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Guidelines for biological filtration of secondary effluent for water reuse

Lignes directrices relatives à la filtration biologique de l'effluent secondaire pour la réutilisation de l'eau

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Contents

Page

Foreword

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

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

Introduction

Global water consumption has been increasing by approximately 1 % annually since the 1980s, due to population growth, socio-economic development and changing consumption patterns. It is expected that global water demand will keep increasing at a similar rate, and that by 2050 the water use will have increased by 20 %-30 % compared to the current level[9]. Water reuse is an efficient measure to alleviate the global water shortage problem and is a common action for many countries in the world. “Fit for purpose” is a consensus in the field of water reuse, which reduces the demand for fresh water by reusing secondary effluent in different scenarios, such as urban miscellaneous water, circulating cooling water, process and product water, etc. Treated secondary effluent acts as an important source of water supply, providing opportunities to strengthen traditional water supply in some cities, particularly where long-distance transfers are required to meet water demands. Organics and nitrogen in wastewater are the key indicators for the management and control of water reuse in various countries.

Biological filtration, as a mainstream technology for wastewater treatment and reuse, is widely used for advanced treatment of secondary effluent to achieve the effective removal of carbon, nitrogen and solid substances. However, due to differences in technological, economic, social and environmental conditions, there is no unified guideline on technical recommendations for biological filtration on a global scale. This hinders the effective application of biological filtration as a “fit for purpose” practice to treat secondary effluent.

Guidelines for biological filtration of secondary effluent for water reuse

1 Scope

This document provides guidance for biological filtration of secondary effluent for water reuse. It specifies general recommendations, process components and technical recommendations of each component, post-treatment process and water reuse applications.

This document is applicable to all types of stakeholders involved in implementing biological filtration for advanced treatment of secondary effluent for water reuse.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
biological filtration
wastewater treatment process depending on the physical filtration of the *filter media* (3.7) filled in the treatment infrastructure and the biochemical action of the biofilm attached to the filter media

3.2
biofilter
bed of inert *filter media* (3.7) with large holes through which wastewater is caused to percolate for the purpose of purification by means of an active biological film (bacteria bed) on the inert filter media

Note 1 to entry: Also known as biological filter.

[SOURCE: ISO 6107:2021, 3.72, modified — The preferred term has been changed from “biological filter” to “biofilter”; Note 1 to entry has been modified.]

3.3
biological aerated filter
BAF
combination of contact oxidation and filtration by means of artificial aeration, intermittent backwashing and other measures, aiming to remove organic pollutants, ammonium nitrogen and suspended solids

3.4
backwash rate
flow rate of backwashing water or backwashing air passing through *filter bed* (3.6) per unit area per unit time

Note 1 to entry: Backwash rate is generally represented as $m^3/(m^2{\cdot}h)$.

3.5
denitrification filter
DNF
biofilter (3.2) for the purpose of denitrifying nitrate nitrogen in wastewater

3.6
filter bed
filter that consists of layers of *filter media* (3.7) arranged over one another so that a liquid flowing through one filter media does not carry it into the next to clog it

Note 1 to entry: Also known as graded filter.

[SOURCE: ISO 6707-1:2020, 3.3.4.45, modified — The preferred term “graded filter” and the admitted term “leaching field” have been removed; in the definition, “coarse gravel, coarse sand, and fine sand” has been changed to “filter media”; Note 1 to entry has been added.]

3.7
filter media
materials used in the *filter bed* (3.6), such as coarse gravel, fine gravel, ceramsite, coarse sand and fine sand serving as support for microorganisms’ adhesion and growth, and also with the function of physical interception and filtration for suspended solids in supplied water

3.8
graded gravel layer
granular material layer which is laid between the water distribution system and the *filter bed* (3.6), to prevent the *filter media* (3.7) from leaking into the water distribution system

3.9
heterotrophic denitrification
process by which bacteria convert nitrate nitrogen into nitrogen and other gases using organic matter (such as methanol, acetic acid, sodium acetate, etc.) as energy and electron donor

3.10
volumetric nitrogen loading rate
amount of nitrogen (such as ammonium nitrogen and nitrate nitrogen) removed per cubic meter of *filter bed* (3.6) per unit time

Note 1 to entry: Volumetric nitrogen loading rate is generally expressed as kg N/(m^3·d).

4 General

4.1 Overall recommendations

The general recommendations for applying biological filtration of secondary effluent for water reuse are as follows.

a) Biological filtration is applicable for the treatment of both raw wastewater and secondary effluent of municipal wastewater treatment plants. Also, it is suitable for the biological treatment of industrial wastewater with water quality characteristics similar to those of municipal wastewater.

b) Biological filtration can be applied alone or integrated with other wastewater treatment technologies. The selection of biological filtration should be based on different considerations of influent water quality and treatment, along with comprehensive analysis of technical, economic and environmental factors.

c) The construction of biofilters should be based on topographic, meteorological, geological conditions, operation and environmental safety factors. Measures should be especially taken to avoid freezing, odour, flies and corrosion.

d) The form and flow direction of the corresponding reactors of the biological filtration systems should be designed and selected according to different influent water quality and treatment considerations.

4.2 Basic process

Possible process flow diagrams for applying biological filtration for carbon and NH_3-N (ammonium nitrogen) removal, total nitrogen removal of effluent containing NH_3-N and nitrate nitrogen removal are shown in Figure 1, Figure 2 and Figure 3, respectively. Possible structure diagrams of biological aerated filter (BAF) (one/two stages) and denitrification filter (DNF) are also given in Annex A.

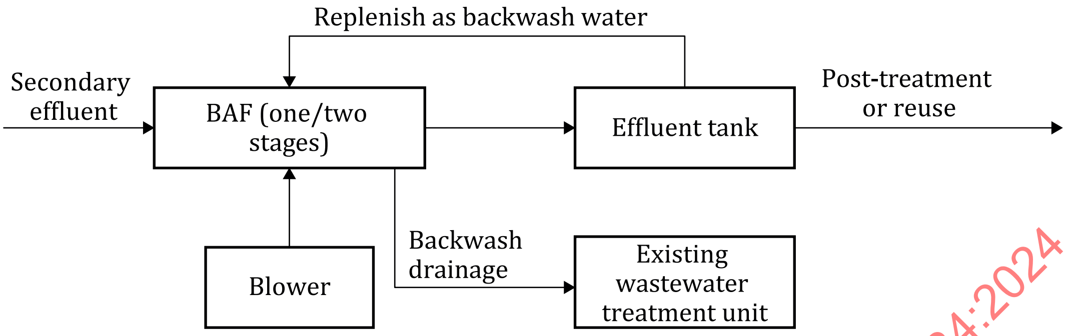


Figure 1 — Possible process flow diagram for applying biological filtration for carbon and NH_3-N removal from the secondary effluent

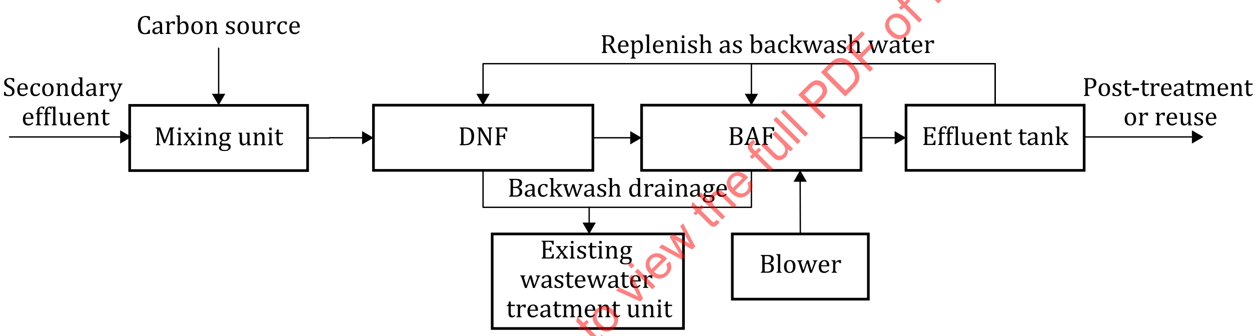


Figure 2 — Possible process flow diagram for applying biological filtration for total nitrogen removal from the secondary effluent containing NH_3-N

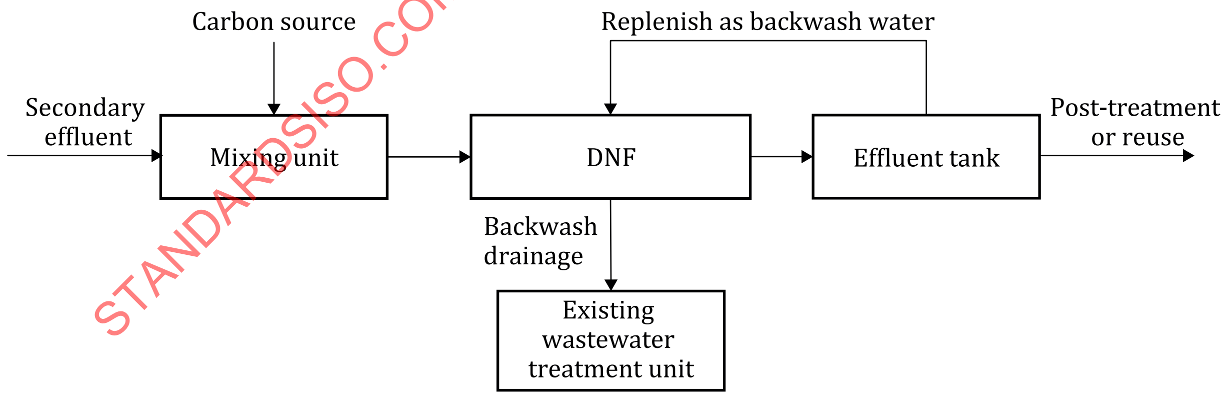


Figure 3 — Possible process flow diagram for applying biological filtration for nitrate nitrogen removal from the secondary effluent

5 Process components

5.1 Biofilter unit

The components of the biofilter unit (BAF and DNF) that should be considered are shown in Table 1. Possible structure diagrams for BAF and DNF are shown in Annex A.

Table 1 — Major components of the biofilter unit

Components	BAF	DNF	
		Upflow	Downflow
Influent distribution area	✓	✓	—
Water inlet ditch	—	—	✓
Water and air distributor	✓	✓	✓
Graded gravel layer	✓	✓	✓
Filter bed	✓	✓	✓
Process aeration system	✓	—	—
Backwash drainage ditch	✓	✓	✓
Water outlet system	✓	✓	✓
Automatic control system	✓	✓	✓

5.2 Mixing unit

The purpose of the mixing unit is to mix secondary effluent and external carbon source from the carbon source dosing tank.

5.3 Backwashing unit

The backwashing unit is mainly comprising backwash water pump and blower.

5.4 Controlling unit

When applying biological filtration, automatic control systems for centralized and decentralized controlling should be adopted. The control of related equipment is generally set up on-site, by programmable logic controller (PLC) and central control room.

6 Technical recommendations of the biofilter unit

6.1 Filter media

Filter media can be made of the following materials:

— graded crushed mineral (e.g. quartz sand);

— granular activated carbon;

— mineral beads or granules (e.g. ceramsite);

— particulate matter containing reduced sulfur and iron for autotrophic or combined heterotrophic and autotrophic denitrification to save external carbon sources;

— foamed beads (e.g. foamed ceramics);

— plastics of regular size and shape (e.g. polypropylene ball);

— plastic sheets or tubes assembled as modules to give a lightweight support media with a voidage of 90 % or higher.

The characteristics of filter media should be:

— good strength, not easily broken;

— large specific surface area;

— good hydrophilicity;

— no toxic or harmful ingredients should be produced in the treated water.

Examples of type, diameter and density of filter media in water reuse applications using biological filtration are given in Annex B.

6.2 Water and air distributor zone

Water and air distributor zones are composed of the cover board of the water-collecting ditch, the water and air distributor, and the water inlet pipe and air intake tube. The cover board of the water-collecting ditch is made of carbon steel or stainless steel. Air distribution tubes consist of main tubes and branch tubes. The branch tube for air conditioning is installed above the cover board of the water-collecting ditch. The size of the water-collecting ditch should be determined according to the volume of the treated water, the amount of filter water, the amount of backwash water, the flow rate and the thickness of the cover board. The diameters of the air main intake tube and the branch tube should be considered according to the backwash rate, the pressure in the tube and the speed of water flow. Water distribution pipes and air distribution tubes should be made of stainless steel.

6.3 Configuration of the biofilter unit

The set-up of a biological filtration unit involves fixed investment, operational costs, etc. By adopting the standardized configuration process, a configuration scheme which is applicable for centralized and decentralized treatment is obtained. The process flow diagram for setting up a biofilter unit is shown in Figure 4.

The size of the biofilter unit and the number of compartments is related to the volume of the treatment water, the quality of influent and effluent water and the surface of loading rate.

The selection of filter media should be based on the actual situation and the volume of filter media is linked with its volumetric nitrogen loading rate and the removal amount of major pollutants. The particle size of filter media can be adjusted, according to the type of pollutants that should be removed.

Appropriate multi-level gradation should be considered for the configuration of graded gravel layer to ensure the retention effect of pollutants, according to the particle size of filter media.

Attention should be paid to foaming during biofilter operation. Foaming can result in considerable reduction of the performance of biological filtration and it can increase maintenance and operating costs. There are generally two kinds of foaming: biological and chemical foaming. The water quality characteristics and organic loading rate (OLR) are the main factors affecting biological foaming, while chemical foaming is usually related to a loading shock caused by the presence of synthetic surfactants. Foaming can be monitored by performing specific foam-tests (foam power, scum index, foam rating and filamentous abundance) for better foaming management. Optimizing the OLR values or applying chemical methods (adding oxidants and disinfectants or coagulants) are generally effective methods for antifoaming.

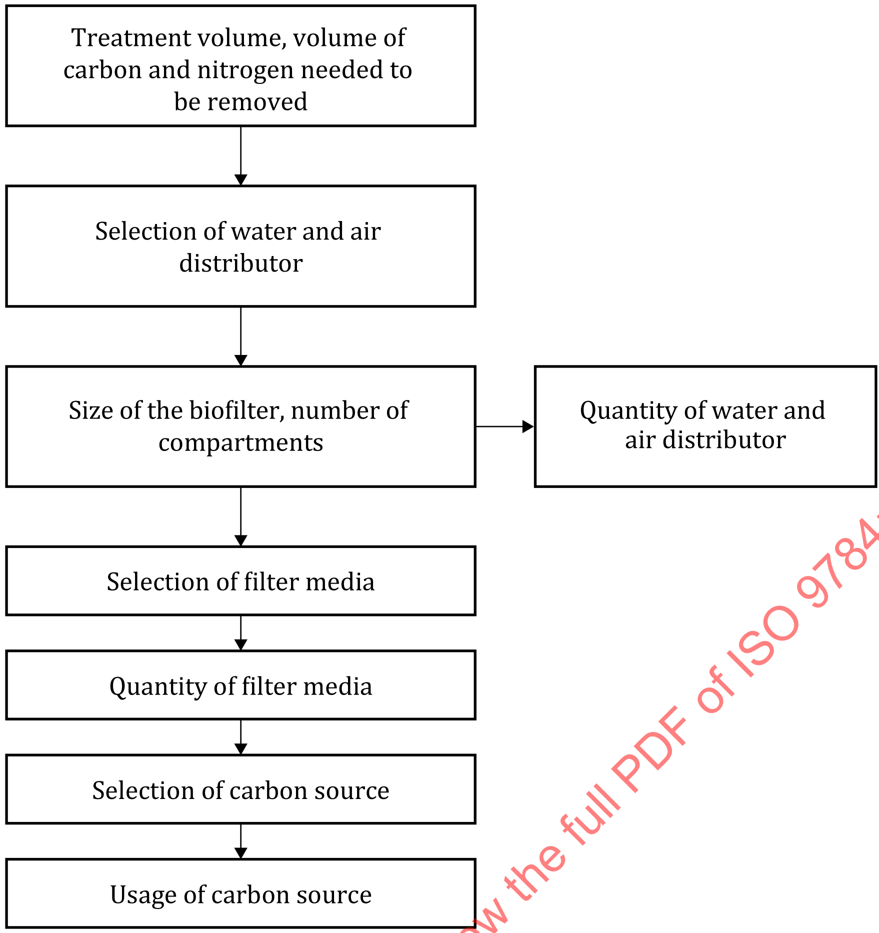


Figure 4 — Process flow diagram for setting up a biofilter unit

7 Technical recommendations of the mixing unit

The configuration of the mixing unit ensures the mixing of secondary effluent and external carbon source. External carbon source is usually needed in the denitrification process of low carbon to nitrogen secondary effluent, especially for heterotrophic denitrification. The external carbon source in use can be organic chemicals (e.g. methanol, sodium acetate, glacial acetic acid), organic wastewater (e.g. the raw wastewater), controlled-release carbon source, anaerobic fermentation broth of organic solid waste (e.g. kitchen waste, sewage sludge), etc. The dosage of external carbon sources should be reasonably determined based on the amount of nitrate nitrogen to be removed in the process and stoichiometric relation of denitrification. The addition of external carbon sources can be reduced when applying autotrophic denitrification or combined heterotrophic and autotrophic denitrification, and its dosage can be calculated based on the stoichiometric relation between the amount of nitrate nitrogen to be removed and the autotrophic and heterotrophic denitrification reactions.

8 Technical recommendations of the backwashing unit

8.1 Backwashing mode

Backwashing in BAF and DNF can be carried out by air scouring, water washing or combined air and water backwashing. The backwash water is usually replenished from the treated effluent in effluent tank, and backwash drainage should be collected into the existing wastewater treatment unit for further treatment. Backwash cycle, backwashing intensity and time are related to volumetric nitrogen loading rate, filtration time and pressure drop of filter bed. The backwash procedure in biological filtration can refer to some cases given in Annex B.

8.2 Equipment

The backwash water pump can be a submersible sewage pump or a horizontal centrifugal pump. There should be at least two backwash water pumps: one in operation and the other for backup.

The backwash blower can use roots blower. There should be at least two root blowers: one in operation and the other for backup.

9 Technical recommendations of the controlling unit

9.1 Monitoring instrumentation

Monitoring indicators in biological filtration usually include indicators of both water quality and biofilter operation (water quality and quantity, water level, pressure drop of filter bed, etc.). Generally, online monitoring means are recommended. The automatic monitoring instrumentation for biological filtration may mainly depend on the application of online pH meter, NH_3-N, nitrate nitrogen and total nitrogen analysers, COD (chemical oxygen demand) analyser, SS (suspended solid) meter, ORP (oxidation-reduction potential) or DO meter, waterflow meter and level meter, pressure meter of filter bed, etc. The detection of effluent toxicity may also be included if there are local regulations on effluent toxicity management. The control parameter in biological filtration can refer to some cases given in Annex B.

9.2 Monitoring system

The recommended monitoring site and frequency will depend on the application. Table 2 suggests possible parameters to monitor and frequency, to be adjusted case by case.

Table 2 — Recommended monitoring parameter and frequency

Parameter	Monitoring site		Monitoring frequency
	BAF	DNF	
pH	Influent /effluent	Influent /effluent	Daily or continuous
NH_3-N	Influent /effluent	Influent	Daily or continuous
NO_3-N	—	Influent /effluent	Daily or continuous
Total nitrogen	Influent /effluent	Influent /effluent	Daily or continuous
COD	Influent /effluent	Influent	Daily or continuous
SS	Influent/ effluent	Influent/ effluent	Daily or continuous
DO	Aeration zone	Influent	Daily or continuous
ORP	Aeration zone	Denitrification zone	Daily or continuous
Effluent toxicity	Effluent	Effluent	On demand

9.3 Control system

Biological filtration should be equipped with an integrated automatic control and detection system. The control system should set an alarm device, and the alarm should go off when the pressure in the air intake tube of backwashing is less than its set value. The control system should also have the safety control function under the accident condition of mechanical and electrical equipment. Technologies such as soft-sensing and machine learning may be considered for carbon source dosing and process control.

10 Post-treatment process

Post-treatment process can be required for higher quality effluent. The selection of post-treatment process depends on the water quality recommendations of water reuse. Generally, post-treatment processes include ozone oxidation, membrane filtration (e.g. microfiltration, ultrafiltration, reverse osmosis), disinfection, etc. Examples of post-treatment processes in water reuse application using biological filtration are cited in Annex B.

11 Water reuse applications

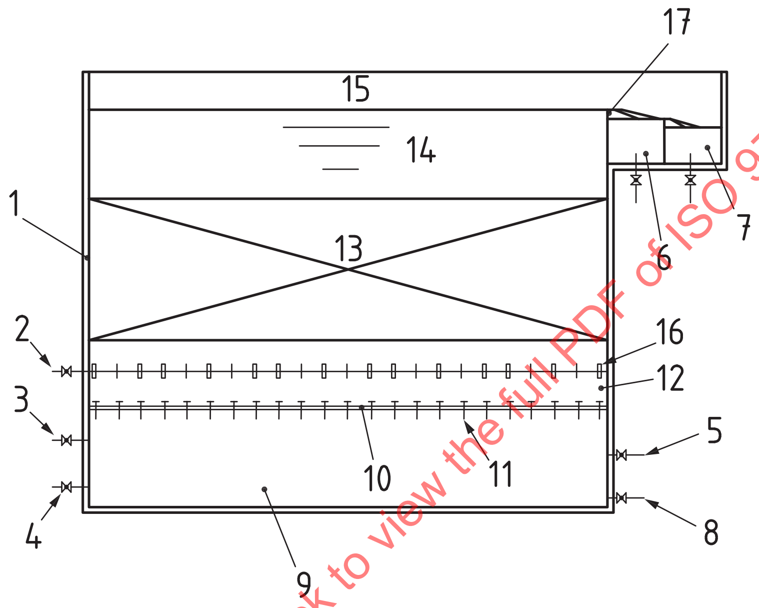
The main water reuse scenarios include river and lake water supply (being aware that local regulations can apply), urban miscellaneous use (e.g. landscape irrigation, toilet flushing, road cleaning, fire extinguishing), industrial reuse, etc. Raw water source of secondary effluent can be municipal wastewater, industrial wastewater, or a mixture of them. Cases of secondary effluent reuse application using biological filtration in different countries, operation and control parameters of biological filtration units, post-treatment process, water quality and reuse application scenarios, can be found in Annex B. Some descriptions and examples of autotrophic denitrification in biological filtration are also included in Annex C.

Annex A
(informative)

Example structure diagrams of BAF and DNF

A.1 BAF

Figure A.1 illustrates the components of a biological aerated filter (BAF).



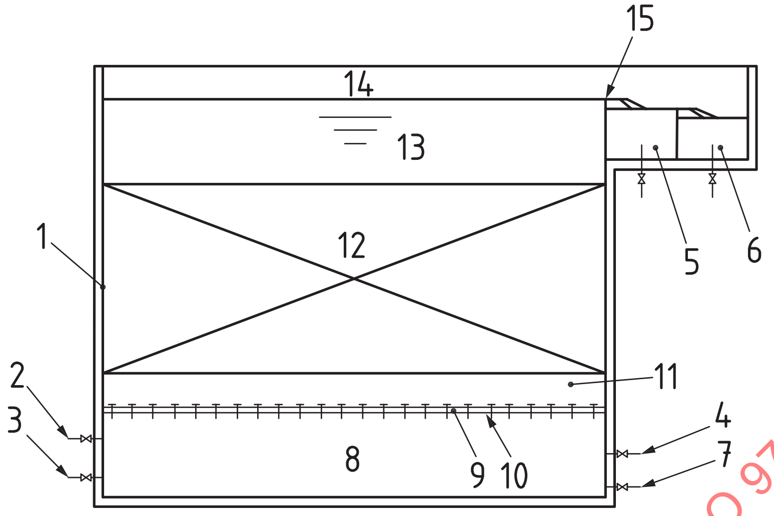
Key

1	filter body
2	aerator pipe
3	air intake tube of backwashing
4	water inlet pipe
5	water inlet pipe of backwashing
6	backwash drainage ditch
7	water outlet ditch
8	blowdown pipe
9	water inlet ditch
10, 11	water and air distributor
12	supporting layer
13	filter media layer
14	water collecting ditch
15	freeboard level
16	aerator
17	water outlet weir

Figure A.1 — The structure diagram of a BAF

A.2 Upflow DNF

Figure A.2 illustrates the components of an upflow denitrification filter (DNF).



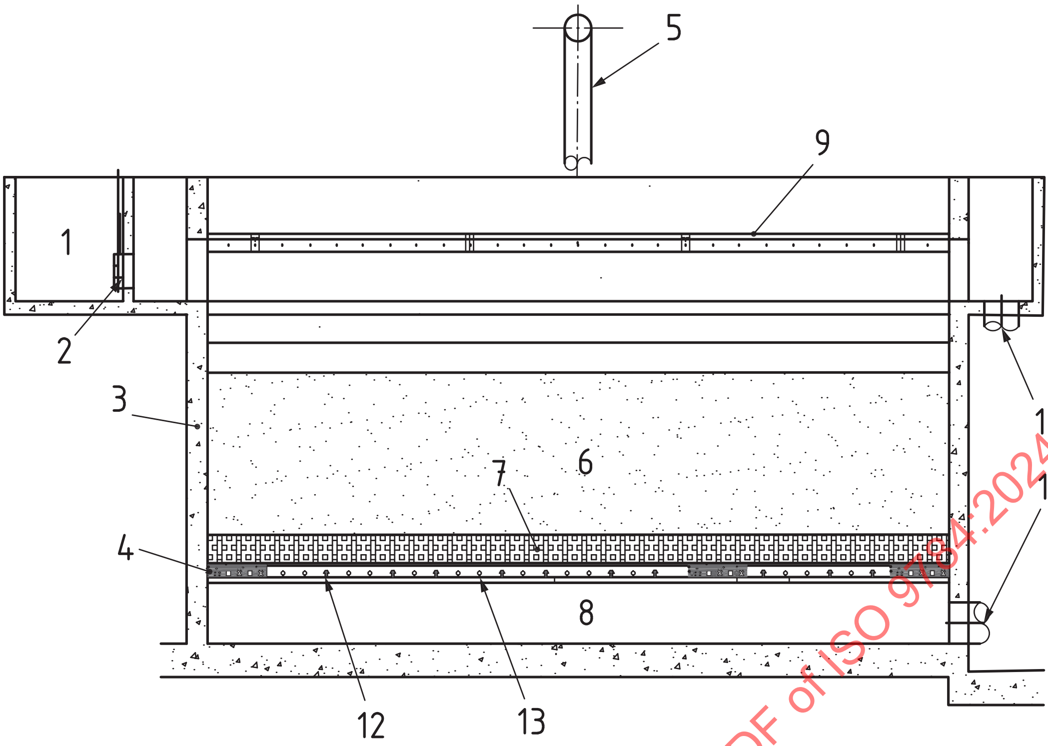
Key

1	filter body
2	air intake tube of backwashing
3	water inlet pipe
4	water inlet pipe of backwashing
5	backwash drainage ditch
6	water outlet ditch
7	blowdown pipe
8	water inlet ditch
9, 10	water and air distributor
11	supporting layer
12	filter media layer
13	water collecting ditch
14	freeboard level
15	water outlet weir

Figure A.2 — The structure diagram of an upflow DNF

A.3 Downflow DNF

Figure A.3 illustrates the components of a downflow DNF.



Key

1	total water inlet ditch
2	water inlet valve
3	filter body
4	water and air distribution area
5	air intake tube of backwashing
6	filter media layer
7	supporting layer
8	water collecting ditch
9	water inlet ditch
10	backwash drainage pipe
11	process effluent and backwashing water inlet pipe
12	branch pipe for air conditioning
13	cover board of water collecting ditch

Figure A.3 — The structure diagram of a downflow DNF

Annex B
(informative)

Cases of water reuse application using biological filtration for secondary effluent treatment

Table B.1 contains reference values for different water reuse applications using biological filtration for secondary effluent treatment.

Table B.1 — Examples of water reuse applications

Types of wastewater	Quantities of treated and reuse water (m^3/d)	Influent of biological filtration system (mg/l, average value)	Water reuse process	Operation and control parameters of biological filtration units: Filter media type, diameter and density	Operation and control parameters of biological filtration units: Volumetric nitrogen loading rate, hydraulic retention time and surface loading rate	Operation and control parameters of biological filtration units: Types and dosages of carbon sources during denitrification	Operation and control parameters of biological filtration units: Backwash procedure	Operation and control parameters of biological filtration units: Control parameters	Reuse application scenarios	Reuse water quality: Conventional water quality (mg/l)	Reuse water quality: Suggested microbiological and disinfection control	Project site	Commission time
municipal water	1 000 000	COD:60 BOD:20 TN:20 NH_3-N:1 TP:1 SS:20	DNF+MF+disinfection	— ceramsite — 4 mm to 6 mm — ≤ 1 g/cm^3	— 1,1 kgN/(m^3·d) — 21 min — 8,4 m/h	Methanol, 3,5 g/g NO_3^--N	— Air: 54 m^3/(m^2·h), 4 min — Water: 25 m^3/(m^2·h), 10 min — Air+Water: 6 min	— Nitrate nitrogen and COD of influent and effluent — Water quantity, water level, pressure drop of filter bed	— river and lake water supply — industrial reuse — urban miscellaneous use	COD:40 BOD:6 TN:10 NH_3-N:1 TP:0,5 SS:10	— For river and lake water supply, fecal coliform is recommended to be less than 1 000 MPN/l for ornamental landscape water and 500 MPN/l for recreational landscape water, respectively. Residual chlorine is recommender to be at least 0,05 mg/l with a minimum contact time of 30 minutes (only in the case of chlorination).	Beijing, China	2014
municipal water	600 000	COD:60 BOD:20 TN:25 NH_3-N:8 TP:1 SS:20	DNF+BAF+MF+ozone oxidation+disinfection	— ceramsite — 4 mm to 6 mm and 3 mm to 5 mm — ≤ 1 g/cm^3	**DNF:** — 1,1 kgN/(m^3·d) — 18,6 min — 8 m/h **BAF:** — 0,25 kgNH_3-N/(m^3·d) — 40,3 min — 4,5 m/h	Methanol, 3,5 g/g NO_3^--N	— Air: 61 m^3/(m^2·h), 4 min — Water: 15 m^3/(m^2·h) to 30 m^3/(m^2·h), 10 min — Air+Water: 6 min	— Nitrate nitrogen and COD of influent and effluent — Water quantity, water level, pressure drop of filter bed	— river and lake water supply — industrial reuse — urban miscellaneous use	COD:30 BOD:6 TN:10 NH_3-N:1,5 TP:0,3 SS:10		Beijing, China	2015
48 % municipal water + 52 % electronic industrial park wastewater	140 000	COD:18 BOD:4,54 SS:3 TN:9,35 NH_3-N:0,95 TP:0,24	BAF+DNF+ozone oxidation+UF	— ceramsite — 3 mm to 5 mm and 4 mm to 6 mm	**BAF** — 0,24 kg NH_3-N/(m^3·d) — 24 min — 10 m/h **DNF** — 0,8 kgN/(m^3·d) — 18 min — 10 m/h	Glacial acetic acid, 8 g/g NO_3^--N to 14 g/g NO_3^--N	**BAF** — Air: 54 m^3/(m^2·h), 3 min — Water: 18 m^3/(m^2·h), 15 min — Air+Water: 3 min **DNF** — Air: 54 m^3/(m^2·h), 3 min — Water: 18 m^3/(m^2·h), 20 min — Air+Water: 4 min	— Nitrate nitrogen and COD of influent and effluent — Water quantity, water level, pressure drop of filter bed	— urban miscellaneous use (60 000 m^3/d) — river and lake water supply (80 000 m^3/d)	COD:12,6 BOD:3,5 SS:2 TN:4,42 NH_3-N:0,41 TP:0,08		Jiangsu, China	2020

[a] Suggested microbiological and disinfection control for landscape irrigation should take into account the treated wastewater quality levels defined in ISO 16075-2.