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Biological equipment for treating air and other gases — Requirements and application guidance for deodorization in wastewater treatment plants

Équipements biologiques pour le traitement de l'air et autres gaz — Guide d'application pour la désodorisation dans les stations d'épuration des eaux usées

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Foreword

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This document was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases.*

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Introduction

There are tens of thousands of wastewater treatment plants (WWTPs) running worldwide, most of which produce odour gas as secondary pollution. The typical contaminants in odour gas include hydrogen sulfide, ammonia and volatile organic compounds (VOCs). Besides, hydrogen sulfide in odour gas can also lead to severe corrosion on structure and pipeline and increases the risk of accidental poisoning.

Among different techniques, biological techniques have been recognized as a cost-effective and most applied method for WWTPs deodorization. Biological methods treat the odour gases through microbial metabolism. Their advantages are low operational cost, simple to operate, very safe to use and having lower secondary pollution levels. The typical biological equipment includes biofilter, biotrickling filter and bioscrubber. The biological techniques were used for about 70 years to effectively treat the odour gas emitted from WWTPs. A great amount of experience has been gathered on biological equipment from work carried out on numerous sites around the world. However, the biological odour gas treatment facilities varied greatly from case to case, both in configuration and performance.

Therefore, it is necessary to develop a standard at the international level by collating the successful experiences together and providing a guidance for the installation and application of biological odour treatment equipment worldwide.

Biological equipment for treating air and other gases — Requirements and application guidance for deodorization in wastewater treatment plants

1 Scope

This document specifies the requirements and application guidance for biological deodorization systems in wastewater treatment plants (WWTPs). The specific requirements include odour gas characterization, process selection, equipment manufacture and installation, start-up and operation, performance evaluation, security and secondary pollution control.

The guidance can help the development and maintenance of biological deodorization systems in WWTPs and benefits the owners and operators of WWTPs.

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
wastewater treatment plant
WWTP
plant that purifies wastewater with physical, chemical, biological methods or a combination of those to make the discharge conform to the requirements of discharge standards or the need for environmental protection

3.2
odorant
substance which has the potential to get volatilized and stimulate a human olfactory system so that an odour is perceived

Note 1 to entry: Typical odorants in WWTPs include sulfur-containing compounds (hydrogen sulfide, organic sulfides), nitrogen-containing compounds (ammonia, amines) and volatile organic compounds (VOCs).

3.3
odour gas
waste gas containing odorants emitted from industrial, civil or domestic processes

3.4
odour source in WWTPs
structure or equipment emitting odour gases in a wastewater treatment plant

Note 1 to entry: In WWTPs, the primary odour source includes the wastewater pre-treatment units, anaerobic treatment units and waste sludge treatment units. Sulfides including hydrogen sulfide are the typical odorants from the raw wastewater. Sulfides, ammonia and VOCs are the typical odorants from the waste sludge. The emission increases where there is turbulence or disturb in the wastewater or waste sludge.

3.5
odour concentration
quantitative indicator of odour intensity through tests with olfactory organs

Note 1 to entry: The value of odour concentration is the diluted multiples of the odour gas samples to the detection threshold value of panellists using clean air.

Note 2 to entry: The odour concentration of the raw odour gas varies greatly from case to case and is affected by odorants emission rate and configuration of collection system. Odour concentration can be measured according to different methodologies such as ASTM D 1391, EN 13725 or GB/T 14675-93.

Note 3 to entry: The odour concentrations measured by different methods cannot be compared directly.

3.6
bioreactor for deodorization
biological reactors used to treat odour gases collected from different odour sources to minimize the emission of odorants

Note 1 to entry: Biological reactors for waste gas treatment are typically biofilm reactors with microbial colonies immobilized on the surface of packing media, such as a biofilter or a trickling biofilter. The other type of biological reactors are suspended-growth reactors with the microbial populations suspended in a liquid medium, such as a bioscrubber. For WWTPs applications, biofilters and trickling biofilters are much more applied than bioscrubbers.

3.7
biofilter
bioreactor treating waste gas with the aid of biofilm attached to the packing media which moisture is maintained by a prepositive humidifier or intermittent water feeding to the filter bed

Note 1 to entry: The typical packing media employed are organic or/and inert materials randomly packed in the filter beds.

3.8
trickling biofilter
biotrickling filter
bioreactor treating waste gas with free moving liquid layers on the surface of inert packing media to supply nutrients, take away metabolites or control pH for the biofilm attached to the packing media

Note 1 to entry: The typical packing media employed are inert materials randomly or structured packed in the filter beds.

Note 2 to entry: External nutrients addition is required when the packing media cannot offer enough nutrients for the growth of microorganism.

3.9
bioscrubber
absorber transferring contaminants from waste gas to liquid absorbent, and removing the dissolved contaminants by suspended-growth microorganisms in a supplementary space

Note 1 to entry: The built-in device of the scrubbing unit can be a bulk or structured packing or a construction with plates or a rotating disk.

Note 2 to entry: External nutrients addition is usually required.

Note 3 to entry: Pre-humidification is not required.

3.10
filter bed
bed including the packing media and the microorganisms on the surface of packing media

Note 1 to entry: The typical packing media employed are natural or/and artificial materials randomly or structured packed.

Note 2 to entry: The typical microorganisms are bacteria or/and fungi in form of biofilm on the surface of the packing media or free cells in the liquid.

Note 3 to entry: Odour gas passes through the filter bed and gets purified by mass transfer and biological degradation of odorants.

3.11
superficial velocity
volumetric odour gas flow rate divided by the free cross-section area of the bioreactor column, with unit in m/s or m/h

3.12
empty bed residence time
EBRT
total volume of the filter bed divided by the odour gas flow rate

Note 1 to entry: Unit is in s.

3.13
odorant removal efficiency
E
ratio of odorant concentration reduction and inlet odorant concentration

Note 1 to entry: Removal efficiency is also referred to as elimination efficiency.

3.14
odorant removal rate
r
amount of odorants removed by a unit volume of packing material in a unit time

Note 1 to entry: Removal rate (r) is also referred to as elimination capacity (EC) or elimination rate (ER).

Note 2 to entry: It is generally used to evaluate the capacity of the reactors for odorant removal. It is very relevant and useful for the comparison of various bioreactors. It is important to note that E is dependent upon the inlet odorant concentration or EBRT of a bioreactor.

Note 3 to entry: The maximum removal rate is the maximum value of instantaneous elimination capacities in

$g/(m^3 \cdot h)$ while increasing the inlet loading.

3.15
pressure drop
difference in static gas pressure between the inlet and outlet of the equipment

Note 1 to entry: The pressure drop of the bioreactor and odour gas collection duct will affect the energy consumption of the blower and its operational costs. The pressure drop of the bioreactor is mainly decided by the character of the filter bed and the superficial velocity.

4 Odour gas characterization and process design

4.1 Odour gas characterization

4.1.1 The main odour sources in WWTPs are covered and the odour gases emitted from different sources predominantly are collected by a pipeline system. The bioreactor for deodorization is installed at the end of the pipeline system and treats the total mixture of odour gases. In some cases, with small flow rates but high odour concentrations, a separate treatment unit for this source can be useful.

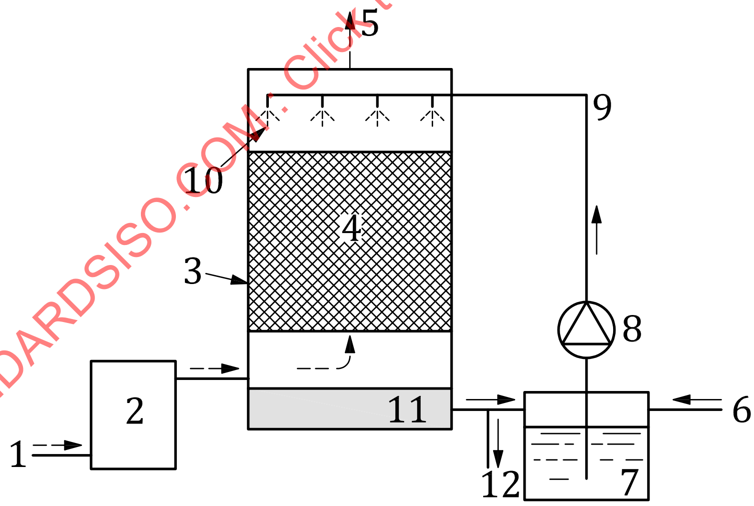
4.1.2 The characteristics of the odour gas include the flowrate, the odorants component and concentration in the odour gas, emission rate of odorants, the temperature and the relative humidity etc. The characteristics of the odour gas affect the design and operation of the odour gas collection and treatment system. An adequate and precise characterization on odour gas helps to achieve better performance and less cost.

4.1.3 When the odour gas collection pipeline system is installed, the characteristics of odour gas can be measured on-site at specific points of the pipeline system.

4.1.4 When there is no gas collection pipeline system, the emission rates (in g/(m^2·h)) of odorants can be measured by using a flux chamber or wind tunnel on the surface of wastewater (referring to EN 13725 for example). For WWTPs not installed yet, the references on previous similar applications are also needed.

4.2 Process design

4.2.1 The biological deodorization process can include some pre-treatment units and a biological reactor in series as illustrated in Figure 1.



Key

1 odour gas	7 water tank
2 pre-treatment unit	8 pump
3 bioreactor column	9 pipeline
4 filter bed	10 spray nozzle
5 treated gas	11 leachate
6 added water	12 drainage

Figure 1 — Scheme of a biological deodorization equipment

4.2.2 Pre-treatment units can be a filter to remove the particulates or a humidifier to increase the relative humidity of odour gas. If the hydrogen sulfide or ammonia concentrations in odour gas are too high to inhibit the microorganisms in the bioreactors, a scrubbers or absorbers as a pre-treatment can also be considered.

4.2.3 The biological reactor is usually a biofilter or a trickling biofilter which includes the reactor column, filter bed and the water feeding system. The water feeding system should include pumps, spray nozzles, pipelines and the water tank. Some chemical or biological agents such as nutrients, pH regulator or inocula can be added in the water tank and sprayed into the filter bed. The leachate can be recycled to water tank or be discharged directly.

4.2.4 When a stand-alone bioreactor cannot meet the requirements for odour gas emission, other additional units, such as a biological stage, a chemical scrubber or an activated carbon adsorber can be installed before or after the bioreactor.

4.2.5 The bioreactors for deodorization include biofilter, trickling biofilter and bioscrubber. Biofilters and trickling biofilters are in widespread use in WWTPs.

4.2.6 The common ranges of the design criteria for biofilters, trickling biofilters and bioscrubbers treating odour gases in WWTPs are shown in Table 1.

Table 1 — Design criteria of the different bioreactors for odour control in WWTPs

Design criteria	Biofilter	Trickling biofilter	Bioscrubber
EBRT (s)	≥20	≥10	≥2
Superficial velocity (m/s)	0,03 to 0,20	0,05 to 0,5	0,5 to 1,5
Superficial velocity (m/h)	100 to 700	200 to 2 000	1 500 to 5 000
Filter bed height (m)	0,5 to 3,0	2,0 to 5,0	-
Pressure drop (Pa/m)	≤200	≤300	-

4.2.7 The blower can be set before or after the bioreactor for deodorization and results in a positive or negative pressure in the bioreactor. Negative-pressure bioreactors with blower after is more applied and should avoid that the negative pressure is too low.

5 Requirement for manufacture, installation and operation

5.1 Manufacture and installation

5.1.1 The design and manufacture of the various structural parts of the reactor shall take into account the requirements on strength, rigidity, fire-proof and leakage-free. The service lifetime of the reactor structure shall be at least 20 years.

NOTE The loads imposed by filter bed are induced by the weights of packing media, moisture in the packing media, the biomass accumulated, and even the flooded water.

5.1.2 Due to the low pH environment induced by oxidation of hydrogen sulfide and volatile sulfur organics, all parts of the bioreactor, the pipes and the blower (if located after the bioreactor) shall be made of corrosion-resistant materials or have special anti-corrosion treatment to adapt to the corrosive and humid environment in the WWTPs.

NOTE In WWTPs, the used materials include fibre-reinforced plastics (FRP), polypropylene (PP), high-density polyethylene (HDPE), polyvinyl chloride (PVC) and 316L stainless steel.

5.1.3 The packing media shall meet the following requirements:

a) sufficient surface area and hydrophilic surface for biofilm attachment;

b) water holding capacity to allow microbial development and avoid frequent spray or bed drying;

c) mechanical strength to maintain the internal structure of the filter bed;

d) maximum porosity, minimum pressure drop, no compaction;

e) stable chemical properties and corrosion resistance;

f) good buffer for nutrients and moisture during times of shutdown.

NOTE The commonly used packing media include wood, bark, soil, compost, peat, porous perlite, granular activated carbon, limestone, seashells, lava rock, gravel, slag, biochar, ceramics, PU foam and different plastic materials.

5.1.4 Packing media shall be evenly filled in the filter bed with no gaps.

5.1.5 The set-up of a liquid distribution system inside the bioreactor shall produce a uniform water irrigation on the top of the reactor bed.

5.1.6 After installation, the bioreactor for deodorization shall pass the performance test and meet the following requirements:

a) leak inspection shall be carried out and gas leakage for the bioreactor shall be strictly controlled to be less than 5 % for negative pressure installations;

b) pipes and joints shall be guaranteed not to crack under 1,5 times the working pressure (vacuum);

c) the flowrate of odour gas collected shall be within 80 % to 120 % of its designed level;

d) the pressure drop of a clean filter bed with a spray shall be less than 200 Pa/m;

e) the amount of spray per unit time shall meet the requirements to maintain no leakage in the pipeline and no clogging in the spray nozzle, and its uniformity shall be considered;

f) the on-off valve and the meter shall work well and indicate correctly.

5.2 Start-up

5.2.1 Microbial inoculants with high biodegradation performance are needed for inoculation. Activated sludge from the aeration tank or secondary sedimentation tank of the WWTP can be used for inoculation or microbes specifically cultured in a laboratory targeting specific compounds.

5.2.2 Microbial inoculants should be added in the leachate recycling tank directly. A recirculation can be applied without odour gas feeding for 1 min to 10 min, based on the packing characteristics, to spread the inoculants into the filter bed.

5.2.3 During the start-up period, the flowrate of the odour gas can be gradually increased from 20 % to 100 % of the full load in 2 to 10 days, which is beneficial to facilitate the rapid formation of biofilm on the surface of the packing media.

5.2.4 The intensity of the spray shall be controlled to avoid washing away the biofilm or flooding the filter bed.

5.2.5 Relatively stable removal for odorants like hydrogen sulfide or decrease in pH of leachate in combination with increasing levels of sulfate can indicate the successful formation of biofilm and start-up of the bioreactor. Conversely, poor odorants removal or a decrease in pH of leachate without sulfate production indicates an unsuccessful start-up and a poor biofilm formation.

5.3 Operation and maintenance

5.3.1 The suitable temperature range of inlet odour gas is approximately 15 °C to 40 °C. Some temperature control measurements will need to be applied if odour gas temperature is outside this range. If the inlet odour gas temperature is below 10 °C, it can be useful to reduce the flow rate through the bioreactor to lower the odour load and the heat loss.

5.3.2 Some condensed water drainage ports shall be set at the bottom wall of inlet or outlet pipelines and shall be opened periodically to discharge the condensed water.

5.3.3 For WWTP, the treated effluent water can be used as the sprayed nutrient solution if the water quality meets the following: SS<10 mg/l, COD<100 mg/l, NH_4-N<30 mg/l, pH 6 to 9 and there is no obvious inhibition of the microorganism.

5.3.4 Intermittent spray of nutrient solution by approximately 2 to 48 times per day can be applied on trickling biofilter. The optimal range for spray rate is 0,1 $m^3/(m^2·h)$ to 1 $m^3/(m^2·h)$. The amount of spray on the filter bed should be strictly controlled.

5.3.5 For biofilter or trickling biofilter treating sulfur-containing compounds only, the leachate pH can be controlled within approximately 2 to 7 or even lower. For those treating ammonia and VOCs, the leachate pH should be within 6 to 9. The conductivity of leachate should be determined for each specific application with reference to the leachate compositions, which is normally less than 1 000 ms/m.

5.3.6 The nozzles shall be checked regularly for any signs of clogging and these should be cleaned or replaced before they become clogged.

5.3.7 The filter bed and the packing media shall be monitored on a regular basis. Packing media shall be washed or partly replaced when abnormal pressure drops, internal collapse, packing media consolidation or breakage occur.

5.3.8 When using online monitoring instruments, the sensors shall be calibrated according to the manufacturer's recommendations and checked at least every six months during the effective service life to ensure accurate and effective gas monitoring. Sensors that have exceeded their validity period and have failed shall be replaced.

5.3.9 If a bioreactor is not operated for a long period (more than 1 week for example), problems such as microbial activity reduction can occur. There shall be a requirement for resuming inoculation and start-up operation.

6 Performance assessment

6.1 Measurement of some specific indexes for odour gas

6.1.1 Flow rate, temperature and relative humidity of the odour gas

At the specific sampling point in upstream or downstream duct of the bioreactor, the flow rate shall be measured by a portable anemometer (with a relative maximum permissible error less than ±10 %) and the gas temperature and humidity shall be measured by a digital hygrometer (with maximum permissible error less than ±0,5 °C for temperature and ±3 % for relative humidity). The measurements for each index shall be repeated three times and an average result shall be calculated.

6.1.2 Pressure drop of the filter bed

The static pressure of odour gas in the duct can be measured by a portable pressure meter or a tube manometer. The difference between the static pressures of the two sampling points (one measuring point shall be located before the bioreactor and another measuring point shall be located after the bioreactor) represents the pressure drop of relative facility.

6.1.3 Concentration of odorants

The concentrations of hydrogen sulfide, ammonia or VOC in the odour gas at the inlet or outlet of the bioreactor can be measured by some portable device with specific sensors (with a relative maximum permissible error less than ±5 %). The sampling port with negative pressure inside the pipe should be sealed to prevent ambient air sucked in when the sensor probe is set into the port. The measurements for each index shall be repeated three times and an average result shall be calculated. The odorants can also be measured by using a sampling bag or sampling solution and a subsequent detection based on the colorimetric method or the chromatography method. Sampling methods and subsequent analysis should be specially considered in case of condensing conditions.

6.1.4 Odour concentration

The odour gas at the inlet or outlet of bioreactor can be sampled and its odour concentration can be detected by trained professionals using an olfactometry or odour sampling bags. The specific procedure and requirements shall follow the relevant national and local standards or technical guidance.

6.2 Calculation of odorant removal efficiency

The performance of bioreactor for deodorization in WWTPs can be assessed in terms of odorant removal efficiency (E). If the composition of raw odour gas is complex, the main odorants shall be identified before their removal efficiencies are determined. The calculation method of odorant removal efficiency can be referred to as follows:

$$E=\left(1-\frac{C_{\text{out}}}{C_{\text{in}}}\right)\times 100\ \%$$

where

E is the removal efficiency (%);

C_{in} is the inlet odorant concentration (mg/m^3);

C_{out} is the outlet odorant concentration (mg/m^3).

6.3 Calculation of odorant removal rate

The odorant removal rate (r) provides a reliable basis for assessing the removal performance of the bioreactor by the following formula:

$$r=\frac{(C_{\text{in}}-C_{\text{out}})\times Q}{V}\times 10^{-3}$$