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Definition of Best Available Techniques (BAT) in Europe for Surface Treatment Using Organic Solvents

Final Report

For our Environment

Umwelt Bundesamt

TEXTE 20/2017

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Environment, Nature Conservation,
Building and Nuclear Safety

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Definition of Best Available Techniques (BAT) in Europe for Surface Treatment Using Organic Solvents

by

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Abstract

Based on the Industrial Emissions Directive (2010/75/EU), the European Commission started at the end of 2014 an information exchange ("Sevilla Process") on best available techniques (BAT), aiming at the revision of the BAT Reference Document for Surface Treatment Using Organic Solvents" (STS BREF 2007).

The directive and the BAT Reference Documents aim at providing harmonized permitting conditions in all EU Member States for the sectors concerned. Germany participates actively in the information exchange to promote an ambitious level of environmental regulation in Europe.

Annex I no. 6.7 of the Industrial Emissions Directive refers to the following solvents using activities:

„Surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with an organic solvent consumption capacity of more than 150 kg/h or more than 200 t/a"

The research project evaluated and documented best available techniques in plants in Germany. Technical information and emission data were documented and assessed for these plants, either applying process-integrated measures or end-of-pipe techniques for emission reduction.

In April 2014, German Environment Agency (UBA) as National Focal Point of the Sevilla process gathered an expert group with representatives of authorities, industry and science to assist in the revision process. In June 2015, the result of the research project were presented to the group during a meeting in the Agency. The expert comments were considered in the final report.

Kurzbeschreibung

Die EU-Kommission hat Ende des Jahres 2014 einen Informationsaustausches zu besten verfügbaren Techniken (BVT) gemäß der Industrieemissionsrichtlinie (2010/75/EU) begonnen („Sevilla-Prozess"), um das BVT-Merkblatt für Anlagen der „Oberflächenbehandlung unter Verwendung von organischen Lösemitteln" (STS BREF 2007) zu überarbeiten.

Ziel der Richtlinie und der BVT-Merkblätter sind harmonisierte Genehmigungsgrundlagen für die betroffenen Anlagen in allen EU-Mitgliedstaaten. Deutschland beteiligt sich intensiv am Informationsaustausch, um die Anwendung hoher Umweltstandards europaweit zu fördern.

Anhang I Nr. 6.7 der Industrieemissionsrichtlinie betrifft folgende Lösemittelanwender:

„Behandlung von Oberflächen von Stoffen, Gegenständen oder Erzeugnissen unter Verwendung von organischen Lösungsmitteln, insbesondere zum Appretieren, Bedrucken, Beschichten, Entfetten, Imprägnieren, Kleben, Lackieren, Reinigen oder Tränken, mit einer Verbrauchskapazität von > 150 kg organischen Lösungsmitteln pro Stunde oder > 200 t pro Jahr"

Das Forschungsvorhaben ermittelt und dokumentiert den Stand der Technik in Anlagen in Deutschland. Von betroffenen Branchen wurden technische Informationen und Emissionsdaten aus Anlagen dokumentiert und bewertet, die entweder produktionsintegrierte Maßnahmen oder fortgeschrittene nachgeschaltete Emissionsminderungstechniken anwenden.

Das Umweltbundesamt (UBA) hat als nationale Koordinationsstelle im Sevilla-Prozess im April 2014 eine Expertengruppe aus Behörden, Industrie und Wissenschaft einberufen, die die Revisionsarbeiten begleitet. Die Ergebnisse des Forschungsvorhabens wurden der Gruppe im Juni 2015 auf einem Fachgespräch im UBA vorgestellt und mit ihr diskutiert. Kommentare der Gruppe wurden im Endbericht berücksichtigt.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BAT	Best Available Techniques
BAT-AEL	BAT Associated Emission Level
BREF	BAT Reference Document
BOD	Biological Oxygen Demand
CO	Carbon Monoxide
COM	European Commission
COD	Chemical Oxygen Demand
EU	European Union
IER	Institut für Energiewirtschaft und Rationelle Energieanwendung
NH_3	Ammonia
NO_x	Nitrogen Oxides
NO_2	Nitrogen Dioxide
RTO	Regenerative Thermal Oxidation
STS	Surface Treatment Using Organic Solvents
SO_2	Sulphur Dioxide
TO	Thermal Oxidizer
TOC	Total Organic Carbon
TWG	Technical Working Group
UBA	Umweltbundesamt (German Environment Agency)
VOC	Volatile Organic Compounds

Summary

The research project was carried out in the context of the revision of the BAT Reference Document for Surface Treatment Using Organic Solvents" (STS BREF 2007). Based on the Industrial Emissions Directive (2010/75/EU), the European Commission started an information exchange in 2014 ("Sevilla Process") to start the revision. The following activities are under the scope of the review process:

„Surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with an organic solvent consumption capacity of more than 150 kg/h or more than 200 t/a".

The project evaluated best available techniques in plants in Germany. Technical information and emission data was collected and assessed from reference plants, either applying process-integrated measures or end-of-pipe techniques for emission reduction.

The focus of the project was on the description of reference plants using

- a biofilter system, representing a cost-effective example for reduction of VOC emissions in different solvent applications like wood coating and metals/plastics coating (see chapter 3)
- a new absorption system for VOC recovery, connected with subsequent reuse of solvents or combustion for heat recovery (see chapter 4)

Additionally, four site visits were carried out to evaluate options for emission reduction in the packaging printing sector (flexographic printing and gravure printing). Finally, cross-media effects of reducing the emission limit in publication rotogravure from 50 mg/Nm^3 to 20 mg/Nm^3 were documented.

In June 2015, the result of the research project was presented and discussed with the extended national expert group consisting of representatives of authorities, industry and science. The group was founded in April 2014 by the German Environment Agency (UBA) to assist in the STS BREF revision process. Together with the group, an initial position for the Kick-off Meeting of the revision was elaborated.

Zusammenfassung

Das Forschungsvorhaben wurde im Kontext der Revision des BVT-Merkblattes für Anlagen der „Oberflächenbehandlung unter Verwendung von organischen Lösemitteln“ (STS BREF 2007) durchgeführt. Gemäß der Industrieemissionsrichtlinie (2010/75/EU)hat die EU-Kommission Ende 2014 einen Informationsaustausch zur Revision des BVT-Merkblattes begonnen („Sevilla-Prozess“). Folgende Tätigkeiten sind im Geltungsbereich des Überarbeitungsprozesses: „Behandlung von Oberflächen von Stoffen, Gegenständen oder Erzeugnissen unter Verwendung von organischen Lösungsmitteln, insbesondere zum Appretieren, Bedrucken, Beschichten, Entfetten, Imprägnieren, Kleben, Lackieren, Reinigen oder Tränken, mit einer Verbrauchskapazität von > 150 kg/h organischen Lösungsmitteln oder > 200 t pro Jahr“.

Das Projekt hat beste verfügbare Techniken in Anlagen in Deutschland evaluiert. Dazu wurden technische Informationen und Emissionsdaten erhoben und in den Referenzanlagen bewertet, die entweder prozessintegrierte Maßnahmen oder End-of-Pipe-Techniken zur Emissionsminderung anwenden.

Der Schwerpunkt des Projektes lag auf der Beschreibung von Referenzanlagen mit

- Biofiltersystem, das eine kostengünstiges Beispiel zur Minderung von VOC-Emissionen in einsetzenden Tätigkeiten darstellt, wie Holz-, Metall- und Kunststoffbeschichtung (siehe Kapitel 3)
- Absorptionssystem zur VOC-Rückgewinnung, das mit der nachfolgenden erneuten Nutzung der Lösemittel oder mit deren Verbrennung zur Wärmerückgewinnung verbunden ist (siehe Kapitel 4)

Zusätzlich erfolgten vier Betriebsbesuche, um Emissionsminderungsmöglichkeiten im Verpackungsdruck zu evaluieren (Flexo- und Tiefdruck). Schließlich wurden medienübergreifende Aspekte einer Minderung der Emissionen im Illustrationstiefdruck von 50 mg/Nm^3 auf 20 mg/Nm^3 dokumentiert.

Im Juni 2015 wurden die Ergebnisse des Projektes mit der erweiterten nationalen Expertengruppe diskutiert, die aus Behörden-, Industrie- und Wissenschaftsvertretern besteht. Die Gruppe wurde im April 2014 durch das Umweltbundesamt (UBA) gegründet, um den STS BREF-Überarbeitungsprozess beratend zu unterstützen. Zusammen mit der Gruppe wurde eine „Initial Position“ für das Auftakttreffen zur Revision erarbeitet (siehe Anhang 2).

1 Context and Objective

This report describes the results of a research project, funded by German Environment Agency and conducted by Ökopol from August 2014 to July 2015. The aim of the project is the development of a contribution to the information exchange for the BAT Reference Document for Surface Treatment Using Organic Solvents" (BREF STS), first published by the European Commission in 2007 and since the end of 2014 under revision.

The information exchange is organized under the Industrial Emissions Directive (2010/75/EU)[IED 2010], covering surface treatment installations for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating. Such activities fall under the scope of the directive if the organic solvent consumption capacity either exceeds 150 kg/h or 200 t/a. However, the BAT Reference Document may also include information on techniques used in installations with a lower solvent consumption.

In the information exchange for the revision of the BAT Reference Document, Germany promotes an ambitious level of environmental regulation in Europe. Therefore, the project aims at the description of plants and processes considered as best available techniques according to the definition of the Industrial Emissions Directive (Article 3, Number 10):

- The techniques should prevent emissions or, if this is not practicable, reduce emissions and minimize the impact on the environment as a whole.
- The techniques should represent the most effective and advanced stage in the development of activities and their methods of operation.
- "Best" in this context means techniques being „most effective in achieving a high general level of protection of the environment as a whole";
- "available" is a technique if a reasonable access of operators can be achieved and if the technique is developed on a scale that allows implementation in the surface treatment activity sector, and
- "available" also means that the technique is considered to be operated under economically and technically viable conditions, taking into account both, costs and advantages;
- "techniques" are not only defined as encompassing the technology itself, but also including "the way in which the installation is designed, built, maintained, operated and decommissioned".

Techniques selected in the project and proposed as BAT are either process-integrated techniques or end-of-pipe techniques. The data collection and assessment follows the Guidance Document of the European Commission for developing BAT Reference Documents (COM 2012). The project did not comprise own measurements; all data was based on information available in companies and public authorities.

The project consisted of the following work packages:

1. Information collection on potential BAT and selection of examples
2. Preparation of data collection
3. Site visits and additional information collection
4. Meetings related to the project

As the BAT Reference Document of 2007 (BREF STS) describes 18 different sectors applying surface treatment, a selection of priority sectors was done in work package 1.

An expert group, organized by the German Environment Agency (UBA) to assist in the revision process of the BAT Reference Document (BREF STS), was informed about the project development and about the project results.

2 Project development

2.1 Information collection on potential BAT and selection of examples

2.1.1 Kick-off meeting and selection method

On 7 April 2014, when the start of the revision of the BREF STS had been announced by the European Commission, the German Environment Agency started an information exchange with national sector experts, asking for proposals for potential reference plants. Participants of the first meeting of the extended national expert group were:

- authorities responsible for permitting and inspection of IED plants in the “Länder” (federal states),
- industry associations and individual companies carrying out surface treatment activities,
- research institutes focussed on the sector.

On the project kick-off meeting on 15 September 2014, the Environment Agency informed the contractor that a collection of BAT candidates from the national expert group was ongoing. It was agreed that Ökopol should do an assessment of the surface treatment sectors to find out relevant potential for VOC emission reduction. Ökopol proposed to actively involve suppliers in the national expert group and to approach suppliers regarding reference lists of recent waste gas abatement projects considered to be potential BAT candidates. Additionally, for assessment of sectors with relevant emission reduction potential, it was agreed to evaluate the Ökopol report on implementation of the VOC Solvents Directive in Germany, prepared on behalf of UBA in 2011, in cooperation with IER (University of Stuttgart). (Ökopol/IED 2011).

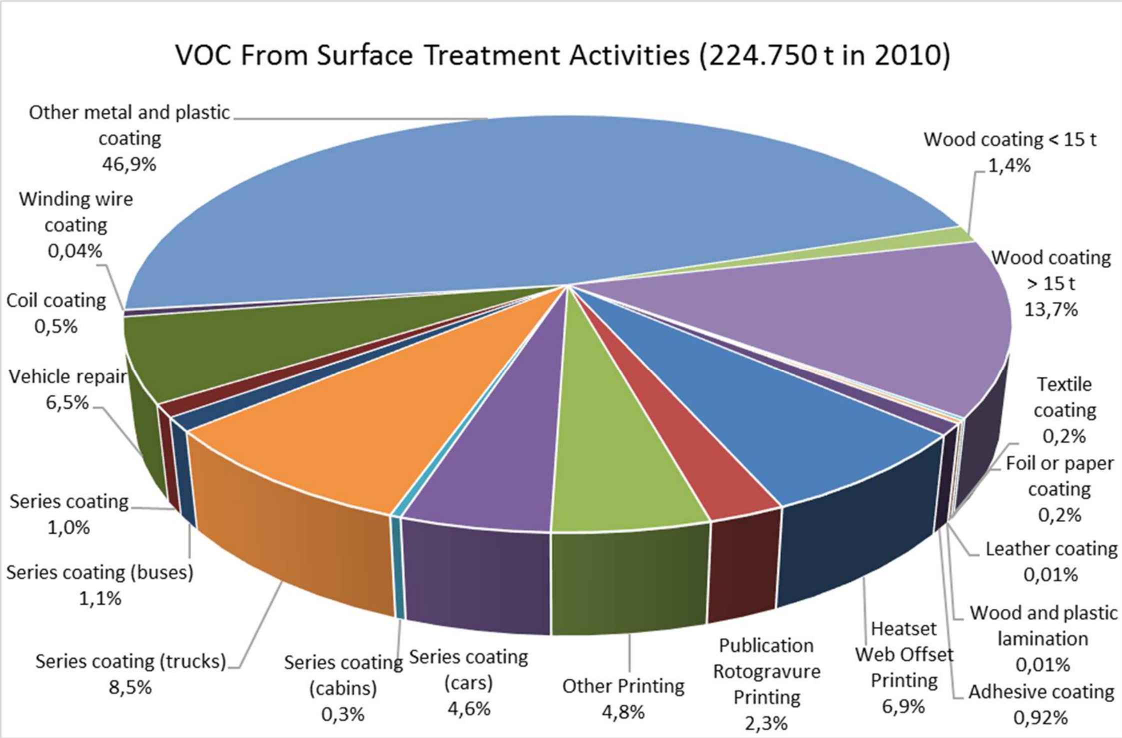
2.1.2 Assessment of priority sectors

For assessment of priority sectors to be selected for description of exemplary BAT, the following criteria were selected.

1. The activity has a relatively high share of total emissions:
   - Activity with few installations, each with relatively high emissions, or
   - Activity with many installations and relatively high total emissions.
   - Assessment is based on Ökopol/IER report on activities using organic solvents (Ökopol/IER 2011).
2. The activity is considered to have a relatively high reduction potential:
   - Installations are knows where emission reduction techniques have been installed that have potential to be generally applicable in similar activities of the sector.
   - The analysis of the BAT Reference Document of 2007 for Surface Treatment Using Organic Solvents shows that the techniques were not described or not described extensively.
3. The activity comprises installations assumed to be cooperating in the project:
   - Contact are established with companies where BAT candidate techniques exist and where information exchange was achieved in former projects.
   - Authorities or industry associations have provided contacts of installations that are expected to support the European information exchange on BAT.
   - Industry associations and/or suppliers have announced to support the data collection.
4. BAT candidate techniques were installed by suppliers expected to be supporting the project or already having announced their cooperation in the European information exchange on BAT:
   - Suppliers have actively informed UBA or Ökopol about the installation of BAT candidates.
   - Suppliers have announced to support the information exchange for documentation of BAT.

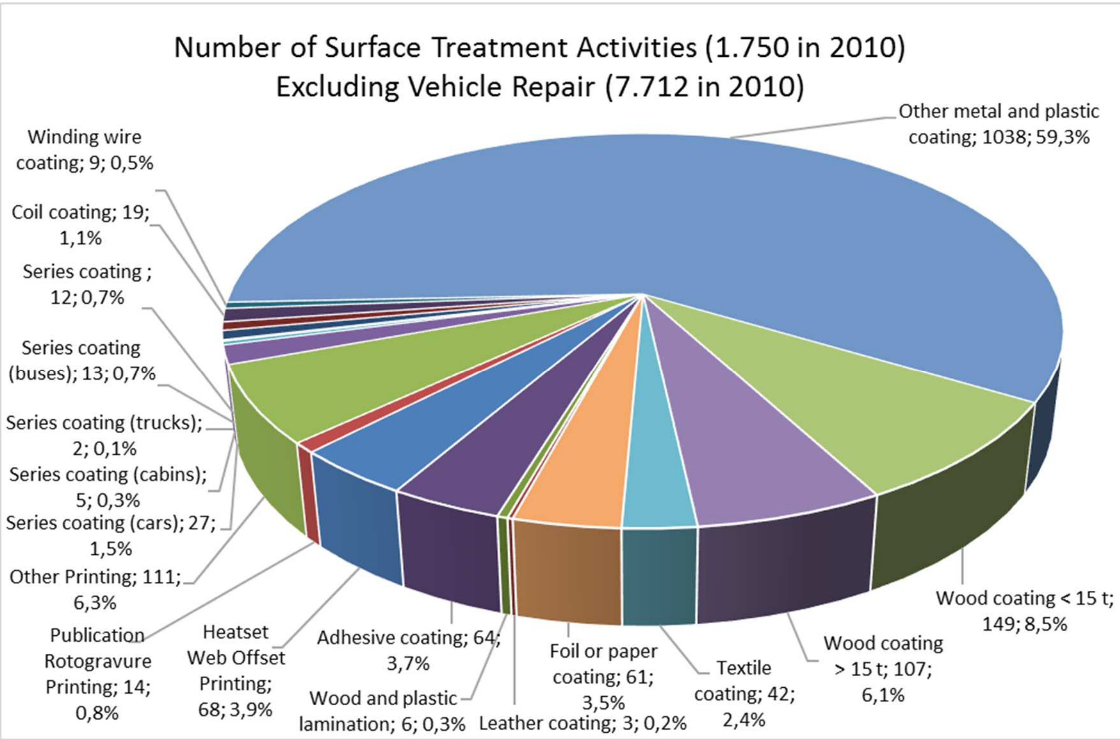
Figure 1 shows estimated VOC emissions and number of installations in Germany in 2010.

Figure 1: Estimated Percentage of VOC Emissions From Surface Treatment Activities Using Organic Solvents in Germany Including Non-IED Activities (224.750 t in 2010)



Ökopol 2016 based on Ökopol/IER 2011

Figure 2: Estimated Number and Percentage of Surface Treatment Activities Using Organic Solvents in Germany (1.750 in 2010) Including Non-IED Activities Excluding Vehicle Repair (7.712 in 2010)



Ökopol 2016 based on Ökopol/IER 2011

Total VOC emissions in 2010 were estimated with 224.750 t in Germany from surface treatment activities using organic solvents (see Figure 1), covered by the VOC Solvents Directive (1999/13/EC) respectively Annex VII of the Industrial Emissions Directive (IED 2010). The dominating activity is “Other metals and plastics coating” (other than vehicle coating) with 1038 installations and 105.474 tons of emissions in 2010. (see Figure 2)

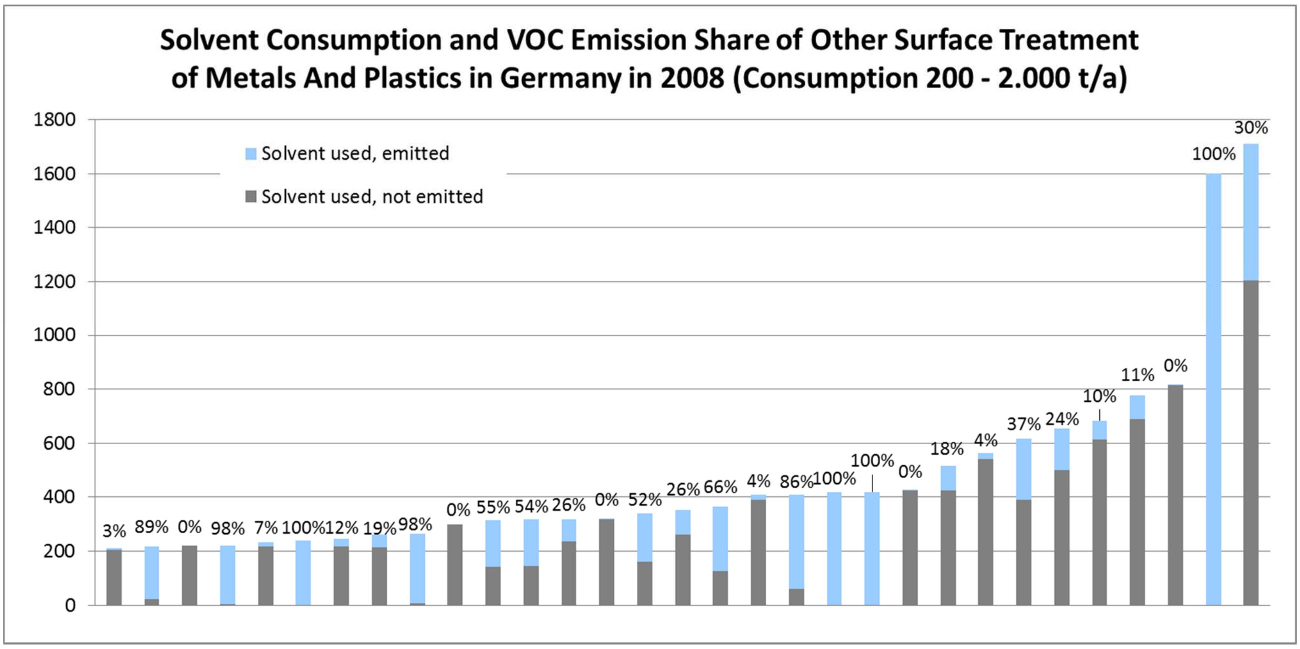
In a research project by the German Environment Agency (Ökopol/IER 2011), data from activities using organic solvents was collected to estimate sector-specific emissions. Data distinguish between solvents used and emitted and solvents used and not emitted (treated or recovered). Where captured emissions are treated (and therefore low) and fugitive emissions are relatively high, a reduction potential can be observed from the data. Data sets do not distinguish between installations covered by IED (with solvent consumption of at least 200 tons per year or 150 kg per hour).

Figure 3 and Figure 4 show installations with carrying out other metals and plastics coating. They are assumed to be under the scope of the IED as their annual solvent consumption exceeds 200 t/a. Each bar is a separate installation. The data set is exemplary and does not cover all installations of the sector. Percentage figures show the solvents used and emitted.

The blue barres show the share of VOC emission for 30 exemplary installations with 200 – 2.000 tons and five exemplary installations with more than 2.000 t/a of solvent consumption in 2010.

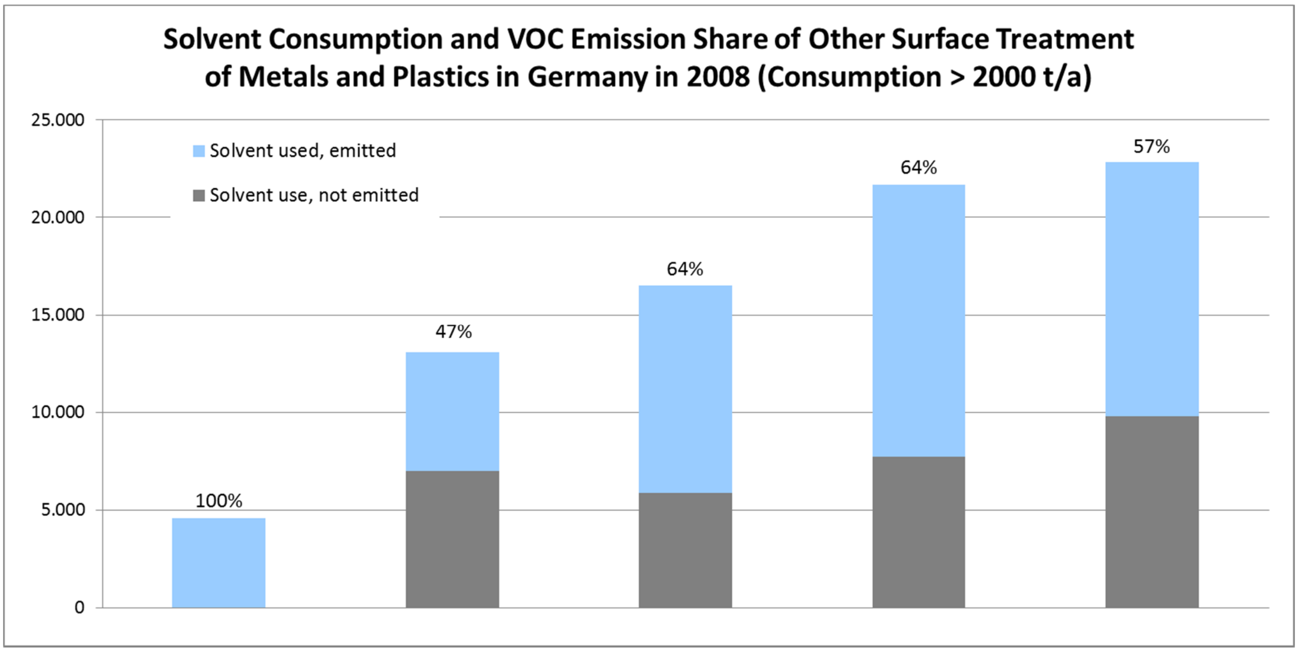
Installations where 100% of solvent consumption is emitted use Reduction Schemes according to Part 5 of Annex VII of the IED or were exempted from limit values as they cannot be carried out under contained conditions (e.g. ship coating). Many installations not emitting 100% solvent input show significant reduction potential. The reduction potential is mainly assumed where installations are not entirely enclosed, and where low VOC concentrations are an obstacle for efficient thermal oxidation.

Figure 3: Solvent Consumption and VOC Emission Share of Other Surface Treatment of Metals and Plastics in Germany in 2008 (Annual Solvent Consumption of 200 – 2.000 t/a)



Ökopol 2016 based on Ökopol/IER 2011

Figure 4: Solvent Consumption and VOC Emission Share of Other Surface Treatment of Metals and Plastics in Germany in 2008 (Annual Solvent Consumption > 2.000 t/a)

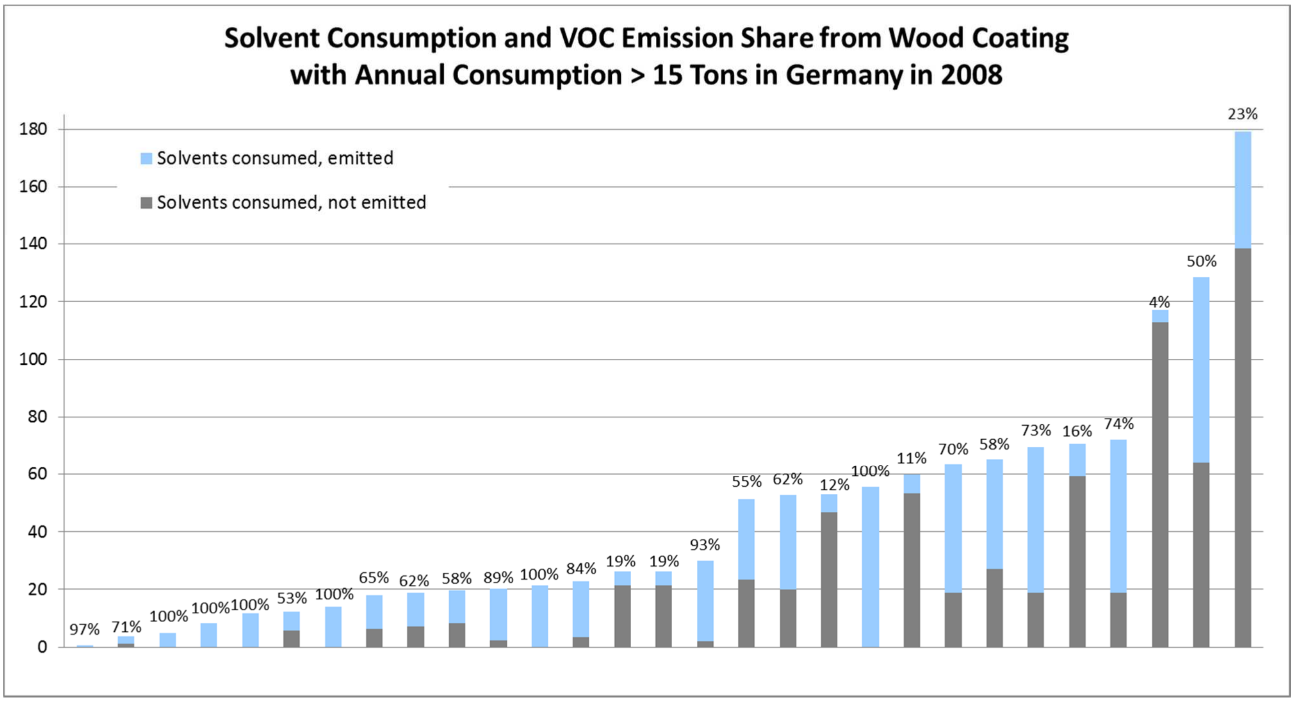


Ökopol 2016 based on Ökopol/IER 2011

A significant share of total emissions arises from 107 wood coating activities, with a permit for solvent consumption above 15 tons per year (13,7%, 30.710 t in 2010). However, in this sector, none of the exemplary installations exceeds an annual solvent consumption of 200 t/a. Therefore, as most installations are not covered by IED, it is less probable to achieve cooperation in the project supporting the information exchange on best available techniques. However, once included in the BREF STS, authorities may also use information of the BREF STS for permitting installations not covered by IED. Therefore, it is intended to collect information about emission reduction and substitution also from wood coating activities not falling under the scope of the IED.

Figure 5 shows that several wood coating companies have a high share of solvents used and emitted. Where this figure is not near 100% (indicating the use of a Reduction Scheme), a high reduction potential is assumed. The reduction potential is mainly associated with installations that are not entirely enclosed, and where low VOC concentrations are an obstacle for efficient thermal oxidation.

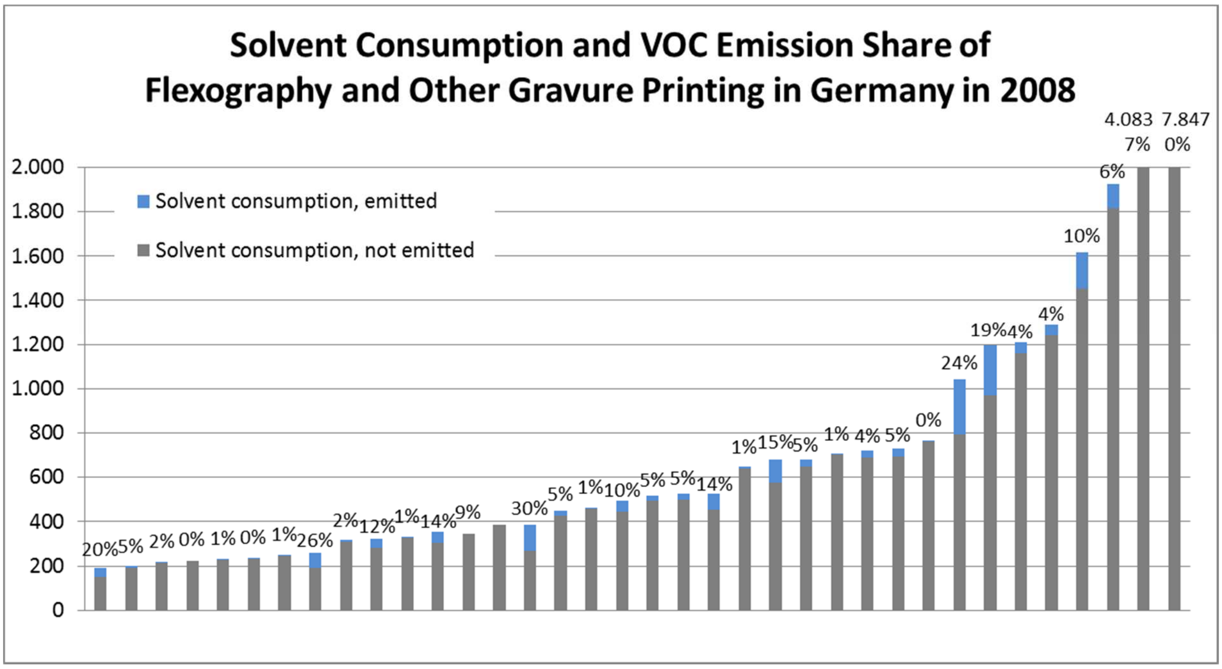
Figure 5: Solvent Consumption and VOC Emission Share of Wood Coating in Germany in 2008 (Permit for Annual Solvent Consumption above 15 t/a)



Ökopol 2016 based on Ökopol/IER 2011

A relevant share of total emissions and individual plant emissions originates from 111 flexography and other gravure printing activities (4,8%, 10.871 t in 2010). In this sector, about 2/3 of exemplary installations exceed an annual solvent consumption of 200 t/a. Figure 6 shows that companies do not have a high share of emissions related to solvent consumption. However, Ökopol experience has shown that reported values of the solvent management scheme are often not reliable regarding the share of emissions captured by the waste gas system, regarding the destruction efficiency of that systems and regarding the mean waste gas flow. Therefore, VOC destruction amounts may be overestimated. Printing machines of the sector achieve a long life time; this leads to a high proportion of relatively old printing machines which are generally insufficiently enclosed. A significant reduction potential is mainly assumed for this sector where peak emissions occur (in particular from automatic parts washing machines) and where low VOC concentrations are an obstacle for efficient thermal oxidation.

Figure 6: Solvent Consumption and VOC Emission Share of Wood Coating in Germany in 2008 (Permit for Annual Solvent Consumption above 15 t/a)



Ökopol 2016 based on Ökopol/IER 2011

2.1.3 Collection of potential BAT candidates from suppliers

For assessment of potential BAT candidates, reference lists were requested from the following German suppliers or engineering companies for waste gas abatement systems:

- AWS Group, Heilbronn (http://www.aws-systems.com),
- Caverion Deutschland/Krantz, Aachen (http://www.krantz.de),
- Dürr Systems/LTB, Bietigheim-Bissingen (http://www.durr-cleantechnology.com),
- Eisenmann, Holzgerlingen (http://www.eisenmann.com),
- Seibu Giken and Envisolve, Langen (http://www.envisolve.com),
- SeibuGiken and Venjakob Umwelttechnik, Sarstedt (http://www.venjakob-umwelttechnik.de),
- Störk Umwelttechnik, Drensteinfurt (http://www.stoerk-umwelttechnik.de),
- Wessel-Umwelttechnik, Hamburg (http://www.wessel-umwelttechnik.de).

2.1.4 Selection of examples

Based on first information from suppliers and on the background of the selection criteria mentioned above, two examples were selected:

- VOC Absorption System (AWS Group) => Metal and plastics coating (vehicle coating example)
  => High relevance of emissions, new technique not described in the BREF STS (2007),
  =>Good access to information expected as provider ensured cooperation on Paint Expo2014
- VOC Biofilter System (Störk Umwelttechnik) => Wood and metal coating (metal coating example)
  => High relevance for several sector activities where low VOC concentration occurs, economic solution (thermal oxidation would require high significant gas consumption and related costs)
  => Good access to information expected as provider ensured cooperation on Paint Expo 2014

Members of the National Working Group were contacted to make proposals for reference plants. Based on the proposals and on company information available at Ökopol, site visits at potential reference plants of relevant sectors were agreed, based on the above mentioned selection criteria:

- packaging printing (flexography and gravure printing)
  => High relevance of emissions, high expected potential for emission reduction
- publication rotogravure
  => New limit value of 20 mg/Nm³ instead of 50 mg/Nm³ due to new classification of toluene
  => Exemplary documentation of cross-media effects.

For packaging printing, the following company was selected due the recommendation of the industry association (IK Kunststoffverpackung):

- Bischof + Klein SE & Co. KG, Lengerich

As well for packaging printing, the following company was selected due the recommendation of the industry association (vdma) and recommendation by the Bavarian Environment Agency (LfU):

- Kurz Leonhard GmbH & Co. KG, Sulzbach-Rosenberg

One packaging printing installation was selected due to former cooperation in a project of the Environment Ministry of Baden-Wurttemberg for developing Guidance on implementing the VOC Directive:

- Anton Debatin GmbH, Bruchsal

For publication rotogravure, the following company was selected as having prepared a cross-media evaluation of the plant when reducing air emissions from 50 mg/Nm³ to 20 mg/m³. For the Nürnberg site, the competent authority had informed the UBA that low emissions were already achieved.

- Burda Druck GmbH, Offenburg and Burda Druck GmbH, Nürnberg.

2.2 Preparation of data collection, site visits, additional information collection

In this work package, forms were prepared for standardized information requests from suppliers and potential reference plants, according to the Commission Implementing Decision on the collection of data and on the drawing up of BAT reference documents (COM 2012).

2.2.1 Questionnaires

The following elements are considered as essentials for the data collection:

Basic data on the company

1. Description of the company, in particular:
- type of products produced
- systems for waste water cleaning, waste gas cleaning and energy production (steam, heat)
- production process, permitted capacity
- containment of solvents (e.g. direct piping from containers to printing plants)
- encapsulation of machinery and during cleaning
- encapsulation of spray applications and cleaning activities
- operation mode (continuous operation or discontinuous, batch operation)
- waste gas extraction system (positioned at machinery/activities or for production hall)
- Automatic parts cleaning machine (solvent-based or alkaline-water-based)

2. Process data:
- Composition of solvents for coating and cleaning
- Additional solvents used for viscosity adjustment
- Type and amount of material coated
- Type and amount of energy used

- Type and amount of waste generation
- Measurement data from emissions to water and air
- Measurement method for emissions monitoring
- If available: TOC raw gas concentration
- If needed (in case of coating): Dust filtration
- Solvent Management Scheme according to IED Annex VII
- Measurement data from waste solvent content analysis
- Energy consumption data (e.g. from waste gas treatment or recovery)

3. Cross-media data of best available techniques:
- Additives and energy consumption for waste gas and waste water treatment
- Waste from waste gas and waste water treatment
- Other cross-media effects from environmental protection measures

4. Applicability restrictions of best available techniques:
- Information on space requirements
- Information on other conditions necessary for transfer from reference plant sto others

5. Cost data of best available techniques:
- Investment costs
- Operational costs (material and energy)
- Maintenance costs

6. Contact data:
- Company data
- Supplier data

2.2.2 Site visits

Members of the extended national expert group were contacted to make proposals for reference plants. Based on these proposals and on knowledge about companies of the sector, the following site visits were prepared and realized:

- Kurz Leonhard GmbH & Co. KG, Sulzbach-Rosenberg: 24 March 2015
- Burda Druck GmbH, Offenburg: 21 April 2015
- Anton Debatin GmbH, Bruchsal: 21 April 2015
- Bischof + Klein SE & Co. KG, Lengerich: 5 May 2015

Additionally, information was received from suppliers and companies for description of the absorption system and the biofilter. Information was evaluated and additional requests were done for completion of the descriptions. Two descriptions can be found in chapters 3 and 4. Additional technical descriptions will be provided in the follow-up project of the UBA (research project no. 3715 53 312 1).

The site visits improved the understanding of options for VOC emission reduction in the sectors and its related cross-media effects. An evaluation of the site visits can be found in chapter 5.

2.3 Meetings related to the project

Besides the kick-off meeting, Ökopol supported the organization and facilitation of the meeting of the extended national expert group on 18/19 June 2015 (main topic: initial position). On the meeting, Ökopol presented and discussed the project results with participants (see presentation in Annex I).

3 BAT Reference Plant – Metal, Plastic And Wood Coating: Biological Waste Gas Abatement System

The following example describes a biological waste gas abatement system installed in a reference plant applying coating of metal and plastic parts on behalf for the automotive sector.

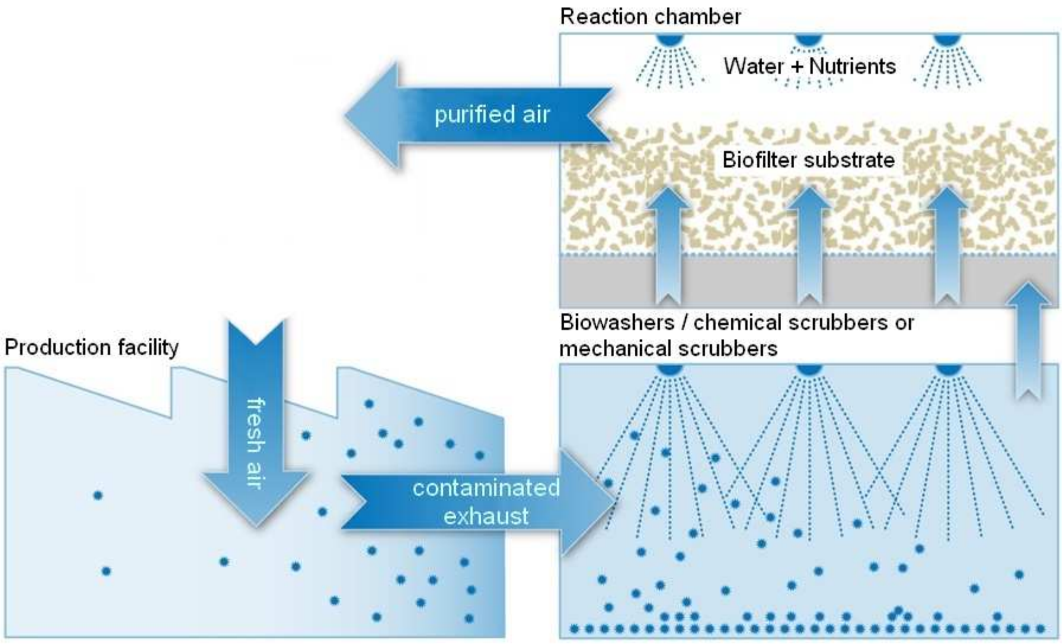
3.1 Description

The biological waste gas abatement system consists of:

- Scrubber for de-dusting and humidification of the waste gas
- Reactor with biofilter substrate for pollutant destruction
- Automatic humidification supplying the microorganisms in the reactor with water and nutrients
- Heat exchanger for heating-up fresh air for the production hall

Figure 7 illustrates the production hall, the scrubber, the reactor and the heat exchanger.

Figure 7: Scheme of the Biological Waste Gas Abatement System



(Störk 2015)

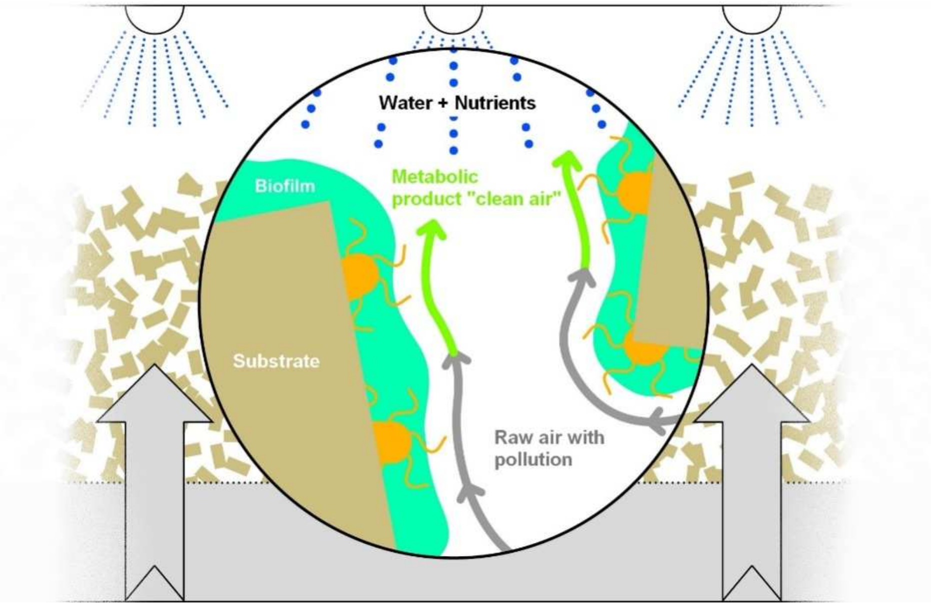
The scrubber is operated counter-current gas flow. The major part of the scrubber water is circulated. If necessary, a waste water treatment system is installed. It minimizes water consumption and ensures compliance with the local discharge limitations of the sewage system.

The biological waste gas abatement system is based on the activity of microorganisms. The organisms biochemically oxidize organic pollutants as well as a part of the inorganic gaseous waste gas compounds. They are converted into non-toxic substances and substances that cannot be smelled.

In the reactor, microorganisms are situated on a solid supporting material. Pollutants contained in the waste gas will be absorbed by the surface of the supporting material (conversion into liquid phase). Pollutants contained in the waste gas will be absorbed on the surface of the supporting material (conversion into liquid phase). By this, they are accessible for the microorganisms. For building-up their own biomass, the microorganisms use pollutants as nutrition and energy source (biological oxidation)(Figure 8).

The reactor contains several layers of packing material. The lower layers consist of coarse-grained material forming the reactor structure. The function of these layers is drainage and air distribution.

Figure 8: Reactor for biological waste gas treatment



(Störk 2015)

The supporting material is the essential part of the waste gas abatement system. It is adopted to each specific case and consists of organic substances (Figure 9). The material is developed and specified by the supplier; it is produced under quality-controlled process conditions.

Figure 9: Biofilter material

(Störk 2015)

For the upper layer, a specific active mix is used which has shown good results regarding the decomposition of hydrocarbons and odour. The material is highly resistant against biological destruction. This leads to a long lifetime. The large pores ensure a high biological abatement performance.

The activity of the microorganisms and hence the function of the biofilter system is only ensured if the supporting material and the biomass are adapted to the process. Adaptation includes the adaptation of the pore volume and the absorption capacity (buffer capacity). This ensures a high total surface of the biofilter and sufficient retention time.

When the system starts operation, the supporting material will be inoculated with a specific bacteria culture adapted to each waste gas composition. By this, the full performance is achieved in short time.

After adaptation to the organic content of the waste gas, a specific biocenosis is established and kept in balance in the filter material. It differs according to the concentration and the type of waste gas composition. The metabolism of the bacteria produces water , CO_2 and biomass. As organic compounds are decomposed, no pollutants are accumulated in the biofilter material.

Microorganisms grow rapidly if nutrients supply is optimized. They adapt quickly to changing living conditions. Depending on the type of nutrients, a certain population is developed over time while other microorganisms will not survive.

Load peaks in the waste gas can be stored in the biofilter due to the high buffer capacity of the material. Stored organic compounds will later be decomposed by the microorganisms.

If the TOC load is not sufficient, microorganisms may need to be fed with a mixture of nutrients to ensure a continuous decomposition process and a stable waste gas abatement performance.

Characteristics of the example plant (metal coating):

- Trade coating, about 140 jobs, founded in 1988
- Parts and series coating of plastics and glass
- Coating systems: 1-component, 2-component, UV coatings
- Solvent consumption< 200 t/y and < 150 kg/y (no IED permit)
- Waste gas volume treated: 60.000 m^3/h
- Scrubber residence time: 1 sec.
- Scrubber water volume: 2 m^3
- Biofilter packing volume: 1300 m^3
- Biofilter residence time: about 40 sec.
- Automatic bacteria water and nutrient supply
- Biofilter packing material: organic substance on basis of wood or bark
- Lifetime of biofilter packing: 3 – 5 years

(Störk 2015)

3.2 Achieved environmental benefits

The biological waste gas treatment system reduces emissions of volatile organic compounds (VOC) and minimizes odour and dust emissions.

3.3 Environmental performance and operational data

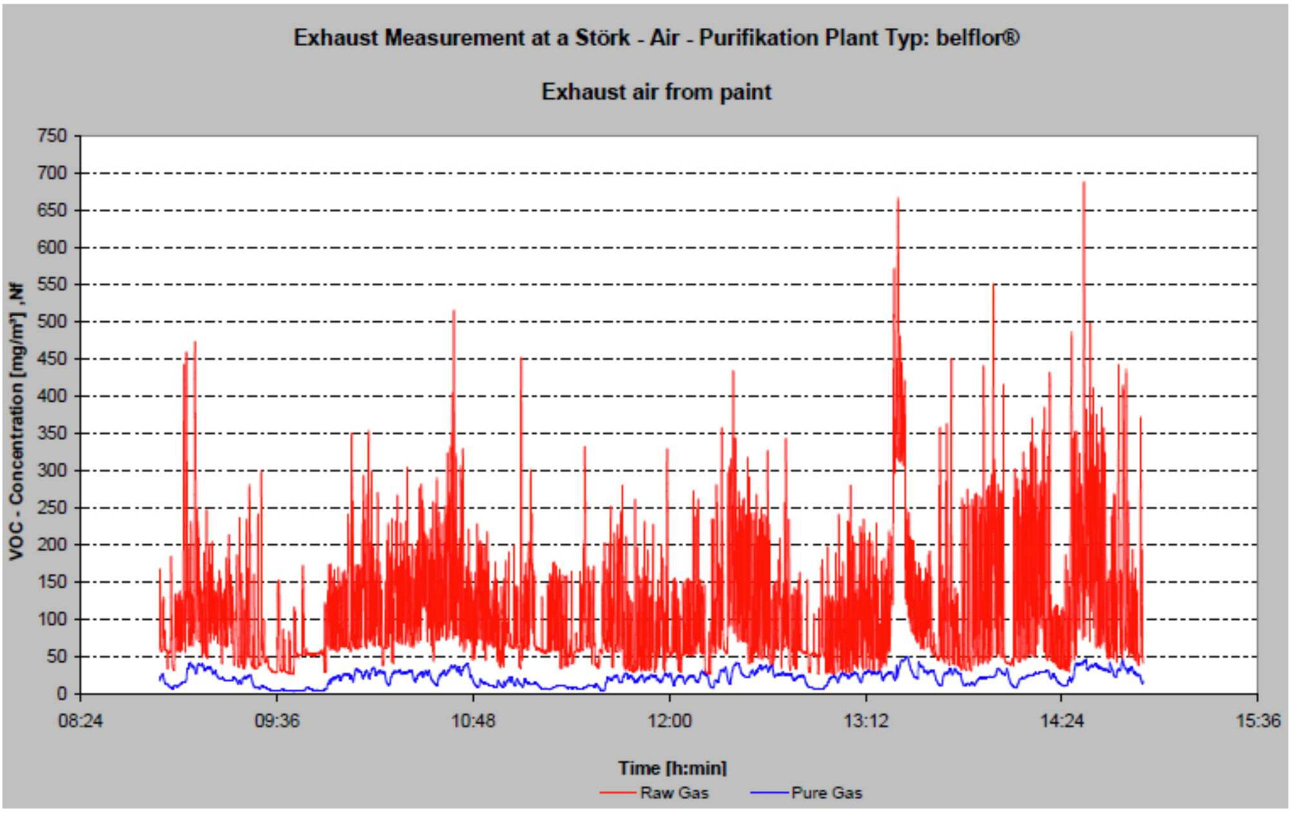
Example plant metal coating:

- Measurements method for TOC: FID (EN 12619:2013-04)
- Measurement period: 30 minutes
- Raw gas TOC concentration varies between 50 – 300 mgC/Nm^3 (see Figure 3)
- Waste gas concentration limits: TOC 50 mg/Nm^3, dust 3 mg/Nm^3,
- Measurement (7.8.2013): TOC 18,3/27,3/34,9 mg/Nm^3, dust max. < 0,32 mg/Nm^3
- Measurement (15.7.2015): TOC max. 41,1 mg/Nm^3, dust max. 0,77 mg/Nm^3
  Measurement uncertainty (15.7.2015): TOC 6,5 mg/Nm^3, dust 0,22 mg/Nm^3

(Störk 2015)

Varying inlet concentrations are buffered by the high packing volume of the biofilter, therefore peak concentrations are decomposed by the bacteria subsequently (see figure 10).

Figure 10: TOC concentration before and after the biofilter



(Störk 2015)

3.4 Cross-media effects

Energy consumption

The biofilter causes low pressure drop in the waste gas stream and therefore requires only a small power increase of the waste gas ventilator. Additional consumption is about 30 kWh (without conventional electricity consumption for ventilation as this is needed anyway for work place safety).

Due to the biological activity in the biofilter, the waste gas outlet temperature is 2°C higher than the inlet temperature. This energy can be recovered in the subsequent heat exchanger for warming-up fresh air needed in the production halls. In winter, depending on the outside temperature level, about 50 – 75% of the heating energy can be substituted.

Waste water

Waste water originates from the operation of the scrubber and the biofilter. The characteristics of the waste water depend from the waste gas composition and the concentration of organic compounds in the waste gas. Usually, discharge to the public sewage system is permitted.

Typical characteristics of the waste water:

- Waste water temperature: 10°C – 30°C
- pH about 6 – 8
- Conductivity: about 500 – 2.000 µS/cm
- COD: about 400 – 2.000 mg/l

Waste

When the supporting material has reached the end of its lifetime, it can be disposed in a biomass incinerator or in a composting plant, as contaminants are not contained but decomposed.

3.5 Applicability

The biological waste gas treatment system can be applied in new plants and for upgrading of existing plants. The system can be used for treatment of all volatile organic compounds (except methane) usually arising from coating activities.

3.6 Economics

Investment and operational costs (see Table 1) depend from the waste gas volume and the level of concentration of organic compounds to be treated.

- Waste gas volume:
  60.000 Nm^3 at full load (about 2.000 h/a)
  30.000 Nm^3 at part load (about 2.000 h/a)
- TOC concentration in waste gas: about 250 mgC/Nm^3
- Investment costs: about 400.000 €
- Operational costs: about 29.000 €/a
- Maintenance frequency: 1 – 3 h per week
- Specific waste gas treatment costs: 0,016 Cent/m^3

  (Störk 2015)

Table 1: Specific operational costs

Consumable	Specific costs	Unit
Electricity	0,10	€/kWh
Water	1,00	€/m³
Waste water	2,50	€/m³
Nutrients	25,50	€/kg
Defoamers	3,00	€/kg
Acids	0,11	€/kg
Alkaline solution	0,12	€/kg
Hydrogen peroxide	0,33	€/kg

(Störk 2015)

Operational costs (electricity, water, nutrients, chemicals, biofilter material, waste water disposal) vary due to the heterogeneous waste gas composition, varying waste gas volumes and changing raw gas compositions. The following values (Table 2) are estimates. Costs for disposal of the biofilter material at the end of its lifetime are neglected because it is assumed that energy recovery in a biomass combustion plant can be done without extra costs.

Table 2: Annual operational costs

Consumable	Specific costs hourly	Specific costs annual	Unit	Total costs €/a	Total costs €/h
Electricity	22,71	90.831	kWh	9.083	2,27
Water	0,33	1.311	m³	1.311	0,33
Waste water	0,11	428	m³	1.069	0,27
Nutrients	0,01	42	kg	1.063	0,27
Defoamers	0,02	72	kg	216	0,05
Chemicals		0	kg	0	0,00
Biofilter material (5 y standing time)		384	m³	20.000	5,00
Sum				**32.741**	**8,19**

(Störk 2015)

3.7 Driving force for implementation

The main reason for implementation of the biological waste gas treatment system are legal requirements. Another reason may be the need for odour reduction.

3.8 Example plants and supplier

Metal coating:

- Vallo & Vogler Oberflächenveredlung GmbH, Industriestraße 10-14, 49191 Belm, Germany Phone: +49 5406-83 10-0
- Internet: www.vallo-vogler.de
- Contact: Mr Dr. Uhr (General Manager) Email: info@vallo-vogler.de

Wood coating:

- Möbelwerkstätten Hunke GmbH, Hellweg 110, 33758 Schloß Holte-Stukenbrock, Germany Phone: +49 5207-91 96 - 0,
- Internet: www.hunke-gmbh.de
- Contact: Mr Hunke (General Manager) Email: hunke@hunke-gmbh.de

Supplier

- Störk Umwelttechnik GmbH, Friedrich-Wöhler-Str. 21 78576 Emmingen-Liptingen, Germany Phone: 02538 91462-11 Email: info@stoerk-umwelttechnik.de
- Internet: www.stoerk-umwelttechnik.de
- Contact: Mr Lütke-Wöstmann Email: u.luetke-woestmann@stoerk-umwelttechnik.de

3.9 Reference literature

(Lütke-Wöstmann 2015)

4 BAT Reference Plant – Metal and Plastics Coating: Absorptive Waste Gas Abatement System

The following example describes an absorptive waste gas abatement system installed in a reference plant applying vehicles series coating of new cars.

4.1 Description

Absorptive waste gas abatement systems are used to concentrate VOC in waste gases for recovery or for combustion. The system consists of

- filter unit (absorption system),
- desorber (desorption system) and
- condensation (solvent recovery)
  or
- thermal oxidation (energetic use).

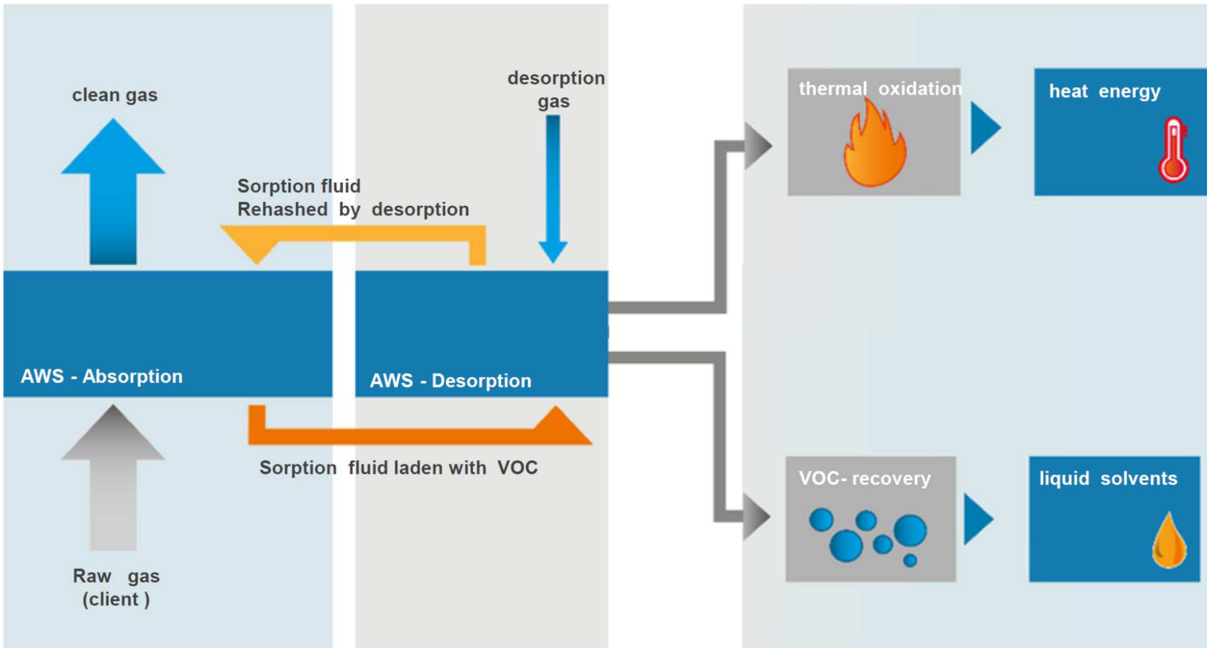
The decision for one of the two options depends on local conditions and is determined by economics. It mainly depends on the need for heat respectively the possibilities to re-use recovered solvents.

Volatile organic compounds originating from the vehicle coating process are collected in the absorption system, which reduces VOC emissions to air. Subsequently, the sorption fluid laden with organic solvents is directed to the desorption unit where solvents are removed from sorption fluid. This is achieved with hot air, which passes through the heated absorbent in a counter current flow.

The hot air laden with solvents is conducted to the condensation plant or to the thermal oxidation.

Figure 11 illustrates the absorption of volatile organic compounds in the sorption fluid, the desorption by hot air in the desorption unit and the subsequent options for using the concentrated solvents.

Figure 11: Scheme of the Absorption Waste Gas Abatement System

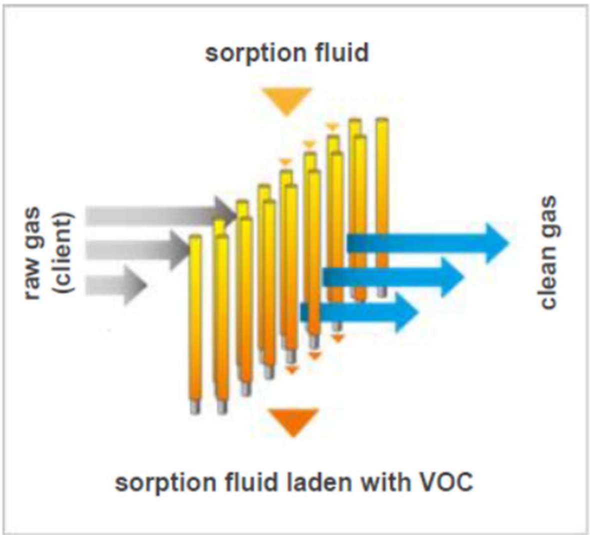


(AWS 2016)

The absorption process takes place in a module that produces a film curtain by means of porous so-called Keder tubes. The curtain offers a large surface for the cross-counter-current of the waste gas.

The modules are characterized by a low pressure loss on the exhaust side. Several modules can be combined in series, depending on the concentration of the waste gas and on the composition of the substances to be absorbed. Absorbent and waste gas are conducted in a cross-counter-current (Figure 12).

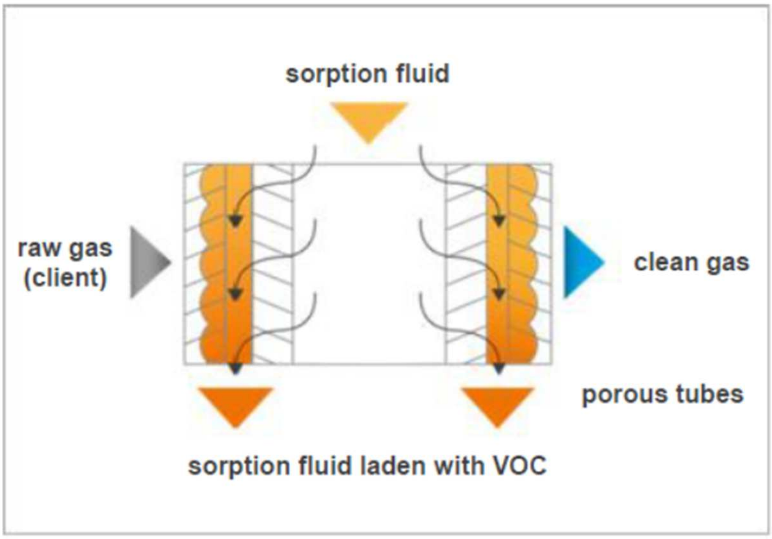
Figure 12: Cross-counter current in the absorption unit



(AWS 2016)

Figure 13 illustrates the flow in the Keder tube of the absorption unit.

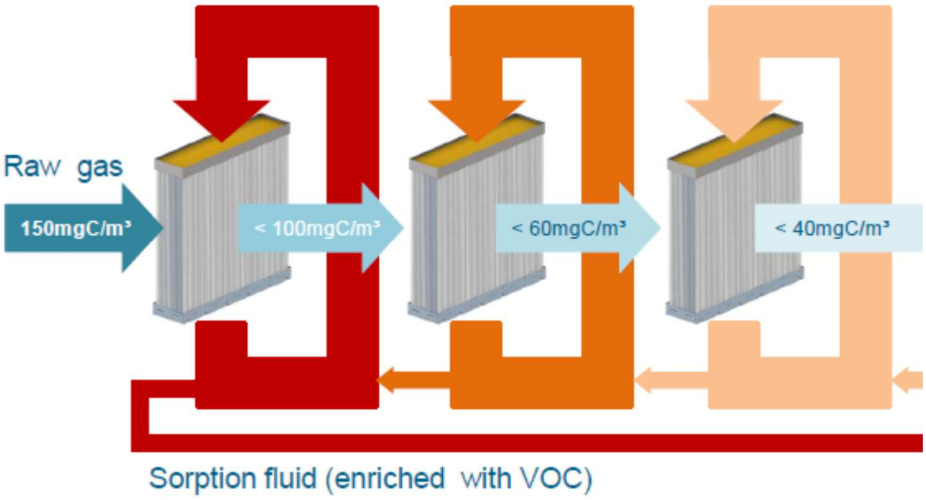
Figure 13: Keder tube in the absorption unit



(AWS 2016)

Figure 14 illustrates a filter cascade of absorption units.

Figure 14: Filter cascade of absorption units

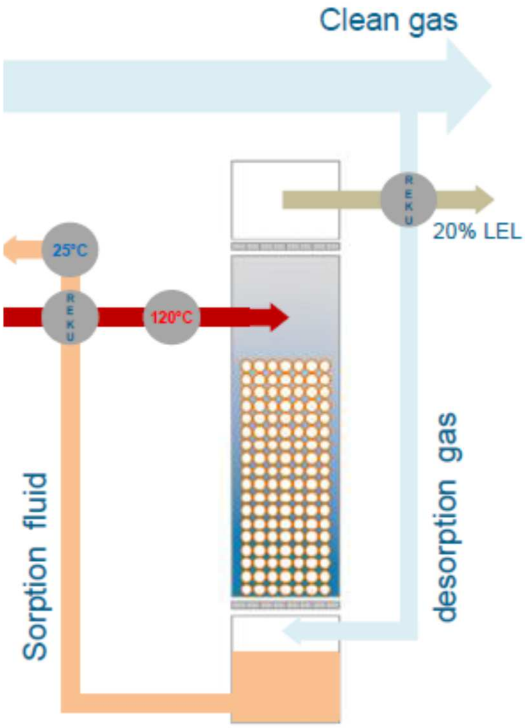


(AWS 2016)

Figure 15 shows details of the desorption unit. The dark red arrow indicates the inlet of laden fluid originating from the absorption, the light red line shows the return of the fluid to the absorption unit.

Before returning to the absorption unit, the outlet of the hot fluid passes a heat exchange unit to heat-up the incoming fluid. For desorption, the incoming fluid is heated to 130° C.

Figure 15: Desorption unit with heat exchange



(AWS 2016)

Characteristics of the example plant:

The absorption plant is used by an automotive manufacturer in Germany to clean the solvent contaminated waste gas from spray booths. In these spray booths car components are painted (mainly plastic parts with a topcoat in series painting). Also manual coating of parts takes place in the spray booths.

The absorption and desorption in this plant is connected with a condensation (recovery) of the solvents.

Dimensions of the entire filter system:
- 20,2 m x 9,7 m x 4,7 (L x W x H)

Exhausted air flow:
- 220 000 m^3/h (2 lines with 110.000 m^3/h each)

Absorber:
- 128 absorption modules
- Quantity of absorbens: ~12.700 litre
- Automatic control of fill level and temperature
- Constant refill of the absorbens

Temperatures:
- Absorption 25°C, desorption 130°C, condensation - 52°C

Raw gas concentration:
- max. 130 mg C/Nm^3

Separation efficiency: (depending on the raw gas load)
- ~17,8 kg VOC/h

Dimensions of the desorber:
- 7,3 m x 7,8 m x 6,5 m (L x W x H)

Volume of packed-bed: ~7,9 m^3

Dimensions of the condensation:
- 11 m x 1,5 m x 3,8 m (L x W x H)

(AWS 2016)

4.2 Achieved environmental benefits

The waste gas treatment system reduces emissions of volatile organic com-pounds (VOC).

Solvents that are concentrated in the absorbent can be regained in liquid form through the desorption system in the plant. The desorbed solvents can alternatively be led to a thermal oxidation.

4.3 Environmental performance and operational data

- Measurements method for TOC: FID (EN 12619:2013-04)
- Measurement period: 30 minutes
- Waste gas concentration: generally < 50 mg/Nm^3
- Average VOC reduction rate: ~65 %
- The maximum concentration of the system is up to 25 % of the lower explosion limit (LEL).
- In the example plant (applying condensation), waste gas is concentrated with a ratio of ~55:1
- In case of thermal oxidation, concentration ratio range between ~30:1 and ~100:1, depending on the raw gas concentration.

(AWS 2016)

4.4 Cross-media effects

Energy consumption

The system leads to an additional energy consumption of natural gas and electricity.

The increase of the exhaust fan electricity consumption is calculated separately from electricity consumption of the exhaust fan operating without waste gas treatment system.

Natural gas:

- 28 m^3/h corresponding to: ~280 kW_{th}

Electricity:

- Absorber ~39 kW_{el}
- Desorber ~25 kW_{el}
- Cooling of sorption fluid ~52 kW_{el}
- Condensation ~359 kW_{el}
- Exhaust air fan (additional) ~76 kW_{el}

Heat used in the process is provided by hot thermal oil produced with natural gas.

Alternatively, a thermal oxidation system can be installed for combustion of concentrated VOC. In case of a retrofit, VOC may be directed to existing thermal oxidation plants, which may increase its efficiency where operated with high variations of raw gas concentration. (AWS 2015)

4.5 Applicability

The waste gas treatment system can be applied in new plants and for upgrading of existing plants. The absorption unit can be implemented in existing ventilation ducts. If not applicable because of restricted space, a separate location of absorption and desorption units is possible.

In case of varying VOC concentrations in the raw gas, the storage capacity of the absorbent can be used to temporally decouple absorption and desorption. (AWS 2015)

4.6 Economics

Investment and operational costs depend from the waste gas volume and the level of concentration of organic compounds to be treated.

- Investment costs: ca. 1.6 Mio. €
- Service and waste disposal: 7100 €/a
- Refill of process utilities: 57 600 €/a
- Energy costs (without fan): 80 €/h
- Other costs (e.g. refill absorbent): 10 €/h
- Specific costs for waste gas treatment: 0.041 Cent/Nm^3

(AWS 2016)

4.7 Driving force for implementation

The main reason for implementation of the absorption waste gas treatment system are legal requirements. The system can be applied for concentration of VOC where coating substances hinder the application of a zeolite absorption rotor (e.g. UV varnishes, high-boiling agents).

The system may be applied where solvent recovery is an objective.

The system is applied where combined heat and power systems are economically viable.

4.8 Example plants and supplier

- BMW Group Werk Landshut, Ohmstraße 2, D-84030 Landshut

Other plants with the same system:

- Dr. Ing. h.c. F. Porsche AG, Porscheplatz 1, D-70435 Stuttgart
- Porsche Leipzig GmbH, Porschestraße 1, D-04158 Leipzig
- Dipl.-Ing. Heinrich Leist Oberflächentechnik GmbH; Ölmühle 5, D-98597 Fambach
- Wilhelm Kächele GmbH, Jahnstraße 9, D-73235 Weilheim an der Teck

Supplier

- AWS Group Aktiengesellschaft
  Inselwiesenstraße 4
  D-74076 Heilbronn
  Fon +49 7131 79788-0
  Fax +49 7131 79788-88
  info@aws-systems.com
  www.aws-systems.com
- Contact:
  Mr Stefan Hermann
  Email: stefan.hermann@aws-systems.com

4.9 Reference literature

(Pfutterer 2016) (Klamser 2016) (Recker 2015) (Walldörfer 2014)

5 Evaluation of site visits and supplier information

5.1 Packaging printing

In the context of the project, three companies were visited carrying out packaging printing:

- Kurz, Sulzbach-Rosenberg: 24 March 2015
- Debatin, Bruchsal: 21 April 2015
- Bischof + Klein SE & Co. KG, Lengerich: 5 May 2015

One of the plant is recommended as reference plant, also for BREF author's site visit:

- Debatin, Bruchsal (packaging printing and adhesive coating)

Kurz and Bischof+Klein have claimed confidentiality issues and made reservations regarding the publication of a detailed plant description. It may be possible to have them fill-out a questionnaire with confidential parts during the official data collection of the BREF revision.

Main lessons learnt from the site visits were (with reference to the presentation in the annex 1):

- Peak emissions from washing machines can be homogenized with smoothers using zeolite, where solvents are used for cleaning. Experience with water-based (alkaline solution) washing machines are generally positive (see slide 13) but involve risks of chemicals (skin, eye) burn. Water-based ultrasonic cleaning can be used for anilox rolls (slide 12). Solvents for thinning and cleaning are stored in small quantities near the machine, if centralized filling stations exists (see slide 9).
- Barrels should use pump system with fully enclosed connections to the barrel (see slides 10, 11).
- Automatic ink mixing systems reduce fugitive emissions from manual ink mixing (slide 7). Direct piping of conventional thinners is installed in new plants. Automatic washing is carried out by new plants. New plants are well encapsulated to prevent from fugitive emissions.
- Machinery is often used for long time, which implies that machines without encapsulation are still frequently used. Examples were found, where companies have made own efforts to install shields for improved enclosure at existing plants (see slide 8).
- Enclosure of the production hall can prevent from fugitive emissions, in particular where old machines without encapsulation are used. In this case waste gas from ventilation of the production hall can be used as combustion air in the dryers.
- Installation of various combustion chambers with flexible operation mode according to the printing machines running (and related VOC load in the raw gas) can help to achieve autothermal combustion of those combustion chambers being in operation. The system requires a combination of ducts from all machines towards a centralized waste gas cleaning system instead of individual or several thermal oxidizers (see slide 6).
- Recuperative thermal oxidizers are the preferred option for reduction of energy consumption in the waste gas cleaning. Heat recovery is most efficient where thermal oil is heated for the dryers. Additionally, heat exchangers for air conditioning of the production hall in winter is realized.

5.2 Publication rotogravure

In the context of the project, one company was visited carrying out publication rotogravure printing:

- Burda, Offenburg: 21 April 2015.

The calculation of a reduction of the half-hour average value from 50 mg/Nm^3 to 20 mg/Nm^3 was assessed by a publication rotogravure printing with two machines and four associated activated carbon absorbers (7500 kg steam per recovery). For compliance with and emission limit value of 50 mg/Nm^3, desorption starts at an emission level of 30 mg/Nm³. By reduction to a start at 20 mg/Nm³, the absorption phase is reduced by 35 min. from 705 min to 670 min. This results in 132 more desorption processes per year (5 % of currently 2640). This results in additional steam requirements of 900 tons. With 40 €/t, 39.600 €/a additional costs are associated as well as about 20.000 €/a for electricity (pumps, cooling, etc.). 900 t steam are associated with 145 t of CO_2 emission from gas combustion.

5.3 Biofilter

It is proposed to add new information on applicability in the annex of the BREF STS (2007) where biological treatment and its applicability are described in section 24.9 “Removal efficiency of waste gas treatment techniques - End-of-pipe techniques: Descriptions and considerations for applicability”.

The section is introduced with the following wording:

The descriptions and considerations for applicability below are intended as an overview only. See the relevant sections in Chapter 20 of this document for additional information. The information in this annex on its own cannot serve as the basis for the selection of a suitable abatement technique.

This introduction is followed by the table below (Table 3). The underlined text is proposed as addition, based on the biofilter reference plant described in chapter 3.

Table 3: End-of-pipe technique and description, conditions for applicability, applicability

End-of-pipe technique and description	Conditions for applicability	Applicable:
Biological		
Biological treatment		
(Not included in calculations of removal efficiency) The waste gas is blown through a bed of organic material in which the VOCs are adsorbed and destroyed (metabolised) by bacteria.	The equipment is simple and not expensive, but needs a lot of space in the case of large airflow. Bacteria are easily killed by changing the composition of the waste gas or by lack of feed in the holiday season. This affects the filter efficiency. No information about operating cost.	Waste gas stream with low concentration <u>up to about 750 mg/Nm³, in case of alcoholic VOC up to about 1000 mg/Nm³</u>. Biodegradable and preferably water soluble components. Odour problems.

(BREF STS 2007, Table 24.14)

6 Elaboration of an initial position

6.1 Commission request

In December 2014, the revision process was started with a stakeholder request for delivery of initial positions. The request by the European Commission's Integrated Pollution Prevention and Control Bureau was structured in two templates to be used for answers of the stakeholders. Besides a Guideline for TWG members, the Commission circulated proposals for "Key Issues for the Review of the STS BREF" and asked specific questions to the stakeholders, e.g. on the future scope, structure and key environmental issues of the document. Additionally, questions on applied processes and BAT candidates were made, as well as questions on indicators for environmental performance and on monitoring.

6.2 Support to the Initial Position of Germany

The UBA was supported by Ökopol in elaboration of the initial position, together with the members of the national expert group (competent authorities of the federal states ("Länder"), responsible for permitting and inspection), and the members of the extended national expert group (industry, suppliers).

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Annex 1 – Presentation for Discussion of Project Results (18.6.2015)

Umweltforschungsplan-Projekt zu innovativen Techniken:
Ermittlung des Standes der Technik in Deutschland

Beste verfügbare Techniken für Anlagen der Oberflächenbehandlung unter Verwendung von organischen Lösemitteln

Präsentation als Diskussionsgrundlage für das Fachgespräch mit der

Erweiterten Nationalen Arbeitsgruppe zur BVT-Merkblattrevision BREF STS

Präsentation: Christian Tebert, Dipl.-Ing. Technischer Umweltschutz

ÖKOPOL GmbH – Institut für Ökologie und Politik

Umweltbundesamt Berlin, 18. Juni 2015

Ökopol
Institut für Ökologie und Politik GmbH

UBA-Forschungsvorhaben BREF STS (2014/15)

Illustrationstiefdruck

- Beschreibung einer Lösemittel-Rückgewinnung
- Energetischer Aufwand zur Reduzierung des Grenzwertes von 50 mg/Nm^3 auf 20 mg/Nm^3
- Offene Frage: Pflicht zur Senkung der Emissionen von 50 auf 20 mg/Nm^3 für Emissionen aus Toluolanwendung?

Holzbeschichtung

- Beschreibung einer biologischen Abgasreinigung

Verpackungsdruck

- Beschreibung von drei Anlagen mit einer regenerativ-thermischen Nachverbrennung (RNV) und weiteren Lösemittelminderungsmaßnahmen

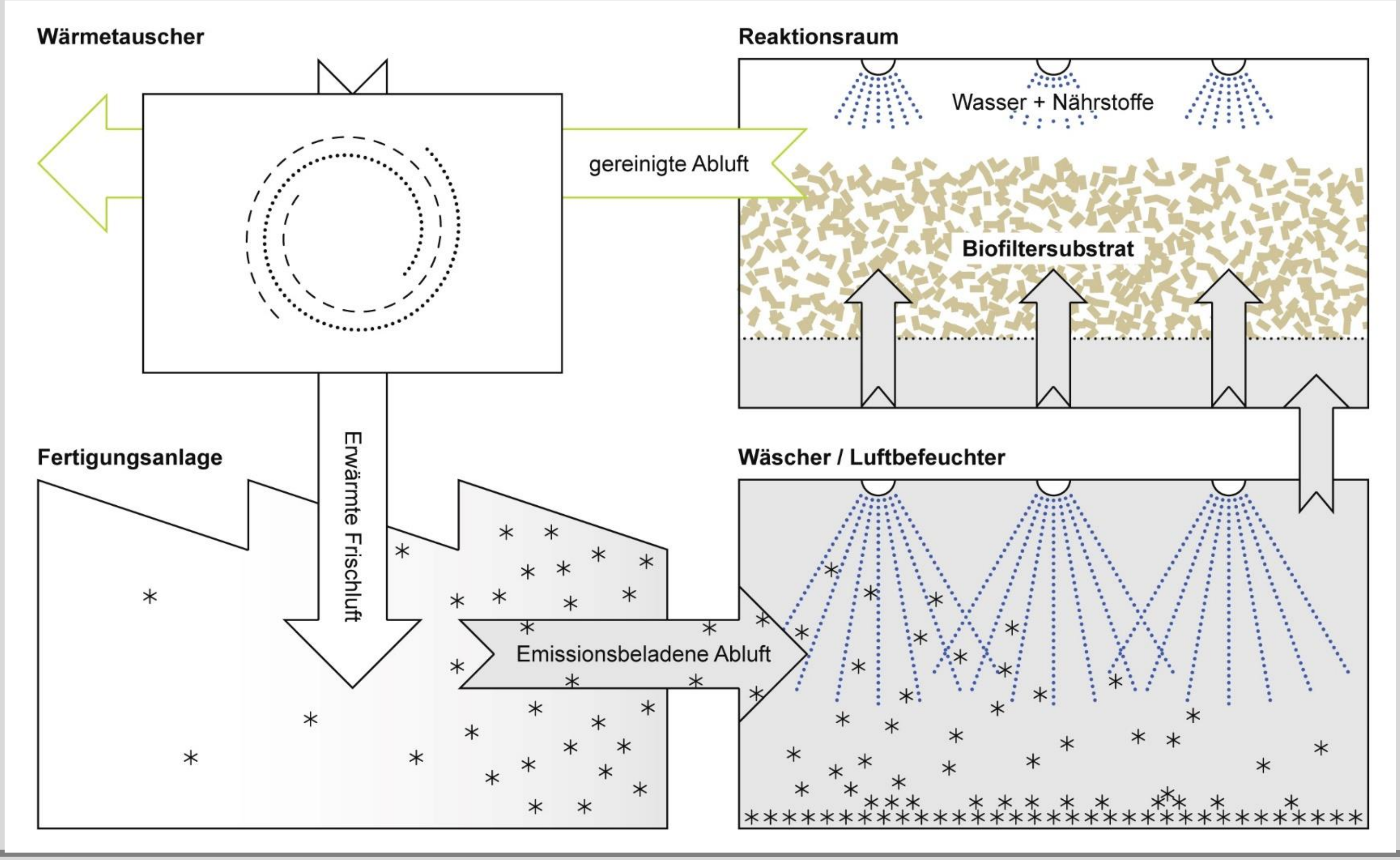
Illustrationstiefdruck

Illustrationstiefdruck

- Beschreibung einer Lösemittel-Rückgewinnung
- Energetischer Aufwand zur Reduzierung des Grenzwertes von 50 mg/Nm³ auf 20 mg/Nm³
- Offene Frage: Pflicht zur Senkung der Emissionen von 50 auf 20 mg/Nm³ für Emissionen aus Toluolanwendung?

Holzbeschichtung

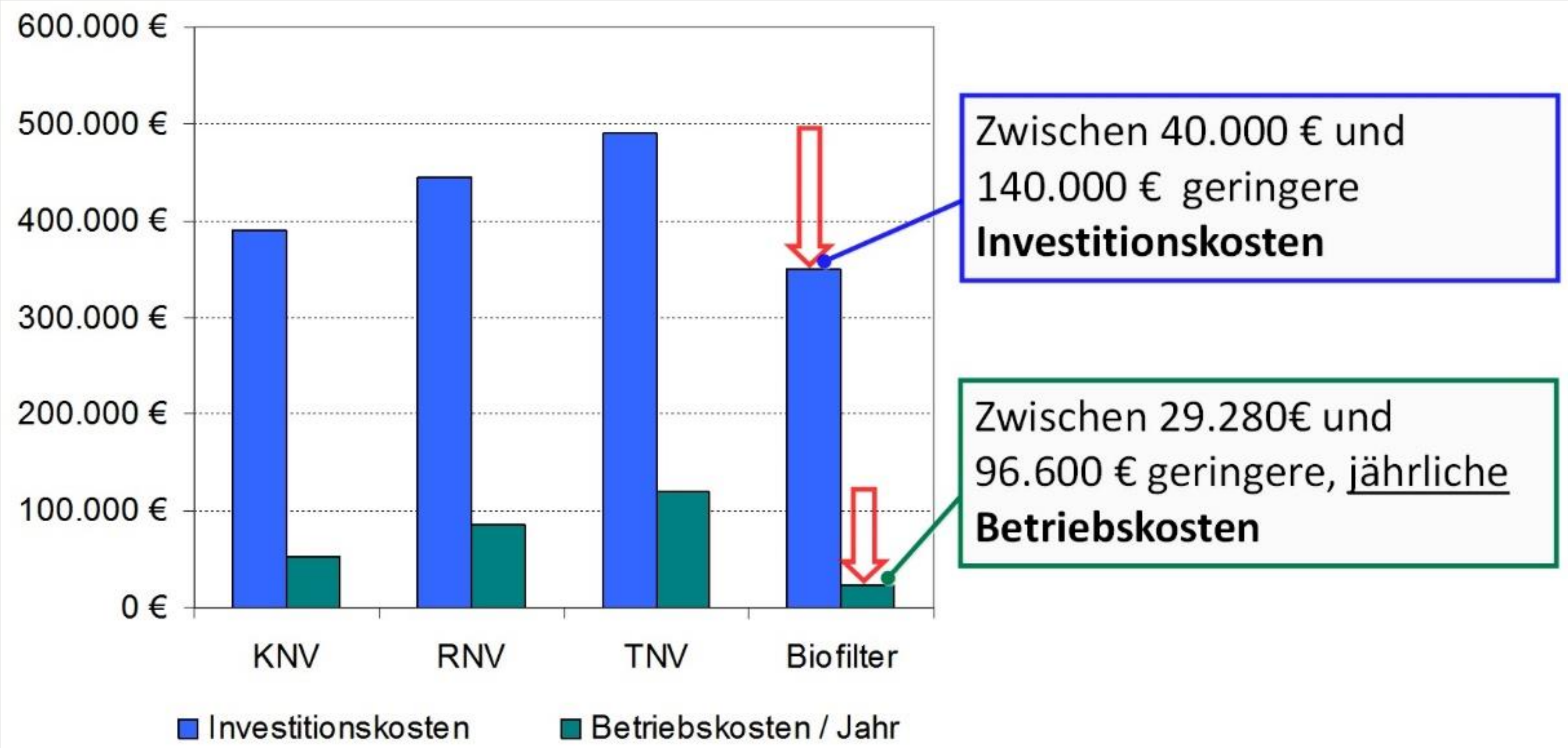
Biologische Abgasreinigungsanlage



Quelle: Störk Umwelttechnik GmbH, 2015

Holzbeschichtung

Biologische Abgasreinigungsanlage



Quelle: Störk Umwelttechnik GmbH, 2015

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Regenerativ-thermische Abgasreinigungsanlage

Verpackungsdruck (Flexodruck, Tiefdruck)

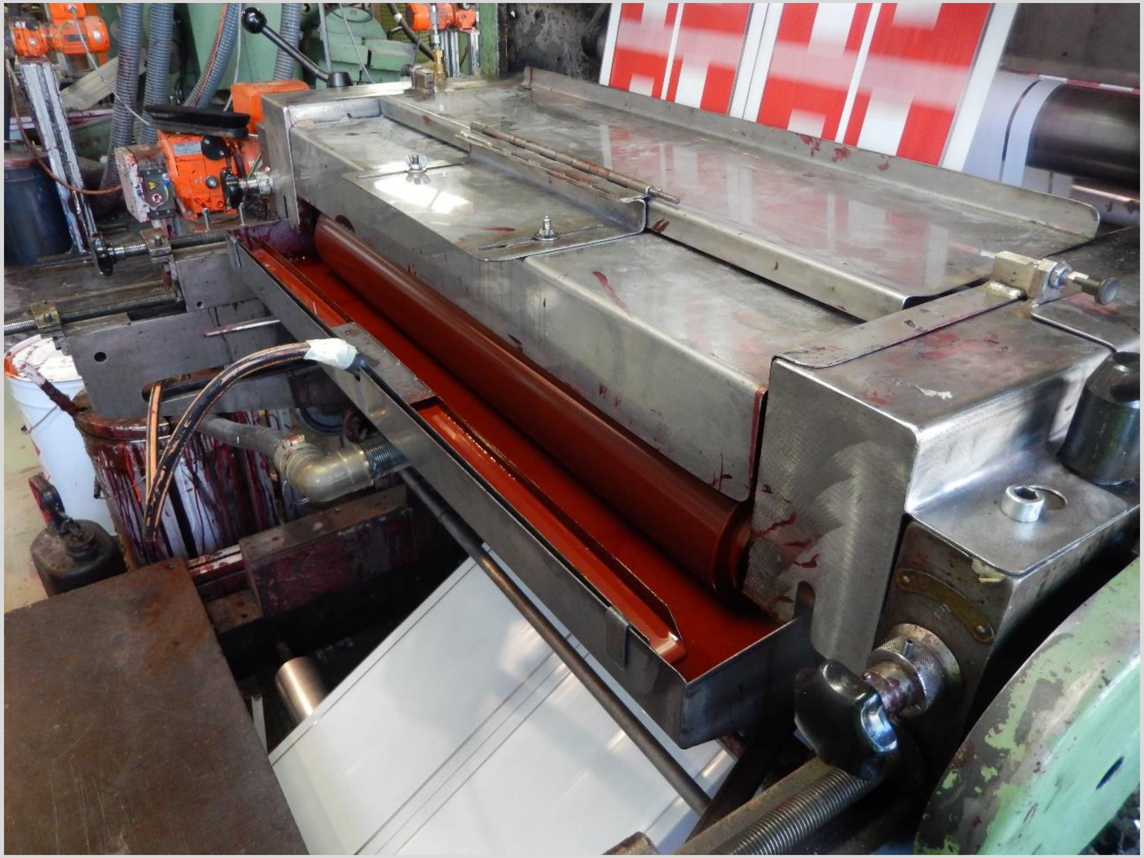
Emissionsminderung durch Schließung diffuser Quellen

- Farbmischsysteme

Verpackungsdruck (Flexodruck, Tiefdruck)

Emissionsminderung durch Schließung kleiner Quellen

- Geschlossene Maschinen
- Schließung von Farbkästen an älteren Maschinen



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Emissionsminderung durch Schließung diffuser Quellen

- „Tankstelle“ für kleine Mengen Verdünner, Verzögerer an der Maschine

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Emissionsminderung durch Schließung diffuser Quellen

- Geschlossene Anschlüsse bei Fasspumpen

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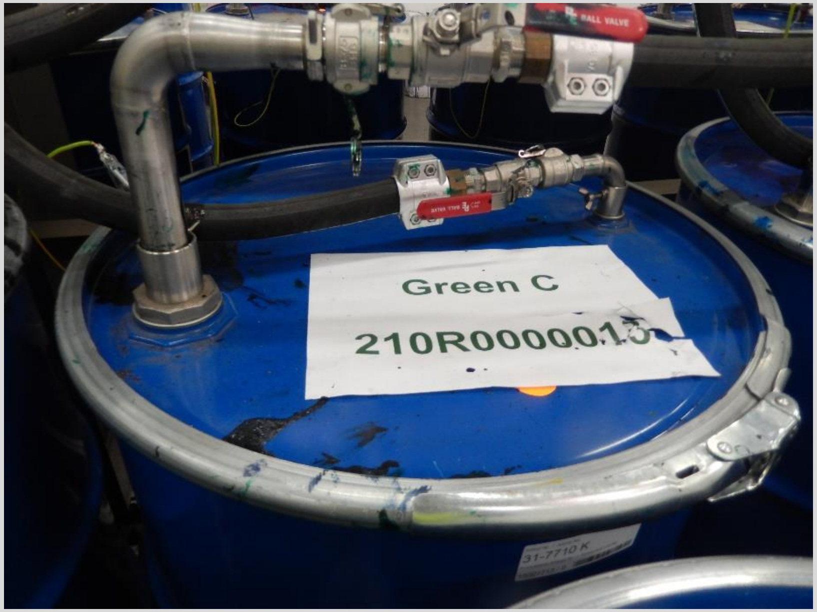
Emissionsminderung durch Schließung diffuser Quellen

- Geschlossene Anschlüsse bei Fasspumpen



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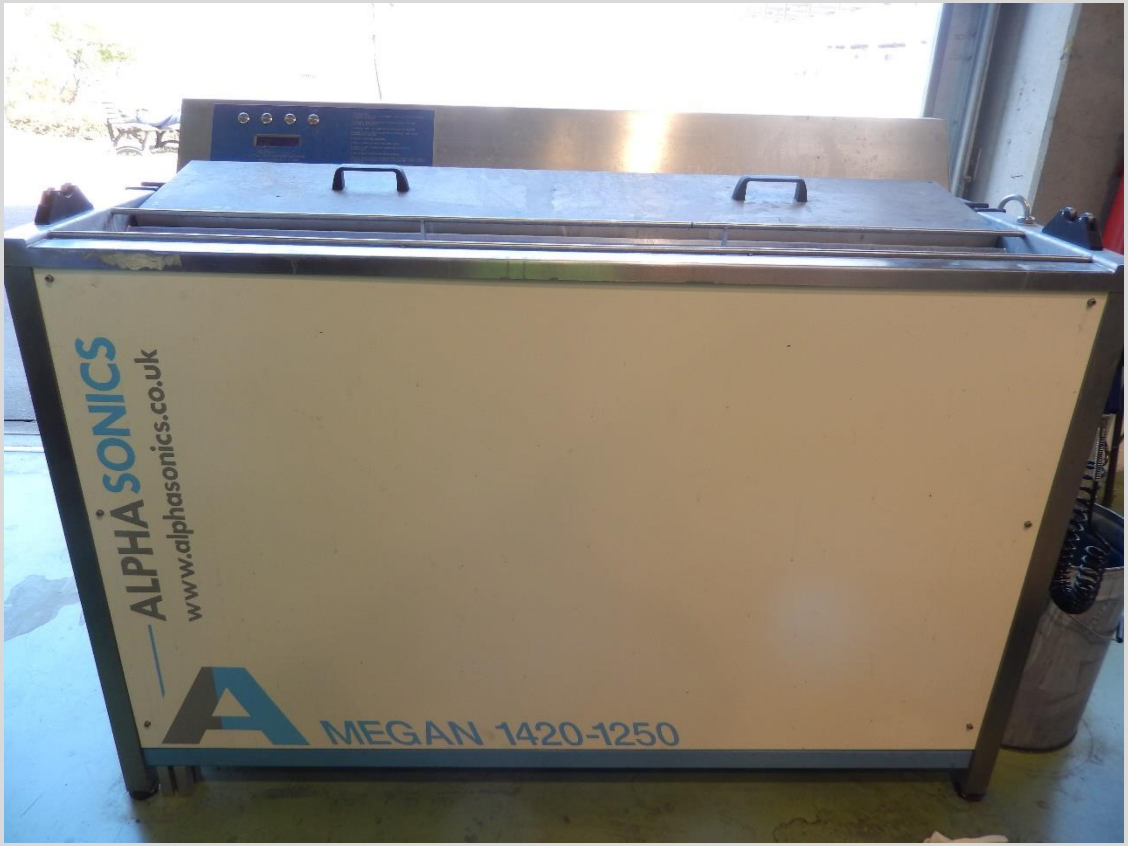
Emissionsminderung durch Schließung diffuser Quellen

- Ultraschall-Reinigung von Zylindern



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Emissionsminderung durch Laugen-Waschanlagen

- Explosionsgefahren gemindert
- Peaks in der Abluftreinigungs-anlage gemindert

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