Reduction of VOC Emissions in the Paint and Coatings Industry

focusing on production modification measures
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1 Description of Problem

The application, and release, of volatile organic compounds can, due to their properties, cause harm to human health and/or contribute to local or trans-boundary formation of photochemical oxidants in the boundary layers of the troposphere, leading to environmental degradation.

To prevent, or mitigate, emissions of volatile organic compounds over the long term, in June 1998 the European Union issued Directive 98/C 248/01 of the Commission on the Limitation of Emissions of Volatile Organic Compounds, referred to in the following as the VOC Directive. This requires registration of all plants or plant components covered by this Directive. Furthermore, their operators must initiate measures, within the stated transition periods and as far as necessary, to prevent or reduce VOC emissions.

The purpose of this Study is to identify measures integrated into the production process for cutting VOC emissions from point and diffuse sources specifically for enterprises manufacturing solvent-based paints and coatings, and to assess these under the aspects of efficiency and costs.

Production modification measures: technical and organizational measures for preventing emissions directly at their sources, or by means of which emissions are reduced, extracted and directed to treatment or disposal.

(This is contrasted with post-production pollutant destruction and exhaust air clean-up, which is not the subject of this Study.)

Particularly of interest in this connection are the following production units:

- unloading stations for feedstocks
- tankfarms
- production equipment, like dissolvers, mills, finish tanks, filters, dosing stations
- holding stores for mobile bins
- rinsing basins for special tools
- cleaning cabinets for mobile bins, drums and containers.
Measures for preventing and/or mitigating solvent-containing emissions can be classified under the following headings:

- process-integrated measures
- product-integrated measures and
- strategic measures in production-support functions.

Possible starting points for **process-integrated measures** for cutting VOC emissions during production will be described in **Chapter 5**, and evaluated under the aspects of their efficiency and costs.
2 Legislation Governing Permit Approval

2.1 EU Directive

As noted in the introduction, in June 1998 Directive 98/C 248/01 of the European Commission was promulgated. This addresses limitation of emissions of volatile organic compounds arising due to certain activities and in specific plants when organic solvents are used.

This Directive has now to be implemented in national legislation by the member countries of the European Union.

The VOC Directive affects in particular small and medium-sized plants, for which up to now national legislation does not require the installation of post-production clean-up equipment, or which have been operating at the limits of VOC standards and threshold values due to their product ranges and quantities.

The paint and coatings industry, that is the manufacturers of coating substances, clear varnishes, printing inks and adhesives, are, according to Appendix I of the Directive, directly affected if they use more than 100 t/a of solvents. These enterprises are now confronted with the challenging tasks of:

- documenting their solvent situation with a high degree of transparency so as to permit tracking of these substances
- projecting their market situation in 2007 - product range, production volumes - under the aspect of the future solvent balance
- identifying measures needed for compliance with the VOC Directive and evaluating these under their cost aspects
- as far as necessary, initiating measures to cut VOC emissions.

2.2 VOC limits and threshold values

Enterprises in the paint and coatings industry as well as manufacturers of coating materials, clear lacquers, printing inks and adhesives using more than 100 t/a solvent must, according to the new VOC Directive and after the transition limits stipulated in this have elapsed, comply as a minimum with the threshold values and limits for solvents as named in the following:
Table 2: Threshold values and limits for solvents in accordance with EC/C 248/01

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Threshold value (t/a)</th>
<th>Emissions limit for exhaust gases (mg C/Nm³)</th>
<th>Limits for diffuse emissions (%)</th>
<th>Total emission limit (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Manufacture of coating materials, clear lacquers, printing inks and adhesives</td>
<td>100-1000</td>
<td>150</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;1000</td>
<td>150</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

It may be assumed that more stringent limit or threshold values arising from the specific situation at the site or from any other officially imposed conditions will continue to apply.

2.3 Implementation of the VOC Directive

Apart from the above threshold and limit values, key components of this Directive are:

- elaboration of a national reduction plan, which will permit operators to take other measures to cut emissions by the same amount that would have been attained by application of the emission standards (in this connection, operators can apply any emissions reduction plan)
- compilation of a solvent balance, to serve for the national responsible regulatory authorities as a basis for checking compliance with emissions standards and for determining what reduction options are open.

The key concerns faced by enterprises in the paint and coating industry emanating from the VOC Directive, and the resulting measures, are summarized in the figure below.
Figure 2: Decision flowchart for implementing the VOC Directive

- Rehabilitation of existing systems,
- Expansion of existing systems or
- New systems

- Solvent consumption > 100 t/a
  - YES
  - Development of works consumption 2007?
    - > 100 t/a?
      - YES
        - Significant modification?
        - NO
        - NO
          - Internal monitoring and documentation of results
          - No further activities
          - Emission limits According to Article 5
            - Pollution control requirements According to Articles 8 and 9
              - Permit
                - Permit application registration necessary
                  - Transition
                    - Systems have meet the requirements of to Article 4 (1) by 31.10.2007

- NO
  - NO
    - NO
      - NO
        - NO
          - NO
3 Approaches to Cutting VOC Emissions in the Paint and Coatings Industry

Sources can be grouped depending on how the emissions they generate leave the production facility:

- in the effluent water or via a wastewater treatment plant
- in the solid waste hauled away for external disposal
- in the fumes exhausted to atmosphere or via an exhaust fume treatment plant.

Figure 3: Solvent emissions

Wastewater from a plant manufacturing paint and coatings on a solvent basis comprises essentially cleaning effluent from washing the floors of the production buildings as well as the transportation and traffic routes. Under the aspect of the solvent balance, this will only be of significance in isolated cases, as the solvent loadings, which they transport, are generally very low, and consequently production modification measures for reduction or prevention will have little influence on the overall emission situation.

For this reason, wastewater as an emission path is eliminated from further consideration in this Study.

The solid waste arising in paint and coatings manufacturing plants comprise essentially disposable packaging, transportation drums as well as sedimentation
and filtration residues. These are likewise of importance for the solvent balance and the overall emissions situation only in isolated cases, and are therefore not considered further.

Effective prevention and/or reduction of solvent emissions is only possible in connection with fume extraction and exhaust.

A basic distinction is made between points and diffuses emission sources.

The determining **causes of emissions** in paint and coatings manufacturing plants are:

- displacements of solvent-laden air when filling and emptying road and rail tankers
- respiration losses at tanks in general
- displacement of solvent-laden air when dosing tanks and dissolvers with feedstocks
- emissions as temperature rises due to chemical reactions or shearing forces in reactors and dissolvers
- displacement of solvent-laden air when decanting and filling intermediate and final products
- diffuse emissions from systems and components that are open or only partially closed
- cleaning of stationary tanks and dissolvers
- cleaning of mobile tanks and small parts.

As a rule, the **originators of emissions** of volatile organic compounds are solvents and binding agents.

Providing the basis for identifying and evaluating measures for improving the solvent balance is the "emissions register". When compiling this emissions register, the current emissions situation of the production facility and each emitter are documented and analyzed as follows:

- systematic collection of data and information
- classification of emission sources, among others, on the basis of:
  - pollutant
  - location
  - formation mechanism
  - coincidence factor
  - means of disposal
- calculation of mass and volumetric flow rates for each emission source
- drawing up quantitative and qualitative balances
- appraisal of emission sources under the aspects of, among others
  - mass flow rate
  - volumetric flow rate
- initiation of further measurement programs as far as necessary.
The key contents of a plant emission register are summarized in the following figure.

Figure 4: Emissions register
4 Process-Integrated Production Modification Measures for Cutting VOC Emissions

As noted above, approaches for preventing and reducing emissions of volatile organic compounds can be categorized as process-integrated measures, product-integrated measures and strategic measures in production-support functions.

Process-integrated measures generally involve technical modifications to prevent emissions right at their source, or by means of which emissions are reduced, extracted and transported away.

In the following sections 5.1 to 5.10, potential process-integrated emission reduction measures are looked at in more detail.

Implementation of the production modification measures described below will result as a rule in the prevention (in enclosed systems) or reduction (by extraction of fumes) of emissions from diffuse sources. They bring about a significant improvement of the emissions situation at the workplace, and will generally permit compliance with the maximum allowable concentrations (MAC) stipulated for places of work.

But it must be noted that changing diffuse emissions by extracting fumes into directed emissions can result in an increase of VOC loadings in the exhaust air stream. This is unavoidable in particular if the exhaust air system is over dimensioned with regard to the fan extraction rate and at the same time the emitters are encapsulated. Therefore a prerequisite for successful reduction of the emissions by modification of production facilities is careful design of the fume extraction equipment.

The following table summarizes individual measures considered in this Study, and their influence on directed VOC emissions and VOC limits for diffuse emissions is indicated as follows:
### Prevention and Control of Industrial Air Pollution in Thailand

- reduction of VOC concentration
- slight increase of VOC concentration
- slight reduction of VOC concentration
- increase of VOC concentration

#### MEASURES | EVALUATION
--- | ---

| Diffuse emissions | Directed emissions |

### 4.1 Unloading system for feedstock dosing and tankfarms

- Installation of a pressure equalizing line
- Isolation of tank by fitting over-/underpressure valves

### 4.2 Dissolver and reactor

- Feedstock charging via closed systems
- Feedstock distribution and dosing via closed systems
- Feedstock dosing or charging from mobile bins into partially closed systems
- Feedstock dosing or charging from drums into partially closed systems
- Interlocking of systems for extraction of solvents and particulates (e.g. no extraction when plant not operating)
- Encapsulation of mobile bins during dispersing / mixing
- Encapsulation of dissolver and condensation
- Encapsulation of dissolver
- Automation of dissolver cleaning
- Volumetric flow minimized by flow restrictors

### 4.3 Holding store for mobile bins

- Covering of mobile bins
## Prevention and Control of Industrial Air Pollution in Thailand

### MEASURES

<table>
<thead>
<tr>
<th>MEASURES</th>
<th>EVALUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4 Dosing station for mobile production bins</td>
<td></td>
</tr>
<tr>
<td>• Flexible hoods</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>• Free jet dosing</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>• Stationary extraction hoods</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>• Automatic shut-off valves</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>4.5 Mills for fine dispersing</td>
<td></td>
</tr>
<tr>
<td>• Covering of mobile container</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>• Covering of mills</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>4.6 Finish tanks</td>
<td></td>
</tr>
<tr>
<td>• Isolation of tanks by under-/overpressure valves</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>4.7 Filter systems</td>
<td></td>
</tr>
<tr>
<td>• Edge or bag filter</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
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<tr>
<td>4.8 Filling systems</td>
<td></td>
</tr>
<tr>
<td>• Extraction hoods</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>4.9 Rinsing basin</td>
<td></td>
</tr>
<tr>
<td>• Encapsulation with directed exhaust air flow</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>• Automatic shut-off valves</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>4.10 Cleaning of mobile production bins</td>
<td></td>
</tr>
<tr>
<td>• Cabinet washer with water-based rinsing system</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>• Cabinet washer with solvent based rinsing system and post production treatment</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>• Cabinet washer with brushes, solvent based and condensation system and sealing of brushes in a separate chamber</td>
<td><img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
</tbody>
</table>
4.1 Unloading system for feedstock dosing and tankfarms

VOC emissions from tankfarms and loading/unloading systems are caused mainly by:

(1) Displacement of exhaust air to atmosphere during loading and unloading of road or rail tankers

- Volumetric flow rate: 20-50 Nm³/h
- Concentration: 1,000-5,000 mg org.C/Nm³, depending on temperature

(2) Respiration losses in the tankfarm to atmosphere

- Volumetric flow rate: < 1 Nm³/h
- Resins concentration: 1,000-5,000 mg org.C/Nm³
- Solvents concentration: 10,000-50,000 mg org.C/Nm³

Measures for cutting VOC emissions and their capital costs are:

(1) Installation of a pressure equalizing line

- Efficiency: Nearly 100%
- Capital costs: approx. 5,000-20,000 DM for one line, depending on number of tanks and distance between unloading station and tankfarm (piping system, valves, flashback arresters)
### 2. Isolation of tank by fitting over-/under-pressure valves

Closes the system at a defined pressure (e.g. -5/+10 mbar)

**Efficiency:**
Nearly 100% because of closed system at a defined pressure

**Capital costs:**
2,500-5,000 DM/tank, depending on pipe diameter and pressure drop

### 4.2 Dissolver and reactor

VOC emissions from dissolver and reactor are caused mainly by:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| **(1) Displacement during liquid feedstock dosing** |  Volumetric flow: 5-10 Nm³/h, depending on installed pump capacity  
Concentration: 1000-5000 mg org.C/Nm³, depending on temperature |
| **(2) Chemical reactions** |  Temperature rise up to 50-70°C  
Concentration up to 10,000 mg org.C/Nm³ |
| **(3) Rising temperatures caused by shearing forces, among others** |  Temperature rise up to 50-70°C  
Concentration up to 10,000 mg org.C/Nm³ |
| **(4) Cleaning of dissolver (shaft and disc) or reactor** |  Concentration: 1000-3000 mg org.C/Nm³ |
Measures for cutting VOC emissions and their capital costs are:

(1) **Feedstock charging via closed systems**

   *Transceiver:* mobile (container, bins with adapter and/or integrated unloading systems)
   *Transmitter:* stationary (pipes)
   *Receiver:* stationary (dissolver)

Avoidance of diffuse VOC emissions to atmosphere by using containers with adapter and charging via stationary closed piping systems. Dosage controlled manually (using delivery containers with definite weight and keeping a tally of number of containers) or automatically by e.g. weighing and automatically initiated switch-off.

**Efficiency:**
100% with pressure equalizing line between container and dissolver/reactor.

**Capital costs:**
10,000-20,000 DM/container system
(2) Feedstock distribution and dosing via closed systems

Transceiver: stationary
(tanks, containers with integrated unloading systems)

Transmitter: stationary
(pipes)

Receiver: stationary
(dissolver)

Avoidance of diffuse VOC emissions to atmosphere by using stationary closed piping systems; distribution and dosing of solvents and resins controlled fully automatically by volumetric flowmeter and automatically initiated switch-off (alternatively by level measurement)

Efficiency:

- Emissions caused by handling of drums or containers are prevented; efficiency nearly 100%
- Increase of throughput capacity / availability by up to 30%
- Reduction of staff costs by up to 30%
- Improved and reproducible quality in dosing
- Only recommended for solvents and resins with a high frequency in usage and/or a high consumption (cost analysis is necessary)

Capital costs:
Site specific
(3) Feedstock dosing or charging from mobile bins into partially closed systems

Transceiver: mobile (bins, container with adapter or integrated unloading system)

Transmitter: mobile/flexible (e.g. pumps with flexible hose on pressure side)

Receiver: stationary (dissolver)

Reduction of diffuse VOC emissions to atmosphere by installation of small charging holes on the dissolver lid (lockable); start-up/shutdown of exhaust air system activated manually or automatically (e.g. dead stop position switch on the cap).

Efficiency:

- Improvement in personnel protection; reduction of emissions at place of work
- Reduction of diffuse emissions by about 100%

Capital costs:
Approx. 5,000 DM/lid

(4) Feedstock dosing or charging from drums into partially closed systems

Transceiver: mobile (drum)

Transmitter: -

Receiver: stationary (dissolver)

Reduction of diffuse VOC emissions to atmosphere by installation of hoppers with, for example, side extraction slit on the dissolver lid; start-up/shutdown of exhaust air system activated manually or automatically (e.g. dead stop position switch on the cap).

Efficiency:

- Improvement in personnel protection; reduction of emissions at place of work
- Reduction of diffuse emissions

Capital costs:
3,000-5,000 DM/lid
(5) Interlocking of systems for extraction of solvents and particulates

Reduction of VOC loadings by interlocking of extraction systems for solvents and particulates to minimize volumetric flows of solvent-diluted exhaust fumes (reduction of respiration losses).

Extraction of particulate emissions by way of a filter to atmosphere; dosing of solids as automatic or semi-automatic system with integrated dust filter and ventilator

**Efficiency:**

Respiration losses of solvents will be reduced. Dilution of VOC emissions will be avoided. Volumetric flow rate will be reduced as much as possible.

**Capital costs:**

Site specific

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(6) Encapsulation of mobile bins during dispersing / mixing

Reduction of diffuse VOC emissions to atmosphere by encapsulation of mobile bins during dosing with an extraction hood; alternatively increase of peripheral extraction

**Efficiency:**

- Improvement in personnel protection; reduction of emissions at place of work
- Reduction of diffuse emissions by 90-100%

**Capital costs:**

5,000-10,000 DM/dissolver, depending on performance
(7) Encapsulation of dissolver, additionally special dissolver lids with integrated condensation system can be used

Encapsulation of open or partially closed dissolver with extraction hood and swivel opening; start-up/shutdown of exhaust air system activated manually or automatically (interlocking with swiveling door).

Volumetric flow rate of extraction system during dosing of liquids and solids about 500-600 m³/h and during dispensing about 15-50 m³/h (slight underpressure).

Valves in the extraction system in position
– ON = dosing
– MIN. = dispensing
– OFF = dissolver not operating

Efficiency:

Improvement in personnel protection; reduction of emissions at place of work

Respiration losses will be reduced (minimized extraction)

Reduction of diffuse emissions by 90-100%

Condensation systems can be used, with cooling by air or mains water depending on temperature attained during dispensing process. The efficiency of this system is very high, with solvent vapors condensed out almost completely and returned to the production bin or vessel.

Reduction of directed emissions by 90-100%

Capital costs:
10,000-15,000 DM/encapsulation system
(8) Automation of dissolver cleaning, dissolver with large production vessels as closed system

Procurement of replacement equipment

Efficiency:
- Improvement in personnel protection; reduction of emissions at place of work
- Reduction of emissions by about 100%

Capital costs:
Automatic cleaning system, e.g. with rotating nozzle and solvent-based cleaning: 20,000-40,000 DM

(9) Volumetric flow minimized by using manually or automatically driven valves and flow restrictors in the extraction system

Efficiency:
- Improvement in personnel protection; reduction of emissions at place of work
- Effectiveness of extraction at each emission source enhanced
- Respiration losses reduced (minimized extraction)
- Reduction of electricity consumption
- Personnel training may be necessary

Capital costs:
Site specific
4.3 Holding store for mobile bins

VOC emissions at holding stores for mobile bins are caused mainly by:

(1) **Respiration losses to atmosphere during temporary storage**

Measures for cutting VOC emissions and their capital costs are:

<table>
<thead>
<tr>
<th>(1) Covering of mobile bins with wooden lids or plastic membranes</th>
<th>Efficiency:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Reduction of emissions at place of work by about 100%</td>
</tr>
<tr>
<td></td>
<td>• Personnel training may be necessary</td>
</tr>
</tbody>
</table>

**Capital costs:**
Costs are negligible

| (2) Provision of special storage areas for bins with separate extraction systems | Efficiency gains and capital costs are site-specific. |

4.4 Dosing station for mobile production bins

VOC emissions at dosing stations for mobile production bins are caused mainly by:

(1) **Displacement during dosing of solvents and resins into open bin**

(2) **Leaks at dosing valves**

(3) **Emission releases during free jet dosing into open bins**

(4) **Diameters of extraction systems are often overdimensioned**

(5) **Correct positioning of the extraction system is not possible or is inconvenient (and therefore not done properly by operators)**
Measures for cutting VOC emissions and their capital costs are:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
<th>Efficiency</th>
<th>Capital costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Flexible hoods</td>
<td>Reduction of diffuse emissions by installation of flexible extraction systems with hood (peripheral or segmental extraction rate of about 500 m³/h; DN 150)</td>
<td>- Improvement in personnel protection; reduction of emissions at place of work by about 100%</td>
<td>approx. 5,000-10,000DM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Free jet dosing</td>
<td>Avoidance of leaks by installation of flexible hoses or lengthening dosing pipelines (offshore dosing)</td>
<td>- Improvement in personnel protection; reduction of emissions at place of work</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Installation of stationary extraction hood</td>
<td>Only if dosing equipment is arranged close together or if replacement equipment is procured</td>
<td>- Improvement in personnel protection; reduction of emissions at place of work</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peripheral or segmental extraction of about 500 m³/h; DN 150</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interlocking of extraction system with automatically driven valves or pumps only recommended for solvents and resins that are often used.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(4) Installation of automatic shut-off valves

Dosing valves (e.g. ball valves) are not shut-off valves, because they do not close fully. If there are no shut-off valves, drip pans have to be installed beneath the dosing valves. For measures to reduce VOC emissions, see Item (3)
4.5 Mills for fine dispersing

VOC emissions at mills for fine dispersing are caused mainly by:

(1) Open mills and mobile container

(2) Outlet of mills (free jet) directed to container of different height

(3) Splashing during inflow into container

Measures for cutting VOC emissions and their capital costs are:

<table>
<thead>
<tr>
<th>(1) Covering of mobile container</th>
<th>Using movable lids; lids equipped with connection for inflow and extraction. Extraction: max. 50 m³/h (DN 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extraction via flexible hoods, Improvement in personnel protection; reduction of emissions at place of work; Reduction of diffuse emissions by nearly 100%</td>
</tr>
<tr>
<td></td>
<td><strong>Efficiency:</strong></td>
</tr>
<tr>
<td><strong>Capital costs:</strong></td>
<td>3000-5000 DM, depending on milling system</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(2) Covering of mills</th>
<th>Installation of hoppers at mill outlets, with flexible tubes and adapter for container lid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Efficiency:</strong></td>
</tr>
<tr>
<td></td>
<td>Improvement in personnel protection; reduction of emissions at place of work</td>
</tr>
<tr>
<td><strong>Capital costs:</strong></td>
<td>3000-5000 DM, depending on milling system</td>
</tr>
</tbody>
</table>
4.6 Finish tanks

VOC emissions at finish tanks are caused mainly by:

(1) Displacement during charging to atmosphere

(2) Respiration losses to atmosphere

Measures for cutting VOC emissions and their capital costs are:

(1) Isolation of tank by under-/overpressure valves

   Efficiency: Nearly 100% because of closed system up to defined pressure (e.g. -5/+10 mbar)

   Capital costs: Approx. 2,500 DM/valve

(2) Elevated exhaust points combined with manual control valve

   Efficiency: Substantial decrease of VOC concentration in exhaust air

   Capital costs: 2,000-5,000 DM
### 4.7 Filter systems

VOC emissions at filter systems are caused mainly by:

1. **Open filter systems**
2. **Cleaning of filter systems**
3. **Operation of potentially leaky filter systems (e.g. sieve-type filter systems)**

Measures for cutting VOC emissions and their capital costs are:

<table>
<thead>
<tr>
<th>Measure Description</th>
<th>Efficiency</th>
<th>Capital costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) <strong>Edge or bag filter</strong> Replacement filter systems to avoid diffuse emissions should be procured</td>
<td>Efficiency: Nearly 100%</td>
<td>5,000-10,000 DM</td>
</tr>
<tr>
<td>(2) <strong>Flexible extraction hood for open filter systems</strong> Efficiency: Improvement in personnel protection; reduction of diffuse emissions at place of work</td>
<td>Capital costs: 2,000-3,000 DM</td>
<td></td>
</tr>
</tbody>
</table>
4.8 Filling systems

VOC emissions at filling systems are caused mainly by:

(1) Displacement of solvent vapor during filling

Measures for cutting VOC emissions and their capital costs are:

(1) **Stationary extraction hood and encapsulation of filling system**

**Efficiency:**
Nearly 100% reduction of diffuse emissions at the workplace

**Capital costs:**
5,000-10,000 DM, depending on size of filling station
4.9 Rinsing basins

VOC emissions at solvent-based rinsing basins are caused mainly by:

(1) Manual cleaning of tools and small bins in open cleaning basins

(2) Drying of tools after cleaning them gives rise to solvent vapor emissions at rinsing basin locations

Measures for cutting VOC emissions and their capital costs are:

(1) Encapsulated rinsing basins (fitted with lids) with automatic, directed exhaust air flow

For loading and unloading parts for rinsing, the lids of the rinsing basins are raised by a knee-operated device; air extraction switches in automatically by opening of the respective pneumatic dampers.

Additionally, solvent vapors are swept by the extraction air flow from the operator gangway to the exhaust duct.

The flow rate is around 2000 m³/h, but matched to the size of the rinsing basin, with VOC concentration 200-300 mg/m³, depending on flow rate and temperature.

Due to the high concentration, cleaning of the extracted exhaust is necessary for compliance with the emissions standards.

Capital costs:
40,000-50,000 DM
4.10 Solvent-based washing of mobile production bins in cleaning cabinet

VOC emissions at solvent-based cleaning cabinets are caused mainly by:

(1) Cleaning cabinets are not completely enclosed systems

(2) The cleaning cycle does not conclude with a drying step, so the cleaning cabinet location is exposed to organic solvents after removal of cleaned bins

(3) Generally, due to the high concentration of VOCs, the exhaust air requires post-treatment, like thermal combustion, for compliance with emission standards

Measures for cutting VOC emissions and their capital costs are:

(1) Cabinet washing installation with water-based (e.g. hot alkaline) rinsing system

   **Efficiency:**
   Emissions reduced by 100%, with no post-treatment needed for VOC removal; wastewater must be treated.

   **Capital costs:**
   300,000-400,000 DM, depending on plant size; additional costs for water treatment plant

(2) Cabinet washing installation with solvent-based rinsing system and exhaust fume cleaning equipment

   Cabinet washing installation with integrated fume extraction and drying is the present state of the art; explosion proofed; cleaning with rotating nozzle and high-pressure jet or rotating brushes.

   Condensing system to remove a major part of the solvent emissions from the exhaust air.

   Distillation plant for recycling used solvent.

   Storage vessels for clean and used solvent.

   **Efficiency:**
   Reduction of diffuse emissions at
workplace by nearly 100%.

Connection to incinerator or other exhaust air treatment plant is necessary for compliance with emission standards.

**Capital costs:**
approx. 400,000 DM, depending on plant size; additional costs for post-production clean-up, e.g. incineration, of exhaust air
5 Strategic measures

5.1 Product-integrated environmental protection

5.1.1 Definition

For practical purposes, product-integrated environmental protection signifies an integrated development of new products and processes, for which all significant risks and environmental impacts throughout the product life cycle have been considered right from the time of start of development.

Key indicators of product-integrated environmental protection are the principles of ecological efficiency and of inherent safety.

A measure of the ecological efficiency is the value added per consumed or polluted environmental unit. Ecological efficiency therefore describes the ratio of economic utilization to a key ecological factor.

**Principle of ecological efficiency:** Minimization of use of resources instead of disposal of resulting wastes and emissions by environmental clean-up technology

The inherent safety is a product/process characteristic necessarily limiting the risk to a level predetermined by the design. The measure of inherent safety is determined by the magnitude of remaining risk potential.

**Principle of inherent safety:** Elimination or reduction of risk instead of subsequent control of risk by monitoring and taking safety precautions.

Tools essential for implementing product-integrated measures are, alongside drawing up the ecological balance, also market analysis, cost analysis and risk analysis.

Today, enterprises are confronted with the challenge of securing and expanding their existing market situation - as a rule with newly launched products - while at the same time exploiting competitive advantages by innovation and strengthening core competencies.

The decision for product-integrated measures, for example to cut emissions of volatile organic compounds, cannot be made by an enterprise in isolation.

Critical influences are the external market constraints - competitive pressure, price development, supply and demand - and the acceptance and willingness to cooperate of the actors in the market - strategic partners, customers, competitors, material and service suppliers.
5.1.2 Measures

Product-integrated environmental protection for cutting emissions of volatile organic compounds signifies specifically for the paint and coatings industry:

- modification of recipes and/or
- modification of the manufacturing process

with the objective of preventing such emissions completely or limiting them to an unavoidable minimum.

Prevention and reducing emissions at source requires that the approach to achieving this must be adopted for the company's own development of products at an early stage, since as development proceeds, the possibilities for intervention rapidly reduce.

Under economic aspects in particular, the latitude for action should thus be exploited in the early phases of product and process development, to permit decisions to be taken that are advantageous for the enterprise over the long term. Despite time pressures and the meager data available at the start, this requires systematic examination of the available knowledge on possible actions and orientation.

To cope with integration of all relevant information, it is important that:

- the development process as a whole is broken down into practical phases, to each of which are unambiguously assigned the requisite personnel resources, budgets, tasks and intermediate objectives
- the results of each phase are evaluated under consideration of the general objective, and when necessary, corrective measures initiated
- users and customers are tied into the overall development process at an early stage
- communications between persons from differing backgrounds of experience, such as marketing, sales, research and development, engineering and production, are promoted
- an effective exchange of information is maintained between parallel lines of development, initiated in the interest of speeding up the process.

Options for improving the emissions situation at a production site are as follows:

- analysis and possibly restructuring of site-specific product ranges on the basis of the ecological balance and a cost-benefit analysis
- company internal restructuring of production, taking in all operating sites, involving concentration of production of emissions-relevant intermediate and final products at one production site, possibly allowing more cost-effective implementation of production modification and post-production pollutant clean-up under consideration of the legal situation at specific sites
• integration of new low-emission products and processes that have already been developed by third parties or have been launched onto the market.
5.2 Strategic measures by corporate departments supporting production

5.2.1 Supply of feedstocks

It is noted right at the outset that the inducement for adopting strategic measures in connection with feedstocks supply is frequently the exploitation of economic advantages, like more favorable purchases, reduction of tied up personnel resources and shortening of lead times.

Reduction or avoidance of diffuse emissions of volatile organic compounds, arising in particular when decanting feedstocks from supply containers to dosing containers, during batching in the as-supplied condition or dosing into open tank systems, is in this respect a beneficial consequence under environmental aspects.

The basis for evaluating measures in connection with feedstocks supply comprises:

- analysis of consumption structures:
  - segmental distribution
  - frequency of use
  - use quantity categories
  - quantity consumption per component and time interval
  - number of components

- analysis of costs of feedstock provision:
  - form of supply
  - supplied unit quantities
  - form of storage
  - stored unit quantities.

The objective is to clearly present the structures of consumption and the current costs of feedstock provision, and so derive savings potentials.

Possible cost-cutting and emission reducing measures are:

1. switching the form of supply from small casks to, for example, tanker trucks
2. conversion of storage systems from small casks to, for example, tank systems or container shelving
3. conversion of dosing to fully automated, closed systems.

The effectiveness of preventing and reducing diffuse emissions is almost 100%.

The capital investments for such conversions must be determined for the specific company and site circumstances. Nevertheless, in particular for companies with a
very large product range, small batch sizes and a wide diversity of feedstocks, savings as follows are possible:

- by exploiting purchaser advantages: up to 5%
- by reducing the staff requirement: some 5 to 10%
- by reducing the costs of disposal for one-way containers/drums: up to 50%.

5.2.2 Production planning

Frequently, the adoption of strategic measures in connection with production logistics is prompted by the exploitation of economic advantages, like enhancement of flexibility and upgrading of production capacity by shortening throughflow times, and reducing tied up personnel resources.

Reduction or prevention of diffuse VOC emissions in particular, which arise especially during cleaning, is in this context more of a positive subsidiary effect, benefiting the environment.

The basis for evaluating measures in the area of production planning is:

- analysis of processes
- batches, batch sizes
- machine occupation times
- lead times
- equipment setting times
- demands for energy and operating supplies
- availability
- quality.

The objective is to present in a transparent way the production complexity and associated costs in the value added chain, and derive savings potentials from these.

Possible cost-cutting and emission reducing measures are as follows:

- switching from linear, order-oriented production (from basic feedstocks) to manufacture from semi-finished products taken from stock
- outsourcing manufacture of intermediate or final products
- outsourcing of functions, like container cleaning, to external service providers.

The principal emission sources, referred to pollutant loadings, in production are dissolvers, mixing tanks, open mills and cylinder mills as well as solvent-based tank cleaning. Subsequent process steps play more a subordinate role, and can be neglected when drawing up a rough balance of emitted pollutant loadings.

The loadings of emitted VOCs at production equipment and tanks are determined essentially by the number of charges and cycles of cleaning over an investigation period. Potentials for preventing or reducing emitted pollutant loadings throughout
the entire production chain are virtually linearly dependent on the potentials for cutting the number of charges and shortening cycles of cleaning.

Potentials for avoiding emitted pollutant loadings during tank cleaning are more or less a linear function of the number of tanks. By switching from solvent-based tank cleaning to water-based (alkali) cleaning, VOC emissions can be prevented completely.

When investing in new equipment, this option should be investigated under technical and economic aspects.