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Arbejdsrapport fra Miljøstyrelsen

VOC Emissions from Manufacturing Processes

Cleaner Technology in the Lacquer and Paint Industry

Jørgen Vineke
Carl Bro A/S

Jürgen Zimmer
Fichtner GmbH & Co. KG

Miljøstyrelsen
Miljø- og Energiministeriet

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Preface

This report describes possibilities for reducing VOC emission from manufacturing processes in the lacquer and paint industry. Regulation according to Danish legislation and EC directives is summarised by way of introduction.

The overall stress will be laid on method description for review, setting-up and assessment of proposals as well as the final action plan. As use for this work a catalogue has been elaborated with emission limiting initiatives. The catalogue describes solutions to different parts of the process with information of expected efficiency and economy.

There is a short description of possibilities for reduction through product development and planning of production including training and education of employees.

The project has been carried out with financial support from the Council concerning recycling and less polluting technology, with the Danish Paintmakers' Association as project manager.

Fichtner · Carl Bro a|s has been the consultant of the Danish Paintmakers' Association regarding the implementation of the project. Employees from Fichtner GmbH & Co. KS in Germany and Carl Bro a|s in Denmark have participated as consultants on the project.

The report can be seen as a continuation of Trade information for the lacquer and paint industry no. 5, 1996 from the Danish EPA (Brancheorientering for lak- og farveindustrien nr. 5, 1996 fra Miljøstyrelsen).

The project has been followed by a group of experts with participation of:

Ole E. Jensen	Teknos Technology A/S
Rikke Østergaard	Teknos Technology A/S
Ole Jacobsen	Akzo Nobel Decorative Coatings A/S

Further employees from the two companies have supplemented on relevant sub fields.

A number of companies in Germany have kindly placed information, material and experience at our disposal for the project, especially Akzo Nobel Coatings GmbH in Berlin and Stuttgart respectively, who kindly placed production facilities at our disposal for inspection.

Besides, a responsible steering committee has been appointed consisting of:

Erik Thomsen	The Danish EPA
Lilian Petersen	The Danish Directorate for National Labour Inspection
Steen Mejlby	SiD (The General Workers Union in Denmark)
Finn Toft Jensen	The County of Vejle (Association of County Councils in Denmark)
Vibeke Plambeck	the Danish Paintmakers' Association
Jørgen Vineke	Fichtner · Carl Bro a|s

Sammenfatning og konklusion

Som resumé gengives tekstdele fra projektets artikel i publikationen ”Ny Viden”, der udgives af Miljøstyrelsen.

VOC begrænsning – step by step – er mulig

Lak- og farveindustrien kan begrænse emission af VOC'er (flygtige organiske forbindelser) til arbejdsmiljøet og det eksterne miljø. Dette dokumenteres i en rapport, der beskriver metoder for kortlægning, opstilling og vurdering af løsningsforslag samt opstilling af endelige handlingsplaner. Begrænsning kan ske gennem produktudvikling og ændret tilrettelæggelse af produktionen herunder uddannelse af medarbejdere. Men i mange situationer er der behov for tekniske tiltag. Til brug for vurdering heraf er der udarbejdet et katalog med forskellige emissionsbegrænsende tiltag, og forventet effektivitet og økonomi er vurderet.

Nye krav til lak- og farveindustrien

Baggrund og formål
Lak- og farveindustrien i Danmark består af i alt ca. 20 malevareproducenter samt ca. 10 lim- og fugemasseproducenter.

Der er i EU-regi vedtaget to direktiver som får betydning for branchens miljøarbejde.

EU-direktiv 1999/13/EF af 11. marts 1999 stiller krav om begrænsning af emissionen af VOC fra bl.a. branchens virksomheder. Direktivet implementeres i dansk lovgivning senest i marts 2001. For de aktuelle virksomheder vil dette betyde krav om dokumentation og opstilling af handlingsplaner med henblik på at overholde fastsatte krav til emissionen fra punktkilder og diffuse kilder.

EU-direktiv 96/61/EF af 24. september 1996 om integreret forebyggelse og bekæmpelse af forurening er implementeret i Danmark med en ny bekendtgørelse om godkendelse af listevirksomhed, *Miljø- og Energiministeriets bekendtgørelse nr. 807 af 25. oktober 1999.* Bekendtgørelsen, der præciserer kravene til redegørelse om anvendelse af bedste tilgængelige teknik (BAT), får betydning for virksomheder i godkendelsessituationen og ved revurdering af tidligere udstedte godkendelser.

Foreningen for Danmarks Lak- og Farveindustri (FDLF) har i 1994-1995 gennemført en kortlægning af mulighederne for anvendelse af renere teknologi i lak- og farveindustrien. Rapport om denne kortlægning er tidligere udsendt som *Brancheorientering for lak- og farveindustrien nr. 5, 1996 fra Miljøstyrelsen.*

I fortsættelse af kortlægningen i 1994-1995 har FDLF gennemført et projekt med vurdering af tekniske muligheder for at begrænse VOC emissionen fra fremstillingsprocesser i lak- og farveindustrien. Formålet er at vise hvilke muligheder, der kan tages i anvendelse, og hvorledes branchens virksomheder kan arbejde med problemstillingen. Medarbejdere fra Fichtner GmbH & Co. KG i Tyskland og Carl Bro as i Danmark har været konsulenter på projektet.

Projektets målgruppe er branchens virksomheder samt miljømyndighederne. Hensigten har været at introducere muligheder for tiltag på bestående virksomheder. Mere vidtgående tiltag, som primært vil være mulige ved en nyetablering, ligger uden for projektet.

Muligheden for at gennemføre projektet er skabt af økonomisk støtte fra Miljøstyrelsen.

Opsamling af relevante erfaringer

Projektet
Hovedvægten er lagt på en metodebeskrivelse for kortlægning, opstilling og vurdering af løsningsforslag samt opstilling af den endelig handlingsplan. Til brug for dette arbejde er der udarbejdet et katalog med emissionsbegrænsende tiltag. Kataloget beskriver løsninger til forskellige dele af procesforløbet med angivelse af forventet effektivitet og økonomi.

Der er en kortere beskrivelse af muligheder for begrænsning gennem produktudvikling og tilrettelæggelse af produktion herunder uddannelse af medarbejdere.

En række virksomheder blandt udstyrsleverandører og producerende virksomheder i Tyskland har velvilligt stillet oplysninger, materiale og erfaringer til rådighed for projektet.

To danske virksomheder, Teknos Technology A/S og Akzo Nobel Decorative Coatings A/S, har deltaget i en teknikergruppe, som har fulgt projektet.

Miljøstyrelsen, Direktoratet for Arbejdstilsynet, SiD, Amtsrådsforeningen og FDLF har været repræsenteret i en styregruppe.

Kravene skærpes

Hovedkonklusioner
For at forstå projektets problemstillinger er det vigtigt, at se på indholdet af det nye VOC-direktiv.

Direktivet om begrænsning af emissionen af VOC betyder for lak- og farveindustrien, at virksomheder med et forbrug af VOC større end 100 tons/år skal:

- Udarbejde dokumentation gennem emissionskortlægning
- Beskrive udvikling frem til situationen i 2007
- Identificere og beskrive tiltag, der opfylder direktivets krav
- Etablere tiltag i nødvendigt omfang

Emissionskravene for branchens virksomheder er vist i Tabel 1.

Tabel 1
Grænseværdier5 i EU-direktiv 1999/13/EF af 11. marts 1999.

Forbrug af VOC, tons/år	**Emissionsgrænse (punktkilder), mg C/norm. m^3**	**Grænse for diffuse emissioner, %**	**Grænse for totale emissioner, %**
100-1,000	150	5	5
> 1,000	150	3	3

Note:
- Emissionsgrænse kan ikke umiddelbart sammenlignes med værdier i Luftvejledningen (Miljøstyrelsen, 06/90), da denne opgiver mg stof pr. m^3.
- Direktivet betyder, at en virksomhed skal overholde enten emissionsgrænse samtidig med grænse for diffuse emissioner eller grænse for de totale emissioner (emissionsgrænse for punktkilder kan da overskrides).

Emissionerne af VOC kan grupperes efter, hvorledes de forlader produktionsfaciliteterne:

- Del af spildevand til kloak eller via internt renseanlæg
- Del af fast affald til ekstern bortskaffelse
- Emission til atmosfæren, direkte eller som rest efter luftrensning

Emissionerne til atmosfæren er af afgørende betydning og samtidig er effektiv begrænsning her mulig. De primære kilder til emissioner er:

- Tankanlæg, påfyldning og oplag
- Påfyldning af råvarer til produktionsanlæg
- Processer i blandekar mv.
- Påfyldning af mellem- og færdigprodukter
- Diffuse udslip fra produktionsudstyr
- Rengøring af udstyr

I forbindelse med opstilling af handlingsplaner og kombination af løsningsforslag er det nødvendigt af opdele forskellige luftstrømme efter luftvolumen og koncentration af VOC. Opdelingen kan anvendes ved valg af hensigtsmæssig håndtering af de enkelte luftstrømme. Koncentrerede strømme kan evt. afbrændes med begrænset anvendelse af støttebrændsel. En løsning med samling af alle luftstrømme kunne medføre, at et betragteligt volumen med lav koncentration af VOC måtte afbrændes ved kontinuert tilførsel af støttebrændsel.

Det er vigtigt, at understrege betydningen af, at de konkrete handlingsplaner skal udarbejdes på grundlag af forholdene på den enkelte virksomhed.

Men det er også vigtigt at fremhæve, at producenterne bør lægge en langsigtet strategi for udvikling af nye produkter, der sigter mod at reducere VOC emissionen, dels under fremstillingen og dels hos kunden. Strategien lægges på basis af samspil mellem markedets krav, råvareleverandører og producenten.

VOC begrænsning – step by step

Vejledning
De generelle trin i arbejdet med emissionsbegrænsning er:

- Etablering af detaljeret emissionsregister
- Vurdering i forhold til myndighedskrav
- Opstilling af scenarier for begrænsning
- Valg af bedste kombination af tiltag
- Opstilling af handlingsplaner
- Opfølgning og rapportering

Trinene beskrives i rapporten med gode vink til, hvorledes arbejdet gribes an.

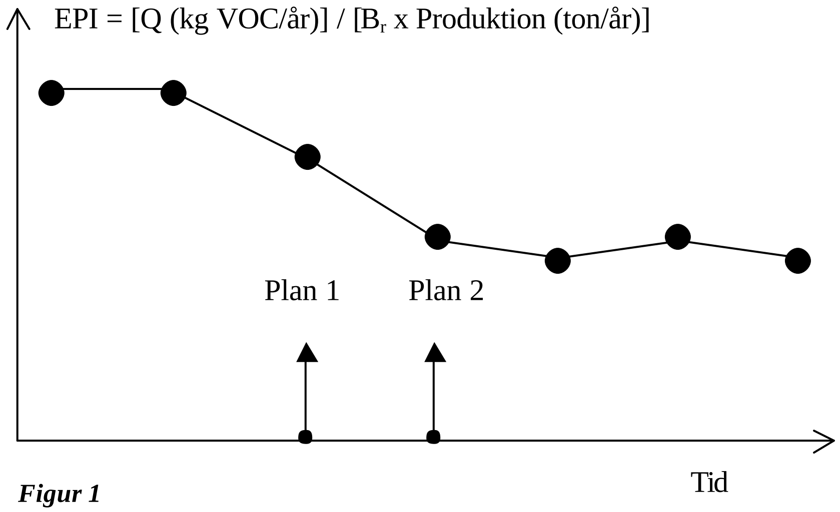
Da der er adskillige delstrømme og processer, som skal kortlægges ved måling af VOC, anbefaler rapporten, at målingerne i høj grad foretages som TOC-målinger (total organisk kulstof) med transportabelt måleudstyr (FID – Flame Ionisation Detector). Målinger bør i nødvendigt omfang kalibreres med traditionelle målinger med opsamling af VOC i kulrør og efterfølgende laboratorieanalyse.

I forbindelse med arbejdet med scenarier, handlingsplaner og efterfølgende opfølgning introduceres et EPI-tal (Environmental Performance Indicator):

$$EPI = [Q \text{ (kg VOC/år)}] / [B_r \times \text{Produktion (ton/år)}]$$

EPI kan påvirkes ved ændring af emissionen (Q) eller ved ændring af de anvendte råvarers karakter (B_r – en vægtet B-værdi). Det skal bemærkes, at B_r-værdien er en teoretisk værdi, som principielt kun kan anvendes for ikke-lugtrelaterede stoffer med samme toksikologiske effekt. EPI kan anvendes på den enkelte virksomhed, men vil ikke umiddelbart kunne anvendes som sammenligningsgrundlag mellem virksomheder. Anvendelsen af EPI sætter fokus på såvel udledningens størrelse som på substitution af farlige opløsningsmidler til mindre farlige opløsningsmidler. EPI kan anvendes som en miljøindikator, der fortæller om udviklingen i virksomhedens miljøperformance og kan som sådan f.eks. indgå som en styringsparameter i et miljøledelsessystem. Den praktiske opgørelse af EPI foretages på basis af produktionsdata sammenholdt med erfaringstal fra emissionsmålinger for enkeltprocesser og/eller på basis af massebalancer.

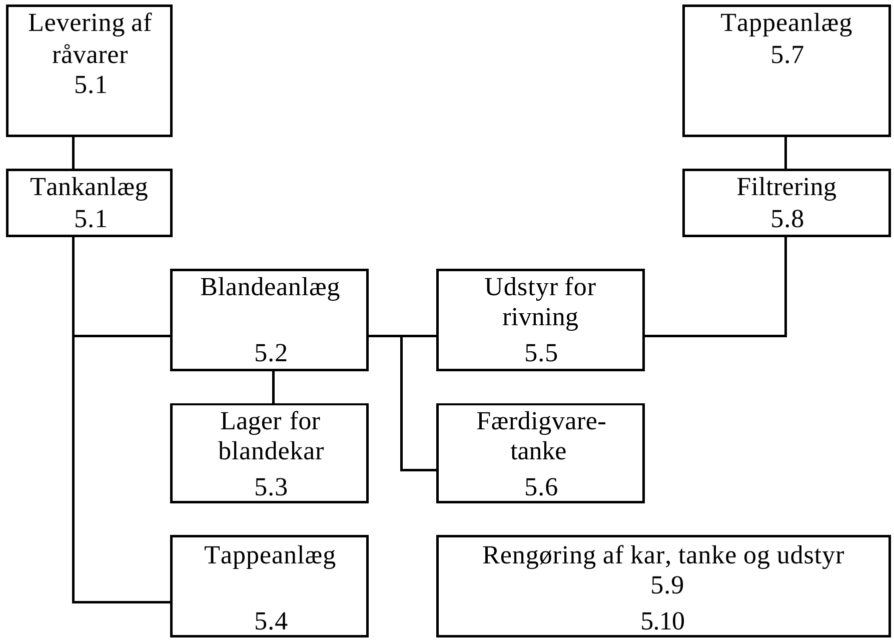
I Figur 1 er vist eksempel på rapportering af udvikling baseret på EPI-tal.



Figur 1
Eksempel på udvikling i EPI-tal over tid og ved gennemførelse af handlingsplaner.

Emissionsbegrænsende tiltag

Katalog
Katalog over emissionsbegrænsende foranstaltninger er baseret på produktions- og delaktiviteter angivet i Figur 2.



Figur 2
Typiske delaktiviteter i lak- og farveindustrien.

Katalogets enkelte elementer er oversigtligt angivet i Tabel *2*. Betydning for emission fra punktkilder og diffus emission er indikeret med pile:

- ↓ Reduktion af VOC koncentration
- ↘ Svag reduktion af VOC koncentration
- ↗ Svag stigning i VOC koncentration
- ↑ Stigning i VOC koncentration

Tabel 2
Emissionsbegrænsende tiltag og deres betydning for diffuse emissioner og punktkilder.

MEASURES	Diffuse emissions	Point source emissions
5.1 Unloading system for feedstock dosing and tankfarms		
• Installation of a pressure equalizing line	↓	↓
• Isolation of tank by fitting over-/under pressure valves	↓	↓
5.2 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	-	↘
5.3 Holding store for mobile bins		
• Covering of mobile bins	↘	-

MEASURES	Diffuse emissions	Point source emissions
5.4 Dosing station for mobile production bins		
• Flexible hoods	↘	↗
• Free jet dosing	↓	↗
• Stationary extraction hoods	↓	↗
• Automatic shut-off valves	↓	↗
5.5 Mills for fine dispersing		
• Covering of mobile container	↘	↗
• Covering of mills	↘	↗
5.6 Finish tanks		
• Isolation of tanks by under-/overpressure valves	↓	↗
5.7 Filter systems		
• Edge or bag filter	↓	↗
5.8 Filling systems		
• Extraction hoods	↘	↗
5.9 Rinsing basin		
• Encapsulation with directed exhaust air flow	↓	↗
• Automatic shut-off valves	↓	↗
5.10 Cleaning of mobile production bins		
· Cabinet washer with water-based rinsing system	↓	↓
• Cabinet washer with solvent based rinsing system and post production treatment	↓	↓
• Cabinet washer with brushes, solvent based and condensation system and sealing of brushes in a separate chamber	↓	↘

For de enkelte kategorier af produktionsudstyr er emissionens karakter angivet sammen med beskrivelse af tiltag med vurdering af effektivitet og økonomi.

Kataloget indeholder endvidere et bilag med fotos af en række tiltag.

Summary and conclusions

As summary parts of the text from the project article in the publication "Ny Viden", issued by the Danish EPA are reproduced.

VOC-reduction - step by step - is possible

The lacquer and paint industry is able to reduce the emission of VOC's (volatile organic compounds) to the working environment and the external environment. This is documented in a report describing methods for mapping, preparation and assessment of solution proposals as well as preparation of final action plans. Reduction can take place through product development and changed planning of production including training of employees. However, in many situations there is a need for technical initiatives. As use for assessment hereof a catalogue has been prepared with different emission limiting initiatives and expected efficiency and economy has been assessed.

New requirements for the lacquer and paint industry

Background and purpose
The lacquer and paint industry in Denmark consists of approx. 20 manufacturers of paints as well as approx. 10 manufacturers of glue and sealing compounds.

Under the auspices of the EC, two directives have been adopted which will become important for the environmental work within the paint industry.

EC-directive 1999/13/EC of 11 March 1999 makes a request for reduction of the VOC emission from among others the companies within this industry. The directive shall be implemented in the Danish legislation in March 2001 at the latest. For the actual companies this will mean requests for documentation and set-up of action plans with a view to meet specified requirements for emission from point sources and diffuse sources.

EC-directive 96/61/EC of 24 September 1996 about integrated prevention and abatement of pollution is implemented in Denmark with a new order regarding approval of listed activities, *The Danish Ministry of Environment and Energy's ministerial order no. 807 of 25 October 1999 (Miljø- og Energiministeriets bekendtgørelse nr. 807 af 25. oktober 1999)*. The ministerial order, clarifying the requirements for statement with regard to use of best accessible technique (BAT), will acquire an importance for companies in the situation of approval and by reassessment of approvals formerly issued.

In 1994-1995 the Danish Paintmakers' Association made a review of the possibilities for using cleaner technology within the lacquer and paint industry. Report regarding this review has previously been published/issued as *Trade Information for the lacquer and paint industry no. 5, 1996 from the Danish EPA* (*Brancheorientering for lak- og farveindustrien nr. 5, 1996 fra Miljøstyrelsen).*

In continuation of the review in 1994-1995 the Danish Paintmakers' Association has completed a project with assessment of technical possibilities for reducing VOC emissions from manufacturing processes within the lacquer and paint industry. The aim is to demonstrate the possibilities being used and how the industry can work with the way of presenting the problems. Employees from Fichtner GmbH & Co. KG in Germany and Carl Bro a|s in Denmark have been consultants on the project.

The target group of the project is companies within the lacquer and paint industry as well as the environmental authorities. The purpose has been to introduce possibilities for initiatives at existing companies. More far-reaching initiatives primarily being possible in connection with a new establishment are beyond this project.

The possibility of implementing the project is created by financial support from the Danish EPA.

Collecting of relevant experiences

The project
The main stress will be laid on method description for review, setting-up and assessment of solutions as well as the final action plan. As use for this work a catalogue has been elaborated with emission limiting initiatives. The catalogue describes solutions to different parts of the process with information of expected efficiency and economy.

There is a brief description of possibilities for reduction through product development and planning of production including training and education of employees.

A number of companies in Germany among suppliers of equipment and manufacturers have kindly placed information, material and experience at our disposal for the project,

Two Danish companies Teknos Technology A/S and Akzo Nobel Decorative Coatings A/S have participated in a group of experts having followed the project.

The Danish EPA, the Danish Directorate for National Labour Inspection SiD (the General Workers Union in Denmark), the Association of County Councils in Denmark and the Danish Paintmakers’ Association have been represented in a steering committee.

Increase of demands

Main conclusions
In order to understand the way of presenting the problems it is important to look at the contents of the new VOC-directive.

The directive concerning reduction of the VOC-emission means for the lacquer and paint industry that companies with a consumption of VOC larger than 100 tons/year shall:

- Prepare documentation through emission review
- Describe the development up to the situation in 2007
- Identify and describe initiatives meeting the demands of the directive
- Establish initiatives to an extent as circumstances may require

The emission requirements for the companies in the lacquer and paint industry are shown in table 1.

Table 1
Limit value in EC-directive 1999/13/EC of 11 March 1999.

Consumption of VOC, tons/year	**Emission limit (point sources), mg C/norm. m^3**	**Limit for diffuse emissions, %**	**Limit for total emissions, %**
100-1,000	150	5	5
> 1,000	150	3	3

Note:

- Emission limit cannot be compared directly with the values in the Air Instruction (Luftvejledningen, the Danish EPA, 06/90), as this states mg substances per m^3.
- The directive means that a company has to meet either the emission limit together with limit for diffuse emissions or limit for the total emissions (emission limit for point sources can then be exceeded)

The VOC emissions can be grouped depending on how they leave the production facilities:

- Part of wastewater to sewer or through internal purifying plant
- Part of solid waste to external disposal
- Emission to the atmosphere, directly or as residues after air cleaning

The emissions to the atmosphere are of major importance and at the same time is efficient reduction possible here. The primary sources for emissions are:

- Tank facility, filling and storage
- Filling of raw materials to production plant
- Processes in mixing vessels etc.
- Filling of semi-finished products and finished products
- Diffuse exhaust from production equipment
- Cleaning of equipment

In connection with set-up of action plans and combination of solutions it is necessary to separate different airflows after air volume and concentration of VOC. The separation can be used by choice of appropriate handling of each airflow. Concentrated flows can possibly be incinerated with limited use of support fuel. A solution with collection of all airflows could cause the fact that a considerable volume with low concentration of VOC had to be incinerated by means of continuous supply of support fuel.

It is important to emphasise the importance of the fact that the concrete action plans have to be elaborated on the basis of the conditions at the individual companies.

However, it is also important to stress that the manufacturers should plan a long-term strategy for development of new products aiming at reducing the VOC emission, partly during production and partly at the customer. The strategy is planned on the basis of interplay between the demands of the market, suppliers of raw materials and the manufacturer.

VOC reduction - step by step

Instruction
The general steps in the work with emission reduction are:

- Establishment of detailed emission register
- Assessment in relation to requirements from authorities
- Planning of scenarios for reduction
- Choice of best combination of initiatives
- Set-up of action plans
- Follow-up and reporting

The steps are described in the report advising how the work can be initiated.

As there are several partial flows and processes having to be reviewed by measurement of VOC the report recommends that measurements to a large extent are carried out as TOC-measurements (Total Organic Carbon) with transportable measuring equipment (FID - Flame Ionisation Detector). Measurements should to the extent required be calibrated with traditional measurements with collection of VOC on active carbon tubes and subsequently laboratory analysis.

In connection with the work with scenarios, action plans and subsequently follow-up an EPI-figure (Environmental Performance Indicator) is introduced:

$$\text{EPI} = [\text{Q (kg VOC/year)}] / [C_r \text{ x Production (tons/year)}]$$

EPI can be influenced by changing the emission (Q) or by changing the character of the raw materials in use (C_r - a weighted C-value). It shall be noted that a C_r-value is a theoretical value in principle to be used only for not odour-regulated substances with same toxicological effect. EPI can be used on each individual company, however it cannot be used directly as standard of comparison between companies. The use of EPI brings both the size of the emission and the substitution of dangerous solvents to less dangerous solvents into focus. EPI can be used as environmental indicator informing about the development of the environmental performance of the company and as such may enter as a management parameter in an environmental management system. The practical making-up of EPI is carried out on the basis of production data compared to experience figures from emission measurements for single processes and/or on the basis of mass balances.

An example of reporting of development based on EPI-figures is shown in figure 1.

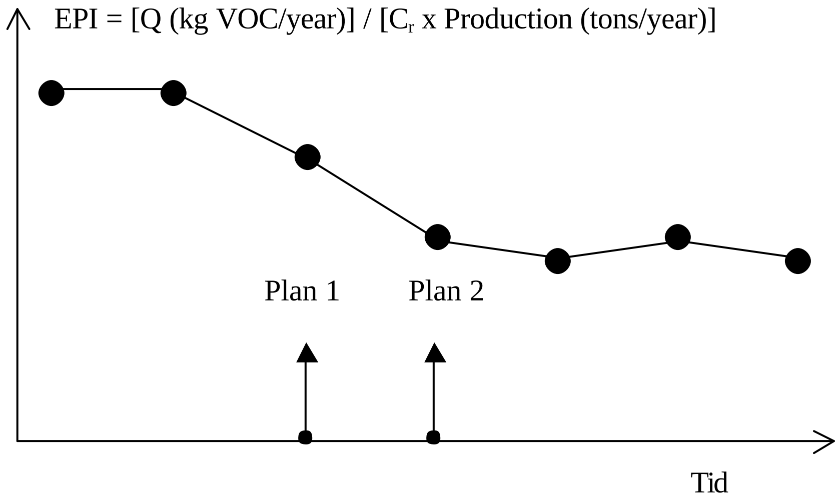


Figure 1
Example of development in EIP-figures over time and by implementation of action plans.

Emission limiting initiatives

Catalogue
The catalogue of emission limiting measures is based on production activities and partial activities indicated in figure 2.

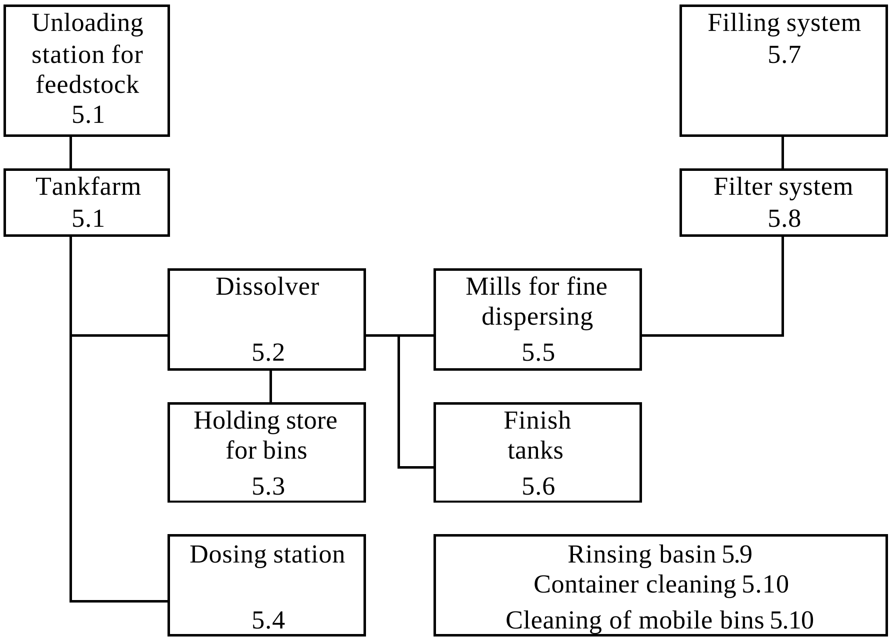


Figure 2
Typical partial activities within the lacquer and paint industry.

An overview of each element of the catalogue is stated in table. The importance for emission from point sources and diffuse emission is indicated with arrows:

↓ Reduction of VOC concentration
↘ Slight reduction of VOC concentration
↗ Slight increase in VOC concentration
↑ Increase of VOC concentration

Table 2
Emission limiting initiatives and their importance for diffuse emissions and point sources.

MEASURES	Diffuse emissions	Point source emissions
5.1 Unloading system for feedstock dosing and tankfarms		
• Installation of a pressure equalizing line	↓	↓
• Isolation of tank by fitting over-/under pressure valves	↓	↓
5.2 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	-	↘
5.3 Holding store for mobile bins		
• Covering of mobile bins	↘	-

MEASURES	Diffuse emissions	Point source emissions
5.4 Dosing station for mobile production bins		
• Flexible hoods	↘	↗
• Free jet dosing	↓	↗
• Stationary extraction hoods	↓	↗
• Automatic shut-off valves	↓	↗
5.5 Mills for fine dispersing		
• Covering of mobile container	↘	↗
• Covering of mills	↘	↗
5.6 Finish tanks		
• Isolation of tanks by under-/overpressure valves	↓	↗
5.7 Filter systems		
• Edge or bag filter	↓	↗
5.8 Filling systems		
• Extraction hoods	↘	↗
5.9 Rinsing basin		
• Encapsulation with directed exhaust air flow	↓	↗
• Automatic shut-off valves	↓	↗
5.10 Cleaning of mobile production bins		
· Cabinet washer with water-based rinsing system	↓	↓
• Cabinet washer with solvent based rinsing system and post production treatment	↓	↓
• Cabinet washer with brushes, solvent based and condensation system and sealing of brushes in a separate chamber	↓	↘

For each category of production equipment the character of the emission is stated together with description of initiatives with assessment of efficiency and economy.

Moreover the catalogue contains an appendix with photos of a number of initiatives.

1 Introduction

In the production and use of solvent-containing paints and coatings, substantial quantities of VOCs are emitted to the surroundings. Therefore, for environmental protection, measures must be implemented to reduce these emissions.

The best and most practical measure for reducing VOC emissions is substitution by alternative and less critical solvents. In this connection, water-based paints and coatings are gaining in importance. Where substitution of organic solvents is not possible, a further measure reduction of the proportion of organic solvents in the products may be considered, such as the development of so-called “high solids” coatings.

Nevertheless, for certain applications currently no substitution possibilities for organic solvents are foreseeable. For this reason, over both the short and medium terms, solvent-containing products will continue to be used. When manufacturing solvent-containing paints and coatings, VOCs are emitted at various points during the production process.

Prior to constructing costly air pollution purification plants, measures for reducing the emissions of VOCs as well as for reducing the volumetric flow should be implemented. Apart from these purely economic considerations, regarding the implementation of emission reduction measures, also other criteria like practicability (no negative effects on operation, access, etc.), ecology (abatement of solvent emissions), safety, and so on have to be taken into account.

To give manufacturers of solvent-based paints and coatings a basis for coming to a decision on new investments in production facilities and/or pollution abatement technology, the **Danish Paintmakers Association** has initiated the project:

"**Cleaner technology in the lacquer and paint industry**"

with one report concerned with “VOC emissions from manufacturing processes” and another report with “Water-based cleaning of mixing vessels and equipment”.

The general aim of the project is to qualify the individual companies within the industry to plan and to implement technology in the manufacturing phase that is actually cleaner.

The results of the study “VOC emissions from manufacturing processes” are described in this report.

In the study “Water-based cleaning of mixing vessels and equipment”- the focus will be on the possibilities of using water-based cleaning of mixing vessels and equipment, and to provide companies with a sound basis when confronted with new investments in cleaner water-based technology. Both reports are available on the Internet - www.mst.dk - homepage of the Danish EPA (Danish versions) and on – www.fdlf.dk - homepage of the Danish Paintmakers’ Association (English versions).

The project period was from January 1999 to February 2000.

The project has been carried out by Fichtner · Carl Bro a|s, with the participation of representatives from the companies Teknos Technology A/S and Akzo Nobel Decorative Coatings A/S.

1.1 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 March 1999 the European Communities issued *Directive 1999/13/EC 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 the study

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.

Process integrated measures mean 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. Photos in Appendix B show an example of a postproduction cleaning plant.

Production units at interest

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 development
- production planning

2 Environmental Regulation

2.1 National legislation and EC directives

As noted in the introduction, March 1999 Directive 1999/13/EC 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.

The VOC Directive will be implemented in national legislation before 30 March 2001.

Danish legislation

Granting of a permit to operate a plant for the manufacture of paints and coatings in Denmark is currently regulated essentially by the following guidelines, laws and ordinances:

- Order regarding approval of listed activities (Bekendtgørelse nr. 807 af 25. oktober 1999 om godkendelse af listevirksomhed) [1]
- Guidelines for approval of listed activities (Vejledning nr. 3, 1993 om godkendelse af listevirksomhed) [2]
- DEPA: Industrial Air Pollution Control Guidelines No. 9/1992 (Vejledning nr. 6 1990 om begrænsning af luftforurening fra virksomheder). A revision is planned issued in 2000
- Information from DEPA, no. 15, 1996 C-values - Industrial Air Pollution (B-værdier)

Subject to their amendment in connection with implementation of Directive 1999/13/EC, these ordinances and guidelines will continue to apply in national legislation.

The VOC Directive

The VOC Directive affects in particular large and medium-sized plants though for a few sectors – like vehicle refinishing – also small-sized plants are covered due to the particular features of these sectors.

For plants emitting certain dangerous substances e.g. chlorinated solvents special limit values apply.

The paint and coatings industry, that is the manufacturers of coating substances, clear varnishes, printing inks and adhesives, is, according to Appendix I of the VOC Directive, 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 allow 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

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[1] For plants having a production capacity exceeding 3000 tons per year.
[2] Compiled under the previous regulation.

2.2 VOC limits and threshold values

According to the Danish legislation the limits and threshold values in Table 2.1 apply.

Table 2.1
Mass flow limits and emission limits for companies that emit organics substances (Industrial Air Pollution Control Guidelines No. 9/1992). In the air pollution guidelines a C-value is fixed as a mean hourly value that must not be exceeded by more than about seven hours a month, i.e. 1% of the time.

Class	**C-value** mg/m^3	**Mass flow** g/h	**Emission limit** mg/normal m^3
I	$\leq$ 0,01	100	5
II	> 0,01 $\leq$ 0,2	2.000	100
III	> 0,2	6.250	300

Additionally, 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 shown in Table 2.2.

Table 2.2
Threshold values and limits for solvents in accordance with Directive 1999/13/EC, Appendix II A. The regulation means that each company shall fulfil the limits for exhaust gases and diffuse emissions ***or*** *the total emission limit (then the limit for exhaust gases can be exceeded.)*

No.	**Activity**	**Threshold value t/a**	**Emissions limit for exhaust gases mg C/n. m³**	**Limits for diffuse emissions %**	**Total emission limit %**
17	Manufacture of coating materials, clear lacquers, printing inks and adhesives	100-1,000 >1,000	150 150	5 3	5 3

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

Key components of the VOC Directive

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

- Elaboration of a *reduction plan* as per Appendix II B, which will allow 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 responsible regulatory authorities and the general public as a basis for checking compliance

with emissions standards and for determining which 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 Figure 2.1.

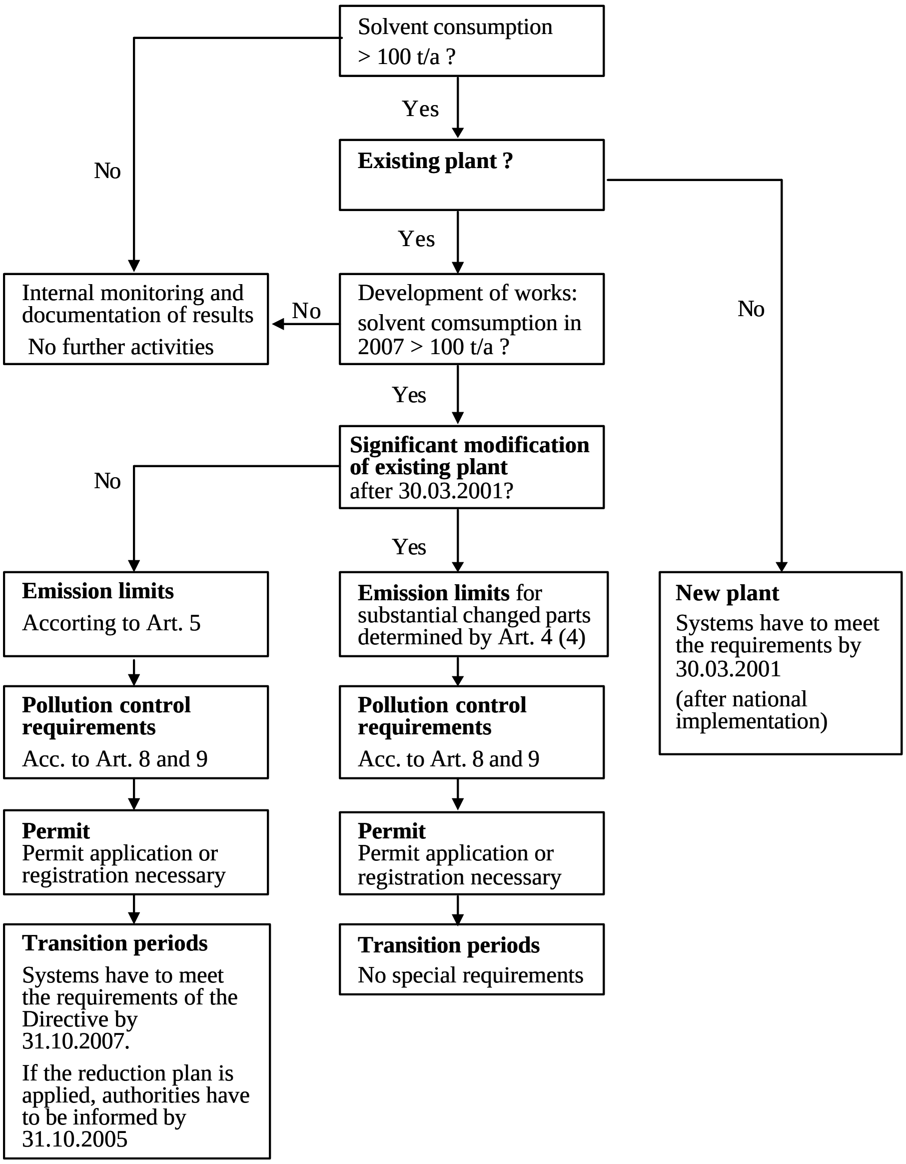

Figure 2.1
Decision flowchart for implementing the VOC Directive.

3 Approaches to Cutting VOC Emissions

Emissions can be grouped depending on how they 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

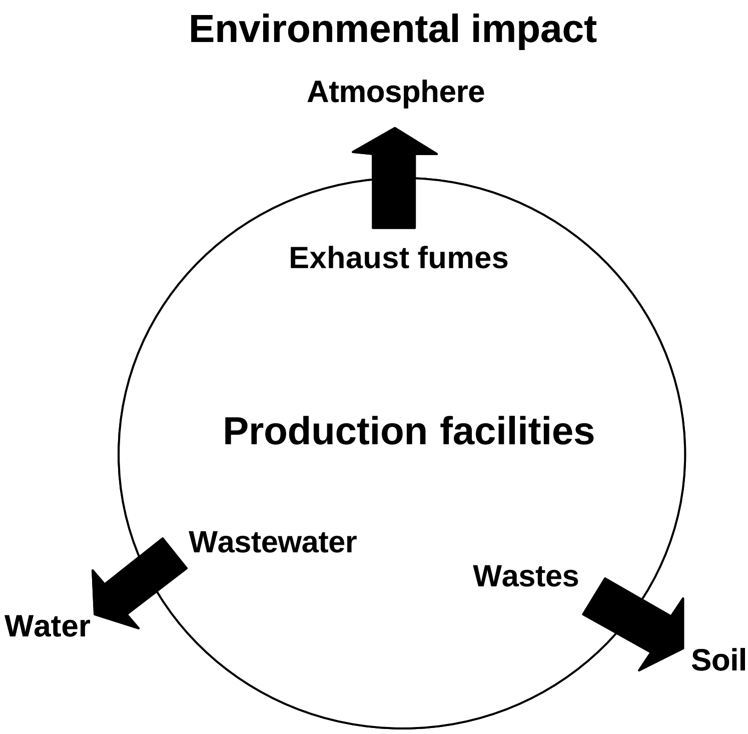

Figure 3.1
Solvent emissions

Wastewater

Wastewater from a plant manufacturing paint and coatings on a solvent basis comprises essentially cleaning effluent from washing the floors of the production buildings and cleaning equipment 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 being transported 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.

Solid waste

The solid waste arising in a paints and coatings manufacturing plant comprises 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.

Fume extraction and exhaust

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

A basic distinction is made between point and diffuse emission sources. A point source is a specific outlet through pipe or stack. Point sources are often established by compulsory ventilation. Diffuse emissions are not related to specific outlets. For instance diffuse discharges, such as emissions from vessels and tanks not furnished with compulsory ventilation.

Causes of emissions

The determining causes of emissions in a paint and coatings manufacturing plant 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.

4 VOC Reduction, Step by Step

4.1 Introduction

This chapter presents a practical and effective method to reduce emissions of VOCs to the atmosphere.

Every company is different from other companies, and the described method should be regarded as a guideline that can be modified according to the nature and needs of each company.

The reduction of VOC serves two main purposes:

1. To comply with present and future regulation (see chapter 2) regarding:

    - emission concentrations
    - immission contribution

2. To reduce the impact on the environment to the extent possible with regard to technical and economical possibilities.

EPI

The last purpose can be expressed by means of an Environmental Performance Indicator (EPI). Such an indicator could be based upon the quantity of emitted solvents per year, in relation to the toxicity of the components (i.e. calculated as the C_r-value (DEPA, guideline no. 9, 1992) and the production volume. The EPI value will be a natural control parameter in an environmental management system, i.e. ISO 14001.

The above is illustrated graphically in Figure 4.1, also containing an example of an EPI.

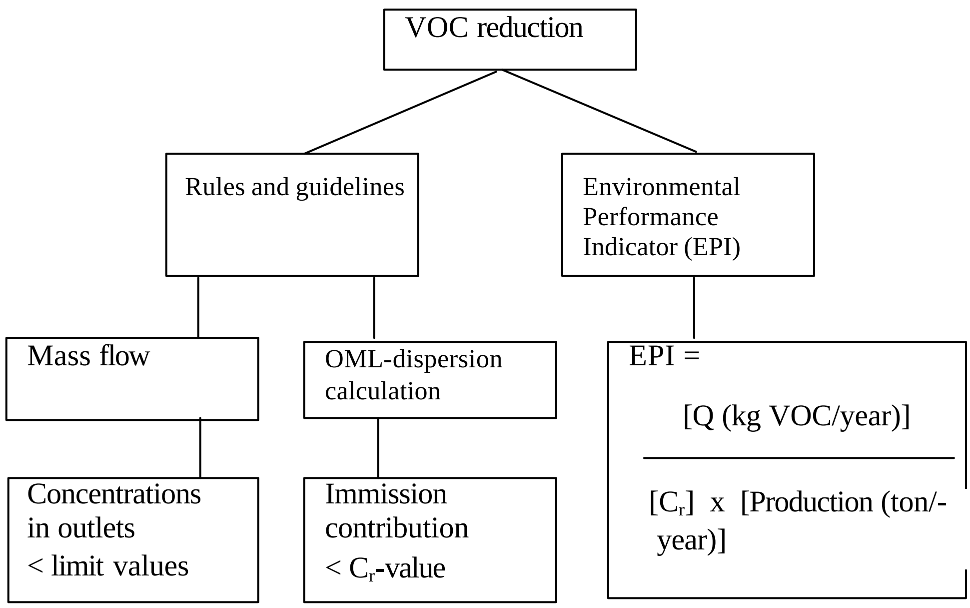

Figure 4.1
Purposes of VOC reduction.

The EPI will require measurements of VOC concentrations but only in the beginning. Afterwards simulations by spreadsheets can be used and only very few measurements are needed.

The C_r-value is a theoretical value to be used only in cases with toxicological substances (not odour-related) with the same effect.

Activities to fulfil above purposes cannot and should not be handled separately but should be regarded as an integrated process. In practice, this means that intermediate reduction methods always should fit into an overall program for fulfilling future reduction goals. This will be illustrated in the next chapter.

4.2 General methodology

Methods for reduction of VOC emissions

Methods for reduction of VOC can be grouped into two categories:

1. Cleaner technology methods (reduction at the source), including substitution
2. Traditional methods (end of pipe solutions), i.e. incineration

Ideally, all reductions should be managed by means of cleaner technology methods or by means of Best Available Technology (BAT). Practise has however shown that in general it is not possible to use only such methods to obtain compliance with rules and guidelines. This is especially the case in relation to older existing plants.

Practise has also shown that using cleaner technology methods before having a total view of the future reduction needs can lead to a substantial increase in the total investment and operation cost for the emission reduction system.

An example is reduction of the concentration of VOC in certain outlets, which are later being combined with other outlets to be cleaned by an incineration plant and where fuel is necessary to maintain the proper incineration temperature. In such a case, it would had been better both from an economic - and also often from an environmental viewpoint to maintain the high VOC concentration and thus reduce (or avoid) the use of e.g. natural gas to obtain the demanded incineration temperature.

This example illustrates the very importance of having a total view of the whole situation before deciding what methods to use for the reduction of VOCs.

Methodology in emission reduction

The recommended methodology in emission reduction is:

1. Survey of present status including detailed knowledge of emissions from all sources

2. Control of compliance with present and future demands regarding emission concentrations and immission contribution

3. Setting up of different scenarios with different combinations of reduction means (by use of “Reduction Catalogue”, see chapter 5). For each scenario control of compliance with rules and guidelines should be made

4. Choosing of best combination of reduction methods on basis of effectiveness, investment cost, operational cost and future reduction possibilities with respect to the EPI for VOCs for the company

5. Action plan including activities, time schedule and responsibility

6. During action plan reporting on activities and EPI values

The method is illustrated graphically in

Figure *4.2*.

In chapter 4.3 each of the activities 1-6 are described in detail.

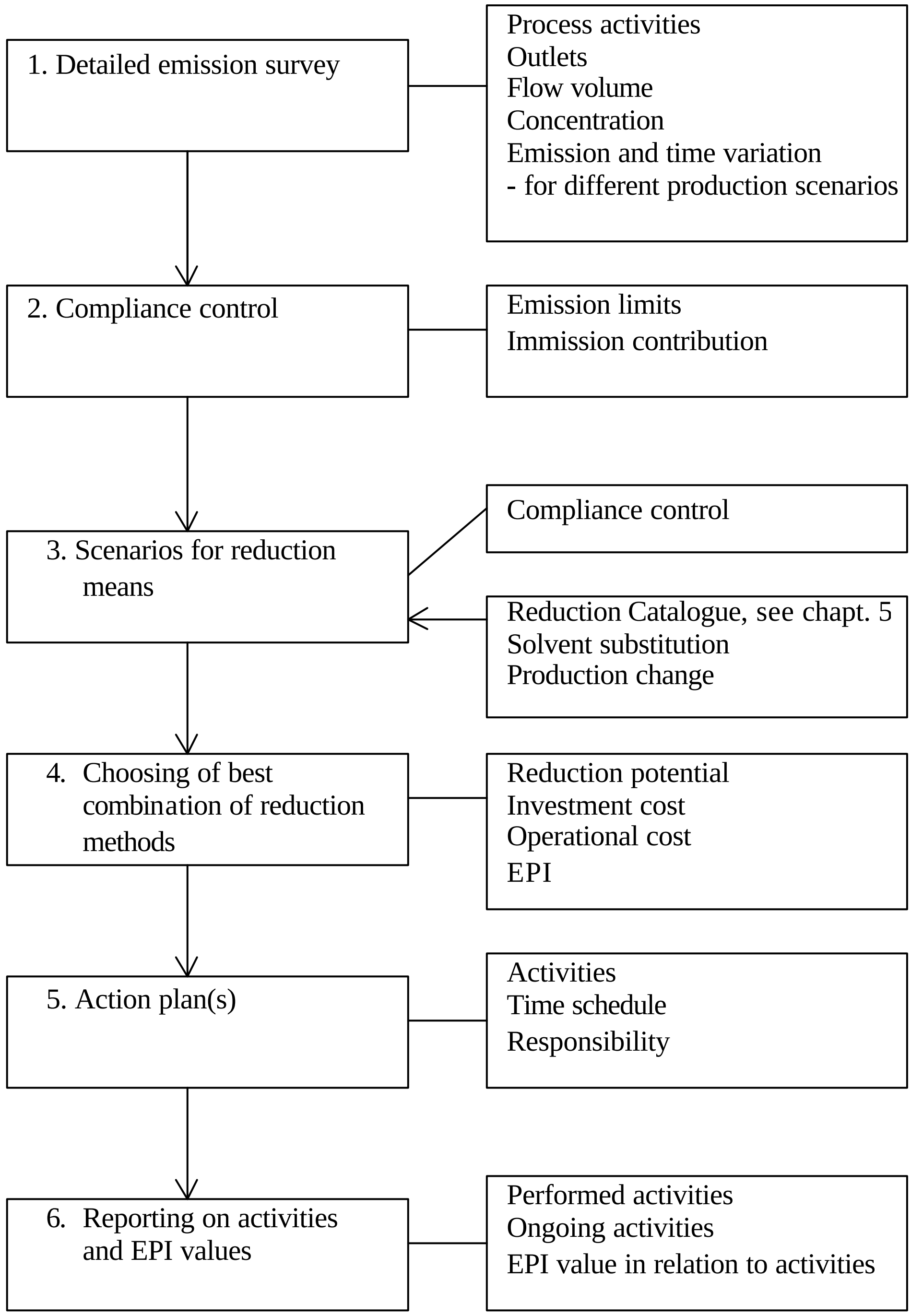

Figure 4.2
General methodology in emission reduction.

4.3 Detailed methodology

In the following, each of the activities mentioned in chapter 4.2 and the corresponding

Figure *4.2* are described in detail.

4.3.1 Detailed survey of emissions from all sources

Purpose

This is the most important activity as it gives the whole foundation for all future activities. The work is time-consuming, but it is very important to understand that only a detailed knowledge of the emissions and the relations to the production can give the background for optimum reduction activities (effectiveness, costs, and future production flexibility).

Listing of all emission sources

This listing should not only include the stacks but also the separate pipes connected to the stacks. All sources including major sources, minor sources and room ventilation (with solvent vapours) should be listed. It is very important to have this listing of sources on a detailed level, as present combination of sources, pipes and stacks is not always based upon optimum considerations concerning environment. This system is illustrated in Figure 4.3, where the pipes are numbered by process and pipe No. 1.1 … Nn.

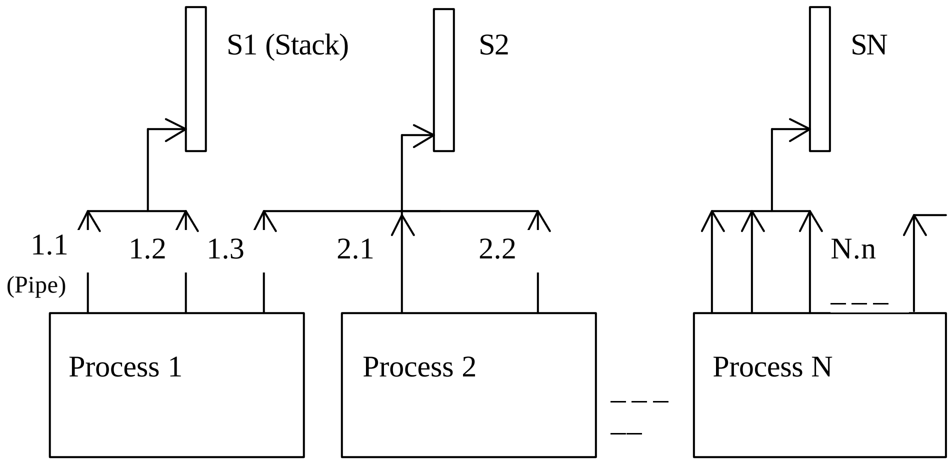

Figure 4.3
System to list stacks, pipes and processes.

Emissions must be correlated to the production that takes place:

- Processes
- Production (receipt)
- Production volume (rate)
- Other relevant production data

Some production scenarios will result in low emissions, other in high emissions. Data on emission measurements should always be registered together with production data.

For each of the processes Process 1 …. Process N in Figure 4.3, emission measurements should be taken for all types of production (receipts) taking place in the company. If the number of receipts is high, the number of measurements can be reduced by interpolation between measurements as follows:

1. Production (receipt) with low emission values
2. Production (receipt) with medium emission values
3. Production (receipt) with high emission values

If interpolation is used, it is recommended that the difference between the lowest and highest emission does not exceed a factor 2. If this not is the case, the number of measurements must be increased. Interpolation between different measurements can be done on basis of vapour pressure.

Emission measurements

As the emission varies during the time of production, it is important that the emission measurements are performed continuously over the production period. This can be obtained by taking a high number of samples on activated carbon tubes. This method is both very time-consuming and very expensive.

A better, easier and more economical method is to use TOC (Total Organic Carbon) measurements by use of a portable FID (Flame Ionisation Detector).

It is a practical experience, that TOC measurements are more reliable than measurements of VOC (by use of carbon tubes). The emission values can easily be calculated into VOC concentrations by knowledge of the mixture of the solvents. Use of TOC measurements are especially of high value for emissions varying with time, which is the case for the processes dealt with in this report.

Based upon the TOC measurements, calibration data, and knowledge on the composition of the solvents in the actual process (the distribution of the different solvents), it is possible to calculate the actual concentration in the gas in mg VOC/m^3. (The detailed calculation method is not described in the present text – but can in most cases be found in the manual of the measuring instrument).

Data can be registered in a spreadsheet as shown in Table 4.1 and Table 4.2. When all data have been collected, it is possible to simulate different production scenarios, i.e. different combinations of processes and receipts. By using the “SORT” and “SUM” functions in the spreadsheet, the emissions from the different processes and stacks can be separated.

Such scenarios should be performed for several (realistic) combinations of processes, receipts and time-relation.

In Table 4.1 and Table 4.2 simple examples are given on a scenario sorted by process (

Table 4.1) and by stacks (Table 4.2).

Table 4.1 is a spreadsheet which can be sorted in different ways. The spreadsheet gives detailed information for all streams for specific processes, i.e. combination of process, receipt, pipe and stack. (More pipes to one stack). The emissions for each separate pipe are given on concentration basis and on emission basis, both related to time (i.e. exceeding 8 hours). The spreadsheet gives a good overview of the emission situation. It will for example be possible to access whether or not it can be a good idea to combine the separate pipes to other stacks (i.e. to collect high concentrations to an incineration unit and low concentrations to a direct outlet).

Table 4.1
Example of scenario with 3 processes sorted by processes. (Concentration values are not shown.)

Pro-cess no.	Re-ceipt no.	Stack no.	Pipe no.	Flow $n.m^3/h$	Temp. ^oC	C_r-value mg/m^3 of gas	Concentration (mg VOC/m^3), time-related data (8 periods)								Emission (g VOC/sec.) time-related data (8 periods)							
1	9	1	1.1	1000	40	0.2									1	2	3	4	3	2	1	1
1	9	1	1.2	1000	60	0.2									2	2	2	2	2	2	2	0
1	9	2	1.3	2000	30	0.2									0	1	2	3	4	3	1	1
Sum				4000											3	5	7	9	9	7	4	2
2	7	2	2.1	2000	20	0.15									1	1	1	1	1	1	1	1
2	7	2	2.2	2000	20	0.15									1	2	3	5	7	5	4	2
Sum				4000											2	3	4	6	8	6	5	3
3	5	3	3.1	3000	60	0.1									1	1	1	1	1	1	1	1
3	5	3	3.2	1000	40	0.1									2	2	2	2	2	2	2	2
3	5	3	3.3	2000	40	0.1									1	2	3	4	1	1	1	1
3	5	8	3.4	4000	20	0.1									0	0	1	1	0	0	0	0
Sum				10000											4	5	7	8	4	4	4	4

C_r-value: Calculated in accordance to DEPA Guideline no. 9, 1992 on basis of composition of gas mixture (approximately = composition of process mixture of solvents). The C_r-value for mixture of gases is calculated on basis of the concentration and the flow in each stream.

Table 4.2
Example of scenario with 3 processes sorted by stacks. (Concentration values are not shown)

Pro-cess no.	Re-ceipt no.	Stack no.	Pipe no.	Flow $n.m^3/h$	Temp. ^oC	C_r-value mg/m^3 of gas	Concentration (mg VOC/m^3), time-related data (8 periods)								Emission (g VOC/sec.) time-related data (8 periods)							
1	9	1	1.1	1000	40	0.2									1	2	3	4	3	2	1	1
1	9	1	1.2	1000	60	0.2									2	2	2	2	2	2	2	0
Sum				2000											3	4	5	6	5	4	3	1
1	9	2	1.3	2000	30	0.2									0	1	2	3	4	3	1	1
2	7	2	2.1	2000	20	0.15									1	1	1	1	1	1	1	1
2	7	2	2.2	2000	20	0.15									1	2	3	5	4	5	4	2
Sum				6000											2	4	6	9	9	9	6	4
3	5	3	3.1	3000	60	0.1									1	1	1	1	1	1	1	1
3	5	3	3.2	1000	40	0.1									2	2	2	2	2	2	2	2
3	5	3	3.3	2000	40	0.1									1	2	3	4	1	1	1	1
Sum				6000											4	5	6	7	4	4	4	4
3	5	8	3.4	4000	20	0.1									0	0	1	1	0	0	0	0

C_r-value: Calculated in accordance to DEPA Guideline no. 9, 1992 on basis of composition of gas mixture (approximately = composition of process mixture of solvents). The C_r-value for mixture of gases is calculated on the basis of the concentration and the flow in each stream.

4.3.2 Control of compliance with present and future limit values

Purpose

The purpose of this activity is to control compliance with existing rules and guidelines and with conditions in environmental permits.

Activities

Control of compliance is made on basis of the emission scenarios. Emission scenarios can be chosen among the scenarios performed in chapter 4.3.1.

The emission scenarios used for control should be the scenarios with the highest emissions and lowest C_r-values estimated by the factor [Emission g/sec.]/[C_r-value]. The scenario with the highest value is the most critical scenario.

The emission is the total emission from all processes and stacks, and the C_r-value is the total value calculated on basis of the formula in DEPA guideline no. 9, 1992.

Compliance with emission concentrations

Control of compliance is performed in accordance with DEPA guideline no. 9, 1992. The mass flow is determined as the [Total flow in kg/working shift]/ [Number of hours in working shift] before cleaning (incineration etc.). The mass flow is easily calculated by use of the emission spreadsheet.

If the mass flow is above the limit given in DEPA guideline no. 9, 1992, all emission concentrations should be below the emission limit for the different classes of organic solvents.

This is controlled on basis of the emission spreadsheet where it is possible to calculate the hourly mean value of the concentrations in the different stacks for the relevant production scenarios.

Compliance with immission contribution limits

Control of compliance with the limits for the immission contribution values (C_r-values, DEPA guideline no. 9, 1992) can be performed either on basis of the mean emission values from the stacks or on basis of a period with maximum values. Both set of values are easily obtained from the emission spreadsheet.

The calculation of the immission contribution should be performed by use of the OML model – multi source version (available at the National Environmental Research Institute – Danmarks Miljøundersøgelser (DMU)). The necessary source data are shown in Table 4.3.

Table 4.3
OML-source data.

No.	**Stack**	**X**	**Y**	**Z**	**HS**	**T**	**VOL**	**DSI**	**DSO**	**HB**	**HBD**	**Q**

X	=	X-value for stack [m]
Y	=	Y-value for stack [m]
Z	=	Terrain level (relative) for stack basement [m]
HS	=	Stack height above terrain [m]
T	=	Temperature of gas [kelvin]
VOL	=	Air flow [normal m^3/sec.]
DSO	=	Outer diameter of stack [m]
DSI	=	Inner diameter of stack [m]
HB	=	General building height [m]
HBD	=	Input of direction dependent buildings (1 = Yes)
Q	=	Emission (g/sec.)

Evaluation of results

If the results of the emission and immission compliance control are that the company does not comply with the limit values, work should be initiated to reduce emissions and/or to modify stack heights to obtain compliance.

If the results of the emission and immission compliance control are that the company is in compliance with the limit values, work should be initiated to continuously improve the environmental performance indicator for VOC (see chapter 4.1, Figure 4.1 and chapter 4.3.5).

4.3.3 **Setting up of different reduction scenarios**

Purpose

The purpose of this activity is to give the best background for choosing the best combination of reduction methods.

Activities

If the company not is in compliance with the limit values for VOCs, the procedure is as shown in Figure 4.4

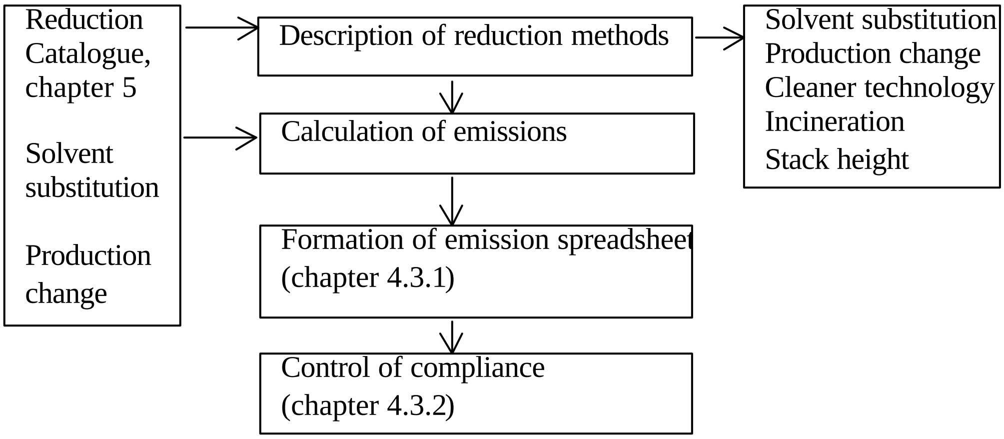

Figure 4.4
The procedure when the company is not in compliance with the limit values.

Only scenarios capable of fulfilling compliance should be regarded.
In finding the best solutions, it is often advisable to review the different streams (pipes) of VOC flows and to assess if other combinations of pipes and stacks would be more relevant. This is specially the case when incineration is necessary. Here it is of utmost importance to obtain as high concentrations as possible to reduce the need for supply energy (for example natural gas).

If the company already is in compliance, it should look upon how to reduce the impact on the environment by reducing the value of relevant EPI. This is illustrated in Figure 4.5, where the dynamic relationship between the different parameters in the EPI formula, the reduction possibilities and the corresponding action plans are shown.

The illustrated EPI should only be regarded as an example.

For use of action plans, please refer to chapter 4.3.5 and for reporting of EPI chapter 4.3.4.

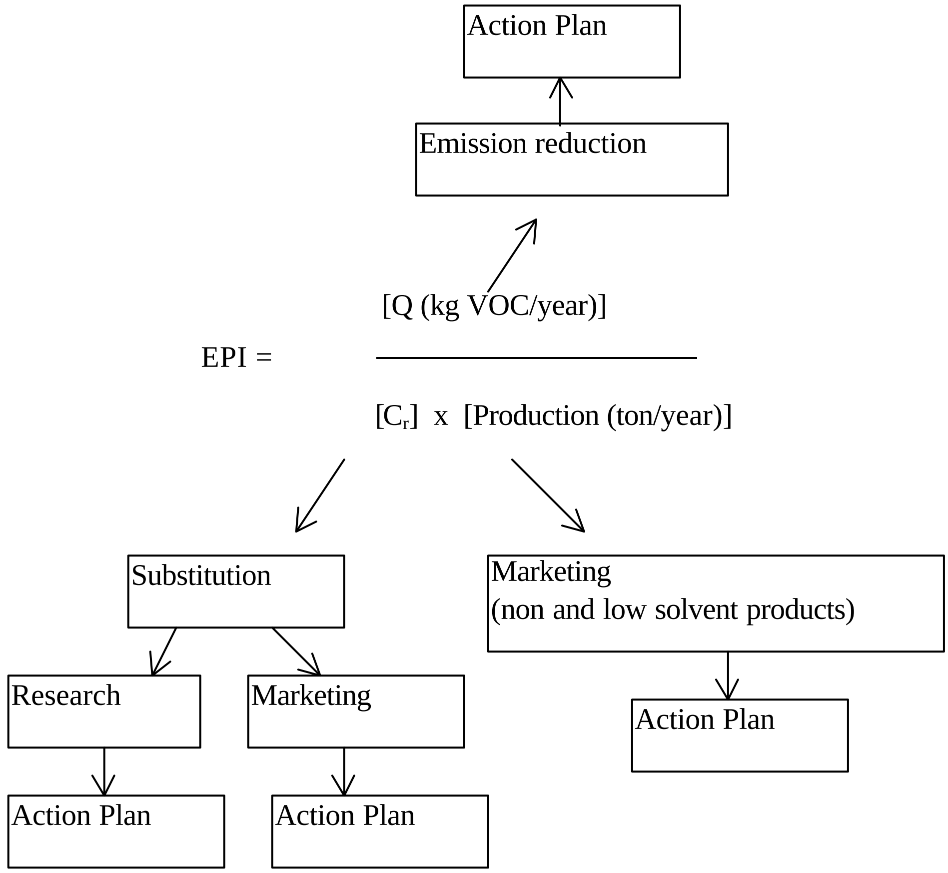

Figure 4.5
From EPI to action plans.

4.3.4 **Choosing the best reduction scenario**

Purpose

In general, there is no specific method to choose the best combination of methods for VOC reduction, but some general advice can be given.

Activities

The different scenarios are compared by a number of parameters regarding reduction efficiency, costs, production related parameters etc.

The different scenarios can be compared as illustrated in Table 4.4.

The parameters used are only examples. Choosing of scenario can be made on basis of the parameters and the importance of each parameter for the company. Common sense and knowledge of present and future needs for the company should be used in this process.

Table 4.4
Parameters to compare different scenarios for emission reduction.

Parameter	Importance for company (scale 1-5)	Scenario 1	Scenario 2	Scenario 3
VOC reduction, kg/year				
% reduction in EPI				
Investment costs, DKK				
Change in operational cost/year, DKK				
Change in energy consumption, DKK				
Production flexibility (scale 1-5)				
Future possibilities to reduce EPI value (scale 1-5)				
Can be established in short time (scale 1-5)				
Proved technology (scale 1-5)				
Reliability (scale 1-5)				
Training and education (scale 1-5)				
VOC reduction/Investment (kg/DKK)				
% reduction in EPI/Investment (%/DKK)				

4.3.5 **Action plans**

Purpose

The purpose of the action plans is:

- To define tasks, time schedule and persons responsible for carrying out the plans
- To inform other involved persons in the company of ongoing and coming activities
- To inform the authorities of ongoing and coming activities
- To report on finished, ongoing and coming activities

The action plans should be available to all relevant persons inside and outside the company.

Activities

Action plans are based upon the results of the activities described in chapter 4.3.4.

Action plans are best organised on a pyramidal structure as shown in Figure 4.6.

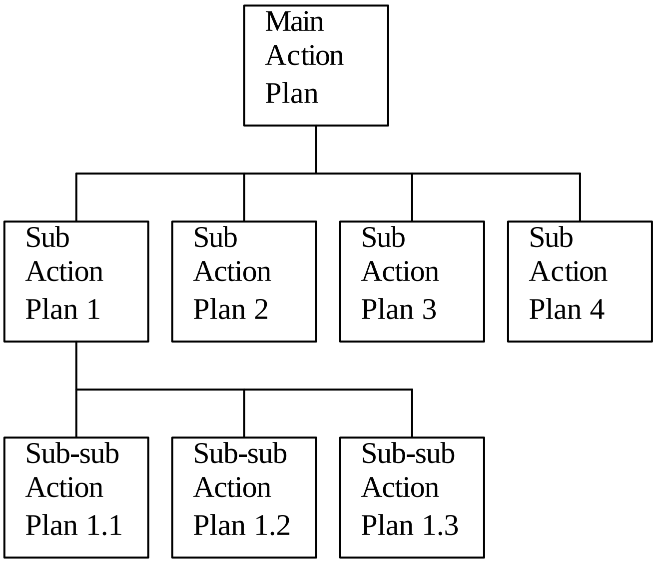

Figure 4.6
Action plan structure.

A dynamic concept for the design of action plans is shown in Table 4.5.

Table 4.5
Example of design of action plan

Action plan no: 1
Name: XX
Responsible: NN

Activity no.	Sub action plan no.	Activity name and description	Respon-sible person (name)	Scheduled start of activity (date)	Scheduled end of activity (date)	Control (name)	Comments, corrections
1.1	1.1						
1.2							
1.3							
1.4	1.4						
1.5							
1.6	1.6						
1.7							
1.8							
1.9							

4.4 Reporting on activities and EPI values

Purpose

The purpose of this activity is to report on finished, ongoing and coming activities and related results with regard to the impact on the environment.

Activities

Different reporting activities can be relevant:

1. Monthly updating of action plans (as Table 4.5). The action plan can be used as a dynamic tool to illustrate the continuing ongoing work and the result hereof
2. Changes in emissions in relation to emission scenarios in form of emission spreadsheet (Chapter 4.3.1)
3. Immission contribution values in % of limit values
4. The development in the value of the Environmental Performance Indicator for VOCs (see chapter 4.3.1)

The reporting activities 2, 3 and 4 can be combined with the action plans to show the effect of the action plans. For the reporting activity 4 this could be illustrated graphically as in Figure 4.7.

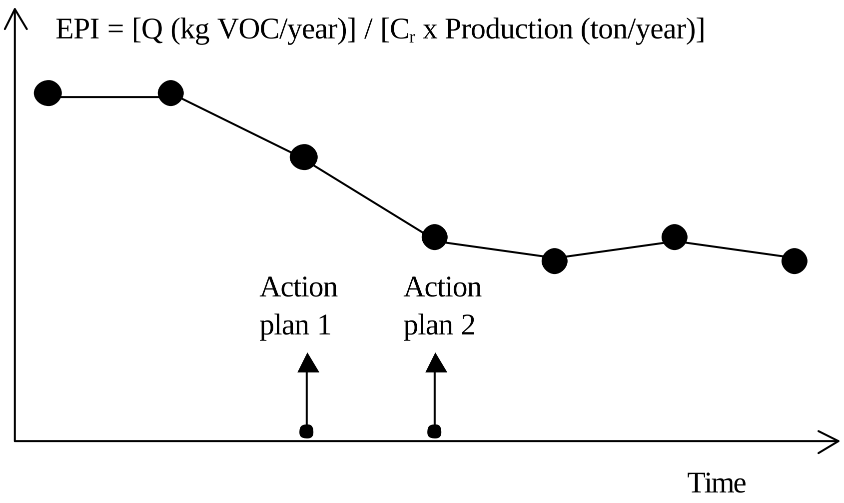

Figure 4.7
Reporting of results of action plans by use of EPI.

5 Process-Integrated Production Modification Measures

This chapter contains catalogue of abatement measures for different post-processes. Measures from the catalogue can be used in the scenarios and action plans described in chapter 4.

Technical modifications

Process-integrated measures generally involve technical modifications to prevent emissions 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 examined more closely.

The capital costs stated in this project are based on costs in Germany and are converted from DM to DKK with a conversion rate of 4. Differences in the size of taxes etc. are not included.

The production units are shown in Figure 5.1 where the numbers refer to sections 5.1 to 5.10.

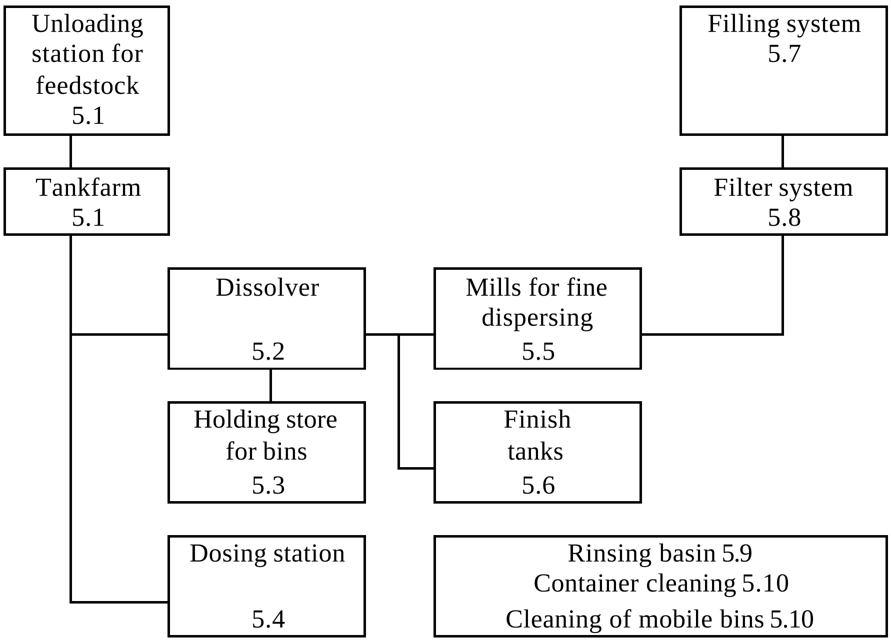

Figure 5.1
Overview of production units in the paint and coatings industry.

Implementation of the production modification measures described in 5.1-5.10 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 lead to 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.

Table 5.1 summarizes individual measures considered in this chapter. The influence on point source emissions and VOC limits for diffuse emissions is indicated as follows:

↓ Reduction of VOC concentration
↘ Slight reduction of VOC concentration
↗ Slight increase of VOC concentration
↑ Increase of VOC concentration

Table 5.1
Measures and their influence on diffuse emissions and point source emissions.

MEASURES	**Diffuse emissions**	**Point source emissions**
5.1 Unloading system for feedstock dosing and tankfarms		
• Installation of a pressure equalizing line	↓	↓
• Isolation of tank by fitting over-/under pressure valves	↓	↓
5.2 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 is 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	-	↘
5.3 Holding store for mobile bins		
• Covering of mobile bins	↘	-

MEASURES	Diffuse emissions	Point source emissions
5.4 Dosing station for mobile production bins		
• Flexible hoods	↘	↗
• Free jet dosing	↓	↗
• Stationary extraction hoods	↓	↗
• Automatic shut-off valves	↓	↗
5.5 Mills for fine dispersing		
• Covering of mobile container	↘	↗
• Covering of mills	↘	↗
5.6 Finish tanks		
• Isolation of tanks by under-/overpressure valves	↓	↗
5.7 Filter systems		
• Edge or bag filter	↓	↗
5.8 Filling systems		
• Extraction hoods	↘	↗
5.9 Rinsing basin		
• Encapsulation with directed exhaust air flow	↓	↗
• Automatic shut-off valves	↓	↗
5.10 Cleaning of mobile production bins		
· Cabinet washer with water-based rinsing system	↓	↓
• Cabinet washer with solvent based rinsing system and post production treatment	↓	↓
• Cabinet washer with brushes, solvent based and condensation system and sealing of brushes in a separate chamber	↓	↘

Examples of some measures are shown on photos in Appendix A.

Avoidance of diffuse VOC emissions to the atmosphere is described in 5.1-5.10.

5.1 Unloading system for feedstock dosing and tankfarms

Emissions

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

Displacement of exhaust air to atmosphere during loading and unloading of road or rail tankers:

Volumetric flow:	20-50 normal m³/h
Concentration:	1,000-5,000 mg org. C/normal m³, depending on temperature

Respiration losses in the tankfarm to atmosphere:

Volumetric flow:	< 1 normal m³/h
Resins concentration:	1,000-5,000 mg org. C/normal m³
Solvents concentration:	10,000-50,000 mg org. C/normal m³

Measures

Measures for cutting VOC emissions and their capital costs are:

A1: Installation of a pressure equalizing line

Efficiency:	Nearly 100%
Capital costs:	Approx. 20,000-80,000 DKK for one line, depending on number of tanks and distance between unloading station and tankfarm (piping system, valves, flashback arresters)

A2: 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:	10,000-20,000 DKK/tank, depending on pipe diameter and pressure drop

5.2 Dissolver and reactor

Emissions

VOC emissions from dissolver and reactor are caused mainly by:

Displacement during liquid feedstock dosing:

Volumetric flow:	5-10 normal m³/h, depending on installed pump capacity
Concentration:	1,000-5,000 mg org. C/normal m³, depending on temperature

Chemical reactions:

Temperature:	Rise up to 50-70°C
Concentration:	Up to 10,000 mg org. C/normal m³

Rising temperatures caused by shearing forces, among others:

Temperature:	Rise up to 50-70°C
Concentration:	Up to 10,000 mg org. C/normal m³

Cleaning of dissolver (shaft and disc) or reactor

Concentration:	1,000-3,000 mg org. C/normal m³

Measures	Measures for cutting VOC emissions and their capital costs are:

B1: Feedstock charging via closed systems
Avoidance of diffuse VOC emissions to atmosphere by using containers with adapter and charging via stationary closed piping systems. Dosing controlled manually (using delivery containers with definite weight) or automatically by e.g. weighing and automatically initiated switch-off.

Transceiver:	Mobile (container, bins with adapter and/or integrated unloading systems)
Transmitter:	Stationary (pipes)
Receiver:	Stationary (dissolver)
Efficiency:	100% with pressure equalizing line between container and dissolver/reactor
Capital costs:	40,000-80,000 DKK/container system

B2: Feedstock distribution and dosing via closed systems
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 flow meter and automatically initiated switch-off (alternatively by level measurement).

Transceiver:	Stationary (tanks, containers with integrated unloading systems)
Transmitter:	Stationary (pipes)
Receiver:	Stationary (dissolver)
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

B3: Feedstock dosing or charging from mobile bins into partially closed systems
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).

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)

Efficiency:	- Improvement in personnel protection; reduction of emissions at place of work - Reduction of diffuse emissions by about 100%
Capital costs:	Approx. 20,000 DKK/lid

B4: Feedstock dosing or charging from drums into partially closed systems
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).

Transceiver:	Mobile (drum)
Transmitter:	-
Receiver:	Stationary (dissolver)

Efficiency:	- Improvement in personnel protection; reduction of emissions at place of work - Reduction of diffuse emissions
Capital costs:	10,000-20,000 DKK/lid

B5: 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

B6: 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:	20,000-40,000 DKK/dissolver, depending on performance

B7: Encapsulation of dissolver, additionally special dissolver lids with integrated condensation system

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 swivelling 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 under pressure).

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 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:	40,000-60,000 DKK/encapsulation system

B8: 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: 75,000-160,000 DKK

B9: 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

5.3 Holding store for mobile bins

Emissions

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

Respiration losses to atmosphere during temporary storage

Measures

Measures for cutting VOC emissions and their capital costs are:

C1: Covering of mobile bins with wooden lids or plastic membranes

Efficiency:	- Reduction of emissions at place of work by approx. 100% - Personnel training may be necessary
Capital costs:	Costs are negligible

C2: Provision of special storage areas for bins with separate extraction systems

Efficiency gains and capital costs are site-specific.

5.4 Dosing station for mobile production bins

Emissions

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

Displacement during dosing of solvents and resins into open bin.

Leaks at dosing valves.

Emission releases during free jet dosing into open bins.

Diameters of extraction systems are often over-dimensioned.

Correct positioning of the extraction system is not possible or is inconvenient (and therefore not done properly by operators)

Measures

Measures for cutting VOC emissions and their capital costs are:

D1: Flexible hoods

Reduction of diffuse emissions by installation of flexible extraction systems with hood (peripheral or segmental extraction rate of about 500 m^3/h; DN 150).

Efficiency:	Improvement in personnel protection; reduction of emissions at place of work by about 100%
Capital costs:	Approx. 20,000-40,000 DKK

D2: Free jet dosing

Avoidance of leaks by installation of flexible hoses or lengthening dosing pipelines (offshore dosing).

Efficiency:	Improvement in personnel protection; reduction of emissions at place of work.

D3: Installation of stationary extraction hood

Only if dosing equipment is arranged close together or if replacement equipment is procured.
Peripheral or segmental extraction of about 500 m³/h; DN 150.
Interlocking of extraction system with automatically driven valves or pumps only recommended for solvents and resins that are often used.

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

D4: 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.

5.5 Mills for fine dispersing

Emissions

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

Open mills and mobile container.

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

Splashing during inflow into container.

Measures

Measures for cutting VOC emissions and their capital costs are:

E1: Covering of mobile container
Using movable lids; lids equipped with connection for inflow and extraction.
Extraction: max. 50 m³/h (DN 50).
Extraction via flexible hoods.

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

E2: Covering of mills
Installation of hoppers at mill outlets, with flexible tubes and adapter for container lid.

Efficiency:	Improvement in personnel protection; reduction of emissions at place of work
Capital costs:	10,000-20.000 DKK, depending on milling system

5.6 Finish tanks

Emissions

VOC emissions at finish tanks are caused mainly by:

Displacement during charging to atmosphere.

Respiration losses to atmosphere.

Measures

Measures for cutting VOC emissions and their capital costs are:

F1: 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. 10,000 DKK/valve

F2: Elevated exhaust points combined with manual control valve

Efficiency:	Substantial decrease of VOC concentration in exhaust air
Capital costs:	2,000-5,000 DKK

5.7 **Filter systems**

Emissions

VOC emissions at filter systems are caused mainly by:

Open filter systems.

Cleaning of filter systems.

Operation of potentially leaky filter systems (e.g. sieve-type filter systems).

Measures

Measures for cutting VOC emissions and their capital costs are:

G1: Edge or bag filter
Replacement filter systems to avoid diffuse emissions should be procured.

Efficiency:	Nearly 100%
Capital costs:	20,000-40,000 DKK

G2:	*Flexible extraction hood for open filter systems*
Efficiency:	Improvement in personnel protection; reduction of diffuse emissions at place of work
Capital costs:	8,000-12,000 DKK

5.8 **Filling systems**

Emissions

VOC emissions at filling systems are caused mainly by:

Displacement of solvent vapour during filling.

Measures

Measures for cutting VOC emissions and their capital costs are:

H1: Stationary extraction hood and encapsulation of filling system

Efficiency:	Nearly 100% reduction of diffuse emissions at the workplace
Capital costs:	20,000-40,000 DKK, depending on size of filling station

5.9 **Rinsing basins**

Emissions

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

Manual cleaning of tools and small bins in open cleaning basins.

Drying of tools after cleaning them gives rise to solvent vapour emissions at rinsing basin locations.

Measures

Measures for cutting VOC emissions and their capital costs are:

I1: 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 vapours are swept by the extraction airflow from the operator gangway to the exhaust duct.
The flow rate is around 2000 m^3/h, but matched to the size of the rinsing basin, with VOC concentration 200-300 mg/m^3, 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:	160,000-200,000 DKK

5.10 **Solvent-based washing of mobile production bins in cleaning cabinet**

Emissions

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

Cleaning cabinets are not completely enclosed systems.

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.

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

Measures

Measures for cutting VOC emissions and their capital costs are:

J1: 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:	1,000,000-1,600,000 DKK, depending on plant size; additional costs for water treatment plant

J2: 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. 1,600,000 DKK, depending on plant size; additional costs for post-production clean-up, e.g. incineration, of exhaust air.

6 Strategy

6.1 **Product development**

Definition

For practical purposes, product development 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 development are the principles of ecological efficiency and of inherent safety.

Ecological efficiency

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

Inherent safety

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 development 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 development, 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 co-operate of the actors in the market - strategic partners, customers, competitors, material and service suppliers.

6.1.1 **Measures**

Product development 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 achieve 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

6.2 Production planning

6.2.1 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 favourable 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

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

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%

6.2.2 **Planning activities**

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 through flow 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

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

The objective is to present the production complexity and associated costs in the value added chain in a transparent way as well as 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

A decision about outsourcing must be based on a total environmental evaluation. It is obvious that moving the operation is not a solution without documentation for better technology at the subcontractor.

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.

6.2.3 **Education and further company-internal training**

Reductions of VOC emissions can be achieved by improved housekeeping, like increased attention to correctly operating air outlet valves.

Therefore, in-depth training of operatives is desirable.

Appendix A: Photos (Catalogue of measures)
Dissolver and reactor

Photo 1:
Dosing of liquid raw material into a Dissolver, condensation system and flexible hose system on the dissolver lid.

Photo 2:
Dosing station for mobile bins with exhaust air extraction and curtain.

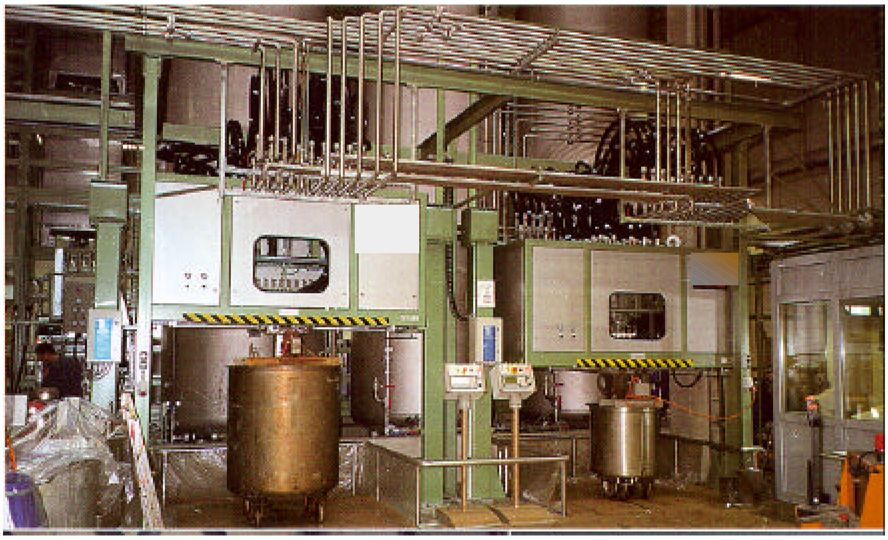

Photo 3:
Dosing station for mobile bins (semi-closed).

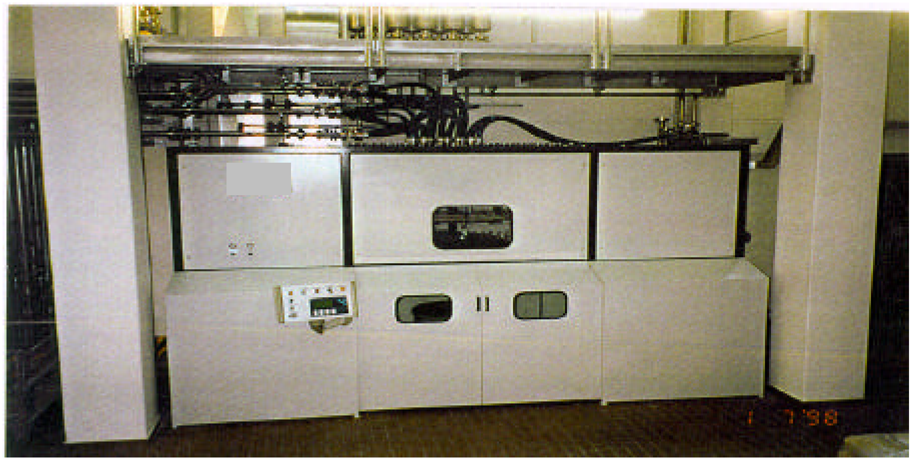

Photo 4:
Dosing station for mobile bins, full encapsulated.

Photo 5:
Dissolver with mobile bin and exhaust air extraction by flexible hose during dosing of liquids and dispersing.

Photo 6:
Encapsulation of dissolver with mobile bin and exhaust air extraction.

Photo 7:
Dissolver with mobile bin and flexible hose with extraction hood.

Photo 8:
Encapsulation of dissolver.

Photo 9:
Encapsulation of dissolver.

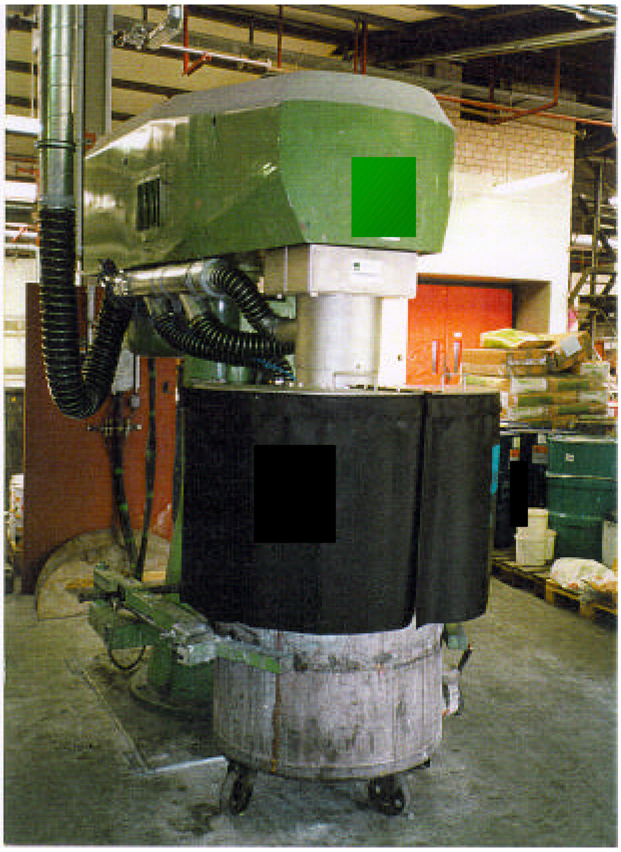

Photo 10:
Encapsulation of dissolver.

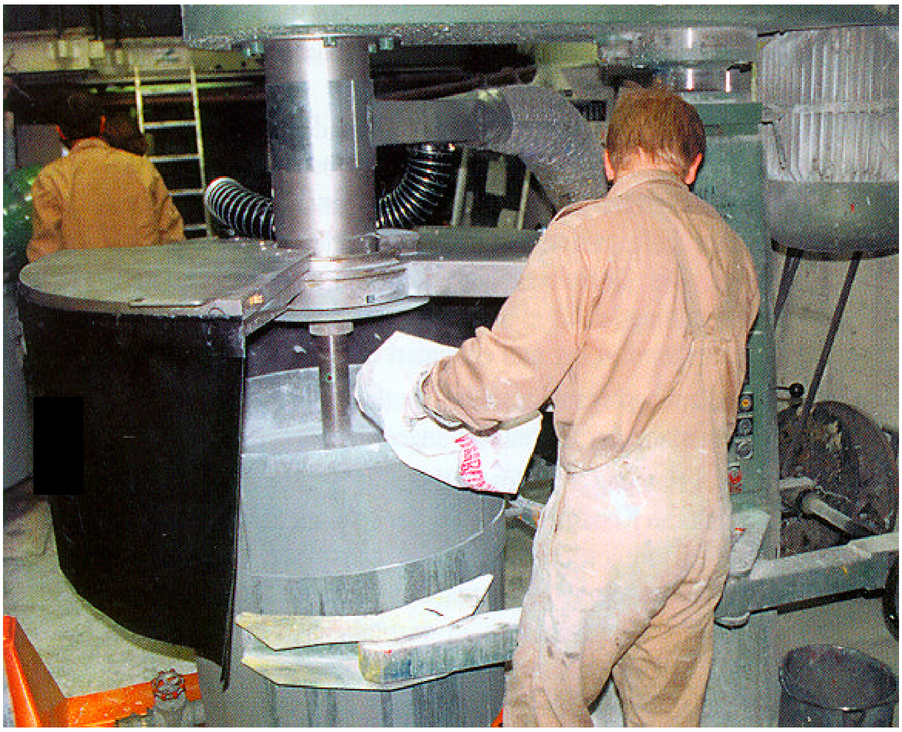

Photo 11:
Dissolver encapsulation with possibilities for manual addition of powder.

Photo 12:
Dissolver with dosing lid.

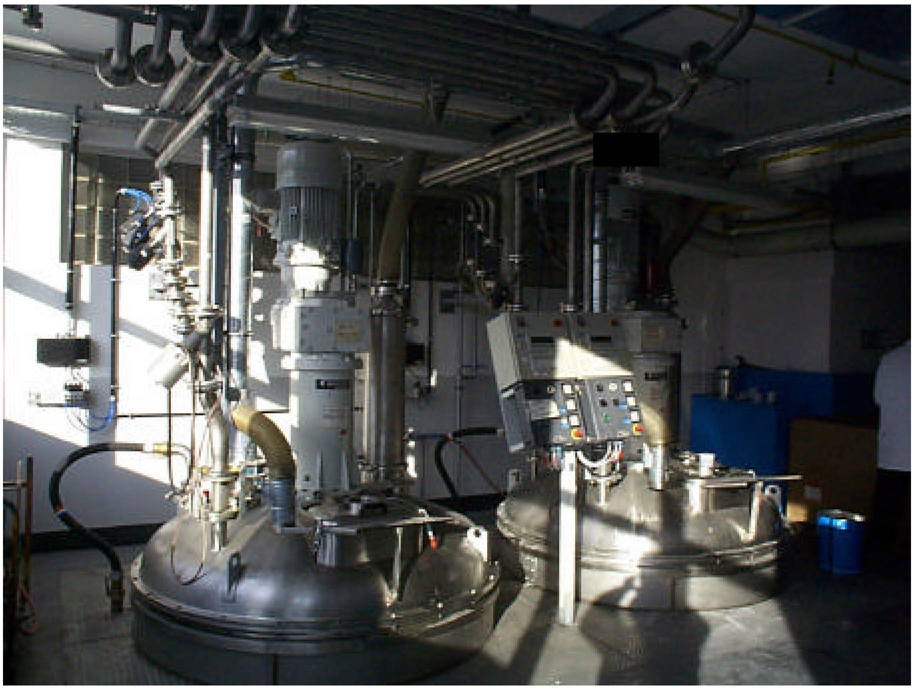

Photo 13:
Closed dissolver system with automatic liquid dosing via pipe and condensation system.

Photo 14:
Closed Dissolver system with automatic liquid dosing via pipe, condensation system and dust extraction system by flexible hose.

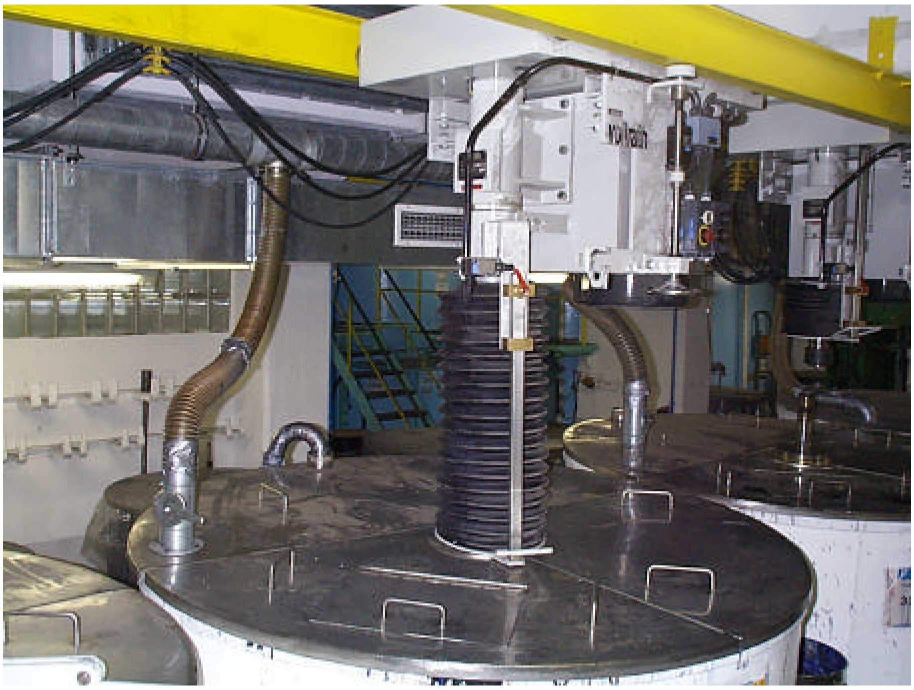

Photo 15:
Finish tanks with exhaust air extraction via flexible hose and concertina expansion joint at the agitator shaft.

Photo 16:
Finish tanks with exhaust air extraction via flexible hose and exhaust air piping system and above the ventilation system for the working environment.

Photo 17:
Automatic filling station.

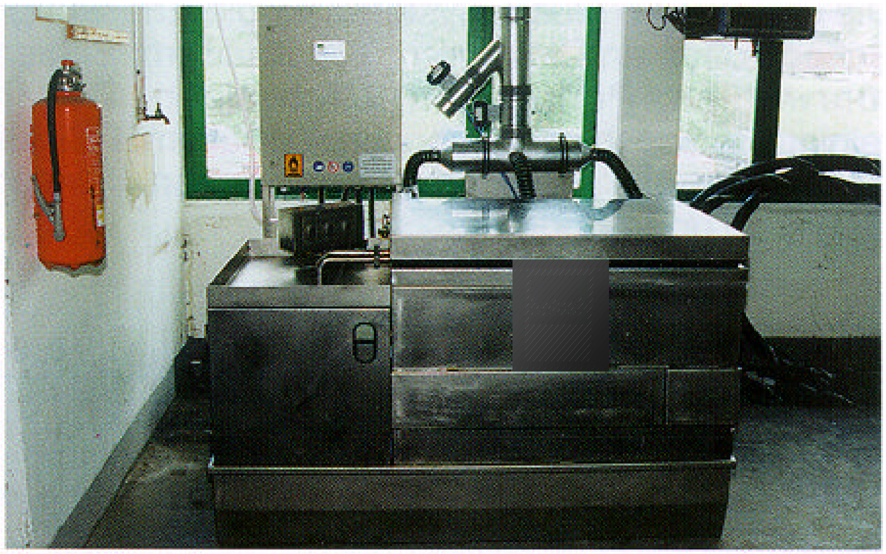

Photo 18:
Rinsing basin with automatic, directed exhaust air flow.

Appendix B: Photos

Example with collecting pipe systems and post production cleaning plant

Photo 1:
Collecting pipe system for exhaust air from the production building.

Photo 2:
Collecting pipe system for exhaust air from the production building.

Photo 3:
Thermal regenerative combustion plant.