Ref. Ares(2021)5966709 - 30/09/2021

D-NOSES

Distributed Network for Odour Sensing, Empowerment and Sustainability

Compilation of good practices in odour pollution 2

D2.5 v2.4

September 2021 (M42)

Deliverable

PROJECT ACRONYM	GRANT AGREEMENT #	PROJECT TITLE
D-NOSES	789315	D-NOSES

DELIVERABLE REFERENCE NUMBER AND TITLE

D2.5 Compilation of good practices in odour pollution 2

Revision: v2.4

AUTHORS

Laura Capelli (POLIMI)	**Cyntia Izquierdo** **Ainhoa Anton** **Carlos Diaz** (AMIGO)	**Rosa Arias** (Ibercivis, Science for Change)	**Miguel Hernández** (Science for Change)

Funded by the Horizon 2020 programme of the European Union

Grant Agreement No 789315

DISSEMINATION LEVEL

✔ **PU** **Public**

CO Confidential, only for members of the consortium and the Commission Services

Revision History

REVISION	DATE	AUTHOR	ORGANISATION	DESCRIPTION
v1.0	06.07.2021	Laura Capelli	POLIMI	Title and Structure
v1.1	13.07.2021	Cyntia Izquierdo, Ainhoa Anton	AMIGO	Summary BREF Pulp & Paper (Section 1.3)
V1.2	20.07.2021	Laura Capelli	POLIMI	First revision of section 1.3
V1.3	26.07.2021	Laura Capelli	POLIMI	Summary BREF FDM (Section 1.2)
V2.0	24.08.2021	Laura Capelli	POLIMI	Addition and revision section 1.1
V2.1	26.08.2021	Laura Capelli	POLIMI	Addition and formatting section 1.2
V2.2	28.08.2021	Laura Capelli	POLIMI	Addition and formatting sections 1.3 and 2
V2.3	30.08.2021	Laura Capelli	POLIMI	1st Revision
V2.4	30.09.2021	Rosa Arias Miguel Hernández	IBERCIVIS SfC	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This deliverable contains original unpublished work except where clearly indicated otherwise.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., Antón A., Diaz C., Arias R., Hernández M. (2021), Compilation of good practices in odour pollution 2, D-NOSES, H2020-SwafS-23-2017-789315.

Summary

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. As a first step, we decided to discuss the practices to manage odour emissions described in the Best Available Techniques (BAT) Reference Documents (BREF) documents, which are the technical reference for all industrial sectors in Europe. Such documents are not specific for odours; 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. Moreover, we tried to collect some examples of real application of good practices from the Consortium partners. Despite the difficulties we encountered, here we report a further example, which adds to the ones already reported in the previous deliverable D2.3. The document is structured in 2 chapters:

Chapter 1. BEST AVAILABLE TECHNIQUES FOR ODOUR EMISSIONS 2: 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. Here, we completed the work that was started with Deliverable D2.3, by finishing to review the BREF Reference Documents about the Food, Drink and Milk Industries (Section 1.2), and the Production of Pulp, Paper and Board (Section 1.3).

Chapter 2. COLLECTION OF GOOD PRACTICES IN ODOUR POLLUTION 2: This chapter has the aim to collect examples of good practices in odour pollution from the consortium partners. As already explained in Deliverable D2.3, the collection of examples turned out to be more difficult than expected, and the COVID-19 breakout didn't help to overcome such difficulties. However, one more exhaustive example regarding a landfill located in Southern Italy is reported and discussed here (Section 2.2).

Index

1. BEST AVAILABLE TECHNIQUES FOR ODOUR EMISSIONS 2

This section presents a schematic description of the good practices for odour emission management and control in the Food, Drink and Milk Industries, and in the Productions of Pulp, Paper and Board, as extracted from the Best Available Techniques (BAT) Reference Documents drafted by the EIPPCB.

1.1 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.

As already mentioned in Part 1 of this Document (D2.3 Compilation of good practices in odour pollution, delivered in May 2020), we believe that in a document aiming to discuss good practices for odour pollution, it is fundamental to mention the reference documents for Best Available Techniques existing on a European level.

The Best Available Techniques (BAT) Reference Documents (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.

As a preliminary work for this task, we produced a list of the BREF documents mentioning odour, and the number of times the term "odour" is mentioned in each document (see Table 1 of

D2.3 *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*).

Among those, we decided to review more in detail those documents in which the term “odour” appears more than 100 times, which are (in decreasing number of citations of “odour”):

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, the summarization work for Deliverable D2.3 has been limited to: waste treatment, refining of mineral oil and gas, intensive rearing of poultry and pigs, slaughterhouses and animals by-products industries.

For this reason, in this new document we finalized the summarization of the BREF documents regarding the Food, Drink and Milk Industries (Section 1.2), and the Production of Pulp, Paper and Board (Section 1.3).

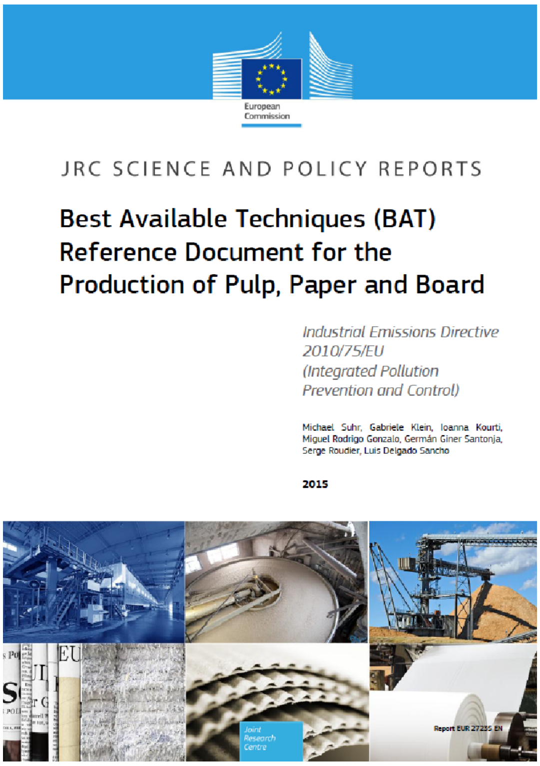

Figure 1. Best Available Techniques (BAT) Reference Documents for the Food, Drink and Milk Industries (2019) and for the Production of Pulp, paper and Board (2015)

1.2 Food, Drink and Milk Industries

Introduction

Food Industries are sometimes a cause of odour complaints, although their odour emissions are not necessarily unpleasant. However, it is nowadays recognized that also the exposure to pleasant odours can cause an annoyance, especially if the perceived odours are intense, or if the exposure is prolonged over time.

The BREF about Food, Drink and Milk (FDM) Industries refers to the following activities specified in Sections 6.4 (b) and (c) of Annex I to Directive 2010/75/EU, namely:

- 6.4 (b) Treatment and processing, other than exclusively packaging, of the following raw materials, whether previously processed or unprocessed, intended for the production of food or feed from:
    i. only animal raw materials (other than exclusively milk) with a finished product production capacity greater than 75 tonnes per day;
    ii. only vegetable raw materials with a finished product production capacity greater than 300 tonnes per day or 600 tonnes per day where the installation operates for a period of no more than 90 consecutive days in any year;
    iii. animal and vegetable raw materials, both in combined and separate products, with a finished product production capacity in tonnes per day greater than:
        - 75 if A is equal to 10 or more; or

    - [300 - (22.5 × A)] in any other case,

  where ‘A’ is the portion of animal material (in percent of weight) of the finished product production capacity.
  Packaging shall not be included in the final weight of the product.
  This subsection shall not apply where the raw material is milk only

- 6.4 (c) Treatment and processing of milk only, the quantity of milk received being greater than 200 tonnes per day (average value on an annual basis).

- 6.11 Independently operated treatment of waste water not covered by Directive 91/271/EEC provided that the main pollutant load originates from activities specified in Sections 6.4 (b) or (c) of Annex I to Directive 2010/75/EU.

The document also covers:

- the combined treatment of waste water from different origins provided that the main pollutant load originates from the activities specified in Sections 6.4 (b) or 6.4 (c) of Annex I to Directive 2010/75/EU and that the wastewater treatment is not covered by Directive 91/271/EEC2;

- the production of ethanol taking place on an installation covered by the activity description in 6.4 (b) (ii) of Annex I to Directive 2010/75/EU or as a directly associated activity to such an installation.

This document does not address the following:

- On-site combustion plants generating hot gases that are not used for direct contact heating, drying or any other treatment of objects or materials.

- Production of primary products from animal by-products, such as rendering and fat melting, fishmeal and fish oil production, blood processing and gelatine manufacturing. This may be covered by the BAT conclusions for Slaughterhouses and Animal By-products Industries (already summarized in D2.3).

- The making of standard cuts for large animals and cuts for poultry. This may also be covered by the BAT conclusions for Slaughterhouses and Animal By-products Industries.

The Best Available Techniques (BAT) Reference Document for the Food, Drink and Milk Industries was published quite recently (December 2019) and explicitly mentions odours 326 times, and more in detail in:

- Section 2.1 regarding the processes and techniques applied across the FDM sector, and especially in the subsections about the treatment of waste waters (Section 2.1.5.3), and the treatment of the emissions to air (Section 2.1.6), where there is a subsection dedicated specifically to odour (2.1.6.3).

- Section 2.3 regarding the techniques to consider in the determination of BAT across the FDM sector

- Sections 3, 4, 7, 10, 11, 15, and 16.3 regarding respectively Animal feed (Section 3), Brewing (Section 4), Fish and shellfish processing (Section 7), Meat processing (Section 10), Oilseed processing and vegetable oil refining (Section 11), Sugar manufacturing (Section 15), and coffee roasting (Section 16.3), which are the processes of the FDM sector for which some odour emissions can be expected.

- Section 17.1 reporting the general BAT conclusions for the FDM sector.

Section 2.1: Applied processes and techniques across the FDM sector

Waste water treatment techniques (Section 2.1.5.3)

This section (and subsections) describes the various waste water treatment techniques, showing the sequence that the techniques typically follow to progressively achieve a better quality of waste water.

Waste water treatment techniques typically include:

- primary treatments, such as (among others) equalisation, neutralisation and screening;
- secondary treatments, which are directed principally towards the removal of biodegradable organics and suspended solids using biological methods, and which can be further divided into aerobic, anaerobic, and combinated (aerobic/anaerobic) treatments; secondary treatment typically include also methods for the removal of nitrogen and phosphorus;
- tertiary treatments, which typically refer to any process that is considered a polishing step, up to and including disinfection and sterilisation systems

In the section regarding secondary treatments, the advantages and disadvantages of aerobic and anaerobic treatments are discussed (Table 2.5 and Table 2.6, respectively).

Here, odour is mentioned as a specific disadvantage related to aerobic water treatments, since the stripping with air/oxygen of the wastewater results in fugitive releases that may cause odours/aerosols.

On the other hand, one of the the advantages of anaerobic treatments is that they cause less odour problems, if appropriate abatement techniques are employed.

Treatment of emissions to air (Section 2.1.6)

This section gives a brief overview of the techniques that are typically applied in the FDM sector to treat the emissions to air. Emissions to air can be divided into ducted, diffuse, and fugitive emissions. Fugitive emissions are a subset of diffuse emissions. Only ducted emissions can be treated. Diffuse and fugitive emissions can, however, also be prevented and/or minimised.

It should be specified that the techniques that can be used for the reduction of VOC emissions are indicated in the CWW BREF, which, as far as odour emissions are concerned, has been summarized in Deliverable D2.1 of this project[1]. Odour is mentioned here among the diffuse emissions:

- odour losses during storage, filling and emptying of bulk tanks and silos;
- stripping of odorous compounds from a WWTP resulting in releases to air;

Section 2.1.6.2 specifies that, in the case of odour, the emission to be treated usually contains a complex cocktail and not just one or two readily definable components. The abatement plant is, therefore, often designed based on experience within other similar installations. The uncertainty caused by the presence of a considerable number of airborne components may necessitate the need for pilot plant trials. The flow rate to be treated is a major parameter in the selection process and very often the abatement techniques are listed against the optimum flow rate range for their application.

It is important to highlight that the purchase of an abatement plant shall include a number of guarantee statements, also regarding the removal efficiency of the process. The form of the process guarantee is an important part of the contract. Guarantee statements relating to odour removal performance can take a number of forms. In the absence of olfactometric data the guarantee could state no perceivable odour outside the process boundary or outside the installation site.

The subsections of section 2.1.6.2 briefly describe some of the techniques that are applied for the treatment of air emissions. In particular, odour is mentioned in Section 2.1.6.2.3 about Absorption, 2.1.6.2.4 about Biological treatment and 2.1.6.2.5 about Thermal treatment, because these are the techniques that are suitable for the abatement of odours and VOCs. No more details about these techniques will be given here, since they have been already described in the aforementioned Deliverable 2.1 of this project.

Section 2.1.6.3: Odour

In section 2.1.6 there is a Subsection specifically dedicated to odour. This is mainly a descriptive section, which generally outlines the characteristics of odour problems, and gives some indication about how odour emissions are managed in different European countries.

Odour is recognized to be mostly a local problem. In many cases, odour complaints are related to the vicinity of housing estates to the emitting activities, especially in those cases of expanding cities, where new houses are sometimes built too close to the industries.

For the FDM sector, odour problems are usually related to waste water treatment operations. Ammonia used in cooling systems may leak or accidental releases may occur which also result in odour complaints.

The next part of the section deals with odour regulation. It is reported that in the vast majority of countries, odour emissions are regulated under the laws of nuisance. Some countries have

[1] 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).

quantified legislation. This quantified legislation can relate to either the magnitude of the odorous emission or alternatively to a maximum concentration of a component or group of components which are known to cause odorous emissions. In Europe, the most common way to quantify odours is through the measurement of the odour concentrations, expressed in ou_E/m^3, by means of dynamic olfactometry, as defined by the EN 13725:2003. Instrumental odour measurements exist but the quantification of odour is still based on olfactometry to a great extent. A description of the existing techniques for measuring odour is also reported in Deliverable D2.1 of this project.

In Germany for example, the legislation for odorous processes is largely directed towards ensuring that the outlet concentration of organics is only related to the process being conducted and the efficiency of the chosen abatement plan. The legislation, under TA Luft, contains a general statement about odour emissions and describes the need to consider containment, the surroundings and the ability of the abatement plan to achieve 99% odour reduction for odour emissions greater than 100 000 ou_E/m^3. For specific process operations TA Luft provides maximum outlet concentrations of organics that should not be exceeded.

However, in general, the legislation governing odorous emissions, if they are not also considered to be harmful, is impact-related and not source-controlled. This means that the need to treat an odorous emission is governed by the impact it has on the surrounding environment following dispersion in the air.

This leads to the possibility to reduce ground level concentrations – and thus the probability of odour complaints – by "simply" enhancing odour dispersion in the air, without any reduction in the magnitude of the odour emission.

Some of the features of an odour emission that can be altered in order to enhance dispersion, and thus reduce resultant ground level odour concentration, are:

- The dispersion of an exhaust emission in the air and hence its resultant ground level odour concentration, will depend upon a variety of factors, including:
    - the height of the discharge;
    - stack temperature (thermal buoyancy) and discharge velocity;
    - configuration of the discharge stack (e.g. horizontal vs. vertical discharge).
- Adding a perfumed component, i.e. a masking agent, is another option for physically treating the odour, but it is not recommended.

As a matter of fact, these considerations are particularly interesting because, to the best of our knowledge, this is the first "official" document in which the possibility to adopt the enhancement of odour dispersion as a solution to reduce odour impacts is explicitly mentioned.

Section 2.1.6.4: Emissions to air control strategy

This section describes the strategy for the control of air emissions. The strategy is divided into a number of evaluation stages, and the extent to which each stage needs to be applied depends on the particular installation situation and certain stages may or may not be required to achieve the levels of protection sought. The strategy can be used for all emissions to air, but it is interesting to highlight that odour has been selected as reference species to illustrate the different stages.

First, Figure 2.4 of the BREF document (Figure 2 here) summarizes the flow chart for the selection of the most suitable abatement technique. This flowchart is particularly useful for large operating sites where there are a high number of discrete odour sources and where the major contributors to the overall odorous discharge are not fully understood.

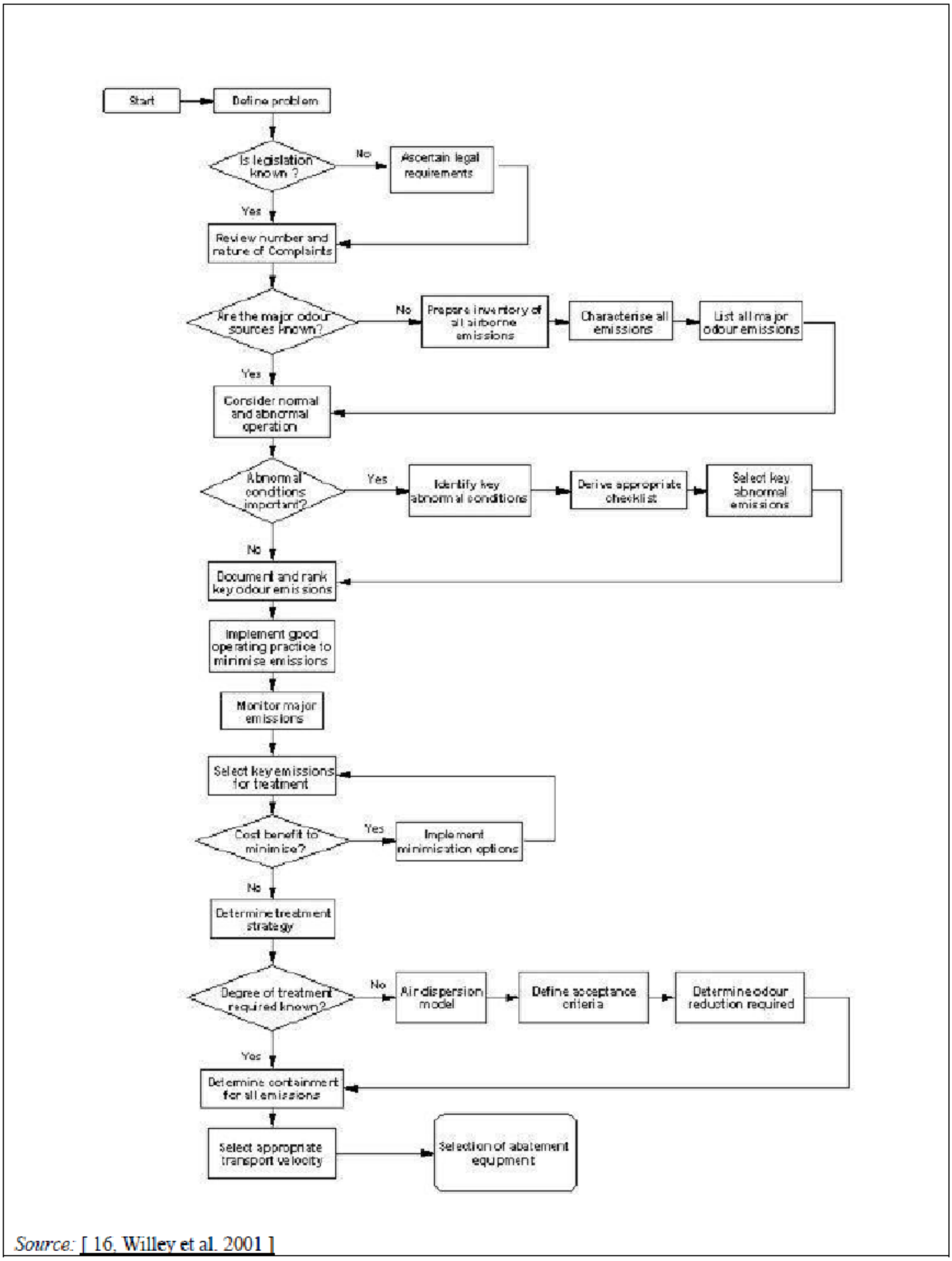

Figure 2. Flow chart for the selection of odour abatement techniques (Source: Figure 2.4 of the BREF Reference Document for the Food, Drink and Milk Industries, 2019)

The different evaluation stages (steps) of the odour control strategy can be summarized as follows.

Step 1: Definition of the problem (Section 2.1.6.4.1)

Information shall be gathered about legislative requirements regarding emissions to air. The local setting, e.g. weather and geographical conditions, may also be relevant when defining the odour problem.

As an example, the number and frequency of complaints and the characteristics related to odour can be reviewed. The location of the complainants related to the installation, together with any comments made by the complainants or the local authority representatives, help to identify what needs to be addressed. A complaints logging system can be set up, which includes a system for answering all complaints made directly to the installation with either a telephone call or personal visit. If the exact processing conditions at the time of the complaint are examined and documented, this can assist in locating the odour sources which need to be controlled.

Any correspondence with the local authority or the local community can be reviewed. The level of activity of the local community, together with the approach and actions taken by the local authority representatives, can enable the severity of the problem to be established and influence the likely timescale available to modify the process or install an abatement plant.

Finally, the prevailing local climatic conditions can be established. In particular, the prevailing wind direction and wind speed and the frequency of inversions. This information can be used to ascertain whether the complaints are largely generated as a result of certain weather conditions or are generated by specific operations carried out at the installation.

Step 2: Inventory of site emissions (Section 2.1.6.4.2)

The inventory includes normal and abnormal operational emissions. Characterising each emission point allows subsequent comparison and ranking with other site emission points.

A systematic way to identify normal operational emissions to air is to work through each process and identify all potential emissions. For example, this study may cover from raw material delivery and storage, production to packaging and palletising/warehousing.

The study can be conducted with varying degrees of sophistication. Process flow sheets or process and instrumentation diagrams can be used during a tour around the site to systematically identify all the emission sources.

Depending on the severity of the problem and the key site operations that cause the problem, it may be necessary to extend this analysis to cover abnormal and even emergency situations.

The odorous emissions can be ranked in terms of the severity of their impact on the surrounding environment. A possible system to devise a ranking order could start with grouping the emissions into categories such as major, medium and minor according to their odour characteristics and the related complaints. The ranking within each category is strongly influenced by the strength of the perceived odour from the source together with the associated airflow and nature of operation, i.e. continuous or non-continuous. This process may require a degree of professional judgement in addition to the factors detailed above.

Step 3: Measurement of major emissions (Section 2.1.6.4.3)

Emissions to air are quantified for determining priorities for prevention and treatment. The measurement will allow the emissions to be ordered in terms of the magnitude of their impact.

In the case of odours, emissions are quantified in terms of Odour Emission Rate, which is calculated as the product of the odour concentration and the associated volumetric airflow, and is expressed in ou_E/s, as defined by the EN 13725:2003.

If the key odorous emissions are known, together with the related flow rates and with the physical location of the emissions within the site, this will allow a possible treatment scenario to be developed.

Air dispersion modelling can enable the impact of the major measured emissions to be fully quantified. The impact, in this respect, is the resultant ground-level odour concentration of the total emissions from the site at varying distances from the site boundary related to climatic conditions, to determine any required action to control odour emissions.

Step 4: Selection of air emission control techniques (Section 2.1.6.4.4)

An inventory of emissions, immissions and complaints can identify the major sources of odour emissions to air from the site that need to be part of a treatment plan or strategy. It enables any sources whose impact can be eliminated or, if not, reduced to be identified. Control techniques include process-integrated and end-of-pipe treatment.

Process-integrated treatment includes substance-related measures, such as selecting substitutes for odorous substances; using low-emission materials as well as low-emission systems and production processes. If, after applying process-integrated measures, emission reduction is still required, further control of odours by the application of end-of-pipe techniques may be needed.

When selecting odour abatement techniques, the first stage is to analyse the flow rate, temperature, humidity, and the concentrations of the odorous emission. Odours often arise due to the emissions of VOC, in which case the abatement technique applied needs to take account of toxic and flammable hazards. Generalised criteria for selecting odour abatement techniques have been discussed in Deliverable D2.1 of this project.

The effectiveness or required performance is considered next. This can be assessed using professional guidance and information from the manufacturers of the abatement techniques. The next step in the selection procedure is a feasibility assessment. The capital and operating costs, space requirements and whether the abatement technique has been proven to be applicable in a similar process are all considered.

Figure 2.5 of the BREF document (Figure 3 here) shows a flow sheet that summarises this process of selecting end-of-pipe odour/VOC abatement techniques.

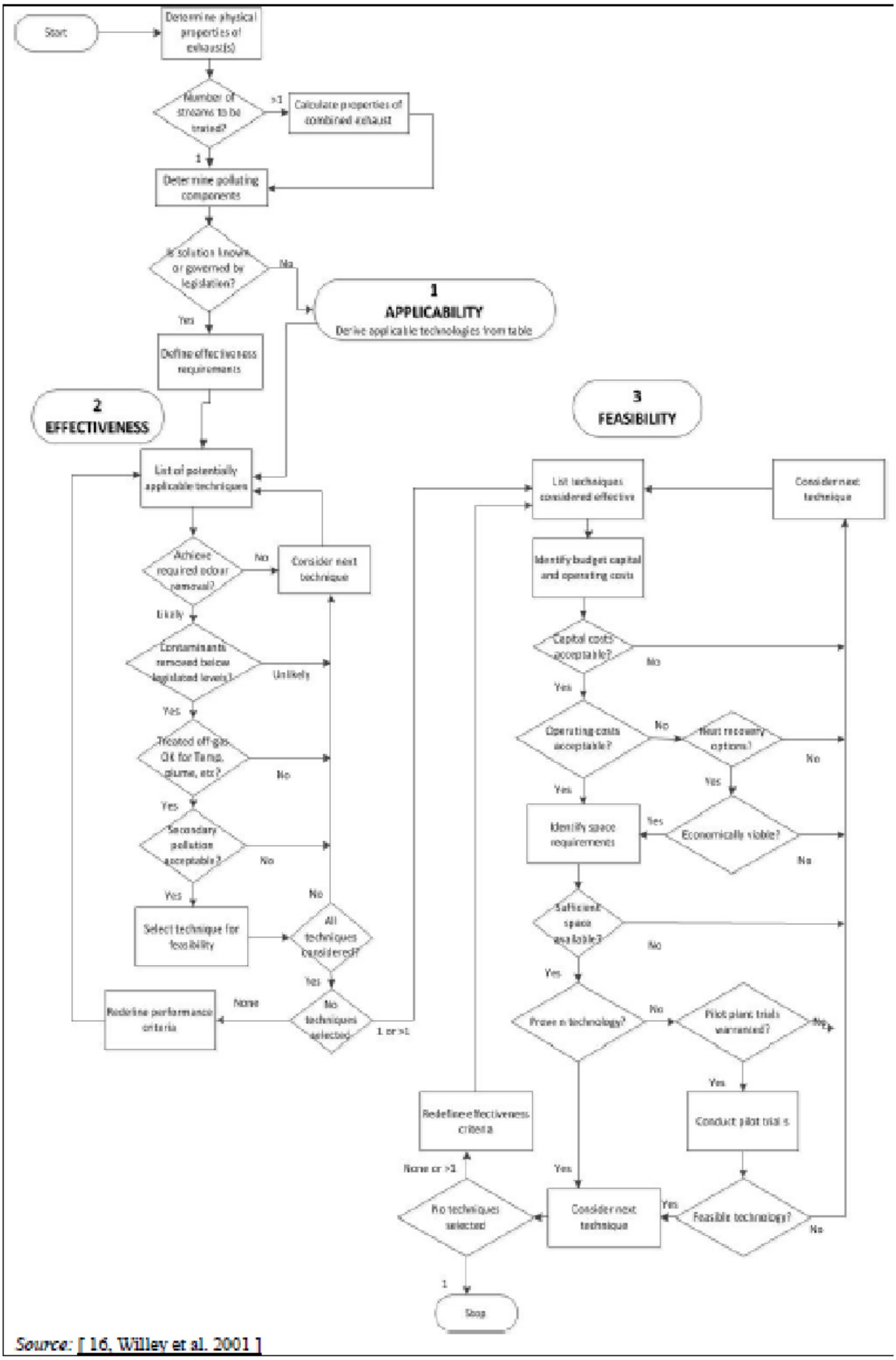

Figure 3. Flow sheet for the selection of odour abatement equipment (Source: Figure 2.5 of the BREF Reference Document for the Food, Drink and Milk Industries, 2019)

Section 2.3: Techniques to consider in the determination of BAT across the FDM sector

This section 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 the BREF document. The techniques described include both the technology used and the way in which the installations are designed, built, maintained, operated and decommissioned.

Techniques to increase energy efficiency (Section 2.3.2)

Among the techniques to increase energy efficiency, odour is mentioned in the sections describing Mechanical Vapour Recompression (MVR, Section 2.3.2.2.4.1) and Thermal Vapour Recompression (TVR, Section 2.3.2.2.4.2), since both these techniques have the potential to reduce odour emissions.

In MVR, the evaporated vapour is compressed by a mechanical compressor and then reused as a heat source. In an example brewery in Germany, the vapour condensation system draws off the boiling vapours produced by the wort boiling process from the whirlpool pan and compresses them with MVR. The compressed vapours are reused as a heating medium for the boiling process. The advantages of condensing the vapours include reductions in the heat and water losses, improvements in the hot water balance of the operation and a reduction in odour emissions. It is reported that approximately one third of the electrical energy consumed by the brewhouse has to be used to drive the vapour compressor system.

In TVR, Water vapor from an evaporator is entrained and compressed with high pressure steam in a thermocompressor so it can be condensed in the evaporator heat exchanger.

Techniques to increase resource efficiency (Section 2.3.5)

Among the techniques to increase resource efficiency, odour is mentioned in the sections regarding the Separation of residues (Section 2.3.5.3), since segregation of by-products reduces 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. Nonetheless, odour can be potentially generated if separated solids are not periodically collected and sent to their subsequent destination.

Moreover, odours are also mentioned in the section about the use of waste water for landspreading (Section 2.3.5.6). It is highlighted that waste water treatment prior to landspreading may be performed to reduce odour emissions during storage (aerated tanks or lagoons, reduced storage time, etc.). It shall be considered that odour can arise during spreading.

Waste water treatment techniques (Section 2.3.6)

Preliminary, primary and general treatment (2.3.6.1)

Among the different techniques for waste water treatment odour is first cited in the section about equalisation (2.3.6.1.1), which is a process aiming at balancing of flows and pollutant loads by using tanks or other management techniques. Here, it is said that adequate mixing and aeration is needed to minimise the formation of scum on the surface of the equalisation tank and to maintain a sufficient dissolved oxygen level to ensure the contents do not become anaerobic, leading to acidity and odour.

Odour is further mentioned in the Section about screening (2.3.6.1.3), which is a process using a device with openings, generally of uniform size, to retain the coarse solids found in waste water. This process usually reduces the risk of odour emissions further downstream in the waste water treatment plant (WWTP). Nonetheless, the screening process itself may cause odour emissions, depending, for example, on the type and size of the solids screened.

Concerning fat trap or oil separator for the removal of FOG and light hydrocarbons (described in section 2.3.6.1.4), which is a plumbing device designed to intercept most greases before they enter the biological waste water treatment, it is specified that, ease of emptying and regular maintenance of the device are essential to prevent odour problems. On the contrary, depending on the type of fat trap, e.g. without continuous fat removal, there may be odour emissions, particularly during emptying.

Secondary treatment (2.3.6.2)

As already mentioned in Section 2.1.5.3 of the BREF document, in the section regarding activated sludge process (2.3.6.2.1.1), which is a biological process where the microorganisms are maintained in suspension in the waste water and the whole mixture is mechanically aerated, and where the activated sludge mixture is sent to a separation facility from where the sludge is recycled to the aeration tank, as a cross-media effect it is highlighted that volatile waste water content can be released into the atmosphere, giving rise to odour.

For pure oxygen systems (2.3.6.2.1.3), which foresee the injection of pure oxygen into an existing conventional aeration plant, it is said that, in comparison with activated sludge systems, odour emissions are reduced as the surface of the aeration tank is essentially unbroken.

Regarding aerobic lagoons (2.3.6.2.1.2), which are shallow earthen basins for the biological treatment of waste water, the contents of which are periodically mixed to allow oxygen to enter the liquid through atmospheric diffusion, they are identified as a potential source of odour nuisance. The same consideration applies to trickling filters (2.3.6.2.1.5), in which waste water is distributed over a filter medium where biomass grows as a film, bio-towers (2.3.6.2.1.6), consisting of tanks where microbial film adheres to the plastic media contained and consumes the organic material; the waste water is often recycled through the bio-tower, and rotating biological contactors (RBC - 2.3.6.2.1.7), which consists of a series of closely spaced circular discs of polystyrene or polyvinyl chloride; the discs are submerged in waste water and rotated slowly through it.

Concerning anaerobic treatments, for anaerobic contact process (2.3.6.2.2.2), which is an anaerobic process where waste water is mixed with recycled sludge solids and then digested in a sealed reactor, and the water/sludge mixture is separated externally, the arising of combustible gases and the formation of metabolites such as short-chain carboxylic acids make the use of closed equipment necessary to prevent the efflux of odour. Odour abatement might be necessary.

Anaerobic lagoons (2.3.6.2.2.3) are similar to aerobic lagoons (see Section 2.3.6.2.1.2), with the difference that the contents of anaerobic lagoons are not mixed. They may give rise to odour problems, typically due to H_2S emissions.

In the anaerobic filter (2.3.6.2.2.4), the growth of anaerobic bacteria is established on a packaging material. The packaging retains the biomass within the reactor and it also assists in the separation of the gas from the liquid phase. In general, there is a need for an additional downstream biological (aerobic) treatment. Odour abatement might be necessary.

Final solids removal (2.3.6.5)

Among the processes for final solids removal, odour is mentioned in the flotation process (2.3.6.5.4), which consists in the separation of solid or liquid particles from waste water by attaching them to fine gas bubbles, usually air. The buoyant particles accumulate at the water surface and are collected with skimmers. It is specified that the system is kept aerobic, so as to keep the risk of odour problems low.

Natural treatment (2.3.6.6)

Integrated constructed wetlands (2.3.6.6.1) are interconnected basins or lagoons planted with a wide variety of aquatic plant species, allowing subsequent waste water treatments. Through the use of appropriate emergent vegetation, odours and pathogens can be controlled.

Sludge and waste treatment (2.3.6.7)

Sludge stabilisation (2.3.6.7.1.2) is a chemical or biological process that stops the natural fermentation of the sludge. The process also improves sludge thickening and/or dewatering and reduces odour and pathogens. Among the possible stabilisation processes, thermal stabilisation has high energy requirements and may release odours. An aerobic stabilisation process has a long residence time, produces odourless sludge and produces gas, which is a source of energy.

Sludge thickening (2.3.6.7.1.3) is a procedure used to increase the solids content of sludge by removing a portion of the liquid fraction. Here odour is mentioned specifying that excessive retention within the tank should be avoided to minimise the possibility of anaerobic conditions occurring with consequent odour and corrosion problems.

The objective of sludge dewatering (2.3.6.7.1.4) is the same as that of thickening (see Section 2.3.6.7.1.3) with the difference that the solid content is much higher. The dewatering techniques generally used are centrifugation, belt filter press, filter press and vacuum filters. Centrifuges are continuous processes which produce a cake of up to 40 % dry solids for certain sludges. Because of the closed nature of the centrifuge, associated odour problems are minimal.

Section 2.3.7: Techniques to reduce emissions to air

This section describes a number of techniques that can be used to reduce emissions to air. Some of them are quite specific for the reduction of odours/ VOCs. Since end-of-pipe techniques for odour abatement have been already extensively described in Deliverable D2.1 of this project, they will no longer be reviewed here. It is clear that the techniques described in deliverable D2.1 are generally applicable, thus they can be effectively adopted also in the FDM sector. The end-of-pipe treatment techniques that are specifically mentioned in the FDM BREF document are:

- Wet scrubber (2.3.7.3.1)
- Plate absorber (2.3.7.3.2)
- Adsorption (2.3.7.3.3)
- Biofilter (2.3.7.3.4)
- Bioscrubber (2.3.7.3.5)
- Thermal oxidation (2.3.7.3.6)
- Catalytic oxidation (2.3.7.3.7)
- Non-thermal plasma treatment (2.3.7.3.8)

Techniques different from end-of-pipe abatement systems are briefly described in the following:

Exhaust gas recirculation (2.3.7.1.2)

This technique is not specific for the reduction of odours but can be adopted to reduce a number of different pollutants. This process implies the recirculation of (part of) the waste gas to a combustion chamber to replace part of the fresh combustion air. This technique is highly efficient and, if correctly operated, as efficient at eliminating odours as other burning methods.

Extension of the height of the discharge stack (2.3.7.3.9)

This relatively "simple" technique allows to reduce the perception of odour problems in the vicinity of the odour source.

Increase of the stack discharge velocity (2.3.7.3.10)

The magnitude of the discharge velocity applied to a final emission to the air can have a significant effect on the resultant ground-level impact of an odorous emission. An increased discharge velocity will result in an increased momentum or buoyancy of the emission. This implies that the discharge will attain an increased elevation thereby allowing more potential for dispersion in the air and hence lower ground-level concentrations, thus reducing odour perception in the vicinity of the source. A typical design range for final discharge velocities from stacks is between 10 m/s and 20 m/s, with an industry standard of 15 m/s. Design velocities of less than 10 m/s are likely to suffer from poor dispersion, whilst velocities above 20 m/s can prove expensive in terms of extraction fan power and operating costs.

Odour management plan (2.3.7.3.11)

An odour management plan is part of the environmental management system (EMS) approach, and it is an important tool for the minimisation of odorous emissions. The technique is applicable to new and existing installations provided that an odour nuisance at sensitive receptors is expected and/or has been substantiated.

As odour arises from different operational areas, it is good practice for the odour management plan to include all potential odour sources and to seek to control them in an integrated way.

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 incidents, e.g. complaints;
- an odour prevention and elimination programme designed to identify the source(s), to monitor odour emissions, to characterise the contributions of the source(s) and to implement elimination and/or reduction measures;
- a review of historical odour incidents and remedies and the dissemination of odour incident knowledge.

In more detail, an odour management plan could encompass the following elements:

- containment and extraction of primary emission sources for treatment via odour removal system(s);
- design factors for abatement system(s) to include assessment of the inlet gas stream for the following parameters:
    - contaminants present (individual contaminants, concentration and variability);
    - flammability (upper and lower explosive limits);
    - flow rate (air flow capacities, continuous/intermittent flow);
    - temperature of gas stream (average and maximum);
    - gas pressure;
    - relative humidity content.
- dispersion of the treated gas flow;
- contingency measures during abnormal events.

Section 3: Animal feed

Odour is mentioned in Section 3.1 “General information about the sector” as one of the key environmental impacts of animal feed manufacturing.

Nonetheless it is also stated that noise and odours are mainly incidental and tend to be relevant to the relatively few compound feed installations occupying inhabited areas. These emissions can be minimised by good management practice and can be legitimately considered at local level.

As a general rule to reduce impacts from this type of productions, loading activities are typically undertaken in enclosed bays to limit the potential for the fugitive release of dust and odour.

Techniques to reduce odour (3.4.2.3)

Under the Section dedicated to the techniques to consider in the determination of the BAT, there is a dedicated Section related to the techniques to reduce odours (3.4.2.3).

The only techniques mentioned here are:

- Non-thermal plasma treatment (3.4.2.3.1), as described in the aforementioned Section 2.3.7.3.8 of the BREF document.
- Biofilter (3.4.2.3.2), as described in Section 2.3.7.3.4.

Some examples of applications of both techniques are also provided.

In a pet food processing facility, a non-thermal plasma system has been installed for emission volumes ranging from 10000 m^3/h up to 200000 m^3/h. The system has the following main properties:

- cleaning efficiency: 75–95 %;
- modular capacity: 20 000 m^3/h;
- power consumption: 10–12 kW per module;

In a UK pet food installation, biofilters using coconut fibres have been applied to retain particles that would normally be emitted into the atmosphere, causing large volumes of odorous gases to spread across the local area, impacting on residents and other receptors. The biofilters are fitted with low air suction to extract air and the air is then passed through the filter which absorbs the odorous particles. With the application of biofilters, a 90 % reduction in complaints about odour has been achieved.

Section 4: Brewing

In the Section describing the applied processes and techniques in the brewing industry, odour is mentioned as possibly originating from the operations of malt mashing (4.2.1.4) and wort boiling (4.2.1.6).

Indeed, in the section describing current consumption and emission levels of the sector (4.3), there is a subsection specifically dedicated to odour (4.3.5.2), stating that the largest source of odour emissions is the evaporation of volatile organic compounds derived from wort boiling. Recovering heat from wort kettles saves energy by condensing approximately 95 % of the vapour. This also reduces odour emissions because condensable odorous vapours are removed from the exhaust air.

Other odour sources are waste water treatment, storage and handling of co-products (surplus yeast) and by-products (spent kieselguhr), oil storage, ventilation of beer cellars and packaging lines and emissions to air from the boiler house.

Techniques to consider in the determination of the BAT (4.4)

Among the techniques to increase energy efficiency (Section 4.4.1), the use of the mash infusion process (4.4.1.1) instead of the mash decoction process is reported to have lower odour emission levels. In the mash infusion process, milled malt is fed, together with warm brewing water, into the mash tun. This mash is heated to a temperature of 78 °C and is stirred constantly. The mash infusion process is carried out entirely in the mash tun. This process is an alternative to the decoction process where the thick part of the mash is separated and boiled in a dedicated mash kettle, i.e. heated to 100 °C.

Moreover, heat recovery from wort kettle vapour (4.4.1.3), is mentioned as one method to reduce odour emissions from wort boiling. Basically, such systems condensate the vapours generated from the boiling wort (e.g. by plate heat exchangers), thereby recovering heat. This also reduces odour emissions because condensable odorous vapours are removed from the exhaust air.

Section 7: Fish and shellfish processing

Odour is mentioned here as a possible concern for some installations.

Emissions to air (7.3.5)

The first subsection regarding air emissions is specifically dedicated to odour (Section 7.3.5.1).

Odour is often a significant form of air pollution in fish processing. Major sources include storage sites for processing waste, cooking of by-products during fish drying processes, and odour emitted during filling and emptying of bulk tanks and silos. Fish quality may deteriorate under the anaerobic conditions found in storage in fish processing facilities. This deterioration causes the formation of odorous compounds such as ammonia, mercaptans, and hydrogen sulphide gas.

The largest odour source in the fish by-products segment is the fishmeal dryers. Odorous gases from reduction cookers consist primarily of hydrogen sulphide (H_2S) and trimethylamine [$(CH_3)_3N$], but are emitted from this stage in appreciably smaller volumes than from fishmeal dryers. The canning processes also release some odours. Fish cannery and fish by-product processing odours can be controlled by means of afterburners, chlorinator-scrubbers, or condensers. The vented smoke also contains VOC. Some installations remove odours from the smoke before it is emitted to the air.

Techniques to reduce TVOC emissions from smoke kilns and odour (7.4.3.1)

Under the section regarding the techniques to consider in the determination of the BAT (7.4) odour is mentioned explicitly as one of the main pollutants to be reduced in air emissions.

The only techniques mentioned here are:

- Non-thermal plasma treatment (7.4.3.1.3), as described in the aforementioned Section 2.3.7.3.8 of the BREF document.
- Thermal oxidation of waste gases (7.4.3.1.3), as described in Section 2.3.7.3.6.

An example of installation is provided for the latter.

At an example smokehouse with an annual production of around 3 000 tonnes of smoked products, waste gases from smoking are burned using a direct flame thermal oxidiser.

The thermal oxidiser is heated to its operating temperature before the smoke generators are operated. During smoking, the exhaust gas fan force-feeds the smoke-laden waste gas through a waste gas bypass flap to a preheater. Here, the dirty gas is heated to 300–350 °C before it enters the combustion chamber, where it is mixed with the hot gases from the gas burner. After treatment, the clean gas is used to preheat the dirty gas by using an integrated heat exchanger and it is cooled to 400–450 °C before it is discharged to air via a flue stack.

It is reported that at 620–660 °C, complete removal of odour emissions is achieved. Direct flame thermal oxidation can be run at temperatures of up to 1 000 °C. The effectiveness of the technique depends on several parameters such as operating temperature, residence time and mixing conditions in the combustion chamber.

Section 10: Meat processing

Current consumption and emission levels (10.3)

In the section of general information about the current consumption and emission levels (10.3.1) the potential environmental effects of the typical processes applied in meat processing installations are reported.

Odour is mentioned in Table 10.3 of the BREF document as a potential environmental effect related to the processes of:

- Deep-frying
- Belt-frying
- Hot smoking
- Cold smoking

Section 10.3.1.5 regarding the emissions to air states that air pollution is produced mainly due to the operation of boilers and smoking chambers. Odour may be a nuisance. Refrigerants may leak, causing air pollution.

Techniques to reduce odour (10.4.3.2)

The only technique described under this section is the recirculation and burning of exhaust gases from frying (10.4.3.2.1), which implies that the air above a fryer is extracted and vented. This exhaust air typically contains VOCs and may lead to odour complaints, thus the recirculation of exhaust gases to the burner minimises these emissions.

Section 11: Oilseed processing and vegetable oil refining

Odour emissions (11.3.6.4)

The section about current consumption and emission levels of this sector (11.3) includes a subsection specific about odour emissions.

It states that odour is produced in all steps where heating is involved. It results from the volatile fatty acids, organic nitrogen compounds and, in the case of rapeseed, hydrogen sulphide and organic sulphur compounds.

The exhausts from aspiration systems in seed preparation and seed pressing, exhausts from meal drying and cooling and the exhaust from the mineral oil system are sources of odour emissions. Odour emissions are generally higher for rapeseeds than for soybeans due to the presence of sulphur-containing substances (H_2S) in the rapeseeds. The sulphur content of the rapeseeds may depend on the crop variety and agricultural practices applied. Sulphur-containing organic substances may decompose under the influence of seeds/meal being exposed to relatively high temperatures in seed heating, seed pressing, seed extraction and meal desolventizing-toasting and meal drying/cooling. Hydrogen sulphide can be a key odour component in the exhaust of the mineral oil system of a rapeseed crushing installation.

Hence, odour can be an issue when the emitting installation is relatively close to residential areas.

Reduction of odour emissions (11.4.2.3)

Within the section dedicated to the techniques to consider in the determination of the BAT (section 11.4), there is a subsection specifically about the reduction of odour emissions.

The techniques that are mentioned here are:

- Bioscrubbing (11.4.2.3.1), as described in the aforementioned Section 2.3.7.3.5 of the BREF document.
- Biofiltration (11.4.2.3.2), as described in Section 2.3.7.3.4
- Wet scrubber in combination with a biofilter (11.4.3.2.3). This technique involves the combined application of a wet scrubber followed by a biofilter to reduce odour emissions. An example is mentioned of a rapeseed installation in Germany reporting efficiencies above 99%.

No further details about these techniques will be given here, since they are already described in Deliverable D2.1 of this project.

Section 15: Sugar manufacturing

Regarding this sector, odour is mentioned among the possible emissions related to the drying of sugar beet pulp. In particular, the storage of wet pulp can cause odour problems.

Techniques to consider in the determination of BAT (15.4)

Among the techniques to increase energy efficiency (section 15.4.1), indirect (steam drying) of beet pulp (Section 15.4.1.2) is indicated as a process that reduces emissions of dust and odour. Indeed, the closed design of the steam dryer system has the advantage that the dust, odour and vented gases are controlled and can be eliminated. Odour is normally released with the gases vented following condensation of the steam generated in the sugar juice evaporation process. The odorous gas can be sent to the boilers for incineration or for removal in a small scrubber.

Also solar drying of sugar beet pulp (section 15.4.1.3), by stopping the conventional pulp dryer, results in a decrease in gas and electricity consumption as well as CO_2, particles and odour emissions.

On the other hand, high-temperature drying of sugar beet pulp (section 15.4.1.4), despite having the advantage of producing animal feed that can be stored for longer than moist feed, results in the emission of dust and odour.

Section 16: Additional sectors

Coffee manufacturing (16.3)

Odour is mentioned here as a potential emission from the coffee roasting process, which is a time-temperature-dependent process whereby chemical and physical changes are induced in green coffee beans.

The outlet of both the roaster and the cooler contain odour components. The concentration of VOC causing this odour is higher at the roaster outlet than at the cooler outlet. The absolute odour emission level depends on the product temperature at the end of the roasting; the amount of air used for roasting, which has a diluting effect; the product itself; and the roasting time. Nitrogen-based compounds, for example amines and sulphur-based compounds, e.g. mercaptans, contribute considerably to the odours emitted by coffee-roasting installations. In the raw gas, odorant contents of up to 300000 ou_E/m^3 have been measured.

Thermal and catalytic oxidation, biofilters and bioscrubbers are examples of end-of-pipe techniques used for reducing TVOC emissions to air. Biofilters and bioscrubbers have proven to be unsuitable for the treatment of waste gases from roasting. Thermal oxidation takes place at temperatures in excess of about 800 °C, and catalytic oxidation from about 350 °C, depending on the type of catalyst. To contain odour impact, for batch roasting or highly intermittent processes, the use of catalytic systems is a best available technique, although it gives rise to NO_X formation in high concentrations.

Section 17: Best Available Techniques (BAT) conclusions for the food, drink and milk industries

General BAT conclusions (Section 17.1)

BAT 1. In order to improve the overall environmental performance, BAT is to elaborate and implement an environmental management system (EMS).

Specifically for the food, drink and milk sector, BAT is to also incorporate an odour management plan (see BAT 15).

BAT 15. 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 (see BAT 1), that includes all of the following elements:

- A protocol containing actions and timelines.
- A protocol for conducting odour monitoring. It may be complemented by measurement/estimation of odour exposure or estimation of odour impact.
- A protocol for response to identified odour incidents, e.g. complaints.
- 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.

BAT 15 is only applicable to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

1.3 Production of Pulp, Paper and Board

Introduction

The processes and activities for the Production of Pulp, Paper and Board are a well-known odour emitting industries.

The Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board was published in April 2015 and explicitly mentions the word odours 138 times, and more in detail in:

- Common processes and techniques for the whole pulp and paper sector (Section 2), and especially in sections 2.2 “Monitoring”, Section 2.6 “Steam and power generation in pulp and paper mills”, Section 2.7 “Waste water treatment plants”, and Section 2.9 “General techniques to consider in the determination of BAT common to all mills”, where there is a subsection specifically dedicated to the reduction of odour (Section 2.9.14)
- Malodorous gases (Section 3.2.2.6.4)
- Collection systems for strong and weak malodorous gases (Section 3.3.15)
- Incineration of strong and/or weak malodorous gases in the recovery boiler (Section 3.3.16.1)

- Incineration of collected malodorous gases (strong and weak gases) in the lime kiln (Section 3.3.16.2)
- Incineration of collected strong malodorous gases in a dedicated NCG burner equipped with scrubbers for SO_2 removal (Section 3.3.16.3)

The Best Available Techniques (BAT) Conclusions were published in September 2014. Unlike the BREF document that is only available in English, these conclusions are translated into 23 languages.

This BREF about Production of Pulp, Paper and Board concerns the following activities specified in Sections 6.1.(a) and 6.1.(b) of Annex I to Directive 2010/75/EU, i.e. the integrated and non-integrated production in industrial installations of:

a) pulp from timber or other fibrous materials;
b) paper or cardboard with a production capacity exceeding 20 tonnes per day.

In particular, this document covers the following processes and activities:

- chemical pulping
  - kraft (sulphate) pulping process
  - sulphite pulping process
- mechanical and chemi mechanical pulping
- processing of paper for recycling with and without deinking
- papermaking and related processes
- all recovery boilers and lime kilns operated in pulp and paper mills

Locally, odour and noise nuisances from pulp or paper mills are expected to remain future priorities for environmental actions in the pulp and paper industry (section 1.7).

Section 2: Common processes and techniques for the whole pulp and paper sector

Emission sources covered (Section 2.2.1.1)

<u>Emissions to air</u>

For atmospheric emissions, several sources for channelled emissions have to be taken into account (mainly combustion processes). The major types of plants in pulp and paper mills that emit pollutants to the atmosphere are listed in Section 2.6.1, and are further discussed in Section 2.2.2.2.1, Section 2.2.2.2.2 and in more detail in the respective sections of the process-related Chapters 3 to 7 that deal with atmospheric emissions.

For a number of processes, diffuse emissions are also relevant and should be considered. Diffuse emissions can mainly play a relevant role in some chemical pulp mills (see Section 2.2.2.2.6 and Section 3.3.15). Collection, treatment and measurement of diffuse emissions from kraft pulp mills are described in Section 2.2.2.2.6 and Section 3.3.15. In most sulphite mills, almost all ground-level SO_2 and odour-containing gases are collected and incinerated or scrubbed (see Section 4.3.22). When reporting the total sulphur emissions from kraft pulp mills, in all the cases where weak gases are not (almost) completely collected and treated, malodorous gases from the large number of non-point sources should be periodically measured, assessed and reported separately. Odour nuisances give a first indication of diffuse emissions released from the processes.

Measurement of diffuse emissions in kraft pulp mills (Section 2.2.2.2.6)

Other cases

In European kraft pulp mills, there are differences in the reported total sulphur emissions, i.e. more or less of the emissions of different sulphur compounds are included in the reported sulphur releases. There are kraft pulp mills in Europe where collection and incineration systems for weak gases are still inadequate, causing high diffuse odorous emissions from the mill area. Typical sources are tank areas at mills with such a dispersed layout that, in practice, technologically and economically viable collection applications are more difficult to implement. In these cases, monitoring requirements should apply to all process-based diffuse emissions and, thus, diffuse emissions need to be measured or otherwise assessed. Determination of actual diffuse emissions is challenging due to the fact that the assessment of emitted gas volumes periodically is very difficult as the volumetric flow rate of the different emission sources varies over time. Sampling devices which can be used in such cases are sampling hoods, flux hoods or tunnels depending on the source design. Gas concentration analysis is carried out by standard methods in the laboratory. Also, direct measurement with e.g. portable FTIR might be applicable. In case of odour, the measurement can be carried out by dynamic olfactometry (EN 13725:2003). Dynamic olfactometry is the reference technique for measuring odours, and its description can be found in Deliverable 2.1 of this project.

As an indicative monitoring method, odour inspections by trained personnel can be carried out. The personnel should be trained to recognise the odour type of the diffuse emissions. If these odours are perceived at the border of the installation site the source of these emissions should be investigated. If the source is assessed as relevant, suitable measures should be taken to reduce or to avoid these emissions. A description of this procedure can be part of the environmental management system, where relevant.

Steam and power generation in pulp and paper mills (Section 2.6)

Under this section, odour is mentioned in the subsection about main fuels utilised and pretreatment (Section 2.6.1.1).

Excess heat (with low steam parameters, i.e. low pressure, low temperature) from the production process can be used for the drying of sludge and biomass, thus increasing the yield of high-pressure steam. Depending on the specific circumstances, waste gas from the pretreatment operations as well as from storage facilities can be used as combustion air, reducing odour and pollutant emissions.

Waste water treatment plants (Section 2.7)

Odour is mentioned here within Table 2.17 (Table 1 here), as a possible drawback related to the use of trickling filters.

Process	Application (average BOD inlet concentration)	Advantages	Drawbacks	Remarks
Low to medium capacity trickling filters	<400 mg/l	Simple construction; low energy consumption; cooling of the waste water, quick recovery after short-term toxic shock (1)	In some cases risk of clogging; odour caused by stripping, higher P emission required for optimum operation (1.0 – 1.5 mg/l)	Risk of clogging and odour are minimal with proper nutrient management. Lifetime expectancy of 15 years or more when properly operated

Table 2. Biological treatment of waste water from pulp and paper mills (Source: Table 2.17 of the BREF Reference Document for the Production of Pulp, paper and Board, 2015)

Substitution of potentially harmful substances with less harmful alternatives (Section 2.9.2.5)

Within the section describing the General techniques to consider in the determination of BAT common to all mills (2.9) odour is mentioned in the subsection regarding the substitution of potentially harmful substances with less harmful alternatives (Section 2.9.2.5).

Some non-exhaustive examples for positive experience with replacements of substances of concern are given.

One example provided (Example b) mentioning odour is about the use of catalytic disinfection to remove germs and biofilms.

Description: Using a solid metal catalyst and a hydrogen peroxide solution as an 'activator', microorganisms are killed by oxidation. Due to the positive charge of the catalyst the negatively charged microorganisms are drawn towards the catalyst, which will take electrons away from the microorganisms and thus partially destroy them. The remaining fragments and their biotenside properties will lead to a detachment of biofilms present in the water system. The biofilms in turn are then attracted by the catalyst and destroyed.

Achieved environmental benefits: no formation of hydrogen sulphide or odour, organic acids or other toxic products, no microbiologically induced corrosion, no undesirable side effects for humans, the environment or materials, H_2O_2 is considerably less dangerous than other biocides.

Driving force for implementation: Implementation of catalytic disinfection stops formation of toxic gases and odour, especially of hydrogen sulphide, and of microbiologically induced corrosion. Use of other biocides is not necessary. In some cases it was possible to reduce the consumption of flocculants.

Prevention of pollution risks from decommissioning (Section 2.9.12)

Here, odour is mentioned under the paragraph about Environmental performance and operational data.

It says that in one case, significant odour nuisances have been reported caused by an aerated lagoon where waste water was led during shutdown and that was left without maintenance. Now there is aeration in the lagoon to prevent the nuisance. A year after the shutdown, the odour was no longer noticed. Negative impacts can be avoided by restoring these kinds of ponds to a satisfactory state.

Section 2.9.14: Reduction of odour

Description

Pulp and paper production is often associated with bad odour by the public. The odour caused by the emissions of malodorous gases such as mercaptans and other reduced sulphur compounds that are released from kraft pulp mills are a particular nuisance due to their repellent odour and their low odour threshold of human detection. The collection and treatment of these malodorous gases are discussed in Sections 3.3.15 to 3.3.16.3.

Although the majority of the odorous compounds are reduced sulphur compounds (e.g. H_2S), there are also odorous compounds originating from the decay and decomposition of organic and biological matter. Decomposition occurs when the conditions become favourable for decaying and putrefying bacteria.

In the kraft pulping process (see Section 3.2.2.6.4), odour is primarily emitted with the release of total reduced sulphur (TRS) compounds from sources such as recovery boiler, lime kiln and a large number of diffuse sources of malodorous gases (continuously and intermittent). In the sulphite and neutral sulphite pulping process, fewer emissions of odour compounds occur. Odour and nuisance may arise due to the emissions of furfural mercaptans, hydrogen sulphide or sulphur dioxide. They are described in Sections 4.2.2.5 and 4.3.22 in more detail.

The main and the most frequently occurring odour emissions related to pulp and paper operations other than chemical pulping are odours from the sources listed below.

- Wood extractives (terpenes, etc.) emitted from wood handling and mechanical pulping.
- Volatile fatty acids from closed water circuits primarily in paper mills that use paper for recycling as fibrous raw material. The starch in waste paper and board can readily decompose to the odorous compounds.
- Decomposed organic products from various sources in waste water treatment and waste sludge handling.

It is important to highlight that this section mentions the importance of odour observations to monitor potential odour problems. It is written that, because complaints are an important trigger for actions to reduce odour, a system for complaint registration and handling is a useful tool to control the current situation, achieve improvements from applied measures and to document or prove the good performance of the mill.

I. Odours from wood handling and mechanical pulping

In units where logs, wood and wood chips are mechanically processed, volatile extractives are emitted into the air. These VOC are odorous. Odorous volatile wood extractives are emitted in debarking and chipping plants and from chip storages. Mechanical pulping by chip refining and log grinding emits odorous VOC. Methods to control VOC emissions from mechanical pulping, and thus odour emissions as well,include various destruction methods such as thermal oxidation. This technique is described in Deliverable 2.1 of this project.

However, in Europe there is no known pulp or paper mill controlling their odours related to VOC emissions. Elsewhere, for example in UPM-Kymmene, Blandin Paper Mill and New Page, Duluth Paper Mill,a Regenerative Thermal Oxidiser (RTO) controls VOC from the main grinder stack (PGW mill) and grinder chamber evacuation vent.

II. Odours related to high degree of water systems closure

In paper mills with closed water systems, dissolved matter accumulates in the circulating white water systems. The concentration increases as a function of system closure until it reaches a stable plateau. In some recycled fibre mills with a high degree of closure, the organic dissolved matter reaches COD concentrations of 40000 mg/l. The availability of this biodegradable organic material under warm and anaerobic conditions is favourable for the decomposition (hydrolysis) of organic matter by acidifying bacteria to volatile organic acids. Carbohydrates are converted to volatile fatty acids such as butyric acid, lactic acid, acetic acid and propionic acids, all of which are odorous.

Possible techniques for preventing or reducing odour in paper mills with closed water circuits are given below.

- Proper design of paper mill processes with focus on optimal sizing and choice of equipment to avoid prolonged retention times, dead zones or areas with poor mixing in water circuits and related units in order to avoid uncontrolled deposits in pipes and chests.
- Design requirements and criteria related to closed-mill processes and the associated 'water-sensitive' operation are crucial to reduce odour problems (not only odour, but also corrosion, scaling and deposits, and to improve process runnability and availability in general).
- Optimal management and operation of the white water system including control and monitoring of inputs, flow rates, and white water characteristics. This also includes maintenance and cleaning of equipment and internal selective clarification of process waters in some cases.
- Use of biocides to control bacteria growth. Biocides will inhibit bacteria growth in water systems but will not reduce concentrations of dissolved matter. Application points of biocides are wire pit, broke, long circulation, etc. The use is often intermittent and 'shock dosing' is often favoured over continuous treatment in terms of costs and efficiency.

- Use of oxidising agents to control odour and bacteria growth. Oxidisers such as hydrogen peroxide may be used to manage local odour problems. Some paper mills successfully apply catalytic disinfection in their water systems for the reduction of microbiological growth.
- Use of calcium nitrate in white water towers and pulp storage towers, if H_2S is formed.
- Installation of internal treatment processes ('kidneys') to reduce concentrations of organic matter and consequently odour problems in the white water system. Internal processes may involve either membrane separation or biological (anaerobic/aerobic) treatment or a combination of both. Internal biological treatment combined with measures to control calcium precipitation are efficient methods for lowering white water COD. Internal biological treatment is applied in some closed or low-effluent paper mills (RCF DE 6, VPK Oudegem, BE, and Papelera de la Aqueria, ES). It should be considered that total closure of the waterloops may have negative effects on paper quality, require additional equipment to operate and some extra chemicals, and may decrease the runnability of the paper machines. In the US there are closed-cycle paper mills with membrane technology in combination with biological treatment (McKinley paper company, New Mexico, USA), see Section 6.3.4.
- Open the closed cycles to bleed out impurities.

Only the last two options quantitatively reduce the dissolved matter and thus also impact positively on wet-end chemistry, chemical consumption and corrosion.

III. Odours related to waste water treatment and sludge handling

In waste water treatment there are several potential areas and reasons for odour generation. In general, conditions where waste water or sludge become anoxic or anaerobic are likely sources of odours.

In waste water treatment, the sources of odours given below have been observed.

- Emission of volatile waste water compounds such as reduced sulphur compounds from sewer systems and pretreatment units. Incoming waste water typically has a high temperature and emissions of odorous gaseous compounds may occur in:
    - mixing waste water streams in the sewer (different pH or different temperatures)
    - open sewers or sewer vents◦primary clarifiers (open surface and overflow
    - waste water cooling towers
    - surface aeration in equalisation tanks.
- Emission of odorous compounds formed through anoxic decomposition of organic matter and under reducing conditions in secondary treatment processes and sludge handling including:
    - anoxic degradation of sludge in primary clarifier
    - insufficient airflow or overloading of trickling filters
    - poor aeration and/or mixing in aeration tank
    - extended retention time of sludge in secondary clarifier
    - sludge storage vents◦sludge dewatering units
    - spill basins

- emission of odorous compounds from sludge dryers.

Possible methods for managing odours related to waste water treatment and sludge handling are:

- Sewer systems and primary treatment:
  - Ensure proper design of sewer systems (controlled vents, closure); this may be an issue for older mills with complex and sometimes open sewer systems.
  - Use of chemicals to prevent/reduce formation of hydrogen sulphide in sewer systems, or to oxidise it. Hydrogen sulphide may either originate from the process upstream or form under the conditions prevailing in the sewers. This measure is only carried out in a few specific problematic cases. Ferrous salts (like $FeCl_2$), pure oxygen and blends of nitrate have been used successfully in this application and also in sludge storage tanks or primary settling tanks with odour problems.
  - If possible avoid air cooling towers for untreated effluent. However, cooling is often required before biological treatment and in some cases due to recipient limitations. Direct cooling of untreated effluent (after primary clarification) in cooling towers is a relatively frequently applied method both in paper and pulp mills in Europe. The alternative is indirect cooling with heat exchangers where the recovered heat may be reusable in other processes. The main operational issues are related to clogging/scaling, and availability needs to be considered in design. Examples of mills applying heat exchangers for effluent cooling are Norske Skog, Follum mills (NO), Billerud AB, Gruvön mill (SE), Palm Eltmann mill (DE)and Stora Enso Oulu and Veitsiluoto mill (FI).
  - Avoid extensive aeration/maintain sufficient mixing in equalisation basins. Good mixing can be achieved, e.g. with submerged mixers. If mixing performance is not adequate, deposits on the bottom can be observed in some cases. Also, extensive aeration in equalisation tanks is a source of odour since the effluent at this point still contains odorous reduced sulphur compounds.

- Secondary treatment process methods:
  - Ensure proper aeration capacity and mixing properties. Very often in paper mills there are changes over time in the production rate, specific pollution loads and/or flow rates which gradually take the actual operation off its optimal operation window. A regular reassessment of the aeration system with regard to this issue is therefore recommended. Aeration systems with surface aerators are especially prone to inefficient aeration and mixing.
  - Ensure proper operation of secondary clarifier sludge collection and return sludge pumping.
  - Limit retention time of sludge in sludge storages by sending the sludge continuously to the dewatering units. Retention of excess biological sludge in storage tanks or thickeners should be limited to a maximum of 3 –5 days. In the case of young sludge age in treatment or if other sludges are mixed into it, even shorter retention periods may be required.

    - Avoid storing waste water in the spill basin longer than necessary. Effluent streams directed to the spill basin tend to be exceptional in composition (high COD, extreme pH, etc.). These streams may become odorous relatively quickly while sitting in the basin. Also, additional streams with low pH may generate the emission of hydrogen sulphide from the basin. As a general rule, the spill basin should always be kept empty and available in case of an accidental spill.
- Use of sludge dryers:
    - Treatment of thermal sludge dryer vent gases by scrubbing and/or biofiltration (such as compost filters). Vent gases from (biological) sludge dryers have a specific unpleasant odour. Vent gas scrubbing and/or biofiltration are potentially efficient treatment methods. In the pulp and paper industry, there are a few mills with thermal sludge drying after mechanical dewatering. In Norske Skog, Follum mills, NO, the excess biosludge and chemical sludge is dewatered mechanically and then thermally in a dryer. Vent gases are treated in a scrubber and a compost filter. The Botnia/UPM-Kymmene Rauma mills, FI, are other examples.

Driving force for implementation

In most cases, the driving forces for implementation of the measures are complaints about unpleasant smells from communities living near the pulp and paper mills. Occupational health and safety and national legislation may be another reason for reducing odour, e.g. in Germany, the Guideline on Odour in Ambient Air, GOAA (in German: Geruchsimmissionsrichtlinie, stipulates that the assessment of the concentration of unpleasant smells in the environment and the derived requirements for odour-emitting plants be performed in a uniform way (definition of odour measurements, frequency, duration, character and intensity of the odour; maximum tolerated odour nuisances). H_2S emissions are not only an odour issue, but also a health issue which has to be addressed for workers' protection (see the Council Directive 98/24/EC).

Example plants

Many pulp and paper mills in Europe have implemented a number of the measures to prevent, control and reduce odour problems in the vicinity of the mills. However, odour is still a cause for complaints in the vicinity of some paper mills. For some of the measures, example mills are referred to under the 'Description' heading above.

Section 3: The Kraft (sulphate) pulping process

Today the kraft process is the principal chemical pulping process worldwide due to the superior pulp strength properties compared with the sulphite process, its applicability to all wood species, as well as to the efficient chemical recovery systems that have been developed and implemented. But the chemistry of the kraft process carries with it an inherent potential problem in the form of malodorous compounds. However, modern mills with an optimised gas collection system can limit unpleasant odours in the neighbourhood to process disturbances or other than normal operating conditions.

By-products of kraft pulping (Section 3.1.10)

This section mentions some by-products of the kraft pulping process having unpleasant odours, such as for instance Crude tall oil (CTO) and Crude sulphate turpentine (CST).

Crude tall oil (CTO) is produced by acidulation of tall oil soap in a batch or continuous process. Crude tall oil is a tar-like dark brown liquid with high viscosity and an unpleasant odour of sulphur compounds from the pulping process. Crude tall oil is normally sold to the chemical industry and the pitch fuel, generated while distilling crude tall oil, is used as a biofuel at the mills. Some pulp mills burn crude tall oil directly for bioenergy.

Crude sulphate turpentine (CST) originates from volatile organic compounds in the pulpwood (conifer). In the pulping processes the wood chips are heated and the terpenes are volatilised. The composition varies depending on the wood species used. α-Pinene is the main component in crude sulphate turpentine. Crude sulphate turpentine contains significant amounts of malodorous sulphur compounds and has a very unpleasant odour and a dark colour.

Overview of input/output for the production of kraft pulp (Section 3.2.1.)

Malodorous gases are collected and burnt. Burning diluted NCG generates no/little net energy and they are mainly burnt for environmental protection reasons and to avoid unpleasant odours in the neighbourhood and for workers. Concentrated NCG (CNCG) have a heat content of 50 –200 MJ/ADt and can replace up to 15 –20 % of the fuel oil used in the lime reburning kiln.

Malodorous gases (Section 3.2.2.6.4)

The problem of kraft mill odour originating from the sulphide in the white liquor, an aqueous solution of sodium hydroxide (NaOH) and sodium sulphide (Na_2S), during pulping has long been an environmental and public relations issue for the pulp and paper industry. It is caused predominantly by malodorous reduced sulphur compounds produced in the kraft pulping process, or total reduced sulphur (TRS), namely, methyl mercaptan (MM), dimethyl sulphide (DMS), dimethyl disulphide (DMDS), and hydrogen sulphide (H_2S). MM, DMS and DMDS are the main volatile organic sulphur compounds and are formed in the pulping process, while hydrogen sulphide is formed in the downstream processes where the pH of the mill streams are reduced to below 10. Although a significant reduction of TRS emissions has been achieved in the pulp and paper industry from approximately the year 2000 to 2010 with advanced collection and odour abatement techniques, subjective nuisance at very low concentrations still causes odour problems in communities surrounding a kraft mill. Furthermore, because of the enhanced sensitivity of the human nose to sulphur compounds due to the variability of odour emissions from day to day, kraft mill TRS emissions will always be a sensitive subject in dealing with the public and surrounding communities.

Two general approaches are implemented in kraft mills to abate odour: thermal oxidation and absorption using scrubbing technologies. Thermal oxidation of TRS is achieved by two steps: collecting non-condensable gases (NCG) in various emission vents and eliminating odorous compounds in the NCGthrough combustion to convert them into non-odorous compounds. Absorption is mainly implemented to destroy H_2S and MM in diluted NCG by scrubbing using a spray tower or packed column.

Odour-and sulphur-containing gases are briefly summarised below.

Concentrated malodorous gases (CNCG)

Malodorous gases - often referred to as non-condensable gases (NCG) - contain gases released during the manufacturing of kraft pulp and volatile compounds entering with the wood. The gases released during cooking, black liquor handling and causticising, i.e. hydrogen sulphide, methyl mercaptan, dimethyl sulphide and dimethyl disulphide, are strongly odorous compounds, which give malodorous gases their characteristic aroma. The volatile compounds entering with the wood raw material, i.e. turpentine and methanol, are not odorous in a pure state, but in pulp mills they contain impurities in the form of odorous components.

Section 3.3: Techniques to consider in the determination of BAT

Stripping the contaminated (foul) condensates and reusing the condensates in the process (Section 3.3.11)

Description

Condensates can be classified as follows.

- Primary condensates: live-steam condensates that are normally clean enough to be reused as boiler feedwater (after polishing).
- Secondary condensates: contaminated steam condensates that are flushed from black liquor, pulp suspensions, etc. Only the dirtiest part of the condensate is stripped.

Stripping systems usually remove malodorous gases (TRS) and COD-contributing substances at the same time. Stripped condensates after treatment can be 1 – 1.5 kg COD/m^3 of condensate. The stripped gases can be inserted into a CNCG treatment system and handled appropriately, i.e. incinerated in a dedicated burner, the recovery boiler or the lime kiln.

Cross-media effects

When steam stripping is used, the non-condensable gases (NCG) have to be incinerated separately in order to avoid the release of concentrated TRS gases into the atmosphere. This is discussed in more detail in Sections 3.3.16.2 and 3.3.16.3. When the stripping of concentrated, contaminated condensates is applied the load to the waste water plant will be reduced and, if there are difficulties to meet the permit conditions, new investments in the effluent treatment plant may be avoided. This also means that less energy is needed for aeration and less energy and chemicals in the sludge treatment. Fugitive TRS emissions from waste water treatment plants can be reduced by the steam stripping of condensates which removes TRS compounds from foul condensates. The stripping of condensates reduces the low level emissions of TRS compounds from foul condensates. The TRS compounds include hydrogen sulphide, methyl mercaptan, dimethyl sulphide and dimethyl disulphide. These emissions are partially responsible for the foul odours from a kraft mill.

Technical considerations relevant to applicability

Steam stripping is a viable in-plant treatment method for reducing COD and odour from kraft mill foul condensates. The process can be applied at both new and existing kraft mills. The condensate stripping column can be separate or it can be integrated into the evaporation plant. In the former case, live steam would be required whereas in the latter case, secondary steam from evaporator effects can be used. However, thermal oxidation of the vapours from the stripper system is necessary. Lime kilns, power boilers and separate TRS incinerators can be used for this purpose.

Driving force for implementation

The majority of kraft pulp mills in Europe carry out steam stripping of contaminated condensates from the cooking and evaporation plant. The stripping of contaminated condensates efficiently removes its odorous components. Stripped condensates may be reused in unbleached and bleached pulp washing and in causticising processes thus achieving reduced water consumption.

Collection systems for strong and weak malodorous gases (Section 3.3.15)

Description

In efficiently designed and operated gas collection systems it is possible to collect and eliminate malodorous gases almost completely. Collection and incineration can cover more than 99 % of the total production-process-based emissions of gaseous sulphuric compounds.

Useful treatment methods are incineration in the recovery boiler (see Section 3.3.16.1), lime kiln (see Section 3.3.16.2) or dedicated TRS burners (see Section 3.3.16.3). Also, scrubbers are used for cleaning dissolving tank vent gases or for reducing SO_2 emissions from the separate TRS burner, the lime kiln or the recovery boiler. An overview of the efficient layout and operation of these gas collection systems is given below.

I. Collection of concentrated malodorous gases

The target is to collect all the concentrated malodorous gases because they have a very high sulphur content.

Collection points for the strong gases in the fibre line are:

- digesters from the flash steam condenser
- turpentine decanters
- foul condensate tanks
- turpentine scrubbers
- tank fumes

The collection point in the chemical recovery line is the foul condensate system, e.g. the foul condensate tanks (for example from evaporation and the recovery boiler), the foul condensate stripper and its condensers.

Gas ducts are equipped with water locks which condense some of the gases and also ensure that the gases flow in the right direction. Ejectors feed the gases to incineration (recovery boiler, lime kiln or separate TRS burner). Collection channels are also equipped with droplet separators and flame arresters, which prevent flames from going backwards in channels (as concentrated malodorous gases contain a large proportion of inflammable gas).

II. Collection of dilute malodorous gases

In effective gas collection systems, almost all dilute or light malodorous gases are collected from the fibre line, the chemical recovery island and the causticizing plant area.

a) The collection points in the fibre line: The collection points in the fibre line are the digester area, the brown pulp washers (for example diffuser or press washers or drum displacer washers), washer tanks, filtrate tanks, the wash liquor tank, knot return tank, oxygen delignification feed tank, and collection liquor tanks. All these emission sources are connected to the weak gas collection system.

b) Collection points in the chemical recovery line: The collection points from the evaporation plant and the tall oil production area include a large number of the tank system's gas release points, e.g. the black liquor, strong liquor and condensate tanks, the intermediate liquor, weak liquor, spill liquor and tall oil soap storage tank, the soap equalisation tanks and the tall oil and soap oil tank. Other collection points are the tall oil cooking gas scrubber, the tall oil reactor and the oil separators. The collected dilute gases are sent to the recovery boiler as combustion air.

c) Collection points in the causticizing plant: A very effective and thorough gas collection system also includes an almost complete collection of all weak malodorous gases in the causticizing plant. The causticising fumes have lower malodorous sulphur contents than other sources. Collection points from the causticizing plant tank area are green liquor tanks, green liquor dreg filters, dreg tanks, green liquor filters, green liquor filtrate tanks, hot water tanks, green liquor oxidation (if existing) and its steam condenser, lime-slaker and its washer, slacker steam washer, causticisation tanks, lime mud filter, white liquor tanks, lime mud storage tank, dilution water tanks, acid tank, canal ventilation system and heat exchanger before the lime kiln. Only in the newest mills are all low concentration malodorous gases in the causticizing plant collected. Typically, causticizing fumes have very low malodorous sulphur contents. Collection from the causticizing plant tank area is almost as effective as the full collection.

d) Dissolving tank vent gases: The dissolving tank vent gas (DTVG) also contains high amounts of TRS-sulphur and particulates (mainly sulphates). Vent gases have not traditionally been classified as non-condensable gases. However, if the vent gas is sent to the recovery boiler furnace, it must be handled in accordance with the instructions for handling dilute non-condensable gases because of its high moisture content. Often these vent gases were only treated successfully with scrubbers. Alternatively, DTVG can also be burnt in more recently built recovery boilers and those modified for DTVG incineration, after removing moisture and particulate matter. This technique has been installed in existing recovery boilers in the Varkaus and Rosenthal mills for example (at an approximate cost of EUR 1 – 2 million per mill to install new fans, cooler, ducts and condensate separation).

If DTVG are burnt in the recovery boiler, a fan draws the vent gases from the dissolving tank, a condenser reduces the moisture of the gas and a scrubber reduces the particulate matter. Then the cleaned vent gas is combined with preheated air and a fan blows the air/gas mixture via ducts to the furnace. As an alternative route, the vent gas can be sent through the scrubber and then to the roof.

Achieved environmental benefits

An efficient gas collection and treatment system is essential for both sulphur emission and odour control. It limits the odour nuisance in the neighbourhood. The collection of malodorous gases has a significant impact on improving the air quality. Mills with an advanced collection system for light and highly concentrated malodorous gases can reduce the duration of odour nuisances to <1% of the operating time.

Environmental performance and operational data

The main target is the almost complete collection and treatment of malodorous gases. Because of the high sulphur and odour content of the strong malodorous gases, these gases should be collected (collection efficiency of >99%) and treated with the highest availability (>97%). For strong gases, back-up systems should be in place and be able to start operation as fast as possible, if needed.

Low concentration malodorous gases should be collected and treated from all other points. Normally, low concentration malodorous gases do not have a back-up system for treatment because the odorous effect is not as strong as it is when the higher concentrations of TRS are released. Efficient systems have an automated monitoring system for the immediate detection of undesired releases which are then reported directly to the control room. Dilute TRS gases should have a high gas collection efficiency (>95 %) and suitable treatment. The availability of the treatment system for light malodorous gases should be over 90 % of the operating hours.

Otherwise the nuisance caused by these emissions to the community is significant. Sulphur emissions are significantly lower with an efficient malodorous gas collection and treatment system.

The equipment of the malodorous gas system also has to comply with security regulations, concerning work safety and inflammable liquids and gases. It must be reliable, properly designed (e.g. sufficient blower capacity to reach the targeted suction performance is vital) and operated by specially trained staff. It is essential that the appropriate process design solutions for malodorous gas systems be accompanied by correct and careful operation by the operators of the plant.

Odorous gases contain a significant portion of water vapour. They also contain organic compounds that readily condense in typical operational conditions. It is important to design the collection system in such a way that dirty condensate can be effectively removed and treated.

The condensate system needs to be designed so that backflow of air (dry out) during condensate removal can also be eliminated during mill shutdown. Many of the operational accidents occur during mill start-up or upsets through condensate formation and re-evaporation.

Maintenance of the gas collection system is important to achieve the best performance and high availability. In strong gas systems, air leakages may cause gas dilution and the gas-air mixture to become potentially explosive. Therefore gas channels are to be kept in perfect condition. In dilute gas channels the problem is different: in process disturbance situations, gases may accumulate in a high concentration and enter the explosive zone. Under normal operating conditions, the weak malodorous gas system is operated at low pressure. Undesired leakages should be monitored continuously and automatically, e.g. by mini-anemometers for flow rate measurements in the pipe system, shuttle valves and the measurement of temperature changes in case of releases, etc.

One of the most important issues is the capacity of the collection system. A common mistake is to select dimensions which are too small for the collection ducts and process equipment, since normally all mills eventually produce more than the original capacity. Also the blower capacity must be sufficient to hold the whole system under low pressure.

To ensure a high availability of the system, water locks should be large enough so that the gases flow as expected. If not, malodorous gases may enter the wrong places in the process or go directly to air and cause a foul odour. The water level in locks should be monitored continuously.

Scrubbers and their nozzles also need surveillance and maintenance, especially when white liquor is used as a washing liquid (white liquor has a higher solids content than in NaOH). The operation of a scrubber should be monitored with measurements and, depending on the gas, the TRS reduction should be at least 50 %, since dimethylsulphide and dimethyldisulphide do not wash out.

The verification of the effectiveness of the collection system and the operating hours that weak gases are vented out via the stack can be calculated in an accurate way by the process automation of the mill.

Cross-media effects

The efficient collection of malodorous (sulphur-containing) gases may cause a disequilibrium in the sulphur/sodium balance. If excess sulphur accumulates in the process, the excess sulphur may require removal from the process, e.g. by leaching the recovery boiler ash.

Incineration of malodorous gases in the recovery boiler may affect the sulphur and NO_X emissions from the recovery boiler.

Incineration of sulphur-containing gases reduces the carbonate content and pH of the recovery boiler's precipitator ash. Before deciding whether to incinerate malodorous gases in the recovery boiler, it would be advisable to study in detail the recovery boiler's capacity to handle the additional sulphur load. Sulphur emissions from the recovery boiler can be reduced by decreasing the sulphidity of black liquors, by increasing the DS content of the concentrated black liquor or by the use of scrubbers.

In stable operation, sulphur emissions are low when incinerating concentrated malodorous gases, provided that the dry solids content of the combustion liquor is at least 72 % and the liquor load is almost full, at a sulphidity of ~40.

If malodorous gases are incinerated with a partial load, the pH and carbonate content of the electrostatic precipitator ash, and the SO_2 content of flue-gases have to be evaluated case by case. A boiler operating continuously at partial load requires higher dry solids than a boiler operating at nominal load or above, in order to secure a trouble-free operation.

Especially concentrated malodorous gases contain nitrogen compounds. These nitrogen compounds consist mostly of ammonia, which is separated from black liquor in the evaporation plant.

Dilute malodorous gases contribute to less than 1 % of the NO_X emissions of the recovery boiler. Their effect on the TRS load of the recovery boiler is significant only when the boiler is outside the normal operation zone, i.e. running at low capacity.

Technical considerations relevant to applicability

The systems described can be installed in new and existing mills. In many older mills some of the washing equipment is of the open type. Collection of vent gases from these sources of dilute gases requires the handling of very high air volumes which may be both technically and economically difficult.

Economics

In some cases, a more complex mill layout can complicate the collection of all the dilute malodorous gases. The piping cost and blower requirements may rise significantly in these cases.

Driving force for implementation

Improved sulphur recovery, which has cost advantages (but may also cause imbalances with regard to the S/Na control). Advanced malodorous gas collection and treatment improves the reputation of kraft pulp mills and the likelihood of general acceptance of their operation in the neighbourhood.

Incineration of strong and/or weak malodorous gases in the recovery boiler (Section 3.3.16.1)

Description

The CNCG can be introduced into the secondary air level of the recovery boiler, which uses their energy content and converts the reduced sulphur compounds into sulphur dioxide. When the dry solids content of the black liquor is high enough (see Section 3.3.17.1), the SO_2 emissions are practically unaffected when CNCG are burnt in the recovery boiler. No further abatement technique (e.g. a scrubber) is required for keeping sulphuric emissions very low (close to zero).

Collected diluted malodorous gases (DNCG) can be incinerated as secondary or tertiary air in the recovery boiler. Depending on the volume of DNCG and the layout of the pulp mill, some mills operate several TRS destruction systems for different departments.

Achieved environmental benefits

Efficient odorous gas collection from all sources and effective treatment minimises sulphur emissions (TRS) and odour nuisances in the neighbourhood.

Environmental performance and operational data

The incineration of both strong and weak gases in the recovery boiler is used at many mills without problems. After burning NCG in the recovery boiler, they are almost completely destroyed and TRS emissions are mostly below 5 mg TRS/Nm^3 (6% O2), determined as an annual average value, and do not cause any more unpleasant smells in the neighbourhood.

The flow rate of the tertiary air level of the recovery boiler where the DNCG may be incinerated is limited and therefore other burning alternatives may be needed as well.

Cross-media effects

Burning malodorous gases in a recovery boiler is a potential source of additional NO emissions because of the ammonia contained in odorous gases. The latest experiments, however, indicate that an increase in NO can mostly be avoided if the malodorous gases are injected in the correct way and in the right location in the furnace of the boiler.

Incineration of collected malodorous gases (strong and weak gases) in the lime kiln (Section 3.3.16.2)

Description

The collected strong odorous gases can be incinerated as secondary air in the lime kiln. Some mills also incinerate the weak odorous gases in the lime kiln, others use alternative methods (e.g. recovery boiler, scrubbers). Depending on the volume of DNCG and the layout of the pulp mill, some mills operate several gas treatment systems for different departments

Achieved environmental benefits

Efficient odorous gas collection from all sources and effective treatment minimises sulphur emissions (TRS) and odour nuisances in the neighbourhood.

Environmental performance and operational data

An example of the availability of an odorous gas treatment system is shown in Figure 3.46 of the BREF document (Figure 4 here).

In this case, the CNCG are burnt in the lime kiln and a dedicated boiler is used as a back-up. The back-up boiler is kept at 11 bar pressure with steam. From 'stop' to 'odorous gas burning' warming of the back-up boiler takes one hour. If burning of the strong odorous gases is not possible, they are vented via a 120 m high stack.

All DNCG are treated in washers (one in the fibre line, one in evaporation and two in the causticising area). If burning in the recovery boiler is not possible, then the gases are vented to the atmosphere via a120 m high stack.

The collection of CNCG is 100 %, and the collection degree for DNCG is almost 100 %. For three months in a two-year period, the CNCG treatment availability was below 97 % but it still reached this target value when considering the calendar year as a whole. The treatment availability for DNCG treatment was comparable or even higher than for CNCG during the reported period although the permit requires only > 90 % availability, i.e. <10 % of the DNCG can be vented to the stack and thus into the atmosphere. An availability of 100% means that the odorous gas treatment systems are on all the time and no odorous gases are vented into the atmosphere. The reasons for decreased availability in this example mill were equipment failures (e.g. April – July 2008, evaporation unit failure), other process problems and start-up time intervals.

The verification of the effectiveness of the treatment system and the operational time that weak gases are vented out via the stack can be calculated by the process automation of the mill. Figure 4 shows an example of such a monitoring system.

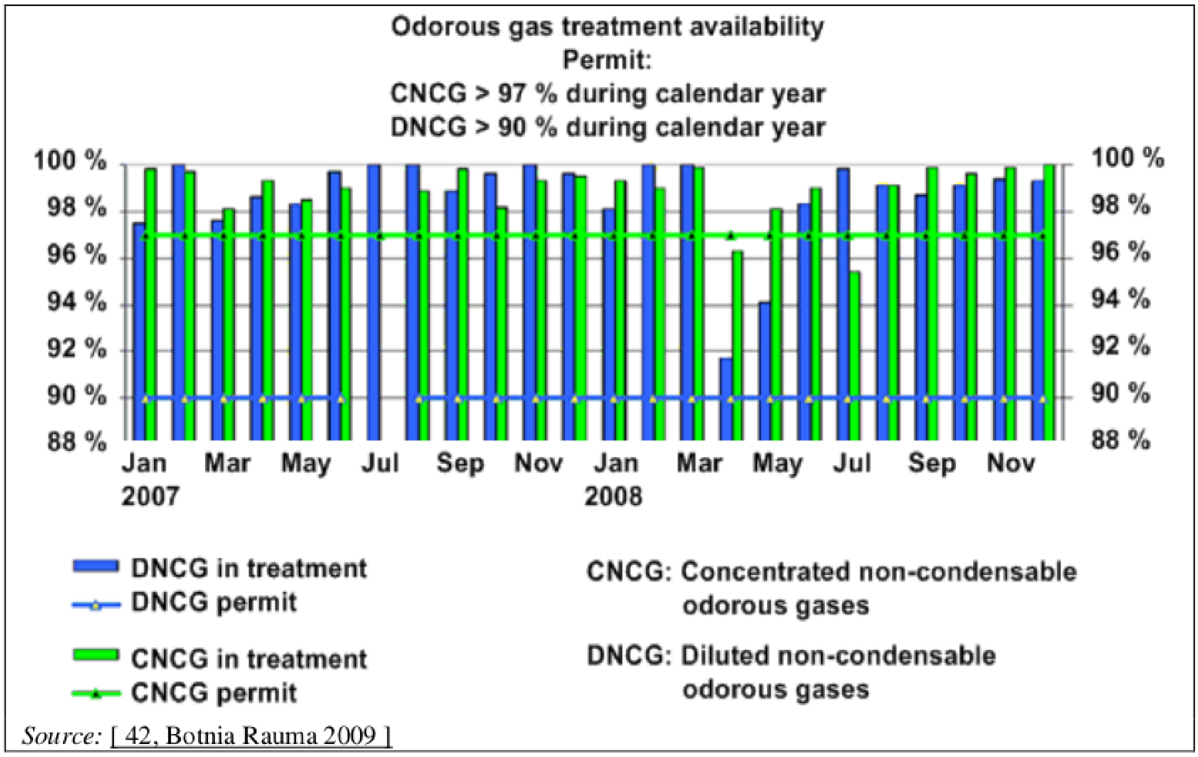

Figure 4. Example of permit requirements and achieved availability of an odorous gas treatment system (Source: Figure 3.46 of the BREF Reference Document for the Production of Pulp, paper and Board, 2015)

Cross-media effects

In most cases, burning malodorous gases in a lime kiln results in an increase in the NO level. Developing low-NO_X technology for lime kiln burning when both malodorous gases and the main fuel are present will require additional measures.

The advantage of burning the odorous gas in the lime kiln is that no extra furnace is needed. The drawback is that sulphur in the gas can only be partially absorbed in the lime. This is because the main sulphur-absorbing compound in the lime kiln is the calcium carbonate ($CaCO_3$) in the lime mud which has a weak absorption capacity. When this capacity is exhausted, SO_2 increases when strong non-condensable gases are incinerated in the kiln. SO_2 emissions correlate with the amount of odorous gas flow. To minimise the formation of SO_2, either the sulphur content in the fuel can be reduced or the sulphur compounds can be scrubbed out of these gases prior to burning in the lime kiln.

Incineration of collected strong malodorous gases in a dedicated NCG burner equipped with scrubbers for SO_2 removal (Section 3.3.16.3)

Description and achieved environmental benefits

The incineration of non-condensable gases, which has the advantage of reducing odour and sulphur emissions (see Sections 3.3.16.1 and 3.3.16.2), can also be carried out in a dedicated burner equipped with a SO_2 scrubber. The dedicated NCG burner utilises the heat value of the CNCG to supply the boiler.

Environmental performance and operational data

In one example, the pulp mill operates two independent, dedicated TRS burners for the incineration of the strong gases, thus guaranteeing process redundancy (reserve capacity in case of failures). The two burners use a joint steam boiler for heat recovery and a joint scrubber. Additionally, there is a torch in place in case of operational disturbances or system malfunctions. If there are still un-burnt strong gases in case of failures, they are released via the stack.

The weak gases are burnt completely in the recovery boiler. Because of the high volumetric rate of the weak gases, no back-up system is in place. Under normal operating conditions there are no odour problems recorded for the mill; for operational disturbances there are specific permit requirements to meet.

Reduction of sulphur emissions (SO_2 and TRS) from the lime kiln (Section 3.3.20)

Selection of fuels and control of the excess oxygen (Section 3.3.20.1)

SO_2 emissions can be prevented or reduced by either using fuels with a low-sulphur content or, if odorous non-condensable gases (NCG) are burnt in the lime kiln, scrubbing out of sulphuric gases prior to burning in the lime kiln.

Flue-gases from the lime kiln may contain minor amounts of hydrogen sulphide due to incomplete washing of lime mud. Many mills also burn strong odorous gases in lime kilns which introduce total reduced sulphur compounds into the kiln.

Installation of improved washing and filtration of lime mud in recausticising (Section 3.3.20.2)

This can help to reduce H_2S (TRS) and odours from the flue-gases of the lime kiln.

H_2S formation in the lime kiln can be controlled by the oxygen level and the amount of remaining sodium sulphide (Na_2S) in the lime mud fed into the cold drying and heating sections of the lime kiln.

Use of an alkaline flue-gas scrubber (Section 3.3.20.3)

If strong non-condensable gases (CNCG) are burnt in the lime kiln, sulphur compounds can be reduced by the use of wet alkaline scrubbers prior to burning in the lime kiln. A small internal

NaOH scrubber for the malodorous gas flow (i.e. not for the total flue-gas flow) will reduce H_2S almost completely, the methyl mercaptan by 70 –90 % while the removal rate for methyl sulphides is lower. An alkali scrubber in one or two washing stages can remove SO_2 effectively from lime kiln flue-gas. The incoming level of SO_2 determines the number of spraying nozzles in the scrubber and the alkali charge. The SO_2 removal efficiency of alkaline wet scrubbers is >90 %.

Selection of fuels, optimised combustion and control of the kiln operation (Section 3.3.21.1)

Description

An integrated recausticising system includes the coordination of the lime mud washing and filtration (see Section 3.3.20.2), selection of fuels, choice of the location where non-condensable gases are burnt (see Section 3.3.16.2) and control of the kiln operation in order to stabilise the process, attain an even lime quality and also achieve low total emissions to air.

I. Selection of fuels

The selection of fuels has a significant effect on the emission from the lime kiln. Burning oil in a lime kiln produces lower NO_X emissions than natural gas, even though oil contains significant quantities of organic nitrogen that are not present in natural gas. This is because of the higher temperatures of the natural gas flame, which causes the formation of more thermal nitrogen oxide than the burning of oil. The firing of the lime kiln with sawdust, pulverised wood or gases obtained by gasification of biomass (bark) also increases NO_X emissions.

In most cases, burning malodorous gases in a lime kiln results in a significant increase in the NO level as the malodorous gases carry additional nitrogen to the kiln. Developing low-NO_X technology for lime kiln burning, when both malodorous gases and the main fuel are present, will require additional investment, and there was no reliable technical solution available at the time of writing (2013).

Electrostatic precipitators followed by wet scrubbers (Section 3.3.22.2)

This leads to the simultaneous removal of sulphuric emissions and odour.

Dedusting of the flue-gas is mostly carried out by means of ESPs but in some mills it is further cleaned with wet scrubbers. As washing liquor, Na(OH) is usually used. The separation efficiency of the wet scrubber also depends on the particle size of the dust and on the dimension (and thus the pressure loss) and efficiency of the last drip catcher.

Section 4: The Sulphate Pulping Process

Technical processes and units (Section 4.1.2)

Sulphite pulping consists of three main entities: the fibre line, the chemical and energy recovery units (excluding calcium sulphite pulping where recovery is not economically possible but where the spent cooking liquor can be evaporated and the components used for other purposes) and waste water treatment plant. As in kraft pulping, some auxiliary systems like reject handling, manufacturing of bleaching chemicals and power generation are connected to the main process steps.

The focus in this section is on the differences between kraft and sulphite pulping. The major differences between the two chemical pulping processes from an environmental point of view are to be found in the chemistry of the cooking process, the chemical recovery system and the fewer bleaching sequences and chemicals required because of the better initial brightness of the sulphite pulp (lower amounts of chromophores in the sulphite pulps). Furthermore, the sulphite process normally releases less odour emissions compared to the kraft process. These differences result in different emission ranges and some differences concerning the abatement techniques applied.

Consumption and emission levels arising from process units (Section 4.2.2)

This section refers to all types of sulphite pulp mills, including NSSC mills.

In sulphite pulping, energy consumption, waste water effluents, emissions generated from the handling of the spent liquor (if calcium is used as a base) and the emissions to air are the main points of interest. For the neighbourhood, odorous gases, noise or annoyances associated with transport of the raw materials and end products may also raise concerns. Indeed, odorous gases and diffuse emissions are mentioned among the most significant emissions of this type of process.

Emissions to air (Section 4.2.2.5)

The major point sources for emissions to air are the recovery boiler, the bark or biomass boiler and other steam blocks for steam production, but potential releases of emissions to air from a number of processes are also to be taken into account.

Sulphur emission levels from sulphite mills and the potential for further reductions are highly dependent on the type of mill. Due to differences between different sulphite processes, the emission levels might show higher variations than in kraft pulp mills.

The emissions released to the atmosphere depend to a large extent on the collection and abatement system used for treatment of gaseous emissions. The following devices and systems can be found in sulphite pulp mills for collecting and purifying emissions to air.

- Cyclone for chip blowing
- The gases from the continuous pressure control relief of the digesters are led to combustion in the recovery boiler or to the primary recovery system where acid from secondary recovery is fortified. In the primary recovery system, the cooking acid is fortified by SO_2 from the relief gases of the digesters and also by SO_2 from the evaporation plant (for increasing total and free SO_2).
- Collecting system for aerating gases from digesters, blow tanks, knot screens, washing filters, all weak and thick liquor tanks and fibre filters. In most cases, these gases are led to combustion in the recovery boiler. In a few cases, these gases are led to wet scrubbers that use NaOH or H_2O_2 as absorption liquid (abatement of SO_2 and also of odour).

- Scrubbers for the absorption of sulphur dioxide in aerating gases from the bleach plant.
- Non-condensable gases from the evaporation are led to combustion in the recovery boiler or to the primary recovery system for acid fortification.
- Absorption of SO2 in the flue-gases leaving the recovery boilers in the acid preparation plant (venturi scrubber system).
- Collection system for ventilation gases from the liquor and condensate tanks of the boiler house, from the weak liquor filter and the mix tank. The gases are led to combustion in the recovery boiler.
- Dust separation from flue-gases from the auxiliary boiler (burning bark, oil or other fuels) with an electrostatic precipitator (ESP) and wet scrubber.
- NO_X reduction in the bark boiler by injection of urea or ammonia (SNCR), and by recirculation of flue-gases.
- Water seals can also be applied as a method to decrease fugitive emissions from the digester.

Emission of odorous gases

Emissions of odorous gases in sulphite pulping are normally limited compared to kraft pulping. However, emissions of furfural mercaptan and H_2S might cause odour and emissions of gaseous sulphur may also cause annoyances. At many mills, emissions of odorous gases are collected and burnt in the recovery boiler (all German and Austrian mills). Another option is treatment in wet scrubbers.

Section 4.3: Techniques to consider in the determination of BAT

Some of the techniques for prevention and reduction of emissions from kraft pulp mills are similar to the measures that can be applied in sulphite pulp mills.

There are particular differences between kraft and sulphite technologies, as for example, collection of ground-level odorous and diffuse process SO_2 gases and combustion in the recovery boiler or washing in scrubbers.

Some techniques of kraft pulping are not valid at all for sulphite pulp mills such as, the collection and incineration of odorous gases in the lime kiln (see Section 3.3.16.2) and the incineration of odorous gases in a separate furnace including a scrubber (see Section 3.3.16.3).

Anaerobic treatment of the condensates and the high COD load in the effluent from the bleach plant (Section 4.3.15)

Stripping of contaminated condensates and reuse of condensates in the process reduces the fresh water intake of a mill and the organic load to the waste water treatment plant. In a stripping column, steam is led counter-currently through the previously filtered process condensates which contain reduced sulphur compounds, terpenes, methanol and other organic compounds.

The volatile substances of the condensate accumulate in the overhead vapour as non-condensable gases and methanol and are withdrawn from the system. The stripped non-condensable gases from the most concentrated condensates are fed into the collection system for strong malodorous gases and are incinerated. Stripped gases from moderately contaminated condensates are collected in the low volume high concentration gas system (LVHC) and incinerated.

Optimising the recovery boiler by controlling the firing conditions (Section 4.3.18)

The combustion of the concentrated spent liquor is carried out in an oxidising atmosphere with a slight excess of oxygen (2 – 7 %). Odorous organic substances that are released from the spent liquor and from ground-level weak gases in many mills are also burnt in the recovery boiler. For load compensation or start-up operation, fuel oil or natural gas is added. During combustion the cooking chemicals are nearly completely (95 – 97 %) split into a solid (MgO ash) and a gaseous phase (SO_2 in the flue-gas). All the MgO is in the fly ash that is separated by use of electrostatic precipitators or multicyclones, dissolved in water and subsequently used for scrubbing SO_2 out of the flue-gas. The recovered cooking chemicals MgO and SO_2 are sent back to the cooking plant.

Collection of odorous gases and diffuse process SO_2 emissions and combustion in the recovery boiler or washing in scrubbers (Section 4.3.22)

Aside from the recovery boiler and the bark boiler, there are other relevant potential releases of SO_2 generated in the process: fugitive releases, i.e. not channelled gas from the acid liquor production, digesters, diffusers or blow tanks, contain high SO_2 concentrations. Lower SO_2 concentrations can be released from the brown stock washing. The higher the concentration of SO_2 in the cooking liquor, the higher the potential fugitive emissions from the processes. For example, the gases withdrawn from the cooking plant contain a significant percentage of the sulphur dioxide charged to the digester as a cooking chemical. They are usually collected and recovered in absorption tanks with different pressure levels both for economic and environmental reasons. SO_2 releases from washing and screening operations and from the vents of some of the steps of the evaporators can also be recovered by collecting the gases and introducing them in the recovery boiler as combustion air. The sulphur dioxide is then recovered from the exhaust gas of the recovery boiler by counter-current multistage scrubbers and reused as a cooking chemical. The overflow can be sent to a one-or two-stage alkaline scrubber (NaOH) which is designed as a kind of back-up system that can be charged with the SO_2-containing exhaust gas in case of failures of the recovery boiler. This gas treatment is not an option for pulp mills which use calcium as a base and do not operate a recovery unit but produce products from all of the spent sulphite liquor. Measures to control the diffuse process of SO2 emissions include recovery and reuse of SO_2 gas from stripping of the SSL after evaporation as a cooking chemical. Some minor quantities of SO_2 (large volumes, low concentration) go to the scrubber system(s). This means that in the case of a calcium mill with a biorefinery concept, the diffuse emissions from the digester section and the ethanol plant should be at the same level as the emissions from a mill with a soluble base and a recovery system.

Odorous gases arise from the same processes as the SO_2-containing gases that are simultaneously released from these processes. Many mills have installed a system for the collection of various vent gases from different processes. The majority of these diffuse odorous gases are collected by the weak gas collection system and used as combustion air in the recovery boiler.

Odorous gases arise in the cooking plant, the evaporation plant, at diffusers and in the brown stock washing. The reduction of odorous gases is carried out mainly by collecting the most relevant fugitive gases and leading them to combustion in the recovery boiler where the exhaust gases are treated by multistage flue-gas scrubbers. Other measures are water seals in the back-pressure pipe from digesters or flue-gas scrubbers for the fugitive emissions from the digesters.

Section 5: Mechanical Pulping and Chemomechanical Pulping

Emissions to air Volatile organic compounds (VOC) (Section 5.2.2.4)

In Europe, there is no known pulp or paper mill that reported on special control measures for their odours related to VOC emissions. Elsewhere, for example in UPM-Kymmene, Blandin Paper Mill and New Page, Duluth Paper Mill, a regenerative thermal oxidiser (RTO) controls VOC from the main grinder stack (PGW mill) and the grinder chamber evacuation vent. No more specific data could be gathered.

Section 6: Processing of Paper for Recycling

Examples of systems for processing paper for recycling (Section 6.1.3)

<u>Packaging paper and board (Section 6.1.3.1)</u>

For the production of packaging paper or board from paper for recycling, i.e. Testliner and corrugated medium, only mechanical cleaning is applied, i.e. no de-inking process is needed. During pulping, coarse rejects are separated and the flake (flock) size is pre-calibrated. The following multistage cleaning and screening system removes heavy particles (e.g. sand), flat disturbing components, stickies, fine sand and leads to deflaking of the stock with good optical homogeneity. For Test liner and fluting systems, some mills are operating with totally closed water loops. Other mills have reopened the closed water loops because of operational difficulties and odour problems.

Consumption and emission levels arising from individual process units (Section 6.2.2)

Odour from vapours and from waste water treatment plants is mentioned among the aspects of concern associated with paper manufacturing based on recovered fibre processing.

Emissions to air (Section 6.2.2.7)

Odour from vapours and from waste water treatment plants, especially in the case of closing up the water circuits below a water consumption of around 4 m^3/t, odours caused by lower organic acids and H_2S may be perceived in the vicinity of paper mills. But annoying odours may also be found in paper mills with less water circuit closure. They may be caused by excessive retention times of process water in the water system (pipes, chests, etc.) or deposits of sludge causing the build-up of hydrogen sulphide. If so, they can be avoided by suitable process engineering measures (see Section 2.9.14 on the reduction of odour). The waste water treatment plant of RCF paper mills may also emit significant quantities of odour. If the waste water and sludge treatment is well designed and controlled, annoying odours can be prevented.

Section 6.3: Techniques to consider in the determination of BAT

Optimal water management, water loop separation and arrangement, counter-current flows and internal water clarification (Section 6.3.3)

The water loops in the production of RCF-based paper can be laid out for minimised fresh water consumption (see also Section 2.9.3 and 2.9.4). In today's water loop systems, process water is reused several times. This requires the continuous monitoring of the process water quality. In many paper mills fresh water is only used for boiler feedwater, the dilution of chemical additives and at locations of the paper machine where a highly solid-free water quality is necessary, e.g. spray pipes and edge sprays.

However, closing up the process water system offers both advantages and disadvantages.

The increase of odour problems due the build-up of organic substances is cited among the disadvantages related to water system closure in paper mills.

Enhanced water system closure leads to a considerable loading of the process water with colloidal and dissolved organic and inorganic compounds which may cause serious problems in the production process if no control measures to avoid possible drawbacks are undertaken.

In totally closed water systems (only applicable for Testliner and Wellenstoff production), additional operational problems may occur which need to be controlled including:

- significant decrease of the oxygen content of the process water, approaching anaerobic conditions associated with a microbiologically induced reduction of sulphate to hydrogen sulphide and the formation of odorous, low-molecular fatty acids;
- significant emission of odorous organic compounds from the dryer section of the paper machine to the surroundings of the paper mill;
- impaired quality of the paper produced, affected by odorous compounds.

In-line biological process water treatment for closed water loops (Section 6.3.4)

Description

A few paper mills producing Wellenstoff and Testliner in Europe and North America had been successful in bringing their waste water discharges to zero and operating a 'closed water system'. However, the inevitable accumulation of dissolved and colloidal organic matter in closed water circuits creates, in most cases, severe problems such as corrosion, unpleasant odours in the paper produced and also in the vapour exhaust of the paper machines. In order to reduce the organic pollution of the process water, treatment techniques ordinarily used for end-of-pipe waste water treatment are adapted to in-mill treatment. A partial stream of the process water (e.g. one third of the white water volume) is treated in biological treatment plants and the purified water is reused for paper production. The main advantage of in-line treatment is that only a part of the COD load from a purge of white water needs to be eliminated to keep a given level of contaminants in the circuits. This makes the in-line waste water treatment plant economically attractive.

Environmental performance and operational data

Internal biological treatment is reported as an efficient method to lower white water COD and consequently odour problems.

Cross-media effects

Anaerobic techniques for in-line treatment reduce the generation of excess biomass to a minimum. The excess biomass can either be reused for paper production or incinerated. The energy demand of the in-line treatment plant (pumps, aerators, agitators) is completely covered by the thermal use of the generated biogas. Compared to the totally closed water system without in-line treatment, the concentration of odorous compounds in the process water (e.g. formic acids, acetic acid, propionic acid and lactic acid) can be reduced by 95%. This results in a significant decrease in emissions of these organic substances in the vapour exhaust of the paper machine. Thus, unpleasant odours can be reduced significantly.

Aerobic biological waste water treatment (Section 6.3.8)

In aerobic biological waste water treatment, the biologically degradable load is reduced in the presence of oxygen by digestion by microorganisms, generating biomass, carbon dioxide and water.

Aerobic biological waste water treatment consumes energy (e.g. for aerators and pumps) and generates sludge that normally requires treatment before utilisation or disposal. Especially during the summer period, the waste water treatment plant of RCF paper mills may emit annoying odours. If the waste water treatment is well designed and controlled, annoying odours can be avoided (see Section 2.9.14).

Section 7: Papermaking and Related Processes

Consumption and emission levels (of paper mills) (Section 7.2.2)

Odour from vapours and from waste water treatment plant (local) are mentioned among the aspects of concern associated with paper manufacturing.

Emissions to air (Section 7.2.2.7)

Odours from vapours and from waste water treatment plants (local)

In paper mills, odours may be emitted (see Section 2.9.14). They may be caused by excessively long retention times of process water in the water system (pipes, chests, etc.) or deposits of sludge causing the build-up of volatile organic acids (volatile fatty acids, primarily acetic and propionic acids). These compounds may be formed by microbial action on organic substances (notably starches) under anaerobic conditions, which may be released at the wet end, during paper drying and during effluent treatment. To a small extent, hydrogen sulphide could also be generated under anaerobic conditions. If so, odours can be avoided by suitable process engineering measures. The waste water treatment plant may also emit significant quantities of odour. If the waste water treatment is well designed and controlled, annoying odours can be avoided.

Section 7.3: Techniques to consider in the determination of BAT

Control of potential negative side effects from closing water circuits (Section 7.3.2)

The enhanced recycling of process water in paper and board machines causes a rise in the concentration of colloidal and dissolved organic and inorganic constituents in these streams. Depending on the characteristics of the pulp in-feed and the used chemicals in papermaking, the closed-up water systems can have an adverse effect on the runnability of the machine, the quality of the end product and even the production costs due to increased use of chemicals. These potential negative effects need to be controlled.

The risk of scaling caused by calcium compounds, slime and pitch problems is pronounced and must be counteracted with an appropriate mixing of water fractions, pH control, increased dosage of machine aids or an appropriate purge of calcium out of the system. If the machine can be operated at over 50°C, the growth of microorganisms and their activity in the water system is diminished. But anaerobic activity may still occur above 50°C (thermophilic bacteria), generating odour in the sulphur-and carbohydrate-rich environment that needs to be controlled.

Aerobic biological waste water treatment (Section 7.3.11)

Aerobic biological waste water treatment consumes energy (e.g. for aerators and pumps) and generates sludge that normally requires treatment before utilisation or disposal. Especially during the summer period, the waste water treatment plant of paper mills may emit annoying odours. If the waste water treatment is well designed and controlled, annoying odours can be avoided (see Section 2.9.14).

Section 8: Best Available Techniques (BAT) Conclusions for the Production of Pulp, Paper and Board

Following definitions are used in this section:

- <u>Non-condensable odorous gases (NCG)</u>: Non-condensable odorous gases, referring to malodorous gases of kraft pulping.

- Concentrated non-condensable odorous gases (CNCG): Concentrated non-condensable odorous gases (or 'strong odorous gases'): TRS-containing gases from cooking, evaporation and from stripping of condensates.
- Strong odorous gases: Concentrated non-condensable odorous gases (CNCG).
- Weak odorous gases: Diluted non-condensable odorous gases: TRS-containing gases which are not strong odorous gases (e.g. gases coming from tanks, washing filters, chip bins, lime mud filters, drying machines).

General BAT conclusions for the pulp and paper industry (Section 8.1)

Water and waste water management (Section 8.1.3)

BAT 5. In order to reduce fresh water use and generation of waste water, BAT is to close the water system to the degree technically feasible in line with the pulp and paper grade manufactured by using a combination of the techniques given below.

	Technique	Applicability
f	Reusing process water to substitute for fresh water (water recirculation and closing of water loops)	Applicable to new plants and major refurbishments. Applicability may be limited due to water quality and/or product quality requirements or due to technical constraints (such as precipitation/incrustation in water system) or increase odour nuisance

Emissions of odour (Section 8.1.5)

BAT 7. In order to prevent and reduce the emission of odorous compounds originating from the waste water system, BAT is to use a combination of the techniques given below.

	Technique
I Applicable for odours related to water systems closure	
a	Design paper mill processes, stock and water storage tanks, pipes and chests in such a way as to avoid prolonged retention times, dead zones or areas with poor mixing in water circuits and related units, in order to avoid uncontrolled deposits and the decay and decomposition of organic and biological matter
b	Use biocides, dispersants or of oxidising agents (e.g. catalytic disinfection with hydrogen peroxide) to control odour and decaying bacteria growth
c	Install internal treatment processes ('kidneys') to reduce the concentrations of organic matter and consequently possible odour problems in the white water system
II Applicable for odours related to waste water treatment and sludge handling, in order to avoid conditions where waste water or sludge becomes anaerobic	

a	Implement closed sewer systems with controlled vents, using chemicals in some cases to reduce the formation of and to oxidise hydrogen sulphide in sewer systems
b	Avoid over-aeration in equalisation basins but maintain sufficient mixing
c	Ensure sufficient aeration capacity and mixing properties in aeration tanks; revise the aeration system regularly
d	Guarantee proper operation of secondary clarifier sludge collection and return sludge pumping
e	Limit the retention time of sludge in sludge storages by sending the sludge continuously to the dewatering units
f	Avoid the storage of waste water in the spill basin longer than is necessary; keep the spill basin empty
g	If sludge dryers are used, treatment of thermal sludge dryer vent gases by scrubbing and/or biofiltration (such as compost filters)
h	Avoid air cooling towers for untreated water effluent by applying plate heat exchangers

BAT conclusions for kraft pulping process (Section 8.2)

<u>Reduction of emissions in strong and weak odorous gases (Section 8.2.2.1)</u>

BAT20. In order to reduce odour emissions and total reduced sulphur emissions due to strong and weak gases, BAT is to prevent diffuse emissions by capturing all process-based sulphur containing off-gases, including all vents with sulphur-containing emissions, by applying all of the techniques given below.

	Technique	Description
a	Collection systems for strong and weak malodorous gases, comprising the following features: covers, suction hoods, ducts, and extraction system with sufficient capacity; continuous leak detection system; safety measures and equipment.	
b	Incineration of strong and weak non-condensable gases	Incineration can be carried out using: • recovery boiler • lime kiln[(1)] • dedicated NCG burner equipped with wet scrubbers for SO_X removal; or • power boiler[(2)] To ensure the constant availability of incineration for odorous strong gases, back-up systems are installed. Lime kilns can serve as back-up for recovery boilers; further back-up equipment are flares and package boiler
c	Recording unavailability of the incineration system and any resulting emissions[(3)]	

(1) The SO_X emission levels of the lime kiln increase significantly when strong non-condensable gases (NCG) are fed to the kiln and no alkaline scrubber is used. 2) Applicable for the treatment of weak odorous gases. (3) Applicable for the treatment of strong odorous gases

Reduction of emissions from a lime kiln (Section 8.2.2.3)

BAT 24. In order to reduce SO_2 emissions from a lime kiln, BAT is to apply one or a combination of the techniques given below.

	Technique	Description
a	Fuel selection/low-sulphur fuel	See Section 8.7.1.3
b	Limit incineration of sulphur-containing odorous strong gases in the lime kiln	
c	Control of Na_2S content in lime mud feed	
d	Alkaline scrubber	

Reduction of emissions from a burner for strong odorous gases (dedicated TRS burner) (Section 8.2.2.4)

BAT 28. In order to reduce SO_2 emissions from the incineration of strong odorous gases in a dedicated TRS burner, BAT is to use an alkaline SO_2 scrubber.

BAT 29. In order to reduce NO_X emissions from the incineration of strong odorous gases in a dedicated TRS burner, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a	Burner/firing optimisation	See Section 8.7.1.2	Generally applicable
b	Staged incineration	See Section 8.7.1.2	Generally applicable for new plants and for major refurbishments. For existing mills, applicable only if space allows for the insertion of equipment

BAT conclusions for the sulphite pulping process (Section 8.3)

For integrated sulphite pulp and paper mills, the process-specific BAT conclusions for papermaking given in Section 8.6 apply, in addition to the BAT in this section.

Emissions to air (Section 8.3.2)

BAT 35. In order to prevent and reduce diffuse sulphur-containing and odorous emissions from washing, screening, and evaporators, BAT is to collect these weak gases and to apply one of the techniques given below.

	Technique	Description	Applicability
a	Incineration in a recovery boiler	See Section 8.7.1.3	Not applicable to sulphite pulp mills using calcium-based cooking. These mills do not operate a recovery boiler
b	Wet scrubber	See Section 8.7.1.3	Generally applicable

Description of techniques for the prevention and control of emissions to air (Section 8.7.1)

NO_X (Section 8.7.1.2)

Technique	Description
Incineration of odorous gases and TRS	Collected strong gases can be destroyed by burning them in the recovery boiler, in dedicated TRS burners, or in the lime kiln. Collected weak gases are suitable for burning in the recovery boiler, lime kiln, power boiler or in the TRS burner. Dissolving tank vent gases can be burnt in modern recovery boilers
Collection and incineration of weak gases in a recovery boiler	Combustion of weak gases (large volume, low SO_2 concentrations) combined with a back-up system. Weak gases and other odorous components are simultaneously collected to be burnt in the recovery boiler. From the exhaust gas of the recovery boiler, the sulphur dioxide is then recovered by counter-current multistage scrubbers and reused as a cooking chemical. As a back-up system, scrubbers are used

Description of techniques to reduce fresh water use/waste water flow and the pollution load in waste water (Section 8.7.2)

Process-integrated techniques (Section 8.7.2.1)

Technique	Description
Stripping the contaminated (foul) condensates and reusing the condensates in the process	Stripping the contaminated (foul) condensates and reuse of condensates in the process reduces the fresh water intake of a mill to the waste water treatment plant. In a stripping column, steam is lead counter-currently through the previously filtered process condensates that contain reduced sulphur compounds, terpenes, methanol and other organic compounds. The volatile substances of the condensate accumulate in the overhead vapour as non-condensable gases and methanol and are withdrawn from the system. The purified condensates can be reused in the process, e.g. for washing in the bleach plant, in brown stock washing, in the causticising area (mud washing and dilution, mud filter showers), as TRS scrubbing liquor for lime kilns, or as white liquor make-up water. The stripped non-condensable gases from the most concentrated condensates are fed into the collection system for strong malodorous gases and are incinerated. Stripped gases from moderately contaminated condensates are collected into the low volume high concentration gas system (LVHC) and incinerated

2. COLLECTION OF GOOD PRACTICES IN ODOUR POLLUTION 2

This chapter has the aim to collect examples of good practices in odour pollution from the consortium partners. As already explained in Deliverable D2.3, the collection of examples turned out to be more difficult than expected, and the COVID-19 breakout didn't help to overcome such difficulties. However, one more exhaustive example regarding a landfill located in Southern Italy is reported and discussed.

2.1 Foreword

The difficulties related to the collection of best practices on odour management from the Consortium partners were already described in the previous deliverable regarding Good practices in odour pollution (Deliverable D2.3). Unfortunately, such difficulties were not overcome in the second part of the project. For sure the COVID-19 breakout, having limited all possibilities of meeting people, didn't help much, either. That is the reason why we were only able to collect one more example of good practice in odour pollution. The example was collected thanks to partner AMIGO, and concerns a landfill in Southern Italy. The example will be further described in the next paragraph.

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

EXAMPLE 6: Landfill ITALCAVE in Southern Italy

1) ABSTRACT

In a non-hazardous waste landfill, an integrated odour monitoring system comprising 2 Instrumental Odour Monitoring Systems (IOMS), two H_2S continuous analysers and two automatic air samplers has been operating since 2018. Automatic air samplers are activated when two consecutive measurements of 20 ppb at 5 min intervals are measured by the H_2S continuous analyser, or when the odour concentration measured by IOMS exceeds 500 ou_E/m^3 for more than 5 min.

Problems with odour emissions were noticed in May-August 2019 with almost a daily automatic samplers' activation, often correlated with complaints of population. Moreover, monitoring campaigns of biogas from the landfill surface, carried out in the same time span according to the UK Environment Agency "Guide to monitoring surface gas emissions in landfills", showed significant increase of surface emissions for certain zones, implying that surface and fugitive emissions from the landfill biogas (LFG) collecting system could have been responsible for such odour emissions.

In September 2019 a Leak Detection and Repair survey was carried out, based on OGI (Optical Gas Imaging) technology that uses high resolution and sensitivity infrared image acquisition and processing to detect the predominant presence of methane in biogas on a stretching band C-H bond: during the campaign for measuring surface biogas emissions, which involved sampling from 167 points over a 84570 m^2 surface, a careful monitoring of wellhead and pipes junctions was carried out with OGI technology.

Pressure distribution data in the LFG piping network along with data collected by thermographic survey were used to identify sources of significant emissions, due essentially to poor biogas uptake caused by pressure unbalance in the collection system and to fugitive emissions from wellhead and pipes connections.

A contingency plan was carried out in order to balance the suction pressures from the critical zones of the landfill, by modifying the position of LFG blower flares, expanding the biogas capture network with new wells and checking/repairing the valves and connections of wellfield system.

The effectiveness of such improvements was monitored in the following months in terms of reduction of surface emissions and odor nuisances, quantitatively measured by IOMS fence monitoring and automatic samplers' activations.

2) PROBLEM DESCRIPTION:

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

The study was carried out in a landfill in the municipality of Taranto, in Puglia Region (South Italy), 1000 m far from the first receptors (scattered houses) in the town of Statte. The site is a single basin divided into two operating lots with 213'000 m^2 surface and capacity of 6.2 Mm^3 of waste. At the date of the 31st December 2020 the total residual volume is 0.35 Mm^3.

The landfill receives non-hazardous waste, mostly sewage sludge and wastes deriving from mechanical-biological treatment of urban wastes.

The LFG wellfield system at the time of the study (Summer 2019) comprised a network of 301 vertical wells in the landfill, coupled with conveyance piping for the transport of LFG to energy recovery equipment (two engines of 1.065 MW and 0.995 MW, recovering 1000 Nm^3/h) and 3 blower-flare facilities with nominal capacity of 2000, 1000 and 500 Nm^3/h, respectively.

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

Problems with odor emissions were noticed in May-August 2019 with almost a daily automatic samplers' activation, often correlated with complaints of population. Also, emission rates of LFG from the surface showed significant increase in the same period. The citizens involved in the odour nuisance live in scattered houses 1000 m from the landfill.

3) REPORTING PHASE:

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

The problem was raised both through the complaints of the population and through several exceedances of the threshold set by the monitoring network located at the landfill fence. The complaints were reported by means of a smartphone App, which will be better described below.

4) MONITORING PHASE:

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

The landfill has an Odor Monitoring Plan developed in three lines of actions: 1) Source monitoring (emission from the landfill surface), 2) Fence monitoring and 3) receptors monitoring.

1. Source monitoring: campaigns of biogas from the landfill surface are carried out according to the UK Environment Agency "Guide to monitoring surface gas emissions in landfills",
2. Fence monitoring: the odor monitoring system, comprising 2 IOMS, 2 H_2S continuous analyzers and two automatic air samplers, has been operating since 2018: automatic air samplers are activated when two consecutive measurements of 20 ppb at 5 min intervals were measured by the H_2S continuous analyzers or when overall odor emissions measured by IOMS exceeded 500 ou_E/m^3 for more than 5 min. Sampling can be activated also on demand by local Environmental Protection agency,
3. Receptors monitoring: the community nearby the landfill can signal odour occurrence and record the frequency, intensity and type of the perceived odour by a smartphone app, which also records time, date, location and description of the odor perceived. The App, called "Nosy", was developed by the landfill management and made available for free to the residents.

- What was the result of the monitoring phase?

1. Source monitoring: methane surface emissions in the most critical zones, located close to the LFG vertical wells, exceeded the limit set by LFTGN 07 (0.1 $mg/m^2/s$), although the landfill, as a whole, never exceeded such value.
2. Fence monitoring: In the May-August period, 117 exceedances of the set values for H_2S or odour were recorded, with an average of 30 per month.

3. Receptors monitoring: 44 reports of citizens with the App “Nosy” occurred in the same period, 35 of them identified as high intensity.

5) EVALUATION PHASE:

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

The data from automatic monitoring system at the fence were elaborated by means of statistical analysis to evaluate the influence of meteorological conditions (wind speed and directions, barometric pressure, temperature); a correlation was also found between the critical odour events (i.e. exceeding the limits set for IOMS and H_2S analyzer) and the reports from the receptors.

Moreover, the fact that source emissions from the landfill zones close to the LFG well were higher was a hint suggesting that the LFG collection system had problems.

During July-August 2019, a preliminary screening with a thermographic detection technique was carried out. OGI (Optical Gas Imaging) technology uses high resolution and sensitivity infrared image acquisition and processing to detect the predominant presence of methane in biogas: an IR EyeCgas model was used with a cooled optical sensor and with a differential thermal sensitivity <12mK at 25°C and Minimum Detectable Leak Rate of 0.35 g/h of Methane.

Since the technique showed good results, on September 2019 a ‘high spatial resolution survey’ of Leak Detection and Repair (LDAR) was carried out: in the latter case, the investigation with OGI technology was carried out during the campaign for measuring surface biogas emissions from 167 points over a 84570 m^2 surface, also involving a careful monitoring of wellhead and pipes junctions of LFG collection system.

- What was the outcome of the data analysis?

Based on the LDAR campaign in September 2019, fugitive LFG emissions measured with a portable FID were detected and results were grouped into classes by concentration. Relevant emissions were found in well-defined areas of the landfill because of two flaws of the LFG collection system: a) surface emissions caused by poor biogas capture and b) leaks from wellhead/pipes junctions. In order to ascertain whether poor biogas capturing was the main cause as compared to valve/fittings fugitive emissions, the barometric pressure of each wellhead was detected: barometric pressure of a properly operating wellhead is slightly negative/zero (around -0.1 mbar). Extremely negative values (less than -0.1 mbar) cause an over-expiration of the area with possible introduction of air by surface, then lowering the calorific content of the gas. Values around 1 mbar indicate an unsuitable suction capacity with likely release of biogas from the surface surrounding the wellhead: a strong correlation between barometric pressure and biogas emissions was found, i.e. high emissivity zones (>10000 ppm) were characterized by positive (around 1 mbar) barometric pressure, whereas zones with low emissions showed slightly negative pressure values. Pressure distribution data in the LFG piping network along with data collected by thermographic survey and FID analysis allowed to clarify that poor biogas capture caused by pressure unbalance in the collection system (rather than valve/fittings fugitive emissions) was the cause of high LFG surface emissions, causing, in turn, odour nuisances.

6) RESOLUTION PHASE:

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

In October 2019 the following actions were undertaken in order to improve the LFG pipe network and balance the suction pressures from the critical zones of the landfill: 1) drilling new uptake wells; 2) modifying the position of LFG blower-flares in order to optimize the distances between low-efficiency capture zones and blowers. 3) Checking and repairing the valves and connections of wellfield system was also carried out, particularly in the northern landfill sector, close to the northern boundary.

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

A consulting Engineering and Chemistry company, together with the developer of the EyeCgas Gas detection Camera were involved in the identification of the problem and preliminary design of the solution, whereas the design and improvement of the LFG pipe network collection was carried out by the landfill engineers.

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

The costs (around 180 k€) were sustained by the landfill. All the works were carried out in September-October 2019.

7) VERIFICATION PHASE:

- Did the solution work? Was the impact reduced?

The solution did work and the impact was reduced.

- How was the effectiveness of the applied solution monitored?

The effectiveness of the solution was measured at the source, at the fence and at the receptors:

  - Source. The 75th percentiles of methane emission from landfill surface dropped from 0.12 mg/m^2/s (August) down to 0.04 mg/m^2/s in December, with a 66% reduction in three months.
  - Fence: the odor critical events dropped from 30 per month to 5 per month during the period October-December
  - Receptors: No complaints were recorded in the period October-December

Since the data of Summer 2020 are available, a significant comparison can be carried out between the two homogenous periods, related to the data monitored at the fence:

  - The 98th percentile of odor recorded by IOMS in the summer (May-August) 2020 was 100 ou$_E$/m^3 against the 440 ou$_E$/m^3 measured in the corresponding

period of the previous year (Summer 2019), with an effectiveness, expressed in terms of reduction of the odour concentration measured, of over 75%.
    - The 98th percentile of H_2S recorded by the Jerome analyzer in the summer (May-August) 2020 was 9 ppb against the 34 ppb, measured in the corresponding period of the previous year (Summer 2019), with an effectiveness, expressed in terms of reduction of the H_2S concentration measured, of over 70%.

The LFG wellfield system in 2020 comprises 364 vertical wells, instead of 301 at the time of the study (Summer 2019).

8) COMMUNICATION PHASE:

- What happened after that?

Reports of the events regarding the odor emissions are quarterly sent to the local Environmental Protection Agency: report transmitted in February 2020 accounted for the events occurring from September to December 2019.

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

The measures adopted in 2019 for increasing LFG capture were described in the annual IPPC report, publicly accessible from the company's website, although no specific actions were undertaken to inform and explain the receptors the causes of the critical odor events in the Summer 2019 or the applied solutions.