling the input specification recommendations for units utilizing biological processes. Separate tables should be completed for each type of feedstock.

In addition to the general input specifications [see 12.1 b)], biological input specifications should be provided as follows:

a) average and maximum concentration (mg/l) for:

   1) Biological Oxygen Demand (BOD);

   2) Chemical Oxygen Demand (COD);

   3) Volatile organic compound (VOC);

4) phosphorous;

5) total solids;

6) salinity;

b) moisture content, measured according to ISO 18134-1, ISO 18134-2 or an equivalent national standard;

c) ash content, measured according to ISO 18122 or an equivalent national standard;

d) total nitrogen measured according to ISO 11905-1 or an equivalent national standard;

e) sulphur, measured according to ISO 16994 or an equivalent national standard.

If alternative standards are used, this use should be explained and justified.

Annex C
(informative)

Sustainability

C.1 General

The following guidance is intended, 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 within the scope of the provisions 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 have been addressed in the provisions of this document.

In this annex, we consider aspects of economic sustainability, 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. This annex is structured as follows:

— Clause C.2: Estimated cost of use calculations;

— Clause C.3: Financing

— Clause C.4: Suitability (Complexity) assessment

— Clause C.5: Planning, stakeholder participation and integration of the treatment unit

— Clause C.6: Compliance monitoring and enforcement of environmental compliance

— Clause C.7: Acceptance and affordability

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

C.2 Estimated cost of use calculations

C.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 C.2.2) and recurring cost (see C.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.

C.2.2 CAPEX

CAPEX comprises all initial investment costs required for implementation of the 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.

C.2.3 Recurring costs

Recurring cost, also commonly referred to as operational expenditure (OPEX) comprises all recurrent costs to keep the system in continuous working order. Recurrent costs include regular operation and minor maintenance costs as well as less regular capital maintenance costs, relating to replacement and renewal costs of components and/or sub units 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 12.7.5 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 to the anticipated life of components and/or sub-units 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.

C.3 Financing

C.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.

C.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 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 to pay. Evidence suggests there is similarly limited public/societal willingness to pay as 'globally, over 80 % of all wastewater is discharged without treatment' (see Reference [175]).

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 not anticipated therefore that household 'willingness to pay' or 'affordability' will be a defining characteristic of financial sustainability of treatment units. Rather, the defining characteristic is the public sector's willingness to organize relevant tariffs and taxes, coupled with a clear understanding of the real ongoing costs of running a treatment unit.

The spreadsheet in the Faecal Sludge Management Toolbox (FSM Toolbox) (see Reference [158]) is a recommended resource for undertaking an overall financial viability assessment for sustainability. Depending on the pre-treatment needs of the technology, the aspect of 'Cost of 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. This pre-treatment is likely to comprise faecal sludge screening (and safe disposal of screenings) and faecal sludge dewatering. In the absence of any specific local information, use of the FSM Toolbox is recommended, which estimates 'Sand Drying Beds' dewatering to within 30 % to 50 % dry solid level at \$560/m^3/year and 'Mechanical Dewatering' to within 20 % to 40 % dry solids at \$220/m^3/year (assumed 2016 prices). Relevant 'scale factors' for each type of dewatering should be applied.

C.3.3 Organizational needs

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 and transfers (donors) 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-scaled operations.

C.4 Suitability (complexity) assessment

Prior to 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 12.7.5.

C.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 city infrastructure projects (e.g. water supply, solid waste) should be conducted. The planning process should allow for appropriate consideration and balancing of various interests of stakeholders. Further, the planning process should be based as far as possible on a comprehensive evaluation of all options. Tools such as scenario analysis can support the planning process. The evaluation of all options should include technical, economic, environmental, institutional and social aspects.

C.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.

C.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 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, related to the reuse of products stemming from the faecal sludge treatment unit.

Further, 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 are 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.