D-NOSES

Distributed Network for Odour Sensing, Empowerment and Sustainability

Compilation of good practices in odour pollution

D2.3

M28, July 2020

Compilation of good practices in odour pollution

PROJECT ACRONYM	GRANT AGREEMENT #	PROJECT TITLE
D-NOSES	789315	D-NOSES (Distributed Network for Odour Sensing, Empowerment and Sustainability)

DELIVERABLE REFERENCE NUMBER AND TITLE

D2.3

Compilation of good practices in odour pollution

Revision: v3.1

MAIN AUTHORS

Laura Capelli	Cyntia Izquierdo Carlos Diaz Ainhoa Anton	Jose Uribe	Rosa Arias
(POLIMI)	(AMIGO)	(ISWA)	(IBERCIVIS)

MAIN REVIEWERS

Nora Salas Seoane
Rosa Arias

(IBERCIVIS)

Funded by the Horizon 2020 programme of the European Union
Grant Agreement No 789315

DISSEMINATION LEVEL

✔	**P**	**Public**
	P	Confidential, only for members of the consortium and the Commission Services

Revision History

REVISION	DATE	AUTHOR	ORGANISATION	DESCRIPTION
v1.0	10.03.2020	Laura Capelli	POLIMI	Title and structure
v2.0	24.05.2020	Laura Capelli	POLIMI	Addition of summary
v2.1	25.05.2020	Laura Capelli	POLIMI	Addition of chapter 1
v2.2	26.05.2020	Laura Capelli, Cyntia Izquierdo, Rosa Arias	POLIMI, AMIGO, IBERCIVIS	First revision of part 1
v3.0	27.05.2020	Laura Capelli, Jose Uribe	POLIMI, ISWA	Addition of chapter 2
v3.1	29.05.2020	Laura Capelli, Cyntia Izquierdo	POLIMI, AMIGO	Revisions
v3.2	17.06.2020	Nora Salas Seoane	IBERCIVIS	Revision of format
	31.07.2020	Rosa Arias		Final revision

STATEMENT OF ORIGINALITY

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

HOW TO CITE THIS REPORT

Capelli L., Izquierdo C., Diaz C., Anton A., Uribe J., Arias R. (2020) Compilation of good practices in odour pollution, D-NOSES, H2020-SwafS-23-2017-789315.

Summary

This report presents the first compilation of good practices in odour pollution led by the quadruple helix of stakeholders within the framework of the D-NOSES project.

One of the aims of the D-NOSES project is to promote good practices in odour pollution, led by quadruple helix actors (i.e. promoted by citizens, administrations or industries that were able to solve the odour problem through different mechanisms in different contexts, increasing the level of sustainability), which can be used as positive examples for project replicability. The final goal would be to collect examples of good practices from the consortium partners, including information about the odour emitting source, the local stakeholders, the regulatory framework (if any), the solution implemented and the evolution over time, which should be possible during completion of the pilot studies foreseen in the project. Meanwhile, this document provides a summary of reference good practices for managing and controlling odour emissions as stated by the European Community in their Reference documents for Best Available Techniques in different sectors (Chapter 1), and also provides a scheme of a co-created questionnaire for the collection of good practices with some preliminary examples collected from the consortium partners (Chapter 2).

The document is structured in 2 sections:

- **Section 1. BEST AVAILABLE TECHNIQUES FOR ODOUR EMISSIONS**:

When talking about good practices in odour pollution in Europe, it shall not be forgotten that the European Community has a dedicated technical body, i.e. the European Integrated Pollution Prevention and Control (IPPC) Bureau (EIPPCB), which has been drawing up specific reference documents containing the so called “Best Available Techniques” (BAT) for different industrial sectors. These are very complete documents describing – for each sector – the applied processes and techniques, the typical emission levels, and the techniques to be considered for the determination of the BAT. Since most of the recently published BREF documents explicitly deal with odour emissions, we considered it as an important reference for a compilation of good practices in odour pollution, to extract the “Best Available Techniques” related to odours, as identified by the EIPPCB. Thus, we first reviewed the existing BREF documents to search for specific reference to odours, and then we selected four industrial sectors to start our analysis with. This chapter provides a summary of the most significant parts relating specifically to odours extracted from the BREF documents. The sectors that were analysed within this document are: waste treatment, refining of mineral oil and gas, intensive rearing of poultry and pigs, slaughterhouses and animals by-products industries.

- **Section 2. COLLECTION OF GOOD PRACTICES IN ODOUR POLLUTION:**

This chapter has the aim to set the basis for the collection of good practices in odour pollution from the consortium partners. The first part of the chapter describes the co-creation work done within the consortium to draft a scheme of questionnaire to be used for the collection of good practices. The second part reports the difficulties encountered in collecting those good practices, mainly because of the negative attitude to be associated with odour problems, even if well managed and/or partially solved. The last part of the chapter provides some examples of good practices collected with the help of consortium partners.

Index

1.
BEST AVAILABLE TECHNIQUES FOR ODOUR EMISSIONS

This section presents a schematic description of the good practices for odour emission management and control in different sectors (i.e. waste treatment, refining of mineral oil and gas, intensive rearing of poultry and pigs, slaughterhouses and animals by-products industries) as extracted from the Best Available Techniques (BAT) Reference Documents drafted by the EIPPCB.

1.1. Introduction to BAT Reference Documents

Foreword: EIPPCB and BAT

- **The EIPPCB**

The European Integrated Pollution Prevention and Control (IPPC) Bureau (EIPPCB) was set up in 1997 to organise an exchange of information between Member States, industry and non-governmental organisations promoting environmental protection on Best Available Techniques (BAT), associated monitoring and developments in them. With the entry into force of the Industrial Emissions Directive (IED, 2010/75/EU), the EIPPCB organises and coordinates the exchange of information that leads to the drawing up and review of BAT reference documents according to the dispositions of the Guidance document on the exchange of information (Commission Implementing Decision 2012/119/EU). The European IPPC Bureau is an output-oriented team which produces reference documents on Best Available Techniques, called BREFs. BREFs are the main reference documents used by competent authorities in Member States when issuing operating permits for the installations that represent a significant pollution potential in Europe. There are about 50000 of these installations in Europe. In the international context, the European information exchange on best available techniques is considered to be an EU contribution to the global process initiated in 2002 at the World Summit on Sustainable Development so that non-EU countries can also reap the benefits of this ambitious work.

- **The elaboration of BREFs**

For each BREF, the European IPPC Bureau sets up a Technical Working Group (TWG) to carry out the exchange of information on BAT. A TWG usually consists of between 100 to 200 experts.

The European IPPC Bureau organises the work of the TWG, fosters the exchange of information, makes a scientific and technical analysis of the vast amount of information exchanged, proposes compromise solutions on issues when views of TWG members differ, and writes the BREF. The European IPPC Bureau acts as a neutral, technically competent and permanent body to all TWGs.

The procedure used to elaborate or review a BREF includes a few plenary meetings of the TWG, sub-group meetings, visits to installations, and submission of draft BREFs for comments.

Practical arrangements for the exchange of information are laid down in the specific guidance documents referred to in Article 13 (3)(c) and (d) of the Industrial Emissions Directive (IED), 2010/75/EU.

These documents aim in particular at guiding the European IPPC Bureau and members of the technical working groups (TWGs) in the drawing up and reviewing the whole series of BREFs.

Once it has been finalised, each BREF is presented by the European IPPC Bureau to DG Environment at the forum (Information Exchange Forum, IEF) established by the IED (ex IPPC Directive).

Introduction

One of the aims of the D-NOSES project is to promote good practices in odour pollution, led by quadruple helix actors (i.e. promoted by citizens, administrations or industries that were able to solve the odour problem through different mechanisms in different contexts, increasing the level of sustainability), which can be used as positive examples for project replicability.

Besides collecting examples of good practices from the consortium partners, possibly as a result of the application of the D-NOSES methodology in the pilot studies, we thought that in a document aiming to discuss good practices for odour pollution, it would have been necessary to mention the reference documents for Best Available Techniques existing on a European level.

The BREF documents prepared by specific Technical Working Groups exist for most industrial sectors, and they are extremely complete documents describing – for the specific sector – the applied processes and techniques, the typical emission levels, and the techniques to be considered for the determination of the BAT. They are public documents, freely accessible and downloadable from the EIPPCB webpage: https://eippcb.jrc.ec.europa.eu/reference

BREF documents are not specific for odours, but they deal with any type of emissions to air, water and soil. However, because odours are now recognized as atmospheric pollutants, most of the BREF documents published in recent years include specific reference to odour pollution and to techniques for the reduction of odour emissions.

Table 1 reports a list of the BREF documents mentioning odours, and the number of times the term "odour" is mentioned in each document: this allows to visualize immediately the documents that provide a specific focus on odour emissions.

Among these, we have highlighted in different colours the BREF documents in which the term "odour" appears more than 100 times.

Among those, there is the BREF on Common Waste Water and Waste Gas Treatment/ Management Systems in the Chemical Sector. This document is a little bit different from the others, since it doesn't describe a production process, but it discusses the techniques that can be applied for wastewater and waste gas treatment. Odour is mentioned 302 times in this document, because, in different sections, it makes specific reference to the techniques that can be used for odour abatement.

This document has been already widely discussed in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf), in which we have extracted from the BREF document all the parts related to odour management and treatment techniques. For this reason, it will be no longer discussed within this document.

The other BREF documents with more than 100 citations of odour are those regarding:

a. Intensive Rearing of Poultry or Pigs (592 citations)
b. Slaughterhouses and Animals By-products Industries (469 citations)
c. Food, Drink and Milk Industries (326 citations)
d. Waste treatment (210 citations)
e. Production of Pulp, Paper and Board (138 citation)
f. Refining of Mineral Oil and Gas (121 citations)

There is also the BREF Monitoring of Emissions to Air and Water from IED Installations, but this doesn't refer to one specific type of industry, but it describes in general the techniques that can be adopted for emission monitoring.

Because they provide specific reference to odour pollution, we decided to go through the above listed documents and extract the useful information regarding the good practices for managing and controlling odour emissions. Because the BREF documents are full bodied and dense of information, we decided first to focus on those documents regarding activities that, based on our experience as odour experts, are more frequently related to odour complaints.

Thus, the summarization work for this Deliverable has been limited to the following activities: waste treatment, refining of mineral oil and gas, intensive rearing of poultry and pigs, slaughterhouses and animals by-products industries.

Title	Year	Link	Odour
Ceramic Manufacturing Industry	2007	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/cer_bref_0807.pdf	3
Common Waste Water and Waste Gas Treatment/ Management Systems in the Chemical Sector	2017	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CWW_Bref_2016_published.pdf	**302**
Emissions from Storage	2006	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/esb_bref_0706.pdf	8
Ferrous Metals Processing Industry	2001	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/fmp_bref_1201.pdf	1
Food, Drink and Milk Industries	2019	http://eippcb.jrc.ec.europa.eu/sites/default/files/2020-01/JRC118627_FDM_Bref_2019_published.pdf	**326**
Intensive Rearing of Poultry or Pigs	2017	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/JRC107189_IRPP_Bref_2017_published.pdf	**592**
Iron and Steel Production	2013	https://eippcb.jrc.ec.europa.eu/reference/iron-and-steel-production	24
Large Combustion Plants	2017	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/JRC_107769_LCPBref_2017.pdf	9
Large Volume Inorganic Chemicals – Solids and Others Industry	2007	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/lvic-s_bref_0907.pdf	21
Manufacture of Organic Fine Chemicals	2006	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/ofc_bref_0806.pdf	13
Monitoring of Emissions to Air and Water from IED Installations	2018	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-12/ROM_2018_08_20.pdf	**183**
Non-ferrous Metals Industries	2016	http://eippcb.jrc.ec.europa.eu/sites/default/files/2020-01/JRC107041_NFM_bref2017.pdf	21
Production of Large Volume Organic Chemicals	2017	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/JRC109279_LVOC_Bref.pdf	50
Production of Pulp, Paper and Board	2015	http://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/PP_revised_BREF_2015.pdf	**138**
Production of Speciality Inorganic Chemicals	2007	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/sic_bref_0907.pdf	29
Refining of Mineral Oil and Gas	2015	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/REF_BREF_2015.pdf	**121**
Slaughterhouses and Animals By-products Industries	2005	https://eippcb.jrc.ec.europa.eu/sites/default/files/2020-01/sa_bref_0505.pdf	**469**
Smitheries and Foundries Industry	2005	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/sf_bref_0505_1.pdf	60
Surface Treatment Using Organic Solvents including Wood and Wood Products Preservation with Chemicals	2007	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-12/sts_bref_0807.pdf	63
Tanning of Hides and Skins	2013	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/TAN_Published_def.pdf	63
Textiles Industry	2003	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/txt_bref_0703.pdf	62

Waste Incineration	2019	https://eippcb.jrc.ec.europa.eu/sites/default/files/2020-01/JRC118637_WI_Bref_2019_published_0.pdf	52
Waste treatment	2018	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/JRC113018_WT_Bref.pdf	**210**
Wood-based Panels Production	2016	https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/WBPbref2016_0.pdf	73
	BREF summarized and discussed in this document (D2.3)		
	BREF used for the compilation of D2.1		
	BREF to be further analysed for D2.5		

Table 1: List of BREF documents citing odours

1.2. Waste Treatment

Introduction

The Waste Treatment Industries are one the most important source of odour emitting industries, due to the unpleasantness of their hedonic tone. The “Waste Treatment” BREF deals with installations of waste treatments (hazardous and non-hazardous) such as:

- *common waste treatments* such as the temporary storage of waste, blending and mixing, repackaging, waste reception, sampling, checking and analysis, waste transfer and handling installations, and waste transfer stations;
- *biological treatments* of waste such as aerobic/anaerobic treatments and mechanical and biological treatments;
- *physico-chemical treatments* of waste such as neutralisation, chromic acid and cyanide treatments, dewatering, filtration, harbour reception facilities, oil/water separation, precipitation, separation of mercury from waste, settlement, solidification and stabilisation, and UV and ozone treatments;
- *treatments of recovery* mainly waste material such as the reconcentration of acids and bases, the recovery of metals from liquid and solid photographic waste, the regeneration of organic solvents and spent ion exchange resins, and the re-refining of waste oils
- *treatments of production* of solid and liquid fuels from hazardous and non-hazardous waste.

This BREF does not cover landfills. The incineration of waste is covered in the Waste Incineration BREF.

The Best Available Techniques (BAT) Reference Document for the Waste Treatment was published in October 2018 and *explicitly mentions odours 210 times*, and more in detail in:

- Odour monitoring (Section 2.3.3.5)
- Techniques for the prevention and control of odour and diffuse/fugitive emissions to air (Section 2.3.5)
- Biological Treatment of Waste (Section 4)
- Physico-Chemical Treatment of Waste (Section 5)
- BAT Conclusions (Section 6)
- Biological treatments (Section 7.3)

Among the 30 BREF documents published, **this is the only BREF in Europe that sets an odour limit of 200 to 1000 ou_E/m^3** as the maximum allowed odour concentration for some BATs related to the biological treatment of waste, as mentioned in the Deliverable D2.2 of this project: Diaz C., Izquierdo C., Capelli L., Arias R., Salas Seoane N. (2019) Analysis of existing regulations in odour pollution, odour impact criteria 1, D-NOSES, H2020-SwafS-23-2017-789315. (https://dnoses.eu/wp-content/uploads/2019/10/D2.2-Analysis-of-existing-regulation-in-odour-pollution-odour-impact-criteria-1.pdf).

The Best Available Techniques (BAT) Conclusions were published in August 2018. Unlike the BREF document that is only available in English, these conclusions are translated into 23 languages.

Section 2.3.3.5: Odour monitoring

Odour monitoring is carried out using analytical methods (i.e. physical and chemical analysis) or sensorial approaches. Sensorial analysis, being assigned to the 'human sensor', are the cause of significant uncertainties.

The techniques used for these analysis include:

- for odour concentration determination (expressed in ou_E/m^3, to control limit values): dynamic olfactometry (measured according to the European standard EN 13725);
- for odour in ambient air: the grid method (according to the European standard EN 16841-1) or the plume method (according to the European standard EN 16841-2) to determine the odour exposure;
- for odour perception in the surrounding area (impact): odour surveys (see odour intensity mapping and odour wheels);
- electronic noses.

Odour monitoring is applicable where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

A brief description with applicability and limitations of these techniques can also be found in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Section 2.3.5: Techniques for the prevention and control of odour and diffuse/fugitive emissions to air

Odour management plan (Section 2.3.5.1)

An odour management plan (OMP) is part of the environmental management system (EMS) of the installation and includes elements to prevent or reduce odorous nuisances.

The OMP includes the following:

- A protocol containing actions and timelines.
- A protocol for conducting odour monitoring. It may be complemented by measurement/ estimation of odour exposure (e.g. according to EN 16841-1 or -2) or estimation of odour impact.
- A protocol for response to identified odour incidents (including the management of complaints: identification of operations carried out, weather conditions such as

temperature, wind direction, rainfall, communication with the authority and with complainant, etc.).
- An odour prevention and reduction programme designed to identify the source(s), to measure/estimate odour exposure, to characterise the contributions of the sources, and to implement prevention and/or reduction measures.

The technique is applicable to new and existing plants provided that an odour nuisance in residential or other sensitive areas (e.g. recreational areas, workplaces) is expected and/or has been reported. By its implementation, the number of complaints from the neighbourhood could be reduced

Prevention or reduction of odour emissions from waste treatment (Section 2.3.5.2)

The main techniques used to reduce odorous emissions are: minimising residence times, using chemical treatment and optimising aerobic treatment.

The techniques given below can be used to minimise odour emissions:
- Minimise the residence time of (potentially) odorous waste in collection, storage and handling systems (e.g. pipes, tanks, containers), in particular under anaerobic conditions (when relevant, adequate provisions are made for the acceptance of seasonal peak volumes of waste).
- Use chemicals to destroy or to reduce the formation of odorous compounds (e.g. to oxidise or to precipitate hydrogen sulphide).
- Optimise the aerobic treatment, e.g. by controlling the oxygen content and frequent maintenance of the aeration system. In the case of aerobic treatment of water-based liquid waste, the optimisation may also include: use of pure oxygen and/or removal of scum in tanks.
- Cover or enclose facilities for storing, handling, collecting and treating odorous waste (including wastewater and sludge) and collect the odorous waste gas for further treatment.
- End-of-pipe treatment (Table 2).

Technique	Reported Odour abatement efficiency (%) (1)	Comments
Adsorption	70–99	—
Wet scrubbing	60–85	—
Alkaline oxidative scrubbing	80–90	Variant of the absorption technique
Thermal oxidation	98–99.9	—
Catalytic oxidation	80–95	—

Biofiltration (2)	70–99	Low shift of pollution to any other media. Few chemical agents added. Low energy consumption
Bioscrubbing (2)	70–80	—
Biotrickling	70–90	—
Moving-bed trickling filter	> 90	—
(1) As reported in the corresponding sections of this document where the techniques are described. (2) Biofiltration and bioscrubbing can be combined into one system to benefit from the advantages of both techniques. The bioscrubber would act as a humidifier and degrade a high portion of the odorous load. It will also display a buffering effect to prevent high concentrations of odorous substances from entering the biofilter, which otherwise might lead to a rise in temperature in the biofilter material due to an increasing degradation process. Elevated temperatures would result in a lower efficiency of the biofilter.		

Table 2. Overview of end-of-pipe odour treatment techniques

Reduction of diffuse emissions (Section 2.3.5.3)

Selection of operational and design measures, as part of the EMS, which can be implemented to prevent or reduce diffuse emissions to air, including VOC, odour and dust emissions.

The operational and design measures might be the following:

- Minimisation of the number of potential emission sources
- Selection of high-integrity equipment
- Corrosion prevention
- Containment and collection of diffuse emissions
- Selection of input waste
- Storage of waste
- Handling of waste
- Mixing of waste
- Maintenance
- Cleaning

Not all measures are applicable for all types of diffuse emissions (dust, bioaerosols, odour, VOCs).

Leak detection and repair programme (Section 2.3.5.4)

A leak detection and repair (LDAR) programme for plants handling volatile materials. An LDAR programme may include the following:

- Storing contaminated waters which have the potential for odours in covered tanks.
- Tanker washing if the load is likely to give rise to odour. The washing water/aqueous waste from the washing needs to be directly discharged to abated storage systems before opening the tankers. Opening tankers for the minimum amount of time possible.

Undertaking maintenance activities for fixing any detected leaks, e.g. replacing valve packing.

Section 4: Biological Treatment of Waste

Applied processes and techniques for Aerobic treatment (including composting) (Section 4.2.1)

For the composting process of windrows under a semipermeable membrane, this membrane covers are a hybrid form of tunnel or in-vessel composting and covered windrow composting. The semipermeable membrane cover, which is water-resistant but also permeable to gas and steam, protects against waterlogging. The cover and the active aeration creates composting conditions under which odours, VOCs and other emissions are largely contained.

Emissions to air of Outdoor aerobic treatment (Section 4.2.2.1.1)

In open/outdoor aerobic treatment plants, emissions to air are diffuse emissions, inherently providing little or no options for direct regular monitoring of channelled emission components.

As there are no end-of-pipe abatement techniques, quality and operational process management aiming at the minimisation of emissions to air, specifically in the case of odour, dust and bioaerosols, as well as the selection of a suitable location for the outdoor composting plant are of utmost importance.

Range	Standard	Monitoring frequency
NI	Continuous measurements. Measurements are calculated as a plume from a source. Not possible to aggregate the values to one single value. No emission limit values.	NI
3100 ou_E/m^3 in 2010 (Screening flow: 1.58 $m^3/h/m^2$)	NI	NI
21624 $ou_E/h/m^2$ in 2011 and 20523 $ou_E/h/m^2$ in 2014 (values corresponding to the first hours of the process). After 10 days, 2809 $ou_E/h/m^2$ without aeration and 3161 $ou_E/h/m^2$ with aeration. After 21 days, 1407 $ou_E/h/m^2$.	NI	NI
NI	The odour in nearby areas is evaluated yearly by odour panel testing with three specialised members who have passed the n-butanol test according to SFS-EN 13725 and typically at least one non-specialised member	Once a year
NI = No information		

Table 3. Odour emissions in several outdoor aerobic treatment plants

Emissions to air of indoor aerobic treatment (Section 4.2.2.1.2)

The most commonly measured parameters at indoor aerobic treatment plants are odour and NH3 which are measured by plants equipped only with a biofilter, or a combination of a biofilter and a wet scrubber, or a combination of a biofilter and an acid scrubber. Some plants use only wet scrubbers or cyclones; others use semipermeable membranes as abatement techniques. On this section of the BREF, several tables from some plants in the UK are shown including the different parameters measured at indoor aerobic treatment plants, the type of measurement (periodic/continuous, the origin of emissions to air, the associated abatement techniques and the flow of the emissions to air (for more information, check the BREF).

Anaerobic treatment (or anaerobic digestion (AD)) (Section 4.3)

Emissions to air (Section 4.3.2.1)

The AD process itself is enclosed but emissions to air, including odour emissions, can occur from inherent processes of the activity, so odours are one of the most commonly monitored parameters for emissions from biological steps of the process (Table 4).

Pollutant measured	Type of measurement	Ranges			
		AD only		AD & aerobic	
		From biotreatment	From biogas combustion	From biotreatment	From biogas combustion
Flow (Nm3/h)	Continuous	57000	NI	16000-53000	NI
	Periodic	480–90000	25.8–48600	12000–99500	500–8900
Odour (ou_E/m^3)	Periodic	0 –12967	7190 *	85 –1500	NI

* Odour emissions from biogas upgrading unit.
NI = No information.

Table 4. Odour emissions to air from anaerobic digestion (AD)

Mechanical biological treatment (MBT) (Section 4.4)

The output from MBT plants is greatly reduced in weight and when adequately stabilised its emissions to air (e.g. of odour and methane) compared with the untreated material could be reduced by approximately 90–98 % when landfilled.

Emissions to air (Section 4.4.2.1)

The emissions to air of pollutants and odorous substances of MBT plants are:

- waste-specific (type, composition, age);
- treatment-specific (aerobic degradation, anaerobic digestion);
- process-specific (type of aeration);

- dependent on operational management;
- influenced meteorologically (weather conditions) in the case of open reactors.

In addition to the release of odorous substances at delivery and during mechanical treatment, the emissions of the plant mainly originate from the following sources:

- aerobic degradation;
- anaerobic digestion;
- exhaust air/exhaust gas treatment.

Table 5 shows the odour concentration measured at mechanical biological treatment plants as well as the type of measurement (periodic/continuous).

Parameter measured	Type of measurement	Range
Flow (Nm^3/h)	Continuous	720–134000
	Periodic	
Odour (ou_E/m^3)	Periodic	74–5550

Table 5. Odour measured in emissions to air from MBT plants (excluding biogas combustion)

Techniques to consider in the determination of BAT (Section 4.5)

<u>Storage management of putrescible waste input for all types of biological treatment (Section 4.5.1.2)</u>

Management and optimisation of the storage of putrescible waste input, in terms of duration, location and size.

- Waste is stored under appropriate conditions in a designated area to manage putrefaction, odour generation, the attraction of vermin and any other nuisance or objectionable condition. This can be achieved by ensuring that waste is processed quickly and waste storage time is minimised.
- Depending on the feedstock type (C:N ratio, degradability, etc.), the capacity for optimal residence time for feedstock material stored prior to processing is an important factor in a site's potential for odour generation. Untreated and improperly mixed material can increase the generation of odours. The separate storage of different waste types may be useful to create specified compost products (e.g. green waste compost, bio-waste compost, bark compost, sludge compost).
- Where the waste storage area is required to be in an enclosed building, it includes a building ventilation system and an emission abatement system that maintain the building under negative air pressure in order to minimise fugitive odour and dust releases from the building. Exhaust air is captured and can be reused to aerate the composting piles before discharge and treatment.

Achieved environmental benefits are the minimisation of odour generation.

Odour management plan (Section 4.5.1.3)

An ‘odour management plan’ identifies the appropriate measures to mitigate odours at the site, including:

- operational measures;
- management of complaints;
- monitoring of odour emissions.

The odour management plan identifies operational measures to mitigate odours.

In addition, as part of the odour management plan, the ‘complaints management’ in the case of single odour emission events includes the following elements that are duly recorded:

- name, address and telephone number of the complainant;
- date and time of the complaint;
- subject of the complaint;
- operations carried out at the time of the complaint;
- weather conditions (e.g. temperature, wind direction, rainfall);
- operational measures taken in response to the complaint;
- communication with the complainant: an immediate reply is given to the complainant.

The odour management plan also includes operational measures such as monitoring of odour emissions.

The odour management plan identifies the circumstances (i.e. when an odour nuisance can be expected and/or has been substantiated) that would require monitoring of odour emissions and, if relevant, the frequency and location of the measurements as well as the measurement method.

The achieved environmental benefits of this technique include:

- reduction of odour emissions;
- reduction of number of complaints from the neighbourhood.

Table 6 shows the odour emissions measured at biological treatment plants.

Type of biological treatment	**Ranges of odour emissions measured (ou_E/m^3)**
Aerobic outdoor	303–5916
Aerobic indoor	139–7433
Anaerobic	29–12967
MBT	74–5550

Table 6. Ranges of measured odour emissions at biological treatment plants

The odour management plan is restricted to cases where an odour nuisance can be expected and/or has been substantiated.

Reduction of channelled emissions of dust, odour, organic compounds, H2S and NH3 (Section 4.5.1.4)

Collection of emissions of dust, organic compounds and odorous compounds, including H2S and NH3, and abatement by:

- biofiltration;
- thermal oxidation;
- wet scrubber; water, acid or alkaline scrubbers are used in combination with a biofilter, thermal oxidation or adsorption on activated carbon;
- activated carbon adsorption;
- fabric filter; the fabric filter is used in the case of mechanical biological treatment.

More information about each technique can be found in the Best Available Techniques (BAT) Reference Document for Common Waste water and Waste Gas Treatment/Management Systems in the Chemical Sector, 2016, as well as in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

The implementation of some of these techniques are forced when citizens start complaining about odours.

Techniques for aerobic treatment (Section 4.5.2)

4.5.2.1 Monitoring of aerobic process to improve the environmental performance

Proper preparation of waste improves the efficiency of the biological process, has an effect on the output quality and contributes to the reduction of odours.

Aeration monitoring aims at ensuring that aerobic conditions are maintained. Furthermore, a high temperature for prolonged periods of time after thermal sanitisation leads to the formation of odorous substances and ammonia.

Specific operational measures to reduce odour emissions from open windrow composting systems are:

- the immediate and efficient processing of delivered waste material with a high potential for formation of odorous substances (e.g. food waste, fresh grass cuttings);
- mixing with well shredded and structured woody garden and park waste (maintaining sufficient storage/supply of bulking agents to address the C:N ratio and porosity);
- regular turning to avoid anaerobic zones forming in windrows;
- limiting the size of the windrows;
- keeping the facility clean (regular cleaning of surfaces, equipment and all traffic routes etc.);
- turning the windrows only when there is an advantageous wind direction relative to the potentially affected neighbourhood where possible.

4.5.2.2 Techniques to limit diffuse dust, odour and bioaerosols emissions

To identify site activities and meteorological conditions that could potentially generate dust, odour and bioaerosols and to adapt the operations to those meteorological conditions.

The following activities/events can generate dust and/or bioaerosols and odour:

- vehicle and equipment movement around the site;
- shredding of feedstock or bulking materials;
- formation and turning of compost piles/windrows and filling of vessels;
- forced aeration of outdoor windrows without covers;
- screening of finished compost;
- spraying of leachate when it is reused in the composting process, in particular when sprinklers are used (resulting primarily in the generation of bioaerosols;
- strong wind.

Specific management measures to reduce dust, odour and bioaerosol emissions are listed below. These control measures are covered by a facility's diffuse emissions management plan, unless evidence is provided that these measures are not feasible, effective or useful in a specific situation.

- Covering of skips in transit to and from the site and in storage.
- Regular housekeeping (e.g. keeping the site, moving machines and loaders in order and clean).
- Site surfaces such as roads and tracks are regularly dampened down and/or swept to suppress dust and bioaerosols. Binders can be used to prolong dust suppression.
- The plant and machinery are well maintained to avoid generation of dust.
- Effective management of moisture, temperature and air supply of all material liable to generate dust and bioaerosols.
- Maintenance of adequate moisture content throughout the composting process to avoid the input feedstocks, composting materials and finished compost drying out and potentially generating dust and bioaerosols when handled.
- Batch irrigation is undertaken when the parameters for moisture content fall below the critical limits. Water is applied evenly.
- Weather conditions and wind direction are monitored and taken into account when undertaking major process activities.

4.5.2.3 Semipermeable membrane covers with forced positive aeration

Windrows or piles are covered with semipermeable membrane covers, which are a method of treating emissions, such as odours, ammonia, VOCs, dust and bioaerosols from an active composting heap.

In contrast to the end-of-pipe techniques, these systems realise the emission abatement at the source. The cover is formed by a textile laminate with the membrane being the middle layer as the functional component. The emission retention is based on the combination of a liquid condensate layer being generated on the inner surface of the cover, which acts as a kind of bio-washer layer dissolving the majority of the gaseous substances, and the semipermeable behaviour of the membrane.

Following the force of gravity, droplets are formed and drip off thus maintaining a steady exchange with unsaturated water which in turn ensures the odour retention capability.

4.5.3.1 Anaerobic process and waste monitoring

Process and waste monitoring system, manual and/or instrumental, minimise operational difficulties, such as foaming, which may lead to odour emissions, among other benefits.

Section 5: Physico-Chemical Treatment of Waste

Stabilisation (Section 5.1.2.1.1)

Liming is used to stabilise a wide range of sludge and waste types. Lime is composed of calcium (and magnesium in the case of dolomitic lime), which gives it flocculation properties; the hydroxyl ions provide basicity. These properties are used for inorganic and organic sludge treatment. Quicklime is hydrated in contact with water, reducing the original water content in sludge, and promoting an exothermic reaction which has a disinfectant action on the sludge and prevents odours.

The combined action of the high pH and the quicklime reaction heat controls odours during sewage sludge and biological waste treatment.

Techniques for the prevention or reduction of emissions to air (Section 5.1.4.2)

It is possible to implement an appropriate combination of techniques such as bag/fabric filter, wet scrubber, biofilter, adsorption.

More information on the environmental performance of each technique can be found in the CWW BREF, and in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Emissions to air (from the re-refining of waste oils) (Section 5.2.2.1.1)

VOC emissions are known to occur. Although the lubricating system is a semi-closed system, it is not gastight, therefore it would be expected that the volatile gases would have boiled off and left the system at normal operating temperatures.

Most plants recognise the odour problems from the re-refining of waste oils. The control of odour from such plants requires a high level of management control and attention. Odours are typically generated during storage, e.g. odour problems can arise by leaving hatches open at the top of each settlement tank and oil storage tank, or in open vibrating sieves.

Recovery of raw material or energy from distillation residues (Section 5.4.3.1)

Vacuum dryers and other drying techniques are used for distillation bottoms to evaporate the residue from the distillation columns and recuperate the solvents. This technique results in an increase in the percentage of solvent recovered. Resins and pigments may also be regenerated and reused. At the same time they may reduce the odour and VOC emissions that may be generated by the bottoms.

Section 6: Best Available Techniques (BAT) Conclusions for Waste Treatment

General BAT conclusions (Section 6.1)

BAT 10. BAT is to periodically monitor odour emissions.

Odour emissions can be monitored using:

- EN standards (e.g. dynamic olfactometry according to EN 13725 in order to determine the odour concentration or EN 16841-1 or -2 in order to determine the odour exposure);
- when applying alternative methods for which no EN standards are available (e.g. estimation of odour impact), ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

The monitoring frequency is determined in the odour management plan (see BAT 12).

The applicability is restricted to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

BAT 12. In order to prevent or, where that is not practicable, to reduce odour emissions, BAT is to set up, implement and regularly review an odour management plan, as part of the environmental management system, that includes all of the following elements:

- a protocol containing actions and timelines;
- a protocol for conducting odour monitoring as set out in BAT 10;
- a protocol for response to identified odour incidents, e.g. complaints;
- an odour prevention and reduction programme designed to identify the source(s); to characterise the contributions of the sources; and to implement prevention and/or reduction measures.

The applicability is restricted to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

BAT 13. In order to prevent or, where that is not practicable, to reduce odour emissions, BAT is to use one or a combination of the techniques given in Table 7.

Technique		Description	Applicability
a	Minimising residence times	Minimising the residence time of (potentially) odorous waste in storage or in handling systems (e.g. pipes, tanks, containers), in particular under anaerobic conditions. When relevant, adequate provisions are made for the acceptance of seasonal peak volumes of waste.	Only applicable to open systems.
b	Using chemical treatment	Using chemicals to destroy or to reduce the formation of odorous compounds (e.g. to oxidise or to precipitate hydrogen sulphide).	Not applicable if it may hamper the desired output quality.
c	Waste Treatment treatment	In the case of aerobic treatment of water- based liquid waste, it may include: ● use of pure oxygen; ● removal of scum in tanks; ● frequent maintenance of the aeration system. In the case of aerobic treatment of waste other than water-based liquid waste.	Generally applicable.

Table 7. Techniques to reduce odour emissions

BAT 14. In order to prevent or, where that is not practicable, to reduce diffuse emissions to air, in particular of dust, organic compounds and odour, BAT is to use an appropriate combination of the techniques given in Table 8.

Technique		Description	Applicability
a	Minimising the number of potential diffuse emission sources	This includes techniques such as: ● appropriate design of piping layout (e.g. minimising pipe run length, reducing the number of flanges and valves, using welded fittings and pipes); ● favouring the use of gravity transfer rather than using pumps; ● limiting the drop height of material; ● limiting traffic speed; ● using wind barriers.	Generally applicable.
b	Selection and use of high-integrity equipment	This includes techniques such as: ● valves with double packing seals or equally efficient equipment; ● high-integrity gaskets (such as spiral wound, ring joints) for critical applications;	Applicability may be restricted in the case of existing plants due to operability requirements.

		• pumps/compressors/agitators fitted with mechanical seals instead of packing; • magnetically driven pumps/compressors/agitators; • appropriate service hose access ports, piercing pliers, drill heads, e.g. when degassing WEEE containing VFCs and/or VHCs.	
c	Corrosion prevention	This includes techniques such as: • appropriate selection of construction materials; • lining or coating of equipment and painting of pipes with corrosion inhibitors.	Generally applicable.
d	Containment, collection and treatment of diffuse emissions	This includes techniques such as: • storing, treating and handling waste and material that may generate diffuse emissions in enclosed buildings and/or enclosed equipment (e.g. conveyor belts); • maintaining the enclosed equipment or buildings under an adequate pressure; • collecting and directing the emissions to an appropriate abatement system via an air extraction system and/or air suction systems close to the emission sources.	The use of enclosed equipment or buildings may be restricted by safety considerations such as the risk of explosion or oxygen depletion. The use of enclosed equipment or buildings may also be constrained by the volume of waste.
e	Dampening	Dampening potential sources of diffuse dust emissions (e.g. waste storage, traffic areas, and open handling processes) with water or fog.	Generally applicable.
f	Maintenance	This includes techniques such as: • ensuring access to potentially leaky equipment; • regularly controlling protective equipment such as lamellar curtains, fast-action doors.	Generally applicable.
g	Cleaning of waste and storage treatment areas	This includes techniques such as regularly cleaning the whole waste treatment area (halls, traffic areas, storage areas, etc.), conveyor belts, equipment and containers.	Generally applicable.
h	Leak detection and repair (LDAR) programme	When emissions of organic compounds are expected, a LDAR programme is set up and implemented using a risk-based approach, considering in particular the design of the plant and the amount and nature of the organic compounds concerned.	Generally applicable.

Table 8. Techniques to reduce diffuse emissions to air

BAT conclusions for the biological treatment of waste (Section 6.3)

Unless otherwise stated, the BAT conclusions presented in Section 6.3 apply to the biological treatment of waste, and in addition to the general BAT conclusions in Section 6.1. The BAT conclusions in Section 3 do not apply to the treatment of water-based liquid waste.

6.3.1.1 Overall environmental performance (BAT for the biological treatment of waste)

BAT 33. In order to reduce odour emissions and to improve the overall environmental performance, BAT is to select the waste input.

6.3.1.2 Emissions to air

BAT 34. In order to reduce channelled emissions to air of dust, organic compounds and odorous compounds, including H2S and NH3, BAT is to use one or a combination of the following techniques: adsorption, biofilter, fabric filter, thermal oxidation, wet scrubbing.

These techniques are described in the CWW BREF, and in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf

6.3.2.2 Odour and diffuse emissions to air (BAT Conclusions for the aerobic treatment of waste)

BAT 37. In order to reduce diffuse emissions to air of dust, odour and bioaerosols from open-air treatment steps, BAT is to use one or both of the techniques given in Table 9.

Techniques		Description	Applicability
a	Use of semipermeable membrane covers	Active composting windrows are covered by semipermeable membranes.	Generally applicable

b	Adaptation of operations to the meteorological conditions	This includes techniques such as the following: ● Taking into account weather conditions and forecasts when undertaking major outdoor process activities. For instance, avoiding formation or turning of windrows or piles, screening or shredding in the case of adverse meteorological conditions in terms of emissions dispersion (e.g. the wind speed is too low or too high, or the wind blows in the direction of sensitive receptors). ● Orientating windrows, so that the smallest possible area of composting mass is exposed to the prevailing wind, to reduce the dispersion of pollutants from the windrow surface. The windrows and piles are preferably located at the lowest elevation within the overall site layout.	Generally applicable

Table 9. Techniques to reduce diffuse emissions to air of dust, odour and bioaerosols from open-air treatment steps

Emissions to water (Section 6.6.3)

Before odours are emitted to the air, liquids can be treated in order to prevent this emission.

With a chemical oxidation process, organic compounds are oxidised to less harmful and more easily biodegradable compounds. Techniques include wet oxidation or oxidation with ozone or hydrogen peroxide, optionally supported by catalysts or UV radiation. Chemical oxidation is also used to degrade organic compounds causing odour, taste and colour and for disinfection purposes.

1.3. Refining of mineral oil and gas

Introduction

Refineries have always been an important source of different types of emissions, thereby including odours.

The Best Available Techniques (BAT) Reference Document for the Refining of Mineral Oil and Gas issued in 2015 *explicitly mentions odours 121 times*, and more in detail:

- the methods for monitoring odours (Section 3.26.1.4)
- the techniques for odour pollution prevention and control from different refinery operations (Section 4)
- the techniques for removing odours from refinery waste gas emissions (Section 4.23)
- the techniques for the reduction of odours from waste water treatment plants and from water buffer tanks (Section 4.24.7)

Section 3.26.1.4: Odour monitoring

This section gives a brief introduction about odour emission from refineries, and then describes the methods that can be used for odour monitoring.

Odours from refineries

Odour is potentially related to the emission of a large number of chemical substances and compounds. In oil and gas refining, these are most likely to be:

- sulphur compounds (e.g. hydrogen sulphide, mercaptans, sulphides, disulphides);
- nitrogen compounds (e.g. ammonia, amines);
- hydrocarbons (e.g. aromatics).

The perception of an odour in the surroundings of a refining plant and, eventually, the nuisance related to it, and the possibility to prevent or reduce this nuisance will depend on various parameters, highlighted below:

- The number of different sources and substances: the resulting odour from a combination of different substances can be perceived as more of a nuisance than the odour of substances emitted separately at the same concentration. Furthermore, in combination with other substances, the characteristic odour of a single substance can be modified so as to be unrecognisable.
- The olfactive thresholds of emitted substances: at the same concentration (or distance from the source), some substances will be strongly perceived as others will have disappeared. In case of a mixture, the combined odour will change as the mixture becomes diluted, until the concentration of each component falls below its own threshold.
- The individual olfactive ability and subjective reaction of exposed persons: odours can be judged as acceptable or unacceptable depending on the physical sensitivity to it, as

well as on psycho-sociological factors which can influence personal preferences. For the same person, an odour can be pleasant when the substance is diluted and become offensive when concentrated.

In general, the human nose is very sensitive to certain substances or components that are typically emitted by oil and, to a lesser extent, by gas refining activities. It should be noted that most of these substances, and especially sulphur compounds, generate odours that are generally perceived as very unpleasant or aggressive.

Odour management plan

Refineries should have an odour management plan as a well identified part of their environmental management system. The odour management plan should include all of the following elements:

- an odour management strategy;
- protocols for conducting odour monitoring;
- a protocol for response to identified odour events;
- an ongoing odour prevention and elimination programme designed to identify the location, nature, emission and dispersion of on-site odours, to characterise the odours, and to implement elimination and/or reduction measures in relation to these odours;
- an implementation timetable for all actions to be taken within this programme;
- reporting procedures to regularly advise management on the results of the plan;
- a review programme for regularly updating the plan.

Because odorous compounds are primarily VOCs and sulphur and nitrogen compounds, various prevention, reduction and abatement techniques can be applied to prevent and limit odour pollution. These techniques are described in the CWW BREF (https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CWW_Bref_2016_published.pdf).

An overview of main odour management and treatment techniques is also available in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Odour monitoring techniques

The techniques that are considered to be most appropriate to the oil refining sector cited in this document are:

- Dynamic olfactometry with human assessors;
- Odour surveys by a committee of residents.

A brief description with applicability and limitations of these techniques can also be found in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Dynamic olfactometry is a sensorial technique for the measurement of odour concentration, which is standardized by a European Norm (EN 13725:2003).

One of the main benefits of dynamic olfactometry is that it provides the necessary input for a well-established odour management plan (OMP).

Odour surveys by a committee of residents involves the use of different questionnaire techniques in order to evaluate the perceived nuisance. Questionnaires are filled in regularly, but always on a voluntary basis. The answers are correlated with meteorological conditions to get a link between actual emission sources and the described nuisance.

At a basic or preliminary step, the respondents are requested to rate the odour perception, the quality, and the level of nuisance on a multi-points scale.

Citizen science as proposed by the D-NOSES project can be seen as an evolution of the questionnaire techniques for the active involvement of citizens in the odour monitoring process.

As stated by the BREF document, the achieved environmental benefits involve a better knowledge and understanding of the conditions under which odour nuisances occur. The results can be used for adjusting plant configuration and operations to reduce odour nuisance and the parameters which have to be assessed to limit olfactory impacts can be determined. Recommendations can be proposed and circulated back to the residents, e.g. specific practices to be avoided under characteristic meteorological conditions, and main sources identified as actually a nuisance and deserving newly adapted prevention measures or abatement techniques. This improves the preparedness, participation and response of the local community potentially exposed to odour.

Furthermore, the technique can also play a key role in the control of the effectiveness and efficiency of odour-reducing actions taken from previous monitoring campaigns.

Section 4: Techniques to consider in the determination of BAT

This section illustrates the techniques that shall be considered in each refinery process for the determination of Best Available Techniques. For those processes that could produce odour emissions, indications are given on the techniques that can be applied in order to reduce such emissions.

Section 4.4: Bitumen production

Relating to the production of bitumen, the BREF document illustrates some techniques to control emissions to the air, thereby specifying some techniques that can be used for odour reduction.

Treatment of the gaseous overheads (Section 4.4.2.1):

Oxidiser overheads can be routed to a scrubber rather than direct water quenching for contaminant removal prior to incineration. The off-gases are condensed in a scrubber, where most of the hydrocarbons are eliminated. The water vapour (sometimes after full condensation) is left in the air stream to incineration at a temperature of approximately 800°C.

Achieved environmental benefits are the reduction of H2S, SO2, SO3, CO, VOC, particulates, smoke and odour emissions.

Use of the heat from incondensable products and condensates (Section 4.4.2.2):

Both incondensable products and condensates from the separator, hydrocarbon and aqueous unit can be burnt in a purpose-designed incinerator, using support fuel as necessary or in process heaters. Oxidiser overhead slop oil can also be treated in the sludge processing or recycled in the refinery slop oil system.
Achieved environmental benefits are the reduction of emulsion of light oil, water and particulates, and the removal of odorous noncondensables which are difficult to treat elsewhere.

Treatment of vents from the storage and handling of bitumen materials (Section 4.4.2.3):

Techniques that may be applied to prevent VOC emissions and odours include:

- venting of odorous gases during the storage of bitumen and the venting of tank blending/filling operations to an incinerator;
- the use of compact wet electrostatic precipitators which have been proven capable of successfully removing the liquid element of the aerosol generated during the top-loading of tankers;
- adsorption on activated carbon.

Achieved environmental benefits are the reduction of emissions of sulphur compounds, VOC, particulates, smoke and odour emissions.

Section 4.20: Products treatment

The treatments used in a refinery to achieve certain product specifications can be divided into two types of processes:

- The first group of processes corresponds to extraction or removal techniques where the component to treat is removed from the stream to be treated, e.g. amine scrubbing for the removal of hydrogen sulphide, and caustic washing for the removal of acids or mercaptans.
- The second group is composed of these systems where the chemical to be treated is not removed from the stream to be treated, e.g. by catalytic dewaxing process.

The techniques that should be considered for the reduction of odours relating to these processes are described below.

Management of the spent caustic (4.20.2)

Caustics are used to absorb and remove hydrogen sulphide, mercaptans and phenol contaminants from intermediate and final product streams. Spent caustic solutions from some sweetening units are odorous and need to be handled in enclosed systems and treated as necessary before release at a controlled rate to the effluent system. Several techniques exist to maximise the reuse of caustics within a refinery. They include recycling within the refinery or outside the refinery or destruction within incinerators.

Techniques to consider are:

- Neutralisation and stripping.
- Incineration which can be an appropriate alternative to waste water treatment because of the very high concentration of cresylics, naphthenes, mercaptans and other organic compounds in spent caustic solutions (COD>>50 g/l).
- Handling and disposal of dry spent caustic in a manner that prevents dust generation. It should not be disposed of to the land.
- Reuse of spent caustic within the refinery.
- Corrosion control on crude distillation units using spent caustic rather than fresh caustic. Unstable chloridric (magnesium) salts that are not extracted from the crude oil in the desalter will decompose upon heating into the crude distiller and cause chloridric corrosion. To prevent corrosion of the exposed equipment, small quantities of caustic (sodium) are injected in the crude oil feed by which the chloridric components are neutralised due to the formation of stable sodium chloride. For the purpose of the neutralisation of chloridric decomposition products, often spent caustic can be used, which is recommended as well to minimise waste generation.
- Recycling to downstream of the crude desalter or sour water strippers.
- Addition to biotreaters for pH control.
- Recycling caustics containing phenols on site by reducing the pH of the caustic until the phenols become insoluble thereby allowing physical separation. The caustic can then be treated in the refinery wastewater system.
- Reusing spent caustic (generally classified into: sulphidic, cresylic and naphthenic) outside the refinery.
- Regenerating or oxidising spent caustic.

Achieved environmental benefits are the reduction of odour emissions and caustic use.

<u>Incineration of foul air vented from sweetening (4.20.3)</u>

Foul air vented from sweetening processes contains sulphur compounds that typically have a strong odour. The range of quantity of sulphur in the foul air vented from the sweetening processes is around 0.7 – 7 kg/day (disulphide concentration can be as high as 400 ppm) for a 10 000 t/d crude unit and the percentage contribution it makes to the stack gases where it is incinerated has been estimated at 0.16 – 2.48%. For this reason, the abatement prior to incineration is not justified and the foul air vented from sweetening processes is incinerated in local furnaces.

Section 4.23: Waste gas minimisation and treatments

This section illustrates the techniques to be considered for waste gas minimisation and treatment. Some of the techniques described are cited as effective in reducing odours.

Hydrogen sulphide and light mercaptan removal (Section 4.23.5.3)

Within the section dedicated to the techniques for sulphur recovery and SO_2 abatement (Section 4.23.5), the hydrogen sulphide and light mercaptan removal process works with a fixed bed or batch-type granular reactant where iron compounds (Fe3O4 and Fe2O3) react with H2S to form FeS2 (pyrite).

It is applied to waste water systems, land oil tanker vents, oil storage and transportation, and bitumen plants. Final polishing for odour control may be required to remove higher mercaptans and dimethyl disulphide.

Despite this being the only process that explicitly mentions odour reduction, all the processes for the removal of H2S can be considered as processes for the reduction of potential odour emissions.

Vapour destruction (VD) (Section 4.23.6.3)

Among the techniques for VOC abatement, the description of vapour description explicitly refers to odour reduction.

Apart from the conventional technique of VOC collection and destruction by routing to a flare system, two specific systems are cited as relevant in this respect.

- Oxidation: the vapour molecules are converted to CO2 and H2O either by thermal oxidation at high temperatures or by catalytic oxidation at lower temperatures.

Directive 94/63/EC (Stage 1) only allows oxidation in special situations, e.g. when vapour recovery is unsafe or technically impossible because of the volume of return vapour.

- Biofiltration: decomposition to CO2 and H2O is achieved at temperatures slightly above ambient by microorganisms located in a solid humidified support medium.

These techniques are described in the CWW BREF (https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CWW_Bref_2016_published.pdf), as well as in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Again, despite this is the only technique whose description specifically refers to odours, since odour emissions from refineries are mostly related to the emission of VOCS, all techniques for the abatement of VOCs are also effective in the reduction of odours. Such techniques comprise als Vapour recovery units (VRU).

Use of nitrates for odour control

This technique is mentioned in the specific section dedicated to Odour pollution prevention and control techniques (Section 4.23.9).

This technique can be used to reduce the odour generated by any equipment (e.g. storage tanks, sewage systems, oil/water separators) where anoxic conditions can lead to the formation of hydrogen sulphide and other odorous mercaptans in contaminated waters from the biodegradation of sulphur organic compounds by bacteria. This technique consists of adding nitrate-based products in septic water areas, in order to replace bacteria feedstock and to favour the development of denitrifying bacteria, which will both reduce added nitrates in nitrogen and existing hydrogen sulphide in sulphates. Nitrate solution can also be injected in bioreactors.

In favourable conditions of use, hydrogen sulphide and mercaptans can be significantly reduced and even virtually eliminated. On the other hand, inappropriate dosing can lead to an excessive contamination of nitrates in the treated waters.

Section 4.24.7: Reduction of odours

This subsection of section 4.27 dedicated to waste water treatment describes the techniques that can be used for the reduction of odours.

Reduction of odours from WWTP

For various steps of WWT, emissions to air of VOCs (including benzene) and odorous components (hydrogen sulphides and mercaptans) are directly related to the surface area of the open separation and collection compartments. The release of dissolved gases in the dissolved gas flotation (DGF) unit increases the effective water area exchanging with air and produces a continuous gas flow through the water column into the gas space above the liquid surface. The substances volatilised by diffusion into the gas bubbles and above the water column are then subject to ambient air convection. The generation of VOCs and odours can be further reduced by covering these units with closed and tightly sealed covers. However, due to eventual fluctuations of the internal pressure, such covers cannot be 100 % tight and have to be mechanically protected by an atmospheric vent. To be considered acceptable in order to protect covers together with minimising convective losses, the usual dimensions of such vents are around 0.90 m minimum height and 10.2 cm maximum diameter. An additional pressure relief/vacuum breaker valve can also be installed, in order to accommodate an exceptional gas exchange rate beyond the vent capacity. Cover vents can be collected and treated with an appropriate off-gas treatment system (e.g. biofilter, activated carbon absorber, incinerator, thermal oxidiser) or can be reinjected into the aeration basin.

VOC emissions from oil separators can be reduced to 3 g/m^3 by covering the CPI and API.

The HC emissions from the waste water systems can be determined by calculation from the exposed surface area of the oil-contaminated untreated water tank (API separator) and an empirical oil evaporation factor of:

- 20 g/m^2 per hour for open oil separator,
- 2 g/m^2 per hour for covered oil separator.

When separators are covered, the flammability/explosion limits and the toxicity concentration thresholds for some gaseous sulphur compounds may easily be reached. Consequently occupational safety and environmental protection should be carefully considered at the equipment design stage, and appropriate procedures should be set up for ensuring safe operating conditions. Safety should be addressed in the case of a fixed roof tank at any step of the WWT.

Reduction of odours from water buffer tanks

Water buffer tanks are used upstream and/or downstream of API/CPI/PPI separation systems to receive variable rate transfers of wastewater containing insoluble floating oils, insoluble suspended oils and solids, and soluble substances. This section also includes process area storm water surge tanks.

As for any other treatment step, the generation of odours from open-top water buffer tanks will be directly related to the surface area of oil and water that will come into contact with air.

Substances will be volatilised by diffusion into the air and be subjected to the convective forces of airflow. The generation of odours can be reduced by maintaining the smallest possible surface area of oil and water in contact with air. For such a purpose, the tank should be routinely checked and maintained free of oil by the operator, and the following actions can be taken.

- Operate the water buffer tank with a fixed roof equipped with a pressure relief/vacuum breaker valve to prevent convective losses when the tank level is static.
- Use an internal floating roof or an external floating roof equipped with at least a primary seal or, more efficiently, a primary and secondary seal between the floating roof and the tank shell, for further reducing the diffusive and convective losses.
- Instead of gravity draining to an open collection system, install an internal oil skimming system to extract oil from the tank through closed piping using a pump station or vacuum truck to minimise the possible loss of volatile substances. For safety reasons, in the case of using a vacuum truck, special care should be paid towards the flash point or H2S concentrations in the liquid phase. The addition of carbonate neutraliser on the vapour phase of the truck can be considered.

By using a fixed roof tank or a floating roof tank, the emission of VOCs and other odorous compounds can be reduced by 80 – 90 % compared to an open system. This ratio can be even higher and reaches 99 – >99.9 % if vented emissions from the fixed roof tank are collected and routed to an appropriate off-gas treatment system (e.g. biofilter, activated carbon absorber, incinerator, thermal oxidiser).

Safety should be addressed in the case of a fixed roof tank.

1.4. Intensive rearing of poultry and pigs

Introduction

As mentioned in the introduction of the BREF document, awareness of the implications and impacts of farming activities, thereby including odour nuisance, has increased over the years, due to an increasing population in rural areas.

One of the major challenges in the modernisation of poultry and pig production is the need to balance the reduction or elimination of the polluting effects on the environment with increasing animal welfare demands, while at the same time maintaining a profitable and economically viable business.

Odour is a local problem but is an issue that is becoming increasingly important as the livestock industry expands and as ever increasing numbers of rural residential developments are built in traditional farming areas, bringing residential areas closer to livestock farms. The increase in the number of farm neighbours is expected to lead to increased attention to odour as an environmental issue as odour emissions can be offensive and give rise to problems with neighbours.

Regarding poultry and pig rearing, odours are emitted in particular from animal housing, manure collection and storage, and landspreading operations. Dust emitted from farms contributes to the transportation of odour.

The Best Available Techniques (BAT) Reference Document for the Intensive Rearing of poultry and pigs issued in 2017 *explicitly mentions odours 592 times*, and more in detail:

- the sections of the poultry production operations that emit odours (section 2.2)
- the end-of-pipe techniques for air cleaning (section 2.4)
- other operations causing odour emissions, i.e. collection and storage of manure (section 2.6), on-farm manure processing (section 2.7), manure landspreading (section 2.8)
- the major on-farm activities causing odour emission (Section 3)
- the techniques to consider in the determination of BAT (Section 4)
- the specific techniques for the reduction of odour emission (Section 4.10)
- the methods for monitoring odours (Section 4.18.4)
- the general BAT conclusions relating to odours (Section 5.1)

Section 2.2: Poultry production

This section gives a brief explanations of the different operations related to poultry productions. In some of these operations, odours are explicitly mentioned as possible pollutants emitted, i.e. pullet rearing and the ventilation of poultry housing.

Section 2.4: End-of-pipe techniques for air cleaning

This section describes the air cleaning systems that can be used as end-of-pipe techniques to remove pollutants from the exhaust air of animal housing. They are applied only in forced ventilated houses because the exhaust air has to be collected and led through the cleaning system by fans.

Modifications to the feed formulation and adaptation of the housing system may not always allow compliance with increasingly stringent emission regulations and targets. This can be seen as a driving force for the development and use of air cleaning systems; even if these techniques do not improve the indoor climate of the animal houses.

The only air cleaning systems that are mentioned in this document are wet scrubbers and biofilters.

A detailed description of these systems is given in the CWW BREF (https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CWW_Bref_2016_published.pdf), as well as in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Section 2.6: Collection and storage of manure

Spatial planning of on-farm manure storage is regulated for the protection of water sources and to protect sensitive receptors in the vicinity of the farm against odour. Regulations prescribe minimum distances, depending on the number of animals and on farm-specific features, such as prevailing wind direction and the type of neighbouring receptors.

A table is provided (Table 2.17, page 109) comparing the benefits and disadvantages deriving from the use of solid manure or slurry-based manure management systems over the entire chain of farm processes and activities.

Section 2.7: On-farm manure processing

Manure processing prior to landspreading may be performed for different reasons, among which reducing odour emissions during storage and/or landspreading, and decreasing the nitrogen content of the manure to prevent groundwater and surface water pollution as a result of landspreading, and to reduce odour.

Odour nuisance that occurs during or after the storage of manure can, in some instances, be reduced by aerobic or anaerobic treatment or by additives.

The water content and volume of the manure can be reduced. In addition, pathogenic microorganisms present in the manure can be deactivated (this prevents the spreading of livestock pathogens to other regions), and odour emissions reduced.

Techniques for manure processing include: separation, aerobic digestion of liquid manure, composting of solid manure, anaerobic digestion of manure, manure additives.

Section 2.7.1: Separation

Separation can be performed by settling or mechanically, with the aim to separate slurry into a stackable solid fraction and a liquid fraction.

On the contrary, liquid manure can be converted into solid manure by mixing it with peat: liquid manure mixed with peat produces less odours than liquid manure alone.

Section 2.7.2: Aerobic digestion (aeration) of liquid manure

On some pig farms, aerobic digestion is used to improve the properties of liquid manure such as to reduce odour emissions from pig slurry by the biological oxidation of volatile organic compounds, to decrease pathogens and BOD content, to produce a stabilised and homogenous liquid manure, and, in some cases, to reduce its nitrogen content.

Section 2.7.3: Composting of solid manure

The composting of solid manure is a form of controlled aerobic treatment which can occur naturally in farmyard manure heaps, and that produces a more stable product, with consistent chemical properties, than the initial material.

For farmers, the main advantage of composting is the significant reduction in the volume of material to be transported and spread. Other potential benefits include efficient decrease in pathogens through generation of heat, reduction in odour, concentration of nutrients and a lighter, friable and more homogeneous product (compost), which is easier to handle than untreated manure.

Section 2.7.4: Anaerobic digestion of manure in a bio gas installation

Anaerobic digestion of pig slurry is carried out in a digester in the absence of free oxygen, and consists of the methanogenic anaerobic decomposition of organic matter by microorganisms. The benefits of the process include the production of biogas, the stabilisation and hygienisation of the digested manure (digestate) which can be landspread as a soil conditioner and a source of nutrients with improved N availability for the plants due to mineralisation, compared to the untreated slurry. Less odour is also produced during landspreading.

Section 2.7.6: Manure additives

Under the generic denomination of manure additives is a group of products made up of different compounds that interact with the manure, changing its characteristics and properties. Among the positive effects claimed there is the reduction of unpleasant odours.

Several types of additives, with different characteristics, may be employed for reducing odours from manure: masking, blocking, absorbing agents, microbiological agents, and chemical additives.

Section 2.8: Manure landspreading techniques

A range of equipment and techniques are used to spread slurry and solid manure to land. These are described in the following sections. Much of the manure was used to be landspread using machinery which spreads manure over the whole soil surface ('broadcast') by throwing it into the air. The diffusion of odours and the risk of pathogen spreading with drifting droplets are other drawbacks of this technique. In some countries (e.g. the Netherlands, Denmark and Belgium-Flanders), the use of band spreaders and injectors for slurry is required to reduce emissions.

Section 3: Current consumption and emission levels of intensive poultry or pig farms

Table 3.1 (page 149 of the BREF document) reports the key environmental issues of the major on-farm activities, and odours are cited several times as potential emissions from the following activities:

- Housing of animals
- Storage of manure in a separate facility
- Storage of residues other than manure
- Storage of dead animals
- Manure landspreading
- On-farm treatment of manure
- Treatment of wastewater
- Incineration of dead animals

Section 3.3.2.1: Emissions from poultry housing

This section describes the various emissions from poultry housing, and provides the ranges of reported air emission levels from poultry houses. The values of the emission factors for odours have been extracted to Table 10.

Type of poultry	Odour emissions [ou/s per bird]
Laying hens – Enriched cage systems	0.102-0.68
Laying hens – Non-cage systems	0.102–1.53
Pullets (cage and not cage systems)	0.042–0.227
Broilers	0.032–0.7
Broiler breeders	0.11–0.93
Turkeys (female) - Whole period	0.4
Turkeys (male) -Whole period	0.71

Ducks	0.098–0.49

Table 10. Range of reported odour emission factors from poultry housing

Section 3.3.2.2: Emissions from pig housing

This section describes the various emissions from pig housing, and provides the ranges of reported air emission levels from pig houses. The values of the emission factors for odours have been extracted to Table 11.

Type of pig	Housing system	Odour emissions [ou/s per animal]
Sows (mating/gestating, farrowing)	Mating and gestating sows (slurry system)	1.3–57
	Mating and gestating sows (solid manure system)	6.6
	Farrowing sows (slurry and combined slurry/solid manure system)	5.6-100
Weaners	Slurry system	1.1–12.1
	Solid manure system and combined slurry/ solid manure system	2.25–3
Fattening pigs	Slurry system	1.14–29.2
	Solid manure system and combined slurry/ solid manure system	4.2–7

Table 11. Range of reported odour emission factors from pig housing

Section 3.3.9: Emissions of odours

In Section 3 of the BREF document there is an entire section dedicated to the emissions of odours: as already mentioned, emissions of odour originate from the activities such as animal housing, manure storage and manure landspreading. The contribution of the individual sources to the total odour emission from a farm varies and depends on many factors such as the general maintenance of the premises, the composition of the manure and the techniques used for handling and storage of the manure. Table 12 reports the ranges for the odour emission factors extracted from the BREF document.

Type of animal rearing	Odour emissions [ou/s per animal]
Pig farms	
Gestating sows kept in individual crates	6.6-39
Gestating sows kept loose	7-39
Farrowing sows and piglets kept in crates with partly slatted floor	10-125
Farrowing sows and piglets kept in crates with fully slatted floor	10-280
Weaners kept in pens with partly or fully slatted floor	3-14

Finishers kept in pens with partly slatted floor	6.5-48
Finishers kept in pens with fully slatted floor	6.5-78
Finishers in deep litter	4
Poultry farms	
Layers in a floor system	0.143-1.53
Layers in cages (colonies), aerated manure belt	0.102-0.68
Layers in cages (colonies), manure belt, no aeration	0.102
Layers in aviary system, belt with or without aeration	0.102-0.34
Broilers on deep litter	0.12-0.4
Female turkeys on solid littered floor	0.4
Male turkeys on solid littered floor	0.71
Ducks on solid littered floor	0.29

Table 12. Reported odour emission factors for different animal categories and housing systems

Section 4: Techniques to consider in the determination of BAT

This chapter describes techniques (or combinations thereof), and associated monitoring, considered to have the potential for achieving a high level of environmental protection in the activities within the scope of this document. The techniques described include both the technology used and the way in which the farms are designed, built, maintained, operated and decommissioned.

Odours are mentioned throughout the whole section when describing the options for the animal nutritional management (Section 4.3), the techniques for the efficient use of energy and water (Sections 4.4 and 4.5), the techniques for the reduction of emissions from poultry houses (Section 4.6), the techniques for the reduction of emissions from pig houses (Section 4.7), the techniques for the reduction of emissions within housing (Section 4.8), the techniques for the reduction of emissions from manure storage, processing and landspreading (Sections 4.11, 4.12, 4.13).

All the techniques that can be applied for reducing odour emissions specifically are reported in a dedicated section (Section 4.10), which has been further summarized here.

Section 4.1: Good agricultural practice for environmental management

A first aspect concerns the location for a livestock farming facility: it can be considered part of good farming practice if adequate distances are ensured between the house/farm and the sensitive receptors requiring protection, e.g. from neighbours to avoid conflicts arising from odour and noise nuisance, or from waters to protect them from the emission of nutrients

Section 4.1.1: Storage and disposal of dead animals

Good housekeeping practices are essential to ensure hygienic on-farm storage of the dead animals which are not going to be incinerated on farm. In anticipation of collection by an authorised waste collector, fallen stock should be stored in closed, leakproof containers to avoid spillage or odour problems. Refrigeration may be necessary, especially in hot climates, when the removal frequency is not regular (e.g. more than weekly).

Section 4.10: Techniques for the reduction of odour emissions

Odours are indigenous to all livestock production operations. Odour mainly originates from the microbial conversion of feed (protein and fermentable carbohydrates) in the intestinal tract of pigs and by the microbial conversion of urinary and faecal compounds in the manure under anaerobic conditions.

Odour is the principal concern of local communities in relation to both pig and poultry farms. Odour arises from animal housing, as well as from manure transfer, storage, and spreading. The odours are diffused in gas form and/or are conveyed by dust. The level of odour that arises from pig or poultry farms varies significantly and the degree of nuisance of a particular odour level varies according to location and context.

Section 4.10.1: General measures for odour prevention

Odour can be reduced in a number of other ways, including:

- by good housekeeping;
- by storing the manure outside under a cover;
- by preventing an airstream from passing over the manure;
- by keeping straw-based manure under aerobic conditions in order to rapidly break down the odorous substances.

For reasons relating to odour, application times and techniques have been developed for landspreading. Some additional techniques to reduce odour in the vicinity of the farm are applied on farm to animal houses with forced ventilation. These include:

- horizontal air outlet channel, which does not mean a reduction of odour, but which diverts the emission point of air from the housing to a different side of the farm, so as to reduce the potential impact for odour-sensitive receptors (e.g. residential areas);
- dilution of the concentration, which is explained below and is based on the proper design of the housing and dimensioning of the ventilation.

<u>Section 4.10.1.1: Dilution of odorants</u>

In many cases, distancing the source from the receptor is the only meaningful way to dilute odorants. In many countries, in order to protect residents against significant odour nuisance, minimum distance regulations for the assessment of odour and the spatial separation of farms and dwellings or residential areas have been established.

Section 4.10.1.2: Discharge conditions

The principles of natural ventilation and forced ventilation result in different waste air discharge conditions.

Essentially, an unimpeded incoming and outgoing flow of outside air must be ensured in the immediate vicinity of the housing (approximately three to five times the building height). With forced ventilation, the use of the area in the immediate vicinity of the housing determines the discharge conditions to be selected, e.g. side wall ventilation leading into the yard, or high discharge stacks above the ridge. In the case of naturally ventilated housing, a local odour may be regarded as acceptable, where the emphasis is predominantly on the effect of the housing emissions further afield.

- Forced ventilation: As a rule, with forced ventilated housing the focus in terms of impact reduction is on achieving sufficient dilution of the waste air by the wind. In order to protect the local neighbourhood, it may be generally advisable to ensure that the emission airstreams pass at a certain minimum height over and beyond local dwellings by raising the source height, so that entrainment of the waste air plume in the wake zone of the building (downwash effect) can be kept to a minimum. This effect can be achieved by increasing the waste air exit velocity and/or raising the height of the waste air discharge stack. Forced ventilation has the advantage of allowing the easy implementation of air cleaning techniques.
- Natural ventilation: In order to ensure sufficient functional efficiency with natural ventilation, certain requirements have to be met, for example the following:
  - roof pitch angle of at least 20 ° for eaves-ridge ventilation in order to generate the necessary thermal upcurrent;
  - mean height difference of at least 3 metres between the inlet air apertures and the waste air apertures with shaft ventilation;
  - dimensioning of the air inlet and waste air apertures in accordance with the livestock occupancy and thermal upcurrent lift height;
  - guaranteed disturbance-free flows of incoming fresh air and outgoing waste air into and from the housing;
  - ridge axis aligned transverse to the prevailing wind direction for new plants.

Section 4.10.1.3: Dietary effects

Dietary protein is a precursor of odour production in the intestines of animals and in manure as the excretion of protein and its metabolites (e.g. urea) in the excreta of pigs provides substrates for bacteria to generate odour; thus, it is logically expected that odour emissions can be reduced as the dietary crude protein level decreases. On the other hand, it is also reported that there is no significant influence of feeding strategies on odour emissions, although the odour quality may change.

Section 4.10.1.5: Odour management plan

The odour management plan can be a part of the environmental management system (EMS) of the farm.

An odour management plan includes the following elements:

- a protocol containing appropriate actions and timelines;
- a protocol for conducting odour monitoring;
- a protocol for response to identified odour nuisance;
- an odour prevention and elimination programme designed, for example, to identify the source(s), to monitor odour emissions, to characterise the contributions of the sources and to implement elimination and/or reduction measures;
- a review of historical odour incidents and remedies and the dissemination of odour incident knowledge

Section 4.10.2: Good operational practice in pig housing

Sources of odour in and around buildings and practices to reduce odour emissions in pig housing include the following:

- Cleanliness: It is good operational practice to keep the pigs and the surfaces in and around buildings clean. Pigs with manure on their skin will have a significantly increased odour emission, as the body heat of the animal will accelerate the release of odours significantly. In addition, reducing the exposed area of manure and avoiding spilled feed induce a direct reduction in odour emissions.
- Dryness: Optimum control of the housing environment, particularly during summer, can contribute to ensuring that pigs excrete in the dunging area while the lying and activity area remain clean and dry. Drinking water losses should be avoided by employing low-loss drinking equipment. For litter-based systems, the level of odorant emissions decreases as the quantity of litter per livestock unit increases.
- Slurry removal: In liquid manure systems, the odorant emissions from the houses can be reduced if the dung and urine are removed from the housing at short intervals or in a continuous process. Long residence times in a manure storage pit and large storage volumes increase the emissions of odorants. As a general principle, pig manure has to be removed to adequate storage pits or be subjected to an appropriate treatment, including landspreading, as quickly as practicable, e.g. by shallow channels with a flushing system for rapid discharge.

Most techniques which are mostly intended for abating ammonia and dust emissions can have a reducing effect on odour emissions. However, it is important to highlight that ammonia-reducing housing systems do not necessarily reduce odour emission.

The main principles utilised by low-ammonia-emission housing systems for reducing emissions to air from pig housing are:

- limiting the exposed area of stored manure;
- frequent removal of manure by a sewerage system, flushing or scraping;
- cooling manure, lowering the temperature of stored manure;
- faster discharge of the manure from slats, by using triangular iron bars, which are easily cleaned;
- decreasing the temperature of the indoor environment, the airflow and velocity over the manure surface while maintaining an acceptable living environment for the animals;
- keeping the litter dry and under aerobic conditions in litter-based systems.

Section 4.10.3: Good operational practice in poultry housing

Odour from broiler housing is reported to increase in offensiveness with the moisture content of the litter.

Sources of odour in and around buildings and practices to reduce odour emissions in poultry housing include the following:

- Cleanliness and dryness: Drinking water losses should be avoided by employing low-loss drinking equipment (e.g. nipple drinkers). The level of odorant emissions decreases as the quantity of litter per livestock unit increases.
- Manure removal: In liquid manure systems, the odorant emissions from the housing can be reduced if the manure is removed from the housing at short intervals or in a continuous process. Long residence times in a manure storage pit and large storage volumes increase the emissions of odorants. As a general principle, manure must be removed to adequate storage pits or be subjected to an appropriate treatment, including landspreading, as quickly as practicable.

There are no consistent differences in odour emissions between conventional housing systems and those designed for low ammonia emission (e.g. with drying of the manure collected on belts) in each specified poultry category.

Section 4.10.4: Slurry storage

Slurry storage can be a highly significant source in terms of odour annoyance potential. Under anaerobic conditions, high concentrations of odorants can be formed in slurry, which can be released in highly concentrated 'puffs' when slurry is being handled. Turbulence, resulting from stirring and pumping, can increase the emissions from the surface by an order of magnitude (factor 10) compared to a still surface.

Odour concentrations over slurry, or in headspaces, can reach tens or even hundreds of thousands of ou_E/m^3, whereas the odour concentration in pig house ventilation air rarely exceeds 5 000 ou_E/m^3.

The techniques for storage having a significant effect on odour emissions are:

- covering of slurry or solid manure during storage;
- location of the store taking into account the general wind direction and/or adopt measures to reduce the wind speed around and above the store (e.g. trees, natural barriers);
- minimisation of the stirring of slurry.

Section 4.10.5: Manure processing

The techniques for manure (solid or slurry) processing having a significant effect on odour emissions are:

- aerobic digestion (aeration) of liquid manure/slurry;
- composting of solid manure;
- anaerobic digestion.

Section 4.10.6: Landspreading

The techniques for landspreading having a significant effect on odour emissions are:

- use of a band spreader, shallow injector or deep injector for landspreading of slurry;
- incorporation of manure as soon as possible.

Section 4.18.4: Odour emissions (monitoring)

This section refers to the monitoring of odour emissions.

The techniques that are mentioned here are dynamic olfactometry according to EN 13725:2003 and field inspections, which have been standardized on a European level after the publication of this BREF document by EN 16841:2016.

A brief description with applicability and limitations of these techniques can also be found in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Section 5.1: General BAT Conclusions

Section 5.1.1: Environmental Management Systems

BAT 1. In order to improve the overall environmental performance of farms, BAT is to implement and adhere to an environmental management system (EMS) that incorporates, among others, the implementation of an odour management plan.

Section 5.1.9: Odour Emissions

BAT 12. In order to prevent, or where that is not practicable, to reduce odour emissions from a farm, BAT is to set up, implement and regularly review an odour management plan, as part of the environmental management system, that includes the following elements:

- a protocol containing appropriate actions and timelines;
- ia protocol for conducting odour monitoring;
- a protocol for response to identified odour nuisance;
- an odour prevention and elimination programme designed to e.g. identify the source(s), to monitor odour emissions, to characterise the contributions of the sources and to implement elimination and/or reduction measures;
- a review of historical odour incidents and remedies and the dissemination of odour incident knowledge.

BAT 13. In order to prevent or, where that is not practicable, to reduce odour emissions and/or odour impact from a farm, BAT is to use a combination of the techniques given in Table 13.

	Technique	Applicability
a	Ensure adequate distances between the farm/plant a and the sensitive receptors.	May not be generally applicable to existing farms/plants.
b	Use a housing system which implements one or a combination of the following principles: - keeping the animals and the surfaces dry and clean (e.g. avoid feed spillages, avoid dung in lying areas of partly slatted floors); - reducing the emitting surface of manure (e.g. use metal or plastic slats, channels with a reduced exposed manure surface); - removing manure frequently to an external (covered) manure store; - reducing the temperature of the manure (e.g. by slurry cooling) and of the indoor environment; - decreasing the air flow and velocity over the manure surface; - keeping the litter dry and under aerobic conditions in litter-based systems.	Decreasing the temperature of the indoor environment, the air flow and the velocity may not be applicable due to animal welfare considerations. Slurry removal by flushing is not applicable to pig farms located close to sensitive receptors due to odour peaks. See applicability for animal housing in BAT 30, BAT 31, BAT 32, BAT 33 and BAT 34.
c	Optimise the discharge conditions of exhaust air from the animal house by using one or a combination of the following techniques: - increasing the outlet height (e.g. exhaust air above roof level, stacks, divert air exhaust through the ridge instead of through the low part of the walls); - increasing the vertical outlet ventilation velocity; - effective placement of external barriers to create turbulence in the outgoing air flow (e.g. vegetation); - adding deflector covers in exhaust apertures located in low parts of walls in order to divert exhaust air towards the ground; - dispersing the exhaust air at the housing side which faces away from the sensitive receptor; - aligning the ridge axis of a naturally ventilated building transversally to the prevailing wind direction.	Alignment of the ridge axis is not applicable to existing plants.
d	Use an air cleaning system, such as: 1. Bioscrubber (or biotrickling filter); 2. Biofilter; 3. Two-stage or three-stage air cleaning system.	This technique may not be generally applicable due to the high implementation cost. Applicable to existing plants only where a centralised ventilation system is used. A biofilter is only applicable to slurry-based plants. For a biofilter, a sufficient area outside the animal house is needed to accommodate the filter packages.
e	Use one or a combination of the following techniques for storage of manure:	

	1. Cover slurry or solid manure during storage;	See applicability of BAT 16.b for slurry. See applicability of BAT 14.b for solid manure.
	2. Locate the store taking into account the general wind direction and/or adopt measures to reduce wind speed around and above the store (e.g. trees, natural barriers);	Generally applicable.
	3. Minimise stirring of slurry.	Generally applicable.
f	Process manure with one of the following techniques in order to minimise odour emissions during (or prior to) landspreading:	
	1. Aerobic digestion (aeration) of slurry;	See applicability of BAT 19.d.
	2. Compost solid manure;	See applicability of BAT 19.f.
	3. Anaerobic digestion.	See applicability of BAT 19.b.
g	Use one or a combination of the following techniques for manure landspreading:	
	1. Band spreader, shallow injector or deep injector for slurry landspreading;	See applicability of BAT 21.b, BAT 21.c or BAT 21.d.
	2. Incorporate manure as soon as possible.	See applicability of BAT 22.

Table 13. Techniques to reduce odour emissions from a farm

Section 5.1.12: On farm processing of manure

BAT 19. If on-farm processing of manure is used, in order to reduce emissions of nitrogen, phosphorus, odour and microbial pathogens to air and water and facilitate manure storage and/or landspreading, BAT is to process the manure by applying one or a combination of the techniques given in Table 14.

	Technique	Applicability
a	Mechanical separation of slurry. This includes e.g.: • Screw press separator; • Decanter-centrifuge separator; • Coagulation- Flocculation; • Separation by sieves; • Filter pressing.	Only applicable when: • a reduction of nitrogen and phosphorus content is needed due to limited available land for manure application; • manure cannot be transported for landspreading at reasonable cost. The use of polyacrylamide as a flocculant may not be applicable due to the risk of acrylamide formation.
b	Anaerobic digestion of manure in a biogas installation.	This technique may not be generally applicable due to the high implementation cost.
c	Use of an external tunnel for manure drying.	Only applicable to manure from plants for laying hens. Not applicable to existing plants without manure belts.

d	Aerobic digestion (aeration) of slurry.	Only applicable when pathogen and odour reduction is important prior to landspreading. In cold climates, it may be difficult to maintain the required level of aeration during winter.
e	Nitrification-denitrification of slurry.	Not applicable to new plants/farms. Only applicable to existing plants/farms when the removal of nitrogen is necessary due to limited available land for manure application.
f	Composting of solid manure.	Only applicable when: ● manure cannot be transported for landspreading at a reasonable cost; ● pathogen and odour reduction is important prior to landspreading; ● there is enough space in the farm for windrows to be established.

Table 14. Techniques for on farm processing of manure

Section 5.1.14: Emissions from the whole production process

BAT 26. BAT is to periodically monitor odour emissions to air

Odour emissions can be monitored by using:

- EN standards (e.g. by using dynamic olfactometry according to EN 13725 in order to determine odour concentration).
- When applying alternative methods for which no EN standards are available (e.g. measurement/estimation of odour exposure, estimation of odour impact), ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality can be used.

BAT 26 is only applicable to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

BAT 28. BAT is to monitor ammonia, dust and/or odour emissions from each animal house equipped with an air cleaning system by using all of the following techniques with at least the frequency given in Table 15.

	Technique	Frequency	Applicability
a	Calculation by measuring the dust concentration and the ventilation rate using EN a standard methods or other methods (ISO, national or international) ensuring data of an equivalent scientific quality.	Once every year.	Only applicable to dust emissions from each animal house. Not applicable to plants with an air cleaning system installed. In this case, BAT 28 applies. Due to the cost of measurements, this technique may not be generally applicable.

b	Estimation by using emission factors.	Once every year.	Due to the cost of establishing emissions factors, this technique may not be generally applicable.

Table 15. Techniques to monitor emissions from animal houses

Section 5.2: BAT conclusions for the intensive rearing of pigs

Section 5.2.1: Ammonia emissions from pig houses

BAT 30. In order to reduce ammonia emissions to air from each pig house, BAT is to use one or a combination of the techniques given below:

	Technique	Animal Category	Applicability
a	One of the following techniques, which apply one or a combination of the following principles: i. reduce the ammonia emitting surface; ii. increase the frequency of slurry (manure) removal to external storage; iii. separate urine from faeces; iv. keep litter clean and dry.		
	0. A deep pit (in case of a fully or partly slatted floor) only if used in combination with an additional mitigation measure, e.g.: - a combination of nutritional management techniques; - air cleaning system; - pH reduction of the slurry; - slurry cooling.	All pigs	Not applicable to new plants, unless a deep pit is combined with an air cleaning system, slurry cooling and/or pH reduction of the slurry.
	1. A vacuum system for frequent slurry removal (in case of a fully or partly slatted floor).	All pigs	May not be generally applicable to existing plants due to technical and/or economic considerations.
	2. Slanted walls in the manure channel (in case of a fully or partly slatted floor).	All pigs	
	3. A scraper for frequent slurry removal (in case of a fully or partly slatted floor).	All pigs	
	4. Frequent slurry removal by flushing (in case of a fully or partly slatted floor).	All pigs	May not be generally applicable to existing plants due to technical and/or economic considerations. When the liquid fraction of the slurry is used for flushing, this technique may not be applicable to farms located close to

			sensitive receptors due to odour peaks during flushing.
	5. Reduced manure pit (in case of a partly slatted floor).	Mating and gestating sows	May not be generally applicable to existing plants due to technical and/or economic considerations.
		Fattening pigs	
	6. Full litter system (in case of a solid concrete floor).	Mating and gestating sows	Solid manure systems are not applicable to new plants unless it can be justified for animal welfare reasons. May not be applicable to naturally ventilated plants located in warm climates and to existing plants with forced ventilation for weaners and fattening pigs. BAT 30.a7 may require large space availability.
		Weaners	
		Fattening pigs	
	7. Kennel / hut housing (in case of a partly slatted floor).	Mating and gestating sows	
		Weaners	
		Fattening pigs	
	8. Straw flow system (in case of a solid concrete floor).	Weaners	
		Fattening pigs	
	9. Convex floor and separated manure and water channels (in case of partly slatted pens).	Weaners	May not be generally applicable to existing plants due to technical and/or economic considerations.
		Fattening pigs	
	10. Littered pens with combined manure generation (slurry and solid manure).	Farrowing sows	
	11. Feeding/lying boxes on solid floor (in case of litter-based pens).	Mating and gestating sows	Not applicable to existing plants without solid concrete floors.
	12. Manure pan (in case of a fully or partly slatted floor).	Farrowing sows	Generally applicable.
	13. Manure collection in water.	Weaners	May not be generally applicable to existing plants due to technical and/or economic considerations.
		Fattening pigs	
	14. V-shaped manure belts (in case of partly slatted floor).	Fattening pigs	
	15. A combination of water and manure channels (in case of a fully slatted floor).	Farrowing sows	
	16. Littered external alley (in case of a solid concrete floor).	Fattening pigs	Not applicable to cold climates. May not be generally applicable to existing plants due to technical and/or economic considerations.
b	Slurry cooling.	All pigs	Not applicable when: - heat reuse is not possible; - litter is used.
c	Use of an air cleaning system, such as: 1. Wet acid scrubber;	All pigs	May not be generally applicable due to the high implementation cost.

	2. Two-stage or three-stage air cleaning system; 3. Bioscrubber (or biotrickling filter).		Applicable to existing plants only where a centralised ventilation system is used.
d	Slurry acidification.	All pigs	Generally applicable.
e	Use of floating balls in the manure channel.	Fattening pigs	Not applicable to plants equipped with pits that have slanted walls and to plants that apply slurry removal by flushing.

Table 16. Techniques to reduce ammonia emissions to air from pig houses

Section 5.4: Description of techniques

Section 5.4.4: Techniques for reducing odour emissions

The techniques for reducing odour emissions include:

- Ensure adequate distances between the plant/farm and the sensitive receptors.
- Cover slurry or solid manure during storage.
- Minimise stirring of slurry.
- Aerobic digestion (aeration) of liquid manure/slurry.
- Compost solid manure.
- Anaerobic digestion.
- Band spreader, shallow injector or deep injector for slurry landspreading.
- Incorporate manure as soon as possible

1.5. Slaughterhouses and Animal By-products Industries

Introduction

The Slaughterhouses and Animal By-products Industries are one the most important source of odour emitting industries, due to the unpleasantness of their hedonic tone.

The "slaughter" activity is considered to end with the making of standard cuts and for poultry, with the production of a clean whole saleable carcass..

Animal by-products activities include the treatments for entire bodies or parts of animals and those for products of animal origin, including the treatments of animal by-products both intended for and not intended for human consumption.

The Best Available Techniques (BAT) Reference Document for the Slaughterhouses and Animal By-products Industries issued in 2005, whose review has recently begun, *explicitly mentions odours 469 times*, and more in detail:

- the General techniques applicable in slaughterhouses and animal by-products installations (Section 4.1)
- the techniques for different operations in Slaughterhouses (Section 4.2)
- the techniques for different operations in Animal by-products installations (Section 4.3)
- the techniques for different operations in Integrated same-site activities (Section 4.4)
- the Additional BAT for animal by-products installations (Section 5.3)

Odour is one of the Key environmental issues considered in this BREF for Slaughterhouses and Animal by-products installations (Rendering, Fish-meal and fish-oil production, Blood processing, Gelatine manufacture, Glue manufacture, Dedicated incineration of carcases, Land spreading/injection, Biogas production and Composting). Odour is typically caused by the decomposition of animal by-products and this has other related environmental consequences, e.g. it reduces the usability of the animal by-products and hence increases waste. Also, the substances causing odour can cause problems during wastewater treatment.

Section 4.1: General techniques applicable in slaughterhouses and animal by-products installations

This section includes techniques applied to wastewater treatment, air pollution and odour control for slaughterhouses and animal by-products installations and their activities from reception of raw materials to "end-of-pipe" solutions.

Short and possibly cold storage of animal by-products (Section 4.1.27)

By-products destined for use or disposal can be stored in closed vessels or rooms in slaughterhouses and animal by-products installations, for as short a time as possible, before further treatment. Depending on the nature of the by-products, such as their inherent odour characteristics and how rapidly they biodegrade and create an odour nuisance, it may be prudent to also refrigerate them, particularly during warm weather and in hot climates. A temperature not exceeding 5 °C, for solids and less than 10 °C, for blood has been reported as being necessary, to prevent odour problems. This applies at both the slaughterhouse and the animal by-products installation.

To optimise the prevention of odour problems, without creating cross-media effects at either, or both, the slaughterhouse and the animal by-products installation requires cooperation between the operators of both. If the handling and storage of by-products at the slaughterhouse is not managed in such a way as to minimise odour problems beyond the actual storage time before despatch, the animal by-products installations will almost certainly have problems, even if they treat the animal by-products immediately. The odour problems associated with animal by-products do not only arise from storage before treatment. Putrescent and putrid animal by-products also produce more malodorous gaseous and liquid emissions during processing than do fresh feedstock. They consequently cause additional odour problems at WWTPs.

Audit odour (Section 4.1.28)

The individual sources of odour and factors which influence the rate and type of malodorous emissions are identified. All of the unit operations and the associated plant and buildings can be assessed for odour generation potential. The reception, handling, storage and preparation and the processing of raw material can be examined. The handling, storage and despatch of processed material, including separation into various products and solid, liquid and gaseous wastes can all be looked at separately. The potential impact of malodorous emissions arising from the plant should be gauged from the nature, size and frequency of operation and the distance of neighbours from the plant. In reported cases any detection of odour at the boundary fence is not acceptable. The effectiveness and appropriateness of existing odour abatement equipment and containment of emissions can be assessed.

Having identified sources of malodorous emissions these can be further characterised. Any odour abatement equipment should be selected according to the requirement of the relevant process and by taking into account the materials it will actually handle.

After installation, operator training and commissioning have been completed, the performance of the technique, including its operation and maintenance should be monitored and any further actions required can be taken as appropriate. Finally, after calculation of emissions from point, volume and area sources modelled across simple and complex terrain, taking into account existing abatement techniques and meteorological and local climatological data, a dispersion modelling will show the odour impact on the surroundings.

Auditing odours should be implemented for the application for an IPPC permit, which environmental benefits are odour prevention and control.

Enclose animal by-products during transport, loading/unloading and storage (Section 4.1.29)

The transport of animals and animal by-products outside installations is outside the scope of the Directive and therefore outside the scope of this document. However, whilst they remain in vehicles, whether within or outside the installation, problems associated with either spillage or leakage of any solid or liquid material or with odour, can be reduced by suitable vehicle design, construction and operation. The reception, off-loading and storage of animals and animal by-products can also be undertaken within enclosed areas, in the case of animal by-products, operated under negative pressure, with extractive ventilation connected to a suitable odour abatement plant. If material is tipped from the delivery vehicle, the receiving hoppers can be covered and sealed after filling.

For loading/unloading, one technique that has been applied is the construction of a tunnel/covered area large enough to accommodate the biggest despatch/delivery vehicle likely to visit the site. Odours can be contained if the tunnel has doors at either end, which make a good seal with the walls and which can be opened and shut rapidly with the minimum of effort and inconvenience.

Achieved environmental benefits are the reduction of odour production.

Design and construction of vehicles, equipment and premises for easy cleaning (Section 4.1.30)

All vehicles, handling and storage equipment and premises can be smooth, impervious and designed so as not to harbour solids and liquids. They should be designed in such a way that eases, the movement and removal of materials, e.g. by ensuring that hoppers have sides which slope downwards, by avoiding angles where materials may stick or be difficult to dislodge and by ensuring that none of the equipment contains any “dead ends”. Floors can have a chemical resistant finish applied, to prevent damage being caused by the chemicals used for cleaning and disinfection.

The implementation of these design premises will lead to ease of operation, cleaning and reduce odour emissions.

Frequent cleaning of materials storage areas - odour prevention (Section 4.1.31)

Areas where by-products, raw materials and waste are stored can be cleaned frequently. The cleaning programme can cover all structures, equipment and internal surfaces, material storage containers, drainage, yards and roadways.

If raw material containers are emptied and washed frequently, e.g. daily, then decomposing and malodorous materials will not accumulate over long periods of time. Delays in the despatch of animal by-products from the slaughterhouse, together with the long distances travelled, without temperature control provide sufficient time for material to deteriorate and if storage, particularly badly controlled storage, continues on a site, even briefly, odour problems will be exacerbated. The adoption of thorough cleaning and good hygiene practices, as a routine reduces malodorous emissions.

Transport blood in insulated containers (Section 4.1.32)

Transporting blood in insulated containers can prevent the temperature from rising by more than 2 °C during the transport, and hence, the prevention of the formation of malodorous substances, by preventing rotting. By preventing rotting of the blood it is more likely to be of a good enough quality to be used and therefore will not need to be disposed of as waste. If it is already destined for disposal it may cause fewer odour problems during processing and during the subsequent waste water treatment.

Biofilters (Section 4.1.33)

Biofilters are cited as a system to reduce odour emissions from this type of plants. Biofilters are described more in detail in the CWW BREF (https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CWW_Bref_2016_published.pdf), as well as in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Odour control using activated carbon filters (Section 4.1.34)

Activated carbon has been used for odour abatement for many years. This type of adsorption system is also described in the CWW BREF (https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CWW_Bref_2016_published.pdf), as well as in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Dilution of odours by capture into one or more chimneys (Section 4.1.35)

The malodorous air is collected from various sources into one or more high chimney stacks for emission, at a suitable height to ensure sufficient dilution and dispersion of the odour, taking into account the local prevailing climate conditions. Reduction of perception of odour problems in the vicinity of the slaughterhouse or animal by-products installation is obtained. No additional by-products are produced.

When this BREF was published, this was the most common method employed at slaughterhouses. Pre-treatment is normally required for the types of odours produced at rendering plants.

Wastewater treatment (Section 4.1.43)

The wastewater produced at the slaughterhouses and animal by-products installations can be a source of malodorous substances. In this section several good practices and techniques are presented in order to avoid them.

Prevention of stagnant waste water (Section 4.1.43.3)

The pipes associated with the drainage and the WWTP can be laid to have sufficient gradient to avoid the stagnation of waste water. This may be done for hygiene reasons, as e.g. stagnant slaughterhouse wastewater will attract flies and rats. Odour problems can also be caused by anaerobic conditions in stagnant water in drainage systems.

Fat removal from waste water, using a fat trap (Section 4.1.43.9)

The correct sizing of chambers is critical to ensure proper separation and to avoid the danger of washout during high or abnormal flows. Ease of emptying and regular maintenance is essential to prevent odour problems.

Minimise liquid seepage and cover wastewater treatment tanks (Section 4.1.43.12)

The base and sides of wastewater treatment tanks can be sealed to prevent leakage into the soil and groundwater and the tops may be covered and ventilated to minimise odour problems. Drainage systems can be provided underneath tanks, to collect any seepage that does occur in the event of an accident.

Minimise liquid seepage and aerate wastewater treatment tanks (Section 4.1.43.13)

The base and sides of wastewater treatment tanks can be sealed to prevent leakage into the soil and groundwater and the contents of the tank may be aerated to prevent the development of anaerobic conditions and a consequent production of malodorous gases.

Section 4.2. Slaughterhouses

This section includes some techniques to prevent and reduce odour emission from different types of slaughterhouse activities.

Section 4.2.1 Slaughterhouses - general techniques applicable at installation level

Continuous, dry and segregated collection of by-products along the length of the slaughter-line (Section 4.2.1.6)

The segregation of liquids and solids destined for use or destruction has several advantages. If sufficient separate collection systems are provided, it reduces cross contamination between different by-products. Segregation of the by-products can, therefore, reduce potential odour problems from materials which even when fresh emit the most offensive odours, i.e. by storing/removing them separately under controlled conditions, instead of having to control a greater volume of mixed by-products.

Refrigeration/cooling of blood (Section 4.2.1.8)

Blood which cannot be processed within a very short time can be cooled to a temperature below 10 °C, at the slaughterhouse immediately after collection (and also at the installation where the blood will be received). This can reduce odour problems and waste water pollution at the blood processing plant.

This way, it can prevent the emission of offensive odours from the liquid blood, caused by the degradation of the blood at both the slaughterhouse and the installation where the blood is used or disposed of. If the blood is rendered fresh, there will also be a lower level of emission of offensive odours and waste water contamination arising from the process.

Section 4.2.2 Slaughter of large animals

Cessation of feeding of animals 12 hours prior to slaughter (Section 4.2.2.1.1)

Stopping feeding the animals 12 hours prior to slaughter reduces the quantity of undigested contents in their stomachs. So, the risk of odour arising from the manure, paunch and soiled bedding could be reduced.

Insulation and covering of pig scalding tanks (Section 4.2.2.3.2)

The scalding tank can be insulated to reduce the heat loss through the sides and covered to reduce evaporation and heat loss from the water surface. The surface may be covered with plastic balls. The reduced evaporation will also result in less odour.

Heat recovery from pig singeing exhaust gases, to preheat water (Section 4.2.2.5.2)

In pig slaughterhouses, the heat of the exhaust of the singeing unit can be recovered to heat water, e.g. to maintain the scalding tank temperature. Reduced energy use to heat water for, e.g. scalding or cleaning and reduced odour, by stopping the direct emission of hot singeing gases.

Trimming of all hide/skin material not destined for tanning immediately after removal from the animal (Section 4.2.2.9.10)

Trimming consists of cutting away from the edges of hides and skins, all unwanted material such as legs, tails, face, udders, testicles, etc. to give the raw material a better shape.

This operation is performed manually, using the appropriate knives, ideally carrying it out as early as possible in the production process of hides and skins. The operation is usually done in the slaughterhouse, although it is sometimes carried out in tanneries.

Odour problems are reduced due to the removal of putrescible trimmings.

Section 4.2.3 Slaughter of poultry

Dust abatement at bird reception, unloading and hanging stations – wet scrubber (Section 4.2.3.1.3)

During the unloading and hanging of birds up to and during slaughter and bleeding, high airborne dust levels are generated from the feathers. This is caused by movement of the birds, especially by their flapping wings. The dust levels can be abated by the use of exhaust ventilation and the dust can be collected in a wet scrubber. The exhausted airstream is passed through a water spray to ensure intimate contact with the scrubbing water, causing the dust particles to be trapped in the droplets. For increased efficiency, the gases can be passed through a venturi collar in which water is atomised, either with-the-flow or as a counter-flow. The increased efficiency is achieved due to the high speeds in the venturi collar and the intensive contact between the gas stream and the water mist. Alternatively a mist may be created by internal static vanes. With this equipment, dust and odour emissions to air can be reduced.

Dust abatement at bird reception, unloading and hanging stations – washable metal mesh (Section 4.2.3.1.4)

As in the previous sections, during the unloading and hanging of birds up to and during slaughter and bleeding, high airborne dust levels are generated from the feathers. The dust levels can be abated by the use of exhaust ventilation. The air may be collected using either local exhaust ventilation or by general ventilation, although the former is more effective. The dust can be collected using a washable metal mesh inserted in extract ventilation ducts., in order to achieve the reduction of dust and odour emissions to air.

Section 4.2.4 Slaughterhouse cleaning

Use of detergents using enzymes (Section 4.2.4.1)

Biochemical cleaning agents containing naturally occurring enzymes can be used for cleaning equipment, floors and walls and for disinfection.

A major poultry processor tested a biochemical cleaning product in an area soiled with faeces, blood, urine, grease, fat and feathers, which was difficult to clean with NaOH. The biochemical cleaning product tested removed all traces of organic matter more efficiently. There was a reduction in odour and less damage to equipment.

Section 4.2.5 Storage and handling of slaughterhouse by-products

Segregated storage and handling of different kinds of by-products (Section 4.2.5.1)

By-products can be collected, handled and stored separately or in categories, depending on their further use or disposal route and on the potential environmental consequences of mixing them. If, e.g. they are the same material but at different stages of degradation and one causes an odour problem, then mixing them would lead to an increased volume of malodorous material and make the whole volume less usable.

The segregation of liquids and solids destined for use or destruction offers several advantages. If sufficient separate storage systems are provided, it reduces cross contamination between different by-products. The segregation of by-products can reduce potential odour problems from those materials which even when fresh emit the most offensive odours.

Achieved environmental benefits are the reduction of odour emissions associated with the storage of malodorous by-products, both at the slaughterhouse and at animal by-products installations.

Section 4.3 Animal by-products installations

This section includes some techniques to prevent and reduce odour emission from different types of animal by-products activities.

Animal by-products installations - general techniques applicable at installation level (Section 4.3.1)

Maintenance of negative pressure in storage, handling and processing areas (Section 4.3.1.2)

Material can be stored in hoppers or on open floors in buildings which are well sealed and kept under a slight negative pressure, whilst ensuring that the air is changed sufficiently frequently for the health and welfare of personnel. Storage times can also be kept to a minimum.

All buildings can be designed and constructed so that they are well sealed to separate different processing areas, such as the raw material reception, storage, cooling and end-product storage areas. The ventilation provided can be capable of maintaining negative pressure and preventing an uncontrolled escape of malodorous air to outdoors. The areas from which ventilation is provided can be connected to suitable odour abatement systems.

Sealed storage, handling and charging of animal by-products (Section 4.3.1.3)

The storage, handling and possibly size reduction equipment, can be sealed or maintained under negative pressure and the air extracted can either be used to provide oxygen in a combustion process, such as incineration, see Section 4.3.8.15, or can be directed to an odour abatement system.

This technique is applicable in all animal by-products installations where the materials can be stored, handled and treated in enclosed equipment and where odour and vermin problems may arise.

Use of fresh refrigerated raw materials (Section 4.3.1.4)

If raw materials are handled as fresh as possible, the quantity of compounds that end up in the wastewater or the air can be reduced. For example, by cooling warm waste, such as soft waste from the slaughter-line and casing-cleaning department, the formation of air and water pollution can be reduced. If it is not possible for the processing to take place within the time it takes for odour problems to develop after slaughter or intermediate treatment, materials may be refrigerated.

Cooling can take place, if necessary, at the slaughterhouse, in transit or at the animal by-products installation. The refrigeration period may be kept to a minimum, sufficient to simply prevent odour/quality problems without delaying treatment of the animal by-products. Good co-operation between the operators of the slaughterhouse, the haulier and the animal by-products installation minimises the need for refrigeration and the time required, if refrigeration is needed at all. Furthemore, it reduces odour emissions from storage and processing.

Rendering (Section 4.3.3)

Totally enclosed rendering line (Section 4.3.3.1)

The transfer of materials throughout the entire processing line, including the conveyance of process gases and liquid effluents, can be undertaken within totally enclosed and sealed handling systems designed, constructed and maintained to prevent possible leakages.

The achievement of enclosed lines can be the reduced liquid and solid leakage and reduced emissions to air.

Continuous rendering of, e.g. fresh raw feathers and hair (Section 4.3.3.3)

The processing of feathers and hair in as fresh a state as possible can minimise emissions to air and waste water. Hydrolysis in a continuous installation using direct steam, followed by mechanical dewatering in a decanter and evaporation of the liquid phase from the decanter in a multiple-effect evaporator can save significant heat energy and reduce odour emissions from storage, processing and waste water treatment.

Bioscrubber – general (Section 4.3.3.8) and Wet scrubbing – general (Section 4.3.3.9)

Biological scrubbers and wet scrubbers can be used to reduce odour emissions from rendering operations. These systems are described in the CWW BREF (https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CWW_Bref_2016_published.pdf), as well as in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

Thermal oxidiser for combustion of vapour, non-condensable gases and room air (Sectión 4.3.3.10)

The direct combustion of malodorous gases can be undertaken for a few seconds at 850 °C. The running cost is high in terms of energy consumption, so expensive heat-exchange systems need to be used to minimise this. The reduction of emissions of low volume/high intensity and high volume/low intensity odours can lead to almost 100 % efficiency and the elimination of whole vapour, to remove the need to be treated in the WWTP.

Burning malodorous gases, including non-condensable gases, in an existing boiler (Section 4.3.3.11)

Malodorous gases, including non-condensable gases produced during rendering may be burned in an existing boiler in the installation. Steam collected from cookers, dryers and evaporators is first passed through a cyclone, to separate out the solid material and then passes through a heat-exchanger, in which the steam is cooled, dewatering the moist air. The water is discharged to a WWTP and the air containing the malodorous substances, including air from the premises, is finally burned in the boiler.

Reportedly highly efficient and if properly operated, as efficient at eliminating odours, including intense odours, as other burning methods.

However, keeping the boiler running incurs an additional fuel use, in order to keep it running during rendering, even when there is no demand for steam. Besides, if the installation does not have a boiler capable of running continuously to burn the malodorous gases in places where there is a demand for abatement, an alternative treatment system may be required. The flowrate needs to be controlled to ensure complete combustion of the malodorous gases. Therefore, this technique is applicable to low volume high concentration odours.

Chlorine dioxide scrubber generated from sodium chlorite – odour abatement (Section 4.3.3.12)

An alternative or complementary technique to burning malodorous rendering gases is to pass the outlet air and water through a recirculating scrubber system. In this case, the scrubber water can be treated with a chemical oxidant to remove offensive contaminants, such as H2S, mercaptans and ammonia-based compounds, such as amines. Chlorine dioxide is effective as a chemical oxidant for controlling decomposition products generated from rendering operations, i.e. products formed by the action of putrefactive bacteria on nitrogenous matter. This technique is reported to be less efficient than burning the malodorous gases.

Chlorine dioxide scrubber generated from sodium chlorate – odour abatement (Section 4.3.3.13)

A sodium chlorate based chlorine dioxide technology can be used as an alternative or complementary technique to burning malodorous rendering gases, through a recirculating scrubber system similar to the previous section. The sodium chlorate system is claimed to have advantages over the sodium chlorite system because of its chlorine-free nature. The chlorite process reportedly adds chlorine to the system, as an unreacted agent. This technique is reported to be less efficient than burning the malodorous gases.

Fish-meal and fish-oil production (Section 4.3.4)

Use of fresh low total volatile nitrogen (TVN) feedstock (Section 4.3.4.1)

Fish can deteriorate under the anaerobic conditions present during storage on the fishing vessel and in the raw material silos in the factory. The deterioration causes the formation of a large number of strong-smelling compounds. Besides NH3, TMA and other volatile basic compounds, various volatile sulphur compounds, such as mercaptans and the highly toxic and strong-smelling H_2S gas, are formed.

The use of fresh feedstock results in reduced nitrogen and sulphide content and consequently reduced odour emissions during storage, processing and waste water treatment.

Incineration of malodorous air, with heat recovery (Section 4.3.4.3)

The air from the press cake, grax and evaporated stickwater drier and other sources such as air from offloading is passed through a scrubber before it is incinerated and the liquid effluent from the scrubber is treated in a WWTP. The odour abatement can be up to 99.5 %.

Dedicated incineration of carcases, parts of carcases and animal meal (Section 4.3.8)

Enclosing buildings for the delivery, storage, handling and processing of animal by-products (Section 4.3.8.1)

Unloading, storage and handling can be undertaken in totally enclosed equipment and in buildings with lockable, self-closing doors, which can be insect rodent and bird proof. The building can incorporate extraction fans through filters to prevent any dust generated from escaping and to minimise local odour problems. Material can be delivered in bulk tipper lorries and transferred directly to an unloading hopper, within an enclosed area. Extracted air can be also burned in the incinerator to reduce odour emissions.

Cleaning and disinfection of delivery vehicles and equipment after each delivery (Section 4.3.8.2)

After being emptied, and at the end of each working day, delivery vehicles and transport skips can be wet-cleaned and disinfected with calculated optimal amounts of sodium hydroxide or sodium hypochlorite. Wash-water can be collected and inactivated on the site, e.g. by being fed into the incinerator, in order to achieve odour reduction and pest infestation.

Carrying carcases (not dragging) (Section 4.3.8.3)

Carcases can be carried, preferably enclosed to prevent floor contamination. Individual small carcases may be transported in wheeled bins with hinged lids. Like this, it is reduced potential for odour from the material which would be spread throughout the installation by the dragging action.

Handling and burning of animal meal as pellets (Section 4.3.8.8)

Animal meal can be received, handled, stored and burned in pellet form. So, this way, the dust and odour emissions at the pre-combustion stages are reduced.

Handling and burning of packaged MBM (Section 4.3.8.9)

Animal meal can be received, handled, stored and burned packaged, e.g. within sealed sacks. For instance, meal may be supplied in, e.g. bags, with the intention that it is burned in those bags, e.g. for occupational health reasons to minimise exposure to material infected or suspected to be infected with TSE or to minimise exposure to airborne dust and odour emissions.

Auger feed of parts of carcases or animal meal (Section 4.3.8.11)

A closed mechanical feed system which avoids the opening of the furnace during charging will prevent emissions from the furnace, the ingress of excess air and cooling. Material can be passed through a pre-breaker or shredder and then fed into the furnace using an auger. Like that, the odour emissions from the furnace are reduced, including the ingress of air, thereby potentially reducing NOx production.

Pumping of parts of carcases or animal meal (Section 4.3.8.12)

A closed mechanical feed system which avoids the opening of the furnace during charging will prevent emissions from the furnace, the ingress of excess air and cooling. Material can be passed through a pre-breaker or shredder and then, if it is sufficiently moist, pumped into the furnace, reducing the odour emissions from the furnace and reducing ingress of air, thereby potentially reducing NOx production.

Sealed storage, handling and charging of animal by-products to incinerators (Section 4.3.8.14)

Hoppers can provide a storage method, which is relatively easy to control and which may be combined with automated, fully enclosed, transfer and handling equipment. Material can be delivered in, e.g. bulk tipper lorries and transferred directly to an unloading hopper, either mechanically via conveyors/augers or pneumatically. Plants burning animal meal are able to use fully enclosed feed systems to minimise biological risk and fugitive emissions.

A cover for the initial hopper into which the animal by-products are tipped when they are received from the slaughterhouse and sealing the process also reduces the risk of malodorous emissions from animal by-products. If the animal by-products are received fresh and are not inherently malodorous, e.g. if the incinerator is on the same site as the slaughterhouse, then typically the material will comprise fresh condemned carcasses and bones. If this material is fed into the storage vessel immediately, the cover may not serve an odour reduction purpose but it will still reduce problems arising from birds and vermin.

The enclosure of raw materials can also reduce odour problems

Ducting of air from the installation and the pre-combustion equipment to the combustion chamber (Section 4.3.8.15)

Storage, handling and possibly size reduction equipment, can be sealed or maintained under negative pressure and the air extracted can then be used to provide oxygen for the incineration process. Air can also be ducted to the incinerator from the building in which the storage handling and grinding equipment are situated. An odour assessment can help to identify the areas which are most likely to lead to odour emissions and these can be selected as the highest priority for capture of air, for incineration.

Enclosure of the process combined with continuous extraction of the air in the storage and handling equipment reduces the risk of malodorous emissions from animal by-products.

When the incinerator is shut down, especially if this is unplanned, it may be necessary to extract malodorous air from the installation and equipment to alternative treatment systems. For planned shutdowns the receipt of feedstock may be temporarily stopped, e.g. to prevent odour emissions.

<u>Continuous incineration (Section 4.3.8.20)</u>

Continuous incineration involves the continuous operation of an incinerator without the repeated heating and cooling associated with batch processes. Continuous incineration may provide a faster disposal route for animal by-products and may reduce odour problems associated with the storage and handling of putrescent materials, before malodorous substances are formed.

<u>Regular cleaning and disinfection of installations and equipment (Section 4.3.8.26)</u>

A regular, e.g. weekly, thorough cleaning of installations and equipment where animal by-products are handled will reduce the risk of diseases being spread by insects, rodents and birds and will help control the formation of malodorous substances.

<u>Operation of odour arrestment techniques when the incinerator is not working (Section 4.3.8.27)</u>

Technical or operational odour controls can be provided to prevent odour emissions at times when the incinerator is not working and is consequently unavailable for odour destruction using malodorous air as furnace air.

Alternative odour abatement plants, such as biofilters, chemical scrubbers or carbon filters may be provided.

<u>Biofilter for odour abatement when the incinerator is not operating (Section 4.3.8.28)</u>

Odours may be produced when the incinerator is not operating and available for odour abatement. The use of a biofilter may be effective for controlling low intensity odours from inherently malodorous and/or putrescent materials.

<u>Carbon filter for odour abatement when the incinerator is not operating (Section 4.3.8.29)</u>

Carbon filters can be used for odour abatement, especially when the total quantity of organic compounds is small. However, they can lead to a significant solid waste, which has to be disposed of. If it cannot be recovered it may be burned in the incinerator. This destroys the malodorous compounds and recovers the energy content of the carbon. Achieved environmental benefits are odour abatement.

Biogas production (Section 4.3.10)

<u>Biogas from manure and fat containing waste (Section 4.3.10.2)</u>

Organic matter is degraded to CH4 under anaerobic conditions. The releases to air, water, and land from the process can be well controlled, whose benefits are the production of CO_2

-neutral energy, the production of fertiliser from the digested manure, the reduction of odour emissions from animal manure and the reduction of nitrogen leakage to the subsoil water.

Section 4.4 Integrated same-site activities

This section includes some techniques to prevent and reduce odour emission from installations that have some of the previous activities integrated at the same site.

Integrated site - slaughterhouse and rendering plant (Section 4.4.1)

A rendering plant may be operated on a slaughterhouse site. The by-products of the slaughter process and on-site wastewater treatment may be treated on a continuous basis, thereby minimising the need for collection and transport, for use or disposal off-site, and the need for storage.

As putrescible materials can be used quickly, there is minimal raw material degradation. The wastewater treatment plant is not required to treat the products of decomposition and the odour problems associated with such treatment are thus avoided. The need for either a frequent collection service, or other means of preventing odour problems such as chilling is also avoided.

Integrated site - slaughterhouse and animal carcase incinerator (Section 4.4.2)

The information here concerns the integration of slaughtering with incineration. The recovery of energy for internal use, e.g. for the production of steam or hot water for use in the slaughterhouse or for other associated activities on the site, such as blood processing and meat processing is obtained as a result. Reduced time between slaughter and incineration, therefore, the by-products are fresher and odour problems are potentially reduced.

Integrated site – rendering plant and animal meal incinerator (Section 4.4.3)

The information here concerns the integration of rendering with incineration. The rendering plant provides the feedstock for the incinerator. The incinerator is capable of burning malodorous gases from the rendering process, and the steam and electricity produced by the incinerator can be used for the rendering process.

Integrating the rendering plant with the incinerator provides a convenient and reportedly effective means of destroying malodorous gases. These arise in rooms, storage vessels and from pretreatment and handling equipment and they include non-condensable gases which have the most intense and offensive odours, which are produced during rendering. These malodorous gases would otherwise require an alternative means of destruction. To ensure that all of the malodorous non-condensable gases are destroyed, the incinerator needs to be running all of the time when they are being produced. Many incinerators operate continuously.

Section 5.3: Additional BAT for animal by-products installations

In previous sections they have described several BATs for the sector. In this section, from the chapter 5 Best Available Techniques, there are some additional BATs not included before.

Where it is not possible to treat animal by-products before their decomposition starts to cause odour problems and/or quality problems, refrigerate them as quickly as possible and for as short a time as possible.

- Additional BAT for rendering:
  When it has been impossible to use fresh raw materials and thereby to minimise the production of malodorous substances, BAT is to do either of the following:
  - burn the non-condensable gases in an existing boiler and to pass the low intensity/high volume odours through a biofilter or
  - to burn the whole vapour gases in a thermal oxidiser and to pass the low intensity/high volume odours through a biofilter.
- Additional BAT for the incineration of animal by-products:
  - operate odour arrestment techniques, when the incinerator is not working, when odour prevention is not reasonably practicable and
  - use a carbon filter for odour abatement, when incinerators are not operating and where odour prevention is not reasonably practicable.

1.6. General conclusions

Looking at the BAT reference documents for the analysed sectors it is of course very difficult to draw general conclusions about the best practices for odour emission management and control. This is due to the fact that the considered industrial sectors are very different from each other, and each of them entails specific processes and operations from which odour emissions can be generated in various ways.

As a general rule, compliance with the BAT is a first requirement for any new or existing installation.

However, based on the analysed documents, it is possible to draw some very general key elements for an optimized management of odour pollution issues.

- Implementation of an odour management plan (OMP):
  An OMP is part of the environmental management system (EMS) of the installation and includes elements to prevent or reduce odorous nuisances, such as:
  - A protocol for odour monitoring. It may be complemented by measurement/ estimation of odour exposure (e.g. according to EN 16841-1 or -2) or estimation of odour impact.
  - A protocol for response to identified odour incidents (including the management of complaints: identification of operations carried out, weather conditions such as temperature, wind direction, rainfall, communication with the authority and with complainant, etc.)
  - An odour prevention and reduction programme designed to identify the source(s), to measure/estimate odour exposure, to characterise the contributions of the sources, and to implement prevention and/or reduction measures.

- Reduction of fugitive/ diffuse emissions:
  The reduction of fugitive emissions can generically be obtained by using covers, or through conveying. Some of these methods are also described in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).
  Also controlling the process temperature may be a viable method to reduce the volatility of odorous compounds and thus prevent emissions.

- Treatment of conveyed emissions:
  End-of-pipe techniques can be applied to treat conveyed emissions and reduce the concentration of pollutants released into the atmosphere. The most appropriate abatement method shall be chosen considering different factors, such as the type and

concentration of pollutants to be treated, the flowrate, as well as its temperature and humidity content.

An overview of the existing techniques, as well as the basic criteria determining their applicability can be found in the Best Available Techniques (BAT) Reference Document for Common Waste water and Waste Gas Treatment/Management Systems in the Chemical Sector, 2016, as well as in Deliverable D2.1 of this project: Capelli L., Diaz C., Izquierdo C., Arias R., Salas Seoane N. (2019) Review on odour pollution, odour measurement, abatement techniques, D-NOSES, H2020-SwafS-23-2017-789315 (https://dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.1.pdf).

The implementation of some of these techniques is sometimes forced when citizens start complaining about odours.

Odour emissions are a very critical issue for many different types of activities, not only those considered as examples within the first part of this document, and solutions are not always simple.

For this reason, the continuous research and development of new techniques and the promotion of a constructive dialogue between industry and society is extremely important for an optimized and successful management of odour pollution problems.

2.
COLLECTION OF GOOD PRACTICES IN ODOUR POLLUTION

This chapter describes the steps of the project related to the collection of good practices in odour pollution, which involved first the co-creation of a suitable questionnaire to tell a successful story related to the management and the resolution of odour issues, and then the distribution of the questionnaires and the collection of examples of good practices from the consortium partners.

2.1. Co-creation of a questionnaire for the collection of good practices

Foreword

In order to facilitate the collection of good practices in odour pollution from the consortium partners and/ or from other third parties, we decided to implement a questionnaire, with the aim of guiding the way for telling a successful story of odour pollution management and somehow homogenize the structure of the collected good practices.

This was done through a co-creation activity whereby we first defined what is meant by the term “good practice” in odour pollution and then we asked the consortium partners to compile hypothetical examples of good practices through which we were able to extract the relevant questions for the compilation of the questionnaire.

This activity was carried out during the Consortium Meeting in Porto, which took place in May 2019.

Definition of "good practice" in odour pollution

The first step of the co-creation activity for the compilation of the questionnaires involved the definition of "good practice" in odour pollution.

Among the consortium partners, we agreed that a good practice in odour pollution could be seen as a successful story in which an existing odour problem from one plant has been solved, thus reducing the number of complaints and improving the quality of life of the plants neighbours.

It was also agreed that a successful case of odour pollution management is a case in which the industry does not have to reduce its activity and no workplaces are lost. This is one major assumption when defining good practices in odour pollution and describing a successful case in which we consider the problem to have been solved.

Co-creation exercise "Good practices in odour pollution" during Porto meeting (15th May 2019)

During the Consortium meeting in Porto, an exercise has been set up in order to gather information from the project partners about what they would expect to read in a successful story of odour pollution management.

The partners were divided in 3 tables, and each table started a discussion by creating a successful story of odour pollution management in order to provide a list of questions that they imagined they would like to have answered for telling a successful story.

To help the co-creation exercise, one plant type was assigned to each table: one wastewater treatment plant, one paper mill, and one composting plant.

The results of the exercise are summarized in the following.

WWTP:

<u>Question</u>: How was the problem raised? How was the problem reported? How did people become aware of the problem?

Example of possible answers:

- FB (social media)
- citizens group/ community spaces (e.g., neighbour association, etc.)
- official channels (e.g., "form" from the municipality or hotlines)
- media
- environmental agency
- experts (or projects)

Question: What happened after the problem was reported? How was the problem understood?

Example of possible answers:

- public meetings/ rountables
- organized groups of citizens (data collection)
- odour study commissioned by the plant

Question: Who analyzed the collected data? How was the data analyzed?

Example of possible answers:

- contact with experts

Question: Who can access the collected data? How can data be accessed?

Example of possible answers:

- online page with public results
- periodic meetings
- community boards
- responsible informed person

Question: How was the problem solved? How long did it take? Did it really work? Who paid?

Question: What happened after that? Is the public properly informed about the end of the process?

COMPOSTING PLANT:

Context of the problem:

Question: How does the story relate to me? Which are the characteristics of the story that allow me to find similarities with other situations?

Question: Which are the characteristics of the plant: size, location, years functioning?

Question: How were citizens impacted? How were industries affected?

Problem description:

Question: What was the problem?

Solution/ change:

Question: How much did it cost?

Question: How long did it take?

Question: What was the drive for the change?

Example of possible answers:

- complaints
- (change in) regulations
- control

Question: If there were complaints, how important were these?

Question: How is the solution been maintained?

Question: Were different stakeholders involved in the solution?

Lessons learned:

Question: What is the advice for other similar industries?

Question: If you had known then what you know now, what would you have done different?

PAPER MILL:

Question: What would be the success?

Question: What was the solution? Which technology was applied?

Question: How was the industry convinced?

Question: How much did it cost?

Question: Who paid?

Question: Who/ what drove the process?

Example of possible answers:

- social pressure
- authority
- juridical system
- good will

Question: What was the preparation/ background that enabled a convincing story for the mill to positively react?

Question: How long did it take?

Question: Who was involved in each step?

Question: How was the problem monitored to decide which solution to be applied?

Outcomes of the co-creation exercise

As a result, we can summarize the outcomes of each working group (table) in one scheme of questionnaire that can be used as an example to tell a successful story in odour pollution management.

To do that, the "story" shall be divided into different phases, each including its specific questions.

The different "phases" into which the story shall be divided are:

1) PROBLEM DESCRIPTION
2) REPORTING PHASE
3) MONITORING PHASE

4) EVALUATION PHASE
5) RESOLUTION PHASE
6) VERIFICATION PHASE
7) COMMUNICATION PHASE

Schemes of questionnaires for telling a successful story in odour pollution management

Based on the previously described co-creation exercise we created a complete version of a questionnaire to be used as a guideline to collect information about successful cases in which odour emission problems have been solved.

After encountering the first difficulties related to the length of the questionnaire, we modified and created a simplified version (i.e. a short version) leaving only the main questions.

Both schemes are reported in the following.

SCHEME OF QUESTIONNAIRE (FULL VERSION)

1) **ABSTRACT** (Brief introduction to the problem - summary)

2) **PROBLEM DESCRIPTION:**
- Which type of plant(s) was (were) involved?
- What is the plant(s) size, location, technical characteristics?
- Which kind of regulations regarding odours apply were the plant(s) are located?
- What was the size of the problem? What was the number of citizens affected?
- For how long have the citizens been affected?
- If there were complaints, how important were these?
- How were citizens impacted?
- How were industries affected?

3) **REPORTING PHASE:**
- How was the problem raised?
- How did people become aware of the problem?
- How was the problem reported?
- How were complaints reported?

4) **MONITORING PHASE:**
- Was the problem monitored? If yes, how?
- How was the problem monitored to decide which solution to be applied?
- Was an odour impact study carried out?
- Who carried out the study?
- Which techniques/ methods were applied?
- How much did it cost?
- Who paid for it?
- What was the result of the monitoring phase?

5) **EVALUATION PHASE:**
- Who analyzed the collected data? How was the data analyzed?
- Who could access the collected data? How could the collected data be accessed?
- What was the outcome of the data analysis?
- Was the data gathered used to design a possible solution for the problem? If yes, how?

6) **RESOLUTION PHASE:**
- Who/ what drove the resolution process?
- What was the strategy for resolution applied? How was the problem solved?
- Which technology was applied?

- Who were the stakeholders involved?
- How were the different stakeholders engaged in the solution of the problem?
- How were the industries convinced?
- How much did it cost?
- Who paid for it?
- How long did it take?

7) **VERIFICATION PHASE:**
- What would be the success?
- Did the solution work? Was the impact reduced?
- Were the citizens less affected? Was the number/ frequency of the complaints reduced?
- How was the effectiveness of the applied solution monitored?

8) **COMMUNICATION PHASE:**
- What happened after that?
- Was the public properly informed about the end of the process?
- What is the advice for other similar industries?
- Which is the “lesson learned”?

9) **ADDITIONAL INFORMATION:**
- Pictures/ videos
- Other actions undertaken
- Other related benefits
- ...

SIMPLIFIED SCHEME OF QUESTIONNAIRE (SHORT VERSION)

1) **ABSTRACT** (Brief introduction to the problem - summary)

2) **PROBLEM DESCRIPTION:**
- What is the plant(s) type, size, location, technical characteristics?
- What was the problem? How many citizens were affected and for how long?

3) **REPORTING PHASE:**
- How was the problem raised? How were complaints reported?

4) **MONITORING PHASE:**
- Was the problem monitored? If yes, how? Which techniques/ methods were applied?
- What was the result of the monitoring phase?

5) **EVALUATION PHASE:**
- How was the data analyzed? How could the collected data be accessed?
- What was the outcome of the data analysis?

6) **RESOLUTION PHASE:**
- How was the problem solved? Which technology was applied?
- Who/ How were the different stakeholders involved in the solution of the problem?
- How much did it cost? Who paid for it? How long did it take?

7) **VERIFICATION PHASE:**
- Did the solution work? Was the impact reduced?
- How was the effectiveness of the applied solution monitored?

8) **COMMUNICATION PHASE:**
- What happened after that?
- Was the public properly informed about the end of the process?

9) **ANY ADDITIONAL INFORMATION**

2.2. Difficulties encountered in the collection of good practices outside the consortium

Collection of Best Practices from the Industry

The collection of best practices on odour management was more challenging than originally conceived. In the planning phase, it was assumed that we could get a decent response from the waste industry using ISWA channels, which include a monthly general newsletter, a dedicated membership newsletter, and of course direct contact with our working groups and members. The newsletters have been used before to collect survey data, and usually receive anywhere between 5% and 10% response. Given the difficulty of the subject we assumed that the response would be lower than normal – but with a newsletter subscriber list of over 3000, even a 1% response should translate to some 30 cases being reported.

The First Attempt

A survey was co-created with the partners and designed to address the relevant questions that were required to analyse and categorise the reported cases and distil into more generalized best practices. Cognisant of the sensitivity of the issue, both the questionnaire and the accompanying introduction were written to ensure the understanding that the cases sought after were ones which resulted in a positive or constructive conclusion. This then could not include conflict cases that required draconian court interventions like fines or closures. By framing successful cases as ones in which the resolutions were positive also for the odour emitter it was assumed this would attract a number of respondents that could be interested in sharing their stories as part of their own PR and relationship management with the public.

A newsletter was sent out with the request to participate in the survey, including an introduction into the project and its value to the industry as a way of avoiding onerous and one-size-fits all regulation. One month later, we still had no response.

The Second Attempt

Once it was clear that no response was coming, an analysis was made of the probable reasons why not. Since it had never happened before that there was no response to a survey sent to our members, it was assumed that it was the survey that could be at fault. After all, the survey was quite long and detailed and this was perhaps too high a barrier to participation. The questionnaire was then redesigned to be more practical, shorter, and simpler for respondents to fill in. It was also surmised that despite our positive spin on the matter, the industry was still reticent to bring any more attention to past problems. So, to further encourage participation, protect the interests of the respondents and guard against their sensitivities, it was also decided to give them the option for full anonymity in the collection and use of their data.

A second mailing was sent out with the new streamlined questionnaire. Unfortunately, this also received no response.

The Third Attempt

By now it was clear that it was not the questionnaire that was the problem, but perhaps the subject. Since we still had hope that our positive approach to the problem should overcome the fears of the industry, it was decided to attempt a more personal approach through our working group members. This involved targeted one on one communication with people we expected to have plenty of experience and examples in dealing with odour management.

The new personal approach resulted in exactly one response (with the promise of one more later). Despite the disappointing response, this approach did uncover more information about the reservations that industry professionals had with reporting information on odour related issues.

Respondent Concerns

Below we report a summary of the explanations given by those we contacted, perhaps understandably in an anonymous and anecdotal fashion:

a. Public Relations Policy
   Even though we wanted cases that were already resolved, some potential respondents still had other cases that were not resolved yet. They expressed concern that they could or should not comment on past cases in case this could have an influence on current cases.
b. Resolution is not always accepted
   According to some, sometimes in a compromise, not everyone is left happy. In these cases, while the issues were mostly settled, not all the stakeholders were satisfied with the outcome. Potential respondents were concerned that any attention brought to the situation would prompt those dissatisfied stakeholders to restart the discussion.
c. Fear of Recognition
   Respondents were not always particularly confident of being able to maintain anonymity while at the same time being able to provide enough information to be useful in the study. Some of the cases can be quite infamous within their own regions and might be easily recognizable to anyone involved or living there.
d. Concerns about abuse
   In at least one case, the prospective respondent was worried that the information could be used against them by irresponsible actors looking to find anything negative to portray the industry in a bad light.

It should be made clear that we would not want to make any judgement as to the validity of the expressed concerns, as indeed it is unlikely to matter. Whether real or imagined, the concerns could not be resolved through personal contact and assurances. It was clear that the lack of response was due to a deeply held discomfort on making any public statement on past odour issues. To be fair, the stakes on the industry side are quite high, including prolonged public disputes, court proceedings, possible fines, costly studies, and risks to their environmental licenses. With these in mind, even taking a very small risk seems inappropriate when that risk seems quite unnecessary.

Possible Improvements

The issue seems to be rooted in a culture that, whether rightly or wrongly, seems to have chosen reduced transparency as a coping mechanism for conflict situations.

Of course, the D-NOSES project aims to help resolve this by replacing it with transparency as a positive stakeholder engagement mechanism. So ironically the project is already working to resolve this issue, albeit in the longer term.

However, in the short term it is difficult to reframe transparency as a safe and constructive behaviour. The communication in the project has always tried to maintain a balanced approach to all stakeholders and stressed the win-win nature of the stakeholder engagement approach and co-created solutions. But this must also be borne out by observable examples of positive results from this approach. The pilot cases can hopefully serve as such cases and set an example to be emulated by others in the industry.

2.3. Examples of good practices in odour pollution collected from the Consortium Partners

General observations about the collection of examples from the consortium partners

Despite the difficulties encountered in the collection of good practices described in Section 2.2 of this document, we finally could collect five examples of good practices in odour pollution with the help of some consortium partners.

Indeed, one of the consortium partners is LIPOR (Portugal), who could tell their successful story in the management of an odour problem through the design of a new plant for waste treatment (Example no. 2).

Other odour experts involved in the consortium partners could provide examples of good practices by making the example anonymous and not citing the plant, nor its location (Examples no. 1 and no. 5). The problem related to citing the plants is that they do not want to be associated to odour problems, not even if it occurs in a positive way, and if the problem is solved.

Only two of the provided examples are provided in a non-anonymous way (Examples no. 3 and no. 4).

Despite the difficulties encountered, we are trying to re-enforce the distribution of the questionnaires and their compilation by guaranteeing anonymity if required, and by trying to increasing the communication level of the project.

EXAMPLE 1: ODOUR REDUCTION FROM THE WASTEWATER TREATMENT FACILITY OF A FOOD INDUSTRY BY MODIFICATION OF THE SLUDGE TREATMENT PROCESS

1) ABSTRACT (Brief introduction to the problem - summary)

This example is about the actions that have brought to the reduction of the odour emissions and the related odour complaints from the wastewater treatment plant of a food industry. After assessing the existence of a problem related to a specific section of the plant, it was redesigned in order to reduce odour emissions.

2) PROBLEM DESCRIPTION:

The plant involved in this example is the wastewater treatment facility of a food industry.

This plant, in its original configuration, comprised a section for the treatment of the wastewaters produced by the food processing, and the sludges deriving from the wastewater treatment were stored in open-air tanks.

People living in the surrounding municipalities have been complaining about odours for years. However, the origin of the odour was not clear, since different industries and potential odour emitting activities are present in the area. Indeed, the food industry was not the only cause of the odour complaints on the territory.

3) REPORTING PHASE:

The problem was raised through the repeated complaints of the population to the local authorities

4) MONITORING PHASE:

The food industry decided to carry out a study to assess its odour impact. The study involved olfactometric analyses and dispersion modelling.

The dispersion modelling considered all the sources of the wastewater treatment facility and, by comparing the relative contribution of each source to the overall odour impact, it was possible to identify the most critical odour source.

The study allowed to highlight that the main cause of the odour impact were the tanks for the sludge storage, whereas the odour emissions related to the wastewater treatment were negligible.

5) EVALUATION PHASE:

Based on the outcomes of the odour impact assessment study it became clear that the main problem for odour emissions were the open tanks for the storage of the sludges formed during the wastewater treatment process.

This evidence allowed for a new design of the plant, which involved a different management of the sludges, aiming to reduce the amount of sludges exposed to the open-air, thus reducing the associated odour emissions.

6) RESOLUTION PHASE:

The new design of the plant comprised an anaerobic digester for the treatment of the sludges produced by the wastewater treatment process.

The process of anaerobic digestion not only allows to reduce the volume of the sludges, but also it reduces their organic content, thus reducing their odour generation potential.

Moreover, another benefit of the new design of the plant is that biogas is produced by the anaerobic digestion process, which is a source of renewable energy.

By means of this significant structural intervention on the wastewater treatment facility, the amount of sludges exposed to open air was greatly reduced. The tanks, which previously served for the sludge storage, were dismissed, and only remained for emergency reasons.

Only a small tank is used for the storage of the sludges (digestate) produced by the anaerobic digestion process. Such digestate, having its organic content reduced by the digestion process, should be less odorous than the sludges entering the anaerobic digestion process.

7) VERIFICATION PHASE:

The success is that, through this intervention, the impact of the plant was significantly reduced.

The effectiveness of the solution was monitored by performing another study of olfactometric analyses and dispersion modelling in the new configuration. This allowed to verify that the impact of the plant was significantly reduced.

Apparently, the complaints were also reduced. However, the effect of the other odour emitting activities co-existing on the territory should also be taken into account.

8) COMMUNICATION PHASE:

The execution of the works on the plant were communicated through the website of the Municipality.

EXAMPLE 2: WWTP EPSAR IN SPAIN

1) **ABSTRACT** (Brief introduction to the problem - summary)

Wastewater treatment plants (WWTP) are potential odour emitters simply because of the nature of the product they treat; even more so when the design of the plant has not taken this problem into account and the nearby population has grown considerably in a few years.

Having an administration such as EPSAR (Public Entity for the Sanitation of Wastewater in the Community of Valencia), committed to minimising the impact of odours from WWTPs and with technically solvent operating companies to tackle this problem, becomes the key to the necessary coexistence between impact generators and receptors.

2) **PROBLEM DESCRIPTION:**

- What is the plant(s) type, size, location, technical characteristics?

The Camp de Turia II wastewater treatment plant is located next to the river Turia and on the opposite bank there is an urbanization of approximately 200 single-family homes.

The plant treats a flow of approximately 10000 m^3/day from several towns and industrial areas.

- What was the problem? How many citizens were affected and for how long?

With the increase in population in the nearby urbanization less than 500 m from the plant on the opposite bank of the river, complaints about bad odours started to be received.

3) **REPORTING PHASE:**

- How was the problem raised? How were complaints reported?

A complaint form was developed by the neighbourhood association of the urbanisation and distributed to the residents. Periodically, these were collected and presented to the town hall by means of an entry register and from there the complaints were submitted to the entity on which the WWTP depends.

4) **MONITORING PHASE:**

- Was the problem monitored? If yes, how? Which techniques/ methods were applied?

The possible causes of the plant's odour problems began to be analysed. Attempts were made to identify emission sources and aspiration flow measurements were taken at several points in the pipes along the different buildings.

- What was the result of the monitoring phase?

Several possible sources were identified:

Chemical deodorization system with an insufficient aspiration flow, no focus on aspiration, no aeration (yes agitation) in homogenization tank (2700 m^3 and an area of 800 m^2), open air deodorization channels...

5) **EVALUATION PHASE:**

- How was the data analyzed? How could the collected data be accessed?

The air flow data collected by the anemometer were used by EPSAR to prepare a project in collaboration with a specialized engineering firm to evaluate the problem.

- What was the outcome of the data analysis?

The administration commissioned a project that included a series of actions aimed at minimising the impact of odours from the WWTP. The work was put out to tender and all the actions were carried out.

6) **RESOLUTION PHASE:**

- How was the problem solved? Which technology was applied?

Chemical deodorization was doubled so that the existing one was used only for deodorizing the drying building and the new one for pre-treatment, de-sanding and primary decanting.

All equipment and channels in the pre-treatment and sludge drying buildings were covered.

A GRP building was built to house the desander channels that were previously outdoors.

A by-pass channel of the homogenisation tank was built to eliminate the sediments accumulated over the years (there was no by-pass) and grids of fine bubble diffusers were installed.

The primary decanters were covered and deodorised.

The aspiration network of the new plant through chemical means was taken to the primary decanters (the previous one reached the fine sieving).

Apart from this set of actions, as the company operating the installations, and always with the aim of minimising our impact due to odour in the community, the reconversion of the WWTP treatment to a prolonged aeration system was proposed. In this way, the primary decantation stage that generates barely stabilized sludge causing serious odour problems was eliminated, and the existing aerobic digesters that were a source of odour complaints in some periods were turned into biological reactors.

On the other hand, and as part of the practices that we carry out in order to minimize the generation of H2S in our facilities, the operation mode of the sludge thickener was modified. This modification consisted of a load feed that reduces the retention time of the sludge in it and with it, the degree of anaerobia that promotes the generation of H2S in this stage of the sludge line.

- Who/ How were the different stakeholders involved in the solution of the problem?

EPSAR has given the necessary economic support to carry out the different actions. SAV-DAM, as the operating company, has provided its technical solvency for the proposal of solutions and/or treatment alternatives. The neighbourhood association together with the town council provided us, and still continues to provide us, with the necessary feedback to detect the need for new actions or, on the contrary, the assurance that what has been done has been effective.

- How much did it cost? Who paid for it? How long did it take?

The cost of the actions was assumed by EPSAR. These actions have been carried out throughout the years in which the SAV-DAM joint venture has been operating the WWTP of Camp de Turia II.

7) VERIFICATION PHASE:

- Did the solution work? Was the impact reduced?
- Odour impact was significantly reduced and complaints stopped.
- How was the effectiveness of the applied solution monitored?

Campaigns were carried out to measure H2S in the area where odour complaints were recorded and regular controls of H2S, VOCs, ammonia, mercaptans and amines are carried out throughout the plant in order to detect sources not previously considered.

8) COMMUNICATION PHASE:

- Was the public properly informed about the end of the process?

Meetings were held with the neighbours' association and the city council to verify the absence of complaints and to report on all actions taken.

In this way, direct and fluid communication was established between the local authorities and the WWTP, minimising the response time to any incident detected and increasing the confidence of the residents in the continuous implementation of good practices aimed at reducing and even eliminating the impact of odours from our facilities.

This direct and fluid communication is still maintained today.

EXAMPLE 3: LIPOR (PORTUGAL): DESIGN OF A NEW WASTE TREATMENT FACILITY ACCORDING TO BEST PRACTICES

1) ABSTRACT:

This example is about an old composting plant + landfill that caused an odour problem to the near-living population. Both plants were closed and re-designed following best practices for waste treatment. Citizens were involved in the design process of the new plants. The old landfill has been converted into a park, thereby providing an exploitable green space in the neighbourhood.

2) PROBLEM DESCRIPTION:

LIPOR inherited the old Composting Unit, inaugurated in 1966, in 1982 when LIPOR was created. Near the composting plant also a dumpsite was active, which was converted to a landfill.

The plant allowed the valorisation of the organic fraction present in MSW for more than 30 years, processing more than 200 tons of mixed waste daily.

There were then and there isn't now in the Portuguese legislation any document regulating odour emissions.

The composting process was carried out in the open, through piles with mechanical tillage to ensure its ventilation.

Due to this the smell around LIPOR was very strong and even today people have memories of passing in the highway (next to the facilities) and closing the windows of the cars. The costs of habitations in the surroundings were lower because of the nuisance.

3) RESOLUTION PHASE:

This composting facility was closed in August 2001 and the landfill was closed a few years later.

During the study phase of the new composing plant, odour was a major concern and was made part of the Tender that was launched for the construction and exploitation of the unit. The request was that it should include the best practices available in odour reduction impacts. LIPOR started building a modern Composting Plant in 2002 and started to operate it in 2005.

The new composting plant has the capacity to treat 60.000 t/year of organic waste that arrives by truck from separate collection schemes for the organic fraction from large producers (restaurants, supermarkets, markets, and some selective collection at the domestic level) and separate collection schemes of green waste.

The quality in the careful selection of organic matter for composting and in the production of the compost is very important and is a key aspect for the viability and success of the project.

The actual compost plant is closed and in depression. Because of this, all air is sucked inside even when a door is open and the odour problems outside are minimalized.

The odour treatment has a capacity to treat 410,000 Nm3/h and consists in two air washers with individual capacity of 200,000 Nm3/h, followed by a biofiltration system with a total area of 3,130 m2, which involves 18 biofilter sections full of wooden roots as a filling material. The treated air extraction system has 3 vertical ducts equipped with axial fans. The conditions of humidity and temperature for each biofilter is controlled and microorganisms can develop their work with no restrictions. Each three years the biofilter material is changed and the roots that are removed are shredded and enters the composting plant to produce compost as a carbon source. The exchange of the material of the biofilters is made in two phases to allow the treatment system to continue to work and minimize the impact.

The landfill was converted to an adventure park that is open to the community in a certain period of the year. In the Adventure Park physical activity, a healthy diet, the respect for the environment and social activities are promoted, which are basic human competencies.

The park has the follow characteristics:

- Car park;
- Picnic area;
- Playground;
- Extreme park;
- Viewpoint;
- Tree climbing circuit
- Minigolf Park (New)
- Walking and cycling routes;
- Thematic spaces (Environmental Education Building; Thematic Games; Exhibitions);
- Mini Football Field;
- Food stand (sale of ice creams, beverages, etc.);
- Bathrooms;
- Surrounding green areas.

Recently an ecological trail was opened that it’s open every day and the population can walk, run and permits a rapid pathway between people that live near Lipor and the train station closer.

5) VERIFICATION PHASE:

At the same time the developing phase was on course, three monitoring committees were created with representatives of the citizens from the three parishes surrounding LIPOR. Initially there were scheduled monthly meetings but were not needed because of the advances of the early phases of the construction were slow and there were no subjects to discuss.

Some of the meetings were complicated because the stakeholders did not believe the problems with odour would disappear but as the project was advancing the tension started to go away as they saw the measures to control odours that were in the project started to be constructed. A clear and open communication with the stakeholders is important.

If there is the feeling that the plant is hiding information, then the tension between the parts will increase.

The commissions were active even after the composting plant started working and recognized the work of Lipor in solving a long-lasting problem.

Currently, LIPOR does not have any complaints related to odour problems in the composting plant.

6) COMMUNICATION PHASE/ LESSONS LEARNED:

With the solutions undertaken to minimize odour impact from their activities, LIPOR now is closer to the population. Their quality of life has improved, the real estate market in the surroundings has improved, and neighbours now have a new green space in the area.

EXAMPLE 4: WWTP IN ATHENS, GREECE

1) **ABSTRACT** (Brief introduction to the problem - summary)

The main municipal wastewater treatment facility of Athens, started operation during the 1980s. As of the mid 90's several revamping phases were implemented in order to upgrade the facility in terms of operation and environmental compliance. The odour issue was significant till the mid 2000's, but several investments for deodorizing and better treatment of the WWT feed, led to the minimization of the problem.

2) **PROBLEM DESCRIPTION:**

- What is the plant(s) type, size, location, technical characteristics?

Municipal WWT South West of Athens, accepts more than 700k m3 per day of sewage

- What was the problem? How many citizens were affected and for how long?

Intense odour incidents that affected a quarter of Athens city population, seasonally for almost two decades

3) **REPORTING PHASE:**

- How was the problem raised? How were complaints reported?

Reported at the press and protests near the area of the facilities

4) **MONITORING PHASE:**

- Was the problem monitored? If yes, how? Which techniques/ methods were applied?

No information available

- What was the result of the monitoring phase?

No information available

5) **EVALUATION PHASE:**

- How was the data analyzed? How could the collected data be accessed?

No data available publicly

- What was the outcome of the data analysis?

No data available publicly

6) **RESOLUTION PHASE:**

- How was the problem solved? Which technology was applied?

Pre-treatment process with removal of heavy solids, gridding, removal of sand and deodorizing.

The pretreated sewage is transferred with submerged pipelines in the facility.

Primary sedimentation tanks collect the primary sludge.

Advanced secondary biological treatment with activated sludge system achieves removal of organic load and significant reduction of nitrogen.

Digestion, dehydration and thermal drying of sludge are the stage of the wastewater treatment.

The processed outflow of WWTP is diffused through pipelines

- Who/ How were the different stakeholders involved in the solution of the problem?

Consortium of companies and the Water Supply and Sewerage company publicly owned

- How much did it cost? Who paid for it? How long did it take?

The revamping lasted about 3 years.

7) **VERIFICATION PHASE:**

- Did the solution work? Was the impact reduced?

The solution worked and the impact is reduced with no reported incidents throughout the year

- How was the effectiveness of the applied solution monitored?

The company running the facility, monitors and reports a series of parameters regarding the process and environmental outcome, therefore covering the odour requirements.

8) **COMMUNICATION PHASE:**

- What happened after that?

Several newsletter published

- Was the public properly informed about the end of the process?

Through the portal of the managing company

EXAMPLE 5: ODOUR REDUCTION BY PLANNING LANDFILL OPERATIONS ACCORDING TO WIND CONDITIONS

2) **PROBLEM DESCRIPTION:**

- What is the plant(s) type, size, location, technical characteristics?

The problem arises at the Landfill where we have short- and long-term storage of waste. Sometimes the problem with odour comes from the slag sorting plant as well as from the bunker in the Waste to Energy (WtE) plant. The landfill is located 500 meters from the nearest housings.

- What was the problem? How many citizens were affected and for how long?

The problem has probably been there for many many years, thought was not spotted until we started with long term storage of waste. The long term storage resulted in that the household waste storage during summertime was prolonged. With warm summers this became a problem. The problem arises when we dig in the loose storage for transporting to the WtE plant as well as when cracking bales into containers, and only when the wind is in the "wrong" direction and intermediate.

3) **REPORTING PHASE:**

- How was the problem raised? How were complaints reported?

The problem was raised by the residents in the nearby area.

4) **MONITORING PHASE:**

- Was the problem monitored? If yes, how? Which techniques/ methods were applied?

We used a very simple method (still are) in an excel sheet. The customer service makes a note when we have a complaint and sends an email to the manager of the landfill for evaluation of what actions can be done to minimize the problem. In the excel sheet we also make a note of wind and weather reports.

- What was the result of the monitoring phase?

We noted that in special weather conditions the odour problem was higher than in other conditions. We try – as far as it is possible – to not dig in the storage during those conditions. This is not always practically for us, as the waste must be transported at some points, thought we have much more focus on this today than before, and all people working with the problem are aware of the problem.

5) **EVALUATION PHASE:**

- How was the data analysed? How could the collected data be accessed?

We have a group in the company that we can call together when analysing is necessary, thought the managers are well aware and do their best to avoid problems.

We have also looked into other techniques as sprays that is said to minimise odours, thought we have decided not to use this because of the price, and we do not believe it will make a real difference.

6) **RESOLUTION PHASE:**

- Who/ How were the different stakeholders involved in the solution of the problem?

Stakeholders: residents, managers at the plant, municipalities.

- How much did it cost? Who paid for it? How long did it take?

Only working time.

7) **VERIFICATION PHASE:**

- Did the solution work? Was the impact reduced?
- How was the effectiveness of the applied solution monitored?

8) **COMMUNICATION PHASE:**

- What happened after that?

We have had a regular communication with the residents, we have invited them to see the facility, to smell the different smells, and talked to them about what we do all the time. All actions from our side has been communicated to the residents and they have been encouraged to send in an email/SMS or phone us whenever odour arises. This communication has been one of the success-factors as we have been able to make changes in the way that we have been working with the storage process internally.

- Was the public properly informed about the end of the process?

The process will not end as long as the company has neighbours.