Commission of the European Communities

environment and
quality of life

Hydrocarbons
Identification of air quality problems in Member States of the European Communities

Report

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Hydrocarbons Identification of air quality problems in Member States of the European Communities

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Executive Summary

Not only inorganic chemicals like SO_2 or NO_x but also the emission of organic chemicals (hydrocarbons) can cause severe adverse environmental and/or health effects. These effects may be caused by the emitted substances themselves or by their transformation products. Hazard assessment of hydrocarbons therefore has not only to take into account the emitted substances but also their potential transformation products.

Emission

The amounts of organic chemicals emitted in the member states of the EEC are not very well known. Therefore, estimation methods have to be applied that are generally based on production or consumption rates and emission factors. Unfortunatelly even these data often are not exactly known but have to be estimated, too.

Emission source categories taken into account comprise industrial processes emissions, use of solvents, vehicle exhaust emissions, natural emissions and some other small contributors. The emissions of these sources were split up into the categories "unsaturated", "unreactive" and "other" organic compounds in order to give at least an impression of the composition. Additionally, emitted amounts of single compunds were estimated. These estimations mainly were restricted to:

- Piority chemicals, selected by their hazardousness (Benzene, acetaldehyde, acrolein, epichlorohydrine, styrene, ethyleneoxide, acrylonitrile, vinylchloride, phenol and 1,2-dichloroethane. Formaldehyde was not taken into special account as this substance is treated by a seperate working group of the EEC.)

- Halogenated solvents. (Dichloromethane, trichloromethane, tetrachloromethane, tri- and tetrachloroethenes) Although not solvents in the first place Cl-F-hydrocarbons were also added in this item.

- organic chemicals in vehicle exhaust. (Ethene, 1,3-butadiene, benzene, toluene, xylenes. These and further emissions from road traffic can be deduced from this report in considerable detail).

In the report the emitted amounts are compiled seperately per source category and per country. Road traffic and total solvent use appear to be the two main contributors (80 % of the estimated total in the EEC).

Immission (ambient air concentrations)

Measurements of ambient air concentrations are performed for total or nonmethane (NMHC) hydrocarbon content or for single organic compounds. NMHC measurements are relatively cheap and automatically to perform. These measurements are not suited to assess the adverse environmental and/or health effects caused by hydrocarbon immissions. NMHC measurements can only be helpful in the detection of heavily polluted areas. For most of the member states of the EEC only very limited NMHC measurements have been performed. Immission measuremts for single compounds were performed to an even lower extend. As the number of measurements and the measured concentrations for the single compounds vary considerably, the reader has to be refered to the data compiled in the list of substances (chapter immission). We feel that the list of substances taken into account is fairly complete. Addition of further substances would not introduce chemicals which are released in large amounts. Due to the limited available information hazard assessments could be performed only for a limited number of substances. For the performance of these assessments additional information about the smog formation potential and the toxicity of the compounds had to be collected. Comparision of the immission data and the information about toxocity revealed that the population living in cities of the EEC member states may be exposed to rather high additional cancer risks. These risks may exceed 10^{-4} and are mainly caused by benzene and halogenated hydrocarbons.

According to the measured and published immission data it is probable that aliphatic and aromatic hydrocarbons are the dominant organic air pollutants. Although, most of these substances do not occure at such high concentrations that they can cause directly adverse health effects, hazard assessment of these substances should take into account that these compounds can be transformed to much more toxic or environmentally relevant substances by chemical reactions in the atmosphere. Oxygenated and nitrated transformation products are probably the most important ones with respect to possible adverse environmental and/or health effects.

These transformation products may also contribute to the European forest decline. Ozone, peroxyacetylnitrate (PAN), and other peroxynitrates are believed to be the most important chemicals with respect to forest decline. But other possible transformation products, especially nitro aromatics may also contribute to this phenomenon.

It is felt that the information available for hydrocarbon emissions, immissions, transformation products etc. for the member states of the EEC is not sufficient for a reliable hazard assessment. Further investigations especially on immissions and transformation products have to be performed and further and more detailed information on emissions is needed. As a first step it is recommended to collect these data for a limited number of substances. A list of such priority substances was compiled within the project and is given in the capter "Final conclusions" of this report.

Various measures can be applied in order to reduce hydrocarbon atmosphere emissions. Abatement techniques do exist since many years but one has to recognize that coherent governmental actions in the Member States have generally been, up to now, very limited, probably due to the complexity of the problem.

Two ways are available for reducing VOC emissions into the atmosphere :

- reduction of the solvent content of products currently used for industrial operations, but mainly for household applications,
- reduction of the VOC content of flue gases ejected into the atmosphere.

The first way is the most satisfactory but the difficulties encountered explain why the efforts developped since many years by producers of paints, inks, etc... have not yet resulted in the commercialization of products with low solvent contents, fully accepted by the public or by industrialists. Manufacturers are now insuring that this evolution is favorably in progress.

The following actions are vigourously recommended :

1. Public authorities should financially support the development of new products with reduced solvent contents.

2. They should also help commercialisation of these new products by information campaigns aimed at the public and by the creation of quality labels for some products.

The second way for reducing the emissions is more suitable in the short term, the corresponding techniques are now available :

- the condensation technique is likely the most promising because of the development of new heat exchanges, of heat pumps, of refrigerating devices. The condensation technique does not degrade the products and, under certain conditions, allows their recycling.
- the activated carbon technique has been used since a very long time. The technologies are well developped and the progresses in the knowledge of ad-

sorption phenomena will permit to commercialize, in the coming years, new generations of activated carbons specific to the adsorption of particular organic compounds. The main problem is the regeneration phase which needs complex systems of steam or inert gas production, not always easily used by small companies.

- the absortpion technique has not been fully developped because of the generally low solubility of many solvents in water. Developments are now in progress for using washing liquids other than water (oil for instance). The use of specific bacteria seems to open new ways of development in order to economically destroy organic molecules.
- thermal incineration was the first technique to be used for destroying organic molecules. The disregard of basic recommandations (temperature and time of residence) and the cost of energy have often made this technique to be considered as deceiving. This technique with low capital costs is well suited for installations with little flue gas.
- catalytic incineration has been developped to reduce the energy expenditure. The basic recommendations (temperature and time of residence) are the same as for thermal incineration. The risk of poisoning remains the main problem. The knowledge of the mechanisms of the catalytic phenomena makes now possible the development of new catalysts with lower operating temperatures.

This second way for reducing the emissions is generally expensive and it is vigorously recommanded to establish cost-efficient regulations on well-selected activities (firstly : painting, printing, storage of high vapour pressure organic compounds). It is also recommended to develop the use of simple and reliable monitoring devices in order to check the good operation of the abatement systems.

The compilation of immission data showed that vehicle exhaust hydrocarbons may cause additional cancer risks for the population. Therefore it is recommended to perform immediate actions in order to reduce the emissions from the vehicles. For the time being, it seems that the best available technology (already used in USA and Japan) : catalyst, should be used for this purpose.

Lead elimination in gasoline will result in increased aromatic contents, which, as regards health hazards, is undesirable. Therefore ways should be sought for reducing or, at least, maintaining, aromatic content, such as for instance resorting to oxygenated derivatives ; branched alcohols or other oxygen-containing compounds may be used instead of aromatics to improve the octane number of gasoline. Nevertheless, one has to verify that use of oxygen-containing compounds has not other detrimental effects on the environment (formation of aldehydes).

1. Introduction. Organic compounds as an air pollution problem

The third Action Programme of the European Commision calls for the development of a comprehensive strategy to assure air quality. According to the principles laid down in that Action Programme measures should be taken by the Commission to:

i. protect human health and to contribute to the protection of the environment,
ii. reduce the long range transport of air pollutants which might cause a direct or indirect effect on human health and/or the environment,
iii. to ensure the harmonized development of the Common Market.

Especially during recent years it became evident that not only emitted inorganic chemicals as CO_2 or NO_x can cause severe environmental problems, but that this is also true for organic chemicals. As the concentrations of organic chemicals in ambient air mostly are rather low however, it is not probable that it will be possible to detect environmental or health damages which are directly caused by the acute toxicity of organic air pollutants. Health or environmental effects caused by the chronic toxicity of air pollutants therefore are of special importance. Even more attention has to be paid to air pollutants which can cause irreversible effects e.g. cancerogenic or mutagenic substances. Minor air pollution problems also can arise from the emission of odorous organic chemicals. These emissions mostly do not cause health effects, but the emission limits for such substances often are rather low because of the subjective impairments they may cause when present at relatively low concentrations.

In order to assess the importance of air pollutants one has to take into account not only their toxicity but also their potential to contribute to photosmog formation and their potential to be transformed to toxic substances. These reactions and transformations usually take place after the substances are released

to the troposphere. The products of these processes may be much less or much more toxic than the emitted substances. Furtheron, the products show other physico-chemical properties than the emitted substances. Mostly they are more soluble in water and therefore accumulated in cloud and rain water. The concentrations in the water phase achieved by this mechanism may become fairly high.
Persistent chemicals which are not toxic or harmful according to present day knowledge do not lead to direct air pollution problems. Nevertheless, these substances may cause problems because they are transported through the air to locations where they are no longer unreactive. The fluorochlorohydrocarbons, which contribute to ozone deplition in the stratosphere and by this way indirectly may cause environmental and/or health effects, are one example for a group of such substances. Persistent and toxic substances are also distributed through the air and by this way every living being will be exposed; even persistent substances with rather low vapour pressures like DDT or PCB's are distributed all over the world. If these substances additionally can accumulate in the food chain, they may reach concentrations at which environmental and/or health damages have to be expected.

To assess the importance of single compunds for air pollution the previously mentioned aspects are not sufficient. Additionally it is necessary to know the amounts of each compound emitted to the troposphere. These amounts are often not known, but with the aid of emission factors and the knowledge of produced or consumed amounts values they can be estimated.

The aim of this study therefore is to collect information about the emission, immission, transformation and toxicity of hydrocarbons in order to become capable to better assess the air pollution situations caused by hydrocarbons in the member states of the EEC. A further aim of the study is to collect information about measures already active or underway in order to abate air pollution in the various member states of the EEC.

2 - DEFINITIONS

Considering the complexity of the topics to be studied, clear definitions are necessary.

The justifications for studying Organic Compounds are numerous and diverse :

- short term toxicity (for human beeings and ecosystems)
- long term toxicity (" " " " ")
- photooxidant smog formation potential
- inflammability and explosivity
- odours
- etc...

Every scientist or technologist has, in practice, his own definition directly related to the particular category of problems he has under study.

Figure 2.1 presents a very simplified structure of the main categories of organic chemicals.

Strictly speaking, Hydrocarbons are molecules which contain only C and H atoms.

Organic chemicals or Organic Compounds are molecules which may contain not only C and H atoms, but also other atoms, such as O, N, Cl, F, P, S, etc... and even metals or other metalloïds.

Volatile Organic Compounds (VOC) are substances of which vapour pressures at ambiant temperature are high enough to assume that these compounds are in vapour phase. EPA has given the following definition : organic compounds which have a vapour pressure higher than 0,13 Pa in the current conditions (20°C and 1013 hPa).

Methane is mainly released by natural sources and its concentrations in ambient air are generally high (1 to 2 ppm, i.e. 600 to 1 300 $\mu g/m^3$). Since it is non toxic and practically unreactive in photochemistry, it is usually kept out of emission inventories and emission measurements. Therefore, one speaks of Non-Methane Hydrocarbons (NMHC) or of Non-Methane Volatile Organic Compounds (NMVOC).

Among these Organic Compounds, some are photochemically reactive in the atmospheric environment, or may have biological effects, or are odorous, etc...

Commonly speaking, the terms "Hydrocarbons" and "Volatile Organic Compounds" are often used indistinctly.

In this study only volatile organic compounds will be considered. Defining volatility is not difficult but in practice rather useless. Here, any substance that, during any industrial or other process or application, is transferred to the atmosphere in the gaseous state will be a volatile organic compound (VOC). Thus, the material avaporating from the particles of an aerosol is an emission of VOC's, whereas an oil mist is not. Emissions that can escape this pragmatic definition are negligible.

3. EMISSIONS

3.1 INTRODUCTION

Contrary to the inventorying of SO_x and NO_x up to the present not much experience has been gained with nation-wide or regional estimations of emissions of organic compounds. Understandably so, regarding the differences. SO_x- and NO_x-emissions are mainly related to combustion processes. SO_x-emissions can easily be assessed with fuel consumption data, sulfur content of fuels and S-fractions retained in ashes. NO_x-emissions are estimated with emission factors based on a still growing amount of measurements. Emissions of organic compounds (hydrocarbons, as they usually are named) are, on the other hand, related to a variety of origins that can be grouped into two broad categories: combustion and evaporation. The first is dominated by internal combustion engine exhaust, the second category comprises production and application losses but also natural emissions from vegetation.

A second difference stems from the compounds itself. SO_x and NO_x comprise only few different substances. Hence physical properties, transport phenomena, hazards etc. can be investigated within surveyable frameworks. Examining organic compounds at large, however, implies the interference with very many different substances that show extreme variations in toxicity, reactivity, emission rates etc. Attempts to make selections based on hazard criteria still may result in a hundred or so (or more) different compounds the sources of many of these being very incompletely known.

A third difference originates from the important role played by evaporation, many evaporative emissions being dependant on ambient temperarature.

In consequence, inventories of organic compounds are scarce. Detailed investigations, including geographical distribution and based on visits to individual plants, land use data etc. have been performed in several industrialized regions in the FRG (1) and -nation wide - in the Netherlands (2). Very many different substances or groups of substances are considered. This is a very laborious operation. A more time-saving approach is multiplying generalized source strength parameters (such as production rates or vehicle mileage) with suitable emission factors. This inevitably yields a more superficial geographic distribution and less reliable emission estimations of several industrial branches. This type of inventorying has been done in the UK (3) and within the scape of the PHOXA-project (4), where a distinction between (groups of) substances has been made in accordance with model requirements.

Regarding the results there is no sharp distinction between these two approaches as fas as organic compounds are concerned. This is because the majority of the emissions has inevitably to be estimated by statistical means (road traffic and solvent emissions) and obviously there will be a relationship between the effort and the resulting degree of detailedness.

Finally, rough, nation-wide estimations have been done by the OECD (5). At present, this organisation is working on a second inventory. In this, no distinction is made between substances, only total non-methane hydrocarbons are considered.

In the present case a screening study is required. That is to say, for each member country an inventory is needed of contributions from main source types. Geographical distribution is only relevant as far as main concentrations of sources are concerned. To make s screening possible it is not sufficient to collect emissions of total hydrocarbons. Some differentiation is needed anyhow.

Apart from comprehending contributions to ozone generation, some other potential health hazards should be taken into account. Most inventories available at present do not meet these requirements.

In this chapter the choice of substances and of source types is reported as well as the estimation techniques used. Attention is given to the accuracy of the results. For each member-country results are presented in tables and in a map, showing local concentrations of emissions.

3.2 SUBSTANCES

Considering the huge amounts of different VOC's that are emitted it is obvious that some selection should be made. It will also be obvious that selection should take place by the application of one or more hazard criteria. It has however already been pointed out that the result still may comprise many different compounds, partially with incompletely known sources. And without or with very incomplete knowledge of source types only a haphazard inventory can be made.

Actually, hazard criteria for their own part are very difficult to make. In practice, TLV's, toxicity data, scarce knowledge about vegetation hazards etc. are used, although it is known that TLV's should not be used for thir purpose. Toxicity data are in many cases not easily comparable. Immission concentration limits would be a more appropriate tool but for their scarcity.

After some attempts to make a selection it finally was agreed to use a list of priority compounds, drawn up by the Dutch Ministry of Housing, Physical Planning and Environment (6). Each of these compounds has been described into great detail - or will be so in the near future - in so-called criteria documents (7). The organic compounds in this list are:

benzene
toluene
styrene
methylene chloride
chloroform
tetrachloromethane
1,2-dichloroethane
vinyl chloride
epichlorohydrine
ethylene oxide
propylene oxide
acrylonitrile
phenol

Apart from these it was considered worthwile to add:

acetaldehyde
acroleïn
CL-F-hydrocarbons

and to discard propylene oxide. With this list at least a certain number of compounds is given about the hazards of which there is general agreement.

The emissions of these substances form only a small part of those of total VOC's. The large amounts of non-priority substances should be considered mainly because of their ozone forming potential and should be subdivided in this respect. Sufficiently is known about reactivity to place the majority of substances on a reactivity scale, but unfortunately there are several source types of which the composition of their emissions is insufficiently known. In any inventory, therefore, a compromise is needed between knowledge of compositions and detailedness of subdivisions. For screening purposes it is considered sufficient to separate unsaturated hydrocarbons (mainly olefins) and unreactive substances from the total. What remains then is mainly paraffinic and aromatic.

Apart from the large quantities of volatile material emitted, it is well-known but quantitatively still poorly described that many highly toxic substances in small or even extreme small quantities are released into the air. Among these attention has been paid mainly to polycyclic aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), polychlorinated dibenzo-p-dioxins (PCDD's) and polychlorinated dibenzofurans (PCDF's). Heating or burning organic material is the main source of many of these substances. The less oxygen is available for the process, the larger emissions are. Analytical problems, emission phenomena (gaseous or adsorbed to particulates) and source parameter definition (operation and maintenance) are the reasons that no reliable emission factors are available. The most important sources of PAH's are residential coal firing, coke manufacturing, anode baking in primary aluminium production and road transport. Estimatedly 3000 ton/year are emitted in the EEC by these four sources by using emission factors mainly from a recent review (53). This figure may however be in considerable error. It should further be emphasized that not all PAH's are a hazard.

Waste incineration has been recognized not only as a source of PAH's but also of PCDD's and PCDF's. For these species emissions of 1-10 mg/ton waste have been reported (54).

Because of the very scarce knowledge about the impact on the environment and the special characteristics of emission phenomena it was decided not to incorporate these species into the list of substances for the emission inventory of this study.

SOURCE TYPES

A list could be made of all activities that transfer VOC's to the atmosphere including those that are suspected to do so. Then for any of these activities an emission factor and (at least some) knowledge about the composition of the emissions is needed. Such a list would be rather extensive. To clear up the picture the two broad source groups - combustion and evaporation - should be considered.

Stationary combustion sources are relevant only when relatively low temperatures are involved and when there is a fair chance of imperfect maintenance. It will be clear, then, that powerplants, industrial boilers and commercial/residential combustion sources will contribute negigibly, little and - at least in some countries - substantially respectively. Mobile sources, on the other hand, are well-known to contribute largely to total emissions. These, together with evaporation losses control total VOC emissions. A classification of the latter can be made as follows:

Production	Industrial	- Losses from apparatus (valves, flanges etc.) - Evaporation from free surfaces (including those of some bulk polymers) - Vent losses - Spilling losses (improper house keeping)
Storage and handling	Industrial/ Commercial	- breathing losses - transfer losses
Application	Industrial	- same as industrial production
Application	Commercial/ Residential	- Use of VOC's containing products (solvents)

When emissions from other mobile sources than road traffic are added together with the combustion and storage of wastes, the rough sketch of anthropogenic emissions is complete. Vegetation, however, is also a source of VOC's. In general, all green plants are potential emitters-It has been shown that trees are responsible for the majority of natural emissions. Next to these forest-fires should be mentioned.

From the foregoing a first approach to source type selection is possible.

It can easily be seen that the only source group still difficult to handle is that of industrial processes. There are many of them and several emit VOC's to an extent that affects only indoor air quality. Expectedly the main emitters are petroleum refineries and (petro)chemical industries, simply because of the large quantities of VOC's handled. A selection from the latter group can be made with help of production rates and emission factors. Industrial processes other than the production of chemicals that emit considerable quantities of VOC's are still abundant but can be grouped considering the fact that in many of them solvents are involved. By estimating national solvent consumptions many source types disappear from the inventory but on the other hand a more reliable emission rate is gained. It should be borne in mind that this approach can hinder abatement studies. It should be pointed out further that, taking chemical industry as a source type, here also solvents are emitted. The most important emitters of solvent vapours, apart from chemical industry, are processes that apply coatings (automobiles, metal products, paper coating etc).

Other industries that emit VOC's in relevant quantities are coke manufacturing, foundries, fermentation processes (bread baking; beer, wine and spirits production). Some of them are only of local importance.

For the purpose of this study a source type selection has been made as presented in table 3.1.

3.4 EMISSION ESTIMATION; EMISSION FACTORS

3.4.1 General

Obviously the appropriate way to assess emissions would be measuring them at sources, representative for specific source types. It will also be obvious that, given the large number of source types, the difficulties that have to be faced in meeting representativity and the fact that usually no single species but a variety of compounds should be taken into account, reliable measured data are scarce.

With this in mind, it is common practice to compose from what knowledge is available average values that more or less represent emissions related to more or less well defined activities. These values (or emission factors) in some cases can be made more reliable by adding engineering knowledge, comparisons between processes etc. A detailed overview of emission factors can be found in (8).

The reliability of emission factors is still subject of much discussion. Qualitative scales are in use (9). An attempt to quantify emissions as to their uncertainty is in progress (10). In the present study an effort has been made to illustrate uncertainty by stating the range of possible values.

Following the list of source types taken into consideration (table 3.1), in this section the estimation of emissions will be discussed, that is, background data of sources and the derivation of emission factors will be reported. In the tables 3.2a and 3.2b the emission factors are presented.

3.4.2 Petroleum refineries

An overall factor for all refinery operations has been reported (5): 0,47 kg VOC/ton crude throughput in 1977 (0.35 kg/ton in 1985 and a predicted 0.3 kg/ton in 1990). These figures are representative for European refineries. For this study an overall factor of 0.4 kg/ton refinery throughput will be used. This factor may vary between 0.2 and 0.6, dependant on quality of housekeeping and age of refinery. The main sources of emissions are storage and handling (ca. 50%). It has been stated that European refineries store all crude and 90% of VOC's in floating-roof tanks. Since fixed-roof tanks emit 10-15 times as much VOC's as floating roof tanks and tanks with inner floaters have about 5-fold emissions, knowledge of storage facilities is important in estimating refinery emissions.
The composition of the emitted material may be taken as that of gasoline vapour. The default composition is: 87 wt.% saturates, 11 wt.% unsaturates and 2 wt.% aromates.

3.4.3 Primary iron and steel industry

3.4.3.1 Coke manufacturing

An average emission factor can be composed from measurements in the FRG (11) and the Netherlands (2):

saturates	: 0.05
ethene	: 0.15
benzene	: 0.05
other aromates	: 0.05
	0.30 kg VOC/ton coke

For old plants this factor may be 2-3 times higher. An important source of VOC's are leaking oven doors.

3.4.3.2 Sinter plants

The emission rate from sinter plants can be deduced from estimations made in the Netherlands (2) and in the USA (12).
The composition can be taken from (12):

saturates	: 0.01
acetylene	: 0.02
ethene	: 0.01
other unsaturates	: 0.01
	0.05 kg VOC/ton sinter

The factor may vary from 0.03 to 0.1.

3.4.3.3 Rolling

CITEPA uses a factor of 0.3 kg/t flat rolled products and of 0.1 kg/t long rolled products.

3.4.4 Grey iron foundries

A rough estimate of 2 kg VOC's/ton cast iron can be used as a first approximation to describe emissions of organic substances from all operations in an average foundry. It is also a rough estimation to describe the composition as 45% saturated hydrocarbons, 50% aromates and 5% aldehydes (2). Amines, phenols and many other substances are released also.

3.4.5 (Petro)chemical industry

3.4.5.1 General

The large number of processes in this sector that emit VOC's prohibits a profound study. Two approaches are possible to nevertheless obtain an impression of the contribution of this industrial branch:

a) Production rates and emission factors can be used to estimate the minimum number of processes that contribute maximally to total mass emissions. A throrough knowledge of chemical industry is necessary for this.

b) A selection can be made of substances to be inventoried based on hazard criteria.

The problems involved with this second approach have already been discussed in par. 2 of this chapter. The priority compounds chosen solve these problems to a certain extent and bring into the inventory a rather randons selection of processes. In order to have the mass emissions of chemical industry represented sufficiently in this study the first approach was used, predictedly resulting in a selection of bulk organic chemicals.

3.4.5.2 Bulk organic chemicals

3.4.5.2.1 Ethene

Thermal cracking of petroleum fracitons yields propene and other olefins simultaneously with ethene but production commonly is expressed in ethene units. Emissions are saturated and unsaturated hydrocarbons. According to (13) (expressed in kg/t ethene): saturates $C \geq 2$: 0.5 - 1.5; unsaturates C_{2-4}: 1.5 - 2.
Modern plants have lower emissions. In this study the following factor is used:

saturates $C \geq 2$: 0.5 (0.3 - 2.5)
ethene : 0.2 (0.1 - 1.0)
other unsaturates : 0.1 (0.1 - 0.5)
0.8 (0.5 - 4)

3.4.5.2.2 1,2-dichloroethane

An overall emission factor may be used, based on production but including some applications (7): 10 kg dce/ton dce produced. This factor may be considerably lower (1.5 - 2). Olefins are also reased from the process, estimated to be 4 kg/t dce.

3.4.5.2.3 Vinylchloride

3.5 kg VC/t VC produced has been estimated as an European average (7). In W. Germany and the Netherlands the factor is 0.04 and new German plants should not exceed 0.02. Other emissions may occur: 0.1 - 0.2 kg ethene and 1 - 2 kg Cl-hydrocarbons per ton VC.

3.4.5.2.4 Polyvinylchloride

The same document (7) reports emission factors for vinylchloride emissions from PVC production (kg VC/t PVC):

	FRG (1977)	Netherlands (1981)	W. Europe
emulsion polymerization	3	-	}8.5 (overall factor)
suspension	1.5	1.5	

According to the UBA (1) the factor in the FRG in 1979 was for

emulsion polymerization : 1
suspension " : 1.5
mass " : 0.5

3.4.5.2.5 Polyethylene

Different emission factors apply to low-density and high-density polyethylene. Estimations in the Netherlands and W. Germany result in the following figures:

	PE-LD	PE-HD
ethylene	: 1.5 (1 - 10)	0.3 (0.2 - 1)
other olefins	: -	0.5 (0.3 - 1.5)
saturates C_{2-10}	: -	5.2 (4 - 15)
	1.5 (1 - 10)	6 (4.5 - 18)

3.4.5.2.6 Polystyrene

According to (7) 1 kg styrene/t PS is released. For certain types of polymer 0.05 - 5 kg n-pentane is emitted per t PS (13).

3.4.5.2.7 Styrene-Butadiene-Rubber (SBR)

The emissions primarily are styrene and 1,3-butadiene:

SBR-rubber : 5 (1 - 10) kg styrene; 0.3 (0.1 - 0.5) kg butadiene
SBR-latex : 1 (0.2 - 2) kg styrene; 0.3 (0.1 - 0.5) kg butadiene

Sources are (7) and (13).

3.4.5.2.8 Carbon black

An emission factor of 1 kg saturated hydrocarbons C_{2-4} and 1.5 kg ethene per ton carbon black can be deduced from (9) and (14). Acetylene emissions are not taken into account.

3.4.5.3 Other chemical processes

In the criteria documents (par. 3 of this chapter) many more emission factors are reported than that have been cited in the preceding sub-sections. Apart from these, literature data give (or enable to compose) factors, as will other sources, partly confidential, do. In tabel 2 a compilation is given.

3.4.6 Fermentation processes

Some manufacturing processes for foodstuffs make use of biogenic phenomena. The baking of bread and similar products is an example for this. Ethanol is released during bread manufacturing and, based on measurements (9) an emission factor of ca. 6 kg per ton bread can be deduced from these data.

The production of alcoholic beverages also is a source of ethanol emissions. Based on the few data available (9,15,16) a linear relationship between % alcohol in the product and ethanol emission rate is suggested. The resulting emission factors are questionable and only give an order of magnitude of emissions.

3.4.7 Solvent evaporation

In any society solvents are used. Industrial production processes need them, metal parts and products are cleaned with them. They appear in formulations of paints, pesticides and numerous other products, are used in aerosol cans, chemical cleaning of wearing apparel etc. A comprehensive matrix can be made of applications and products but this would be a very elaborate work of inventorying and market analysis and would expectedly leave more gaps than data. A far more simple approach is estimating national total consumption of solvents on both an application and composition basis. This leads to two separate inventories of which only partly combinations can be made. Since the majority of sources have small emission rates, both industrial and non-industrial, a geographic distribution proportional to population density is allowed. Corrections for large consumers should however be made.

The composition-based inventory could be made by making mass balances for selected solvents or groups of them:

Emission = (Production + Import - Export) x solvent application factor x abatement factor.

Unfortunately, up to the present most countries fail to have production data of these products in their statistics. Only in the FRG an attempt like this has been done, whilst in the Netherlands a combination of product analysis and market analysis gave insight into non-industrial solvent emissions and the project ER provided industrial emissions. In several countries data are reported about solvent emissions either on an application basis or on a composition basis or on both. A literature survey and analysis yielded default values (17) that are used in this study where other data are not available. The assumption that there will be a certain degree of similarity between solvent consumption patterns in groups of countries was confirmed by this analysis to a certain extent. In the tables 3.3 and 3.4 the results are given.

The only emission factor used in this study is one for automobile manufacturing (9). In some countries this is a large, local area source.

3.4.8 Waste elimination

One of the solutions to the problem of elimination of wastes is their combustion in furnaces. It is to be expected that VDC's will be released from processes like these but both emission rates and species profiles are difficult to generalize due to the varying composition of the combustibles. This problem is least with the incineration of municipal waste since, of all wastes, this material is treated most extensively. Hence some knowledge has been obtained. Because of the relatively uniform composition VOC-emissions expectedly will vary not too much, nevertheless reported emission factors are rather weak. Based upon data from (9) and (28) a factor of 0.15 kg VOC/ton waste will be used in this study. The incineration of industrial wastes still occurs on an occasional basis only. The composition of the wastes varies so much that no emission factor can be given.

The elimination of sewage sludge by incineration or application as a fertilizer is a source of VOC-emissions, but only incidental data are reported.

No general emission profiles are known, attention being given only to the release of toxic substances such as PAH, dioxines and PCB's.

3.4.9 Stationary combustion sources

Large combustion sources, operating at high temperatures and usually well maintained, will emit only very small quantities of VOC's. Starting operations or sharp increases in load may lead to incidental, though still small, detectable emissions. This applies to power plants and large industrial boilers.

What, for statistical purposes, is designated as industrial boilers actually is a group of combustion sources with a very wide range of capacities. For the application to this source category of emission factors data about the capacity distribution per country are needed as well as capacity-dependant factors.

The first need is only recently - and partially - met by an inventory among EC member countries (25). The second cannot be adequately fulfilled presently. Therefore only a rough estimation can be made but, since the contribution to total VOC-emissions is small this need not be considered as a problem.

The same considerations apply to stationary combustion sources from the sector "commercial/public services". These mainly comprise boilers for the heating of utility buildings and have capacities that are comparable to - the smaller - industrial boilers.

The most important category - dependant however on the fuel types used in member states - is residential space heating. The small sources in this category are characterized by low NO_x-emissions but relatively high CO- and VOC-emissions due to the lower operating temperature, incomplete combustion and, on the average, less quality of maintenance. Variation in construction and variation in maintenance are the reasons that VOC-emission factors are not very reliable. This is still more true for VOC-composition about which there exists hardly any information. From very scarce measurements and rough estimations composition profiles can be made (26,27). For this study the following compositions are assumed (table 3.5):

Table 3.5

Assumed composition of VOC's emitted by stationary combustion sources (wt.%)

	saturates	unsaturates	aromates	oxygenates	unreactive
solid fuels	50	10	10	20	10
liquid fuels	65	10	5	10	10
gaseous fuels	20	3	-	2	75

Unreactive species are assumed to be methane. Oxygenates mainly consist of aldehydes. The primitive division of fuel types illustrates the lack of knowledge.

3.4.10 Road-transport

VOC-emissions from road traffic consist primarily of exhaust from internal combustion engines of which gasoline-powered engines in non-catalyst vehicles predominate. An internal combustion engine can be seen as a chemical factory of micro size with a feedstock of varying composition and operating with high temperatures, high pressures and a high cycle speed. Much research has been done on combustion phenomena and nowadays knowledge about emission rates and composition is at least sufficient for modeling purposes. That is to say, exhaust composition of gasoline powered vehicles is reasonably known whilst knowledge about VOC's from diesel and LPG is scarce but these two contribute a small fraction only to total VOC's from road traffic (17).
For the estimation of emissions from a vehicle many parameters have to be taken into consideration. Of these the most important are

fuel type and fuel consumption
type and size of engine
load of engine
load variations of engine
start conditions

Usually, emission factors are used - expressed as g/km - that depend on these parameters but are - partly - converted into

fuel type
vehicle type
vehicle speed
age of vehicle or vehicle parc

Again, vehicle speed is converted for practical purposes into urban, local and highway driving modes, local mode representing any driving other than urban or highway driving. Knowledge about speed-dependency of exhaust emissions as it is today and knowledge about average speed and speed distribution on different road-classes is not sufficient to use a more detailed classification than this one.

Whilst uniformity can be assumed among countries about analytical techniques used (FID instead of NDIR), this need not be the case when parc emissions are estimated. Differences can be expected between countries about parc classification, driving habits and adopted emission factors. Thus it is not certain to what extent reported national emissions are comparable.

On the other hand one could assume that for a vehicle of a certain type, powered by a certain fuel and driven on a certain road type an emission factor can be used, irrespective of the country in which it is operated. Then only the parc age would be necessary as a correction for a harmonized estimation for all countries involved. Taking this assumption as valid such an estimation was made for the following vehicle types:

automobiles, engines < 1.4 l, gasoline
" 1.4 - 2 l, "
" > 2 l, "
diesel
LPG (Belgium, Italy and Netherlands only)
light commercial vans ($<$ 3.5 t GVW), gasoline
, diesel
trucks + road tractors, 3.5 - 5.5 t GVW, gasoline
3.5 - 5.5 t GVW, diesel
5.5 - 12 t GVW, "
12 - 15 t GVW, "
> 15 t GVW, "
autobuses, diesel
special service vehicles, gasoline
, diesel
motorcycles ≥ 50 cm^3 and < 50 cm^3

Any further subdivision was considered not to improve accuracy. It could of course appear, on the other hand, that even this division is too detailed.

It is known that the largest contributors to road traffic emissions are gasoline-powered automobiles and diesel-powered trucks. Therefore, emission factors for these two vehicle types need the most attention. To assess factors for the first category use was made of all available measured data about speed-dependant emissions of VOC's (29 - 32). In fig. IV-1 (Annex IV) these data are presented.

They are the result of measurements of vehicle samples representing national parcs as reliable as possible. Therefore the range of emissions for any speed will more or less reflect the dependance on engine size. This, and existing knowledge about engine size dependancy of emissions in a qualitative sense was the basis for a differentiation of emission factors according to engine size. For emissions of diesel-powered lcv's and trucks use was made of a recent study by TÜV-Theinland (33), results being critically reviewed by experts to make them more generally applicable.
Data for diesel-powered automobiles were taken from TÜV-Rheinland and slightly adapted. All other factors were taken from Dutch estimates (34), this being the only available source. In table IV-3 the emission factors for this comparative analysis are presented (see Annex IV). The same Annex gives the calculated emissions.
The composition of exhaust emissions has been taken from (17); see Annex IV.

Evaporative emissions from gasoline tanks were extensively studied by Schröder (48). From this work a yearly average emission factor can be deduced of 7.5 g/vehicle.day. This value probably is too low.
The representativeness of American data for European automobiles is questionable and other European measurements are not available presently. A discussion with experts from the Umweltbundesamt yielded an adopted value of 13 g/vehicle.day.
On statistical ground it can be made acceptable that evaporative emissions are restricted to urban areas, so this factor should not be expressed in g/km.

3.4.11 Other transport

For an approximate estimation of emissions from diesel engines employed in rail transport and inland navigation an overall emission factor can be used. Emissions from diesel engines, mobile as well as stationary, are reported in (1), (2) and (9).
Emissions from air transport are estimated with factors from one available source (9). They are determined by types of aircraft, engines and aircraft movements but can be averaged into one overall factor by taking into account the main aircraft types only (1). The emission factor is based on a landing take-off cycle

(LTO) consisting of approach, landing, idling, taxiing, take-off and climb-out. The emissions of approach and climb-out are included for heights < 500 m.

A reliable estimation of emissions from harbours is extremely complex. Emissions come from ships movements with reduced power, by different kinds of energy use during berthing and by activities on embankments. They can be related to the different categories of ships if a number of assumptions are made. Since harbours contribute only locally to emission patterns in this study no estimation with emission factors will be presented. Only estimations of some member countries are reported. A detailed attempt to establish emission factors is given in (2).

The composition of exhaust from diesel engines and aircraft turbines is very badly known and therefore assumed to be the same as that from diesel engines in road vehicles. Data reported in (27) suggest that aircraft engine exhaust more resembles diesel exhaust than gasoline exhaust.

3.4.12 Gasoline distribution

Distribution of motor fuels is a considerable source of VOC-emissions. Since the vapour pressure of diesel oil at ambient temperature is three orders of magnitude lower than that of gasoline, only the latter fuel is of interest. The distribution of gasoline is a multi-stage process that starts at refineries and via fuel-depots ends at filling-stations. Emissions at refineries are included in the overall factor for this source type (section 3.4.2). Factors for all stages are given by (49) for breathing and handling losses separately. This distinction is important since only breathing losses depend on temperature. In this study one factor is used for all emissions from depots and filling stations, the contribution of the latter is ca. 60%.

Spilling losses are included, according to (13).

The composition of the vapour obviously is that of gasoline.

3.4.13 Agriculture

The description of agriculture at large as a separate source type yields a somewhat elusive group of widely differing causes of emissions. Exhaust emissions, emissons from stored and spreadour manure (including sludges) by bacteriological processes and emissions from waste burning are involved.

In this study exhaust emissions from agricultural tractors are roughly estimated. Knowledge about emissions from manure and spreaded sludge is very scarce. For agricultural waste burning emission factors are available (9) but no data about amounts burnt could be obtained. Emissions were reported by only a few member countries. These scarce data were used to indicate EC-totals.

3.4.14 Natural emissions

Nature is a noteworthy producer of organic substances and so from time to time discussion arises about the amounts involved in comparison to anthropogenic contributions. Methane is released in very large quantities from wetlands due to bacterial fermentation processes. Coal and natural gas deposits may also emit methane. The latter source type may also emit higher paraffins. Ethylene is released by vegetation but only at very low rates.

As is generally accepted now, the main contribution to total natural VOC-emissions is from rural forested areas. Predominant substances are isoprene and some monoterpenes, of which α-pinene is the most frequently reported species. For the purpose of this study only this source type will be taken into consideration.

Literature about these emissions, chemistry, emission rates and effects is still growing. Present knowledge and reviews are given by (35 - 38).

In contrast to the situation in the U.S., European attempts to inventory natural emissions have been absent until recently. The German-Dutch PHOXA-project incorporated natural VOC's in its emission data base.

It is understood now that emission rates of VOC's from forest vegetation have multiple dependencies. Tree species, climatological and meteorological conditions (light incidence, ambient temperature and humidity), season and shape of the vegetation are examples of this. Evidently then, simple emission factors are not to be expected, the more so as measuring techniques still are in discussion and compositions only partly are known. Another difficulty in inventorying is that only data from American species are available for European forests.

The only possible approach is, making use of these data, to estimate average emissions, applying to European conditions. Present knowledge allows some simplifications to be made. First, it is assumed that only for two vegetation categories an emission factor is needed. These are: all coniferous species and all deciduous species. Secondly, it is assumed that emission rates are only controlled by temperature. This temperature dependency can be described by

$$\log E = aT + b$$

where E = emission rate and T = ambient temperature in °C.

In fact, many observed variations in emissions can to a large extent be explained with temperature variation. It also appears that a distinction between night and day emission factors is necessary. For the comparison of reported data some of them have to be converted, thereby introducing more uncertainty because of translation of biomass to forest area and of leaf resp. needle temperature to ambient temperature.

Eight different investigations between 1980 and 1984 were compared with the investigations of Zimmerman (39). From this, it appeared that there is a reasonable agreement between these results and his. The emission factors, deduced from this comparison are given in table 3.6.

Table 3.6

Emission factors for natural emissions from forests ($kg/km^2.h$) at 30 °C

	coniferous	deciduous
day	6.5	6.7
night	5.5	2.7

Temperature coefficients were estimated by averaging the results of investigations into temperature dependency (40,41,42). For coniferous species Tingey (40) and Yokouchi (41) found 0.032 and 0.07 resp. Flyckt (42) found 0.12 both for isoprene emitting hardwoods and non-isoprene emitting hardwoods. Tingey investigated also the influence of light incidence. From his work values of 0.05 - 0.09 can be deduced. As rough, average values 0.05 $°C^{-1}$ was chosen for coniferous species and 0.1 $°C^{-1}$ for deciduous species. In fig. 3.1a and 3.1 b the factors and the variation with temperature are shown. Considering the composition of natural emissions from forests it should be emphasized that there is insufficiently knowledge to assess average compositions for the two choosen forest categories. Mainly based on Altshuller's review (35) it is assumed that emissions of deciduous species consist of 60 wt.% terpenes and 40 wt.% isoprene, whilst coniferous species emit terpenes only. The reactivity may be too high with this profile because no account is made for paraffins and aromatics, that are shown to be emitted in areas of low latitude (43). No means are available, however, to translate these findings to the European situation.

3.5. EMISSION ESTIMATION; METHODS

Within the framework of this study experts in member states were consulted to collect all available data about VOC-emissions. As has been pointed out in the introduction to this chapter it could be expected that information would be scarce and in some cases presumably difficult to compare between states. Therefore all estimations were made by multiplying activity rates with the accessory emission factors as given in the previous section. Prevalence was given however to information from countries.

In this section the information sources and the methodology of treatment of activity rates arc discussed.

Petroleum refineries

Capacities of individual refineries were taken from (44). The throughout per country is given in (45). Assuming that all refineries within a country were in operation on the same utility level production per refinery was estimated for 1983.

Primary iron and steel industry

Production rates of coke and sinter were obtained from national and EC-statistics (46) for the year

Chemical industry

Production capacities per substance and per plant were taken from (47). Many production data are classified, therefore, if no national production of a substance was known, production was generally assumed to be 65% of capacity. Again, all production facilities for substance within a country were assumed to operate on the same utility level. Base years are not the same for all member states, the estimated emissions refer to 1981-1983. In most cases the uncertainty involved with respect to 1983 emissions will lie within the range of uncertainty determined by the emission factor.

Solvent use

The analysis of solvent consumption patterns (section 3.4.7) was the basis for allocating mass emissions per source type. It was realized that large errors may be entered in this way but since only very few data were reported by member states it was considered useful to make this rough estimation to illustrate possible consumption - and emission - patterns.
Industrial production indicates differences between countries, on the other hand a number of similarities may be assumed. Possible large errors are to be associated with emissions per source type. Total solvent emissions per country are more reliable. No base year can be given but emissions may be taken as representative for recent years.

Fermentation processes

Production data for bread and alcoholoc beverages were a.o. taken from UN-statistics and the Office Int. de la Vigne et du Vin, Paris. The base year for bread is 1983, for beverages production refers to 1981-1983.

Waste elimination

Data are from member countries. There is no available method to estimate emissions per country.

Stationary combustion sources

Fuel consumption data were taken from (45). Coke consumption of the iron and steel industry was subtracted from total industrial coke consumption, the difference being the amount of coke used as a fuel. No information was available for the consumption of wood. This is noteworthy, since within this source category wood combustion is an important contributor to VOC-emissions, especially for toxic compounds.

Road transport

For most countries, except Portugal and Spain, recent data are available for the number of vehicles per type, base years varying from 1981 to 1985. In an attempt to present the most recent situation 1985 was taken as the base year for a harmonized estimation of emissions from all road transport, so some extrapolations had to be made. Specific mileages for vehicle types and mileage fractions per driving mode were taken from analyses done by an ad-hoc working party "Motor Vehicle Emissions" of the EC. These data were not available for all member-countries, so similarities had to be assumed. This also was necessary for the distribution of trucks and road-tractors into weight classes and the gasoline-powered fractions of light commercial vans and trucks.

For Portugal and Spain only some basic data were available. For these countries, then, far-going similarity was assumed with other member countries in order to at least roughly estimate details.

For details of calculations, see Annex IV.

Other transport

Emissions from railroads and internal navigation were estimated by multiplying oil consumption (45) with the emission factor. The emissions from airports are based on LTO-cycles, taken from (50). Emissions from harbours are reported by only a few member countries. By comparison of total numbers of ships movements per country (50) an indication is given of the total contribution of this source type.

Gasoline distribution

Emissions were estimated by multiplying total motor gasoline consumption per country (45) with the emission factor for depots + filling stations.

Agriculture

Emissions from agricultrural tractors were rougly estimated by assuming that the diesel oil consumption by agriculture, according to (45), is used for tractors only.

Natural emissions

For the estimation of a yearly average emission a temperature of 15 °C was used for all member countries. The result therefore is only an indication of the amounts emitted.

3.6 EMISSIONS RESULTS

Multiplication of source parameters (section 3.5) with emission factors (section 3.4) yields estimated emissions. The results are presented in several ways:

- Tables 3.7 and 3.8 give total VOC-emissions per source type and per country as well as totals per source type for the EEC, for industrial and non-industrial sources respectively.
- Annex I contains similar information but extended to some indication about composition. Unsaturated VOC is the sum of olefins (except acetylene) and aldehydes. Unreactive VOC is mainly acetylene, benzene and halogenated hydrocarbons. The remainder mainly consists of paraffinic and aromatic hydrocarbons.

- Annex II lists data of emissions of specific compounds per country. Data for solvent use were taken from table 3.4 and ref. (7). Those for road traffic are from Annex IV. Emission factors (table 3.2a) and estimated production data from ref. (4) made it possible to roughly calculate emissions from chemical industry. Other emissions include those from other industrial sources, from stationary combustion and from ref. (7).
- Annex III maps local concentrations of VOC-emissions per country (44, 47). Only refineries and chemical industries are considered, hence local emissions will be too low.
- Annex IV reports the estimation of VOC-emissions from road traffic as well as their composition.
- Table 3.9 summarizes the emissions for the EEC.

In the tables 3.7, 3.8 and 3.9 and in the Annexes I and II emissions are presented at the left or at the right sides of columns. In some cases two figures are presented. With this, distinction has been made between data reported by countries or by a source like ref. (7) and data, estimated with emission factors and source parameters for this study; the former are presented on the left, the latter on the right sides of columns. This presentation may be helpful in giving, at least in some cases, an impression of different approaches. The way in which emissions were assessed by member country's experts is however not always known.

3.7 SPATIAL AND TEMPORAL DISTRIBUTION OF EMISSIONS

The only presentation of VOC-emissions needed for this study is a total national contribution per source type. With the exception of an indication of large concentrations from industrialized areas neither spatial distribution nor temporal dependance are reported. A short review nevertheless will be given of existing practice used in the preparation of inventories for model studies. For the emissions of road traffic only poor spatial allocation techniques are available. The distribution of highways (or, what is actually needed: roads on which highway driving mode predominates) can indeed be entered into a grid system but not always traffic density is sufficiently known. In absence of these data, emissions have to be assumed to be evenly distributed over all highways. For urban and local driving, there are no statistical means to distinguish between these. The sum of their emissions therefore is distributed propertional to population density, assuming for local road systems and traffic densities on them a similar proportionality.

The temporal resolution of road traffic usually is assumed to be constant for a modeling area in absence of local data. The average of traffic counts reflects rush hours and here a distinction should be made between automobiles and utility vehicles.

Non-industrial solvent consumption undoubtly is fairly well proportional to population density as is, with somewhat less certainty, part of industrial consumption (printing, metal cleaning and paint consumption). A better approach of course is relating these emissions to employment distribution. Other industrial solvent emissions coming largely from chemical industry and paint use in automobile manufacturing can only be gridded satisfactorily when plant locations are known. For the latter industry this usually is the case.

Temporal allocation of non-industrial solvent emissions is based on assumptions only. There are no data available about when consumer products, paint etc. are used. Industrial solvent consumption may be taken as occurring during working hours. A distinction between continuous and non-continuous processes has to be made.

The same, obviously, can be said about other industrial emissions, the locations of which generally are known (refineries, coke plants etc.). Fermentation processes are an exception to this. Whilst spatial distribution will not give large problems, temporal allocation of the emissions is complex. Brewing of beer is a continuous process, bread baking has its own characteristic time pattern whilst wine manufacturing is seasonal-bound.

Finally, gasoline distribution should be mentioned. Emissions from filling stations may be taken proportional to population density but depots obviously may not; their location should be known.

A special form of temporal emission distribution is the dependence of evaporative emissions on ambient temperature. For the estimation of yearly averages this relation at most plays a role in the form of some correction factor but it becomes important into details for inventories to be used for episodic modeling.

The main temperature-sensitive source is road traffic. It should be pointed out that cold start emissions (engine not in thermal equilibrium) are more sensitive to ambient temperature than emissions from the stabilized mode.

Breathing losses from storage tanks are another example of temperature-dependent emissions. But far more important is the temperature sensitivity of natural emissions. The relation between emission and temperature is not sufficiently known.

In conclusion it should be said that the methodology of temporal and spatial allocation of emissions is no independent part of inventorying but dependent on the objectives of the inventory, primarily the scale on which modeling will be done.

3.8 DISCUSSION

Table 3.9 presents the contribution of source categories to total yearly average VOC-emissions in the EEC. As could be expected road traffic and solvent consumption are the most important contributors. According to the discussion in Annex IV road traffic emissions actually may be higher. Including emissions from filling stations these two source categories may be responsible for 85% of total VOC. The importance of road transport emissions is even more clearly illustrated when their contribution to total emissions of unsaturated compounds is considered. This is ca. 65%; solvent consumption does not contribute to unsaturates.

When seasonal influences are considered space heating, differences in cold start corrections of road transport emissions and the influence of ambient temperature on evaporative emissions should be taken into account. Too little is known about these influences to make proper corrections but from a rough estimation it can be presumed that space heating together with the excess emissions from cold starts in the winter are balanced by the increase of evaporative emissions in the summer. On the other hand natural emissions may be only 10% of anthropogenic emissions in the winter but 50% in the summer and on a warm summer day they may become equal to anthropogenic emissions.

Concerning geographic distribution attention should be given to the majority of road transport-VOC being emitted in urban areas (table IV-5). Industrial complexes should also be considered in this respect (Annex III).

The reliability of the estimated emissions will be discussed in the next section.

3.9 UNCERTAINTY

Even without any form of error analysis it will be obvious that the uncertainty of estimated VOC-emissions is determined by the uncertainties of emission factors as well as the errors in source parameters (production rates, consumptions etc.). For the estimation of emissions of specific compounds the uncertainty of the composition has to be added.

It has already been pointed out that the uncertainty of emission factors still is subject of much discussion (section 3.4.1). Prior to at least an application of the Delphi technique as a start of a study of this subject, nothing more can be done than defining uncertainty as an average error and roughly estimate it for important source categories.

Something similar can be said about source parameters and composition. Only in a few cases a more reliable estimation is possible. In table 3.10 the results of an attempt to estimate uncertainty is presented.

Table 3.10

Estimated average error of emissions per country (%)

	emission factor	source parameters	composition	total emissions	emissions of (groups of) specific compounds
Petroleum refineries	20	30	30	35	45
Chemical industry	50	40	50	60	80
Solvent use, total	-	20	50	20	55
, industrial	10	50	n.a.	50	n.a.
, non-industrial	-	30	n.a.	30	n.a.
Road transport	20	15	30	25	40
Gasoline distribution	20	10	30	25	35
Residential fuel consumption	50	10	< 100	50	100
Natural emissions				100	

For EEC-totals these values will be lower, as they are for some countries that have been working on detailed inventorying for some time.

3.10 FUTURE WORK

From this study it appears that there remains many a gap in the knowledge about emissions. Therefore some recommendations are made about studies that should be done to improve VOC-inventorying within the EEC.

1. <u>Road traffic</u>
   1 consensus about emission factors (primarily gasoline-powered automobiles and diesel-powered utility vehicles).
   2 better knowledge of mileages driven in urban, local and highway modes.
   3 composition of catalyst-treated vehicle exhaust.
   4 accurate fuel consumption estimation
2. <u>Solvent use</u>
   1 Mass balances per country and per source type of main species to assess reliable consumption patterns.
   2 estimation of large local emissions.
3. <u>Stationary fuel combustion</u> - Consumption of wood in residential stoves and fireplaces.
4. <u>Chemical industry</u> - General improvement of knowledge about emissions.
5. <u>Waste elimination</u> - including agricultural open burning: same as 4.
6. <u>Natural emissions</u> - Study on European emissions.
7. <u>Uncertainty of emissions</u>
   - first stage : discussion
   - second stage: study

The following priorities are suggested:

1st: 1.3, 2.1, 3 and 6
2nd: 1.1, 1.2, 4 and 7
3d : 1.4, 2.2 and 5

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4 Immissions of organic chemicals in the member states of the EEC

In order to assess the importance of hydrocarbons for air pollution not only the emissions but also the following information about single hydrocarbons has to be available:

- immission
- toxicity
- rate of transformation

Because it is impossible to assess all hydrocarbons a list of substances which should be taken into account was compiled. The substances from the German Technische Anleitung Luft (TA-Luft) /43/ were used as a base for the list. Carcinogenic substances were added to the list when it seemed probable that these substances can be emitted to the air. Further inputs to the list were contributed by TNO and CITEPA. This list contains the relevant information (immission, toxicity, etc.) which was collected for the single hydrocarons. If no information was available only the name of the substance is specified. As the compiled information is necessary in order to perform the further tasks of the study the list is given in the following text.

4.1 List of substances

Explanations for the list of substances

smogform. class	The substances are classified according to a suggestion from the TNO /37/ which is a modification of the EPA classification. Substances which are persistent are marked by a"P"

$\frac{k_{OH}(\text{substances})}{k_{OH}(\text{Methane})}$	class (TNO)	class (EPA)
10-100	A	II
100-1000	B	III
10^3-10^4	C	IV
$> 10^4$	C	V

Emi.
Class

This item contains the emission class according to the German TA-Luft /43/. Values which are discussed in the drafts for the amendment of the TA-Luft are given in parenthesis:

Class permitted concentration in exhaust air; total amount of emitted substances

Class	noncarcinogenic		carcinogenic	
	mg m^{-3}	kg h^{-1}	mg m^{-3}	g h^{-1}
I	20	0.1	0.1	0.5
II	150	3	1	5
III	300	6	5	25

Canc.

Different emission limits are active for noncarcinogenic and carcinogenic substances. Item canc. contains the German classification of carcinogenic substances according to the list of MAK values /44/.

A1	proofed to be carcinogenic to humans
A2	carcinogenic to animals, highly probable carcinogenic to humans, too
B	probable carcinogens

MAK

Maximum permitted concentration at the working place according to the German list of MAK values /44/. If no MAK value has been defined the american TLV (Threshold limit value) is given in parenthesis.

TRK

Technische Richtkonzentration; recommended concentration which must not be exceeded at the working place. These values are recommended instead of MAK values if the substances are carcinogenic. These concentrations do not exclude an enhanced carcinogenic risk for the exposed humans.
Concentration in mg m-3

Vapour Irrt. Human Tox. Aquat. Tox.

Vapour irritancy, human and aquatic toxicity are classified according to the US National Academy of Science (NAS) /45/.

Class	Vapour irritant	Human toxicity	Aquatic toxicity
0	No effect	Nontoxic; $LD_{50} > 15$g/kg	Acute threshold limits above 10000 ppm
1	Slight effect	Practically nontoxic; LD_{50} 5 to 15 g/kg	Threshold limits 1000 to 10000 ppm
2	Moderate irritation; temporary effect	Slightly toxic; LD_{50} 0.5 to 5g/kg	Threshold limits 100 to 1000 ppm
3	Irritating; cannot be tolerated	Moderately toxic; LD_{50} 50 to 500 mg /kg	Threshold limits 1 to 100 ppm
4	Severe effect; may do permanent injury	Toxic; LD_{50} $<$ 50 mg/kg	Threshold limits below 1 ppm

Emi Loc./Dist. This item contains L or D. L means that the substance is emitted from single, strong point sources (e.g. a chemical plant or refinery). D means that the substance is emitted from many small sources which are distributed all over the land (e.g. vehicles)

Emi. Source This item contains numbers from 1 to 31 as a code for the typical possible emission sources of the substances.

1	Traffic/gasoline/lubricants
2	Glue production/adhesives
3	Chemical industry/dye stuffs/pharmaceuticals
4	Textile industry/tanning
5	Rubber industry
6	Food industry
7	Agricultural chemicals/agriculture
8	Household
9	Medicine
10	Solvent (in varnish, paint, resins etc.)
11	Synthetic resins, plastics industry
12	Test gas
13	Perfumes, scents industry
14	Natural sources
15	Photographic industry
18	Galvanic industry
19	Metal industry, degreasing
21	Oil industry, refineries
22	Coking plants
23	Mining industry
24	Electrical transformers
26	Dry cleaning
27	Waste incineration
28	Incineration processes, thermal power plants, etc.
29	Tobacco smoke
30	Bitume industry, bitume consumption
31	Waste disposal sites

These items are only given for substances which belong to class 3 or 4 of the NAS classification.

Immissions

Definition

The concentration of a pollutant in air is called its immission. The air pollutants may be present in the air in molecular form or adsorbed/absorbed to dry/wet aerosols. The concentrations usually are expressed in two different ways:

mass per volume mg/m3, µg/m3....
volume per volume cm3/m3 mm3/m3 ... ppmv, ppbv

In order to convert data from one unit to the other at 20 °C the following equation may be used

$$\mathrm{mg\ m^{-3}} \mathrel{\hat{\approx}} \mathrm{cm3\ m^{-3}}\ \ M/24$$

where M denotes the molar mass of the pollutant.

Sometimes - especially in Germany - immission is only used to indicate the concentration near to the ground, that means only for the indication of human exposure concentrations.

Measured immissions have been compiled for the various countries. As far as available data are given for clean, urban and rural air, further items are peak values, indoor and near traffic concentrations. When the authors used other classifications for the description of their data, these classifications are given in parenthesis. "Clean air" means, that these values were measured at locations which are very distant from possible sources (e.g. atlantic ocean, arctic), so that these values may be taken as global back ground concentrations.

"Near traffic concentrations" means that these concentrations were measured in the vicinity of motorways or comparable roads.

The data given are mean values, although the averaging times used in the various studies and measurements differ significantly (Hours to months). The compiled data therefore can not fulfill the demands listed in the chapter "Presentation of data".

Whenever various mean values were given in the original papers the range of these mean values is presented in the list. Exceptionally high values are given under the item peak values. When 95 or 98 percentile values or comparable data were published, there figures are given in parenthesis besides the mean values.

Data are presented for the following chemical classes

Acetates/Esters
Acids
Alcohols
Aldehydes
Alkanes
Alkenes
Alkines
Amines
Aromatics
Halogenated Hydrocarbons
Fluorochlorohydrocarbons
Ethers
Ketones
Polychlorinated Dibenzodioxins/furans
PAH's
Miscellaneous substances

Within these classes the single compounds are given in alphabetical succession.

Remark : As the commission used "hydrocarbons" in the project title, hydrocarbons is used in this chapter, too. In the other chapters in part other terms are used, e.g. volatile organic compounds (VOC).

Acetates/Esters

Amylacetat

i-Amylacetate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/	II	(670)				

Butylacetate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37 est./	III	950			1	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
EEC		0-5 /85/	

Diethylhexylphthalate (DEHP)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
		10				

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
	0.3-1.9/87,123/		
DK		22/135/	
B		30-130/83/	

Ethylacetate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	1400			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL			0.1/112/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentration µg/m^3
EEC		0-3/85/	

Ethylacrylate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	100			3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/(D)	2,3

Dibutylphthalate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/		(5)			0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
0.1-3.3/87,123/ B		353 Gasphase 101 in Aerosols } /134/	

Methylacetate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II	610			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Methylacrylate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	35			3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/(D)	2,3

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		0.4/112/	0.1/112/

Methylmethacrylate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II	410			3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/(D)	2,3

Vinylacetate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/	II	35			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Acids

Acetic Acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/37/	II	25			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
NL			1.5/117/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
NL	27/117/		

Acrylic acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(II)	(30)			3	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3

Butyric acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)				2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Caproic acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)					

Chloroacetic acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I					

Chloropropionic acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)					

Formic acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/154/	I	9			3	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/D	3-9

Propionic acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II				2	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		0.45/117/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
NL	6/117/		

Valeric acid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)					

Alcohols

i-Butanol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/	III	300			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL			0.2/112/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
EEC		0-9/85/	

n-Butanol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37/	III	300			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Cyclohexanol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	III	200			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3		

4-Hydroxy-4-methyl-2-pentanone

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	III	240				

Ethanol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	1900			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG		17.3-44-6/141/	

Glycol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B-C/37,73/	III				0	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Ethylglycol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	III(II)	75			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

2-Ethyl-1-hexanol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II(-)				1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Furfurylalcohol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
c/37/	I(II)	200			2	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	3,10,11

Methanol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	II	260			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG		13.7-20.6/141/	10-130/83/

Methylglycol (2-Methoxyethanol)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	(II)	15			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Pentanol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	III					

2-Propanol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	980			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Propyleneglycol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B-C/37,73/					0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Triethyleneglycol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	III(-)				0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Aldehydes

Acetaldehyde

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/75,37/	II	90	B		3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3,5,11

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
	0.04		
FRG		8.9-10/141/	0.3-6.5/126/
NL		3.6/117/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
EEC		2-26/85/	

Acrolein (Propenal)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/104/	I	0.25	B		4	4

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	3, 11-13

Immissions:

Count.	Clean Air µg/m³	Urban Air µg/m³	Rural Air µg/m³
NL			1.1/117/
FRG		3-10/108/	

Benzaldehyde

Smogform. Class	Emi. Class	MAK mg/m³	Canc.	TRK mg/m³	Vapour Irrt.	Human Tox.
A-B/37,104/						

Immissions:

Count.	Clean Air µg/m³	Urban Air µg/m³	Rural Air µg/m³
F		0.9-5.7/88/	
NL		3.5-42.7/111/	
			0.66/117/

Count.	Peak Values µg/m³	Indoor Concentrations µg/m³	Near Traffic Concentrations µg/m³
NL	8.3/117/		

Formaldehyde

Smogform. Class	Emi. Class	MAK mg/m³	Canc.	TRK mg/m³	Vapour Irrt.	Human Tox.
C/37 /	I	1.2	B		3	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3-9,14-15

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG	0.3/74/,0.6/92/	3.3/55/, 20/31/, 1.6-13/143/	1-6/143/
NL			7.2/117/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
EEC		8-50/85/	
FRG	99/31/, 69/30/		

Furfural

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	(I)	20			2	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3		

Methacrolein

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/103/						

Alkanes

i-Butane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	2350				

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	0.8/162/		
FRG		2-17/54/,0.8-9.3/6/ 8.4/144/2.1-12.2/141/	
NL		8/112/	2/112/
GB			4.6/160/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG			9.3/6/

n-Butane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	2350			0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
0		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	1.8/162/		
FRG		4-31/54/, 1.8-12/6/ 3-9/107/,25/144/ 5.4-29.2/141/	2/54/
NL		18/112/	4/112/
GB			7/160/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG	61.6/54/ near coke plants 10.4/54/ near refineries		29.2/54/12/6/

Cyclohexane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	1050			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		0.5/112/	0.4/112/
I			0.52/127/
FRG		8.5/144/,1.6-5.3/141/	

Ethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/37,73/	III					

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG		4-25/54/,3.1-6.3/141/	
NL		5/112/	3/112/
GB			6.5/160/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG	47/54/ near coke plants 9/54/ near refineries		6.3/54/

n-Heptane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	2000			0	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG		3-18/6/,6.9/144/ 1.8-11.7/141/	
NL		2.5/112/	0.4-0.5/112/
I			0.25/127/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG			18/6/

n-Hexane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	180			0	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG		1-8/54/,4-19/6/ 16.6/144/,2.8-17.9/141/	
NL		4/112/	2/112/
I			0.23/127/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG			19/6/

Methane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P					0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
0		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	1000-2000		

Methlcyclohexane

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
C/100/	III	2000				

Immissions:

Count.	Clean Air µg/m3	Urban Air µg/m3	Rural Air µg/m3
NL		0.4/112/	1/112/
FRG		3.4/144/,0.7-5.1/141/	

2-Methylpentane

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
B/37.73/	III					

Immissions:

Count.	Clean Air µg/m3	Urban Air µg/m3	Rural Air µg/m3
FRG		3-19/6/,14/144/ 2.9-21/141/	
I			0.5/127/2- and 3-Methylpentane

Count.	Peak Values µg/m3	Indoor Concentrations µg/m3	Near Traffic Concentrations µg/m3
FRG			19/6/

3-Methylpentane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III					

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG		3-14/6/,9.6/144/, 2.1-14.1/141/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG			14/6/

i-Pentane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	2950				

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG		5-29/54/,3-20/6/ 2-4/107/,38/144/ 6.4-52.8/141/	2.7/54/
NL		38/112/	3/112/
I			0.57/127/
GB			5.3/160/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG	65/54/ near coke plant		52.8/54/,20/6/

n-Pentane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/73/	III	2950			0	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG	1.8/162/	3-19/54/,4-18/6/, 18.7/144/,5.1-42/141/	
NL		43/112/	4/112/
I			0.28/127/
GB			3.1/160/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG			18/6/

Propane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	III	1800			0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
0		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	1.6/54/,1/128/		
FRG		4-21/54/,2.6-5.1/141/	
NL		12/112/	5/112/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG	24/54/		5.1/54/
GB			4.6/160/

Alkanes with more than 7-8 carbon atoms

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/73/	III					

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		Octane-dodecane 1.5/112/, 0-20/111/	0.3/112/
FRG		n-Octane: 3/144/,1.2-9.8/141/ n-Nonane: 2.2/144/,1.7-14.4/141/	
IRL			n-Nonane: 0.03-0.13/162/ n-Decane: 0.01-0.07/162/

Alkanes, Alkines

1,3-Butadiene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,73/	II(III)		A2		1	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1	LD	1,3,5

1-Butene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,73/	III					

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG		1.6-5.3/107/,1.8-8.7/141/	
NL			1/112/

i-Butene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,73/	III					

Immissions:

Count.	Clean Air µg/m3	Urban Air µg/m3	Rural Air µg/m3
FRG		6.1/144/	

cis-2-Butene

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
C/37,101/	III					

Immissions:

Count.	Clean Air µg/m3	Urban Air µg/m3	Rural Air µg/m3
FRG		0.2/144/	

2-Chloro-1,3-butadiene

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
	II	36				

Dicyclopentadiene

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
C/37/	III	(30)			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

1,3-Dimethylbutene

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
C/37,101/	III					

Ethene

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
B-C/37,73/	III				0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air µg/m3	Urban Air µg/m3	Rural Air µg/m3
FRG	0.1-1.0/83/ 1.9/54/	4-19/54/,2-10/107/ 4.1-31.4/141/	
NL		6/112/	3/112/
GB			4.9/160/

Count.	Peak Values µg/m3	Indoor Concentrations µg/m3	Near Traffic Concentrations µg/m3
FRG	69/54/ near coke plants 81.4/54/ near refineries		31.4/54/

Ketene

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
	I(-)	0.9				

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L	3

2-Methylbutene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,101/	III					

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG		1.3/144/	

Nonene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C(est.)/37/	III				1	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Pinene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/103/	III					

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
I			6/127/ 1.2/127/

Propene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,73/	III					

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG	0.2/54/	1-5/54/,2-12/107/,1.5-14.1/141/	
NL		7/112/	2/112/
GB			2.1/160/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG	17/54/ near coke plants 27.3/54/ near refineries		14.1/54/

Tetrahydronaphthalene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II(-)				1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3		

Acetylene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A-B/37,73/						

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	2.8/54/,0.4/128/		
FRG		5-19/54/,3.4-28.9/141/	3/145/
NL		7/112/	2/112/
GB			4.4/160/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG	15/54/ near coke plants, 9/54/ near refineries, 130/145/		29/54/

Amines

3,3'-Dichlorobenzidine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	(II)		A2	0.1		

Diethanolamine (2,2'-Iminodiethanol)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	(II)				2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Diethylamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	30			3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	3-5,11,18

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG		10-300/110/ industry	

Dimethylethylamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)	75				

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		10-70000/110/ industry	

Dimethylamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	18			2	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3		

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		10-900/110/ industry	

Dimethylaniline

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)	25				

Ethanolamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
		6				

Ethylamin

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	(I)	18			3	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	LD	3-5

Ethylenediamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II(-)	25			3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3,5,11

Ethyleneimine (Aziridine)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II		A2		3	4

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3

Hexamethylenediamine (1,6-Hexanediamine)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
					1	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3

Methylamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	12			3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	3,4

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG		10-500/110/ industry	

Morpholine (Tetrahydro-1,4-oxazine)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II(-)	70			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

2-Naphthylamin

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	A1				

Triethanolamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/	II(-)				0	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Triethylamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	40			2	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		30-81000/110/ industry	

Trimethylamine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)	(40) tentative			3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	3,7,12

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		10-90/110/ industry	

Aromatics

Aniline

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B-C/37,73/	I	8	B		1	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/(D)	3,5,15

Benzene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A-B/37,73/	(III)		A1	26	1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3,5,10,11

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	1/83/,2/54/,0.3/128/, 0.9/162/,0.1/168/		
FRG		4-21/53,54/,28.3/144/, 9-43/61/,1-11/107/,30/159/, 28/62/,3.9-16.1/116/, 7.3-51.3/141/	5/62/
F		32-131/83/	
GB		346/83/Uxbridge, 8.81-(15)/62/ 5-130/118/,22.7/151/	1.55-(3)/62/, 0.5/118/ 5.3/151/
NL		2.1-80/83/,1.9-13.6/111/ 16/112/, 0.8-4.9/117/	3/112/
I			1.6/127/
GR		18-43/119/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG	348/53/ near coke plants 54/53/ near refineries	8-28/85/,<20/159/	51/54,/109/53/, 43/6/9/62/
GB	577/83/ London		2.82-(4.5)/62/ 1-17 airport /118/ 8.5/151/
GR	151/119/		

Chlorobenzene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B-C/73/	II	230			0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3,5,10,11

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		0.47-0.28/117/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
NL	11.1/117/		

Cresols

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37/	I	22			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3,8-11

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
F		0.3-1.6/88/	

Cumene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/	(II)	245			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
NL		0.3/112/	0,5/112/
		0.25-0.1/117/	
GB		1-20/118/	
GR		6-9/119/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
GB	80/118/		2-10 airport /118/
GR	41/119/		

Dichlorobenzenes/a) 1,2-...b) 1,4-....

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/73/	a) (I)	300			2	1
	II					
	b) (II)	450				

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	3-5,8-11

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		0.37-0.17/117/	
FRG		1.2-37/141/b), 3.3-8.2/141/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG		0-65/85/b	
NL	7.4/117/		

Dichlorphenol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I					

Dinitrobenzene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	1				

Diphenyl

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B-C/37,73/	I	1				

Diphenyloxid

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37 est./						

Dodecylbenzene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37 est./					0	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3

Ethylbenzenes

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37/	II	435			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3,10

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	0.03/168/		
FRG		2-6/54/,4/62/,12.2/144/ 5-24/6/,18-30/107/ 3.2-27.2/141/	0.5/62/
NL		2.2-4/111/,1-3/112/ 2.5-0.8/118/	0.4-1.5/112
GB		0.88-(2.0)/62/,5-59/118/, 3.4/151	0.12-(0.6) /62/,0.6/151/I 0.75/127/
GR		12-20/119/	
IRL			0.02-0.17/162/, 0.001/168/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG		4-21/85/	24/6/1.1/62/
GB	59/118		0.25-(0.5)/62/
GR	47/119/		0-25 airport/118/
			0.75/151/

Ethyltoluenes

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37/						

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		1-2/112/ 2.5-05/117/	0.4-0.7/112/
FRG		1.6-8.3/116/	
GB		1-40/118/,10.3-67.4/141/	
I			0.35/127/
GR		50-97/119/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
GB	104/118/		0-25 airport/118/
GR	224/119/		

Methylnaphthalenes

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II(-)					

Methylstyrene (a,ß)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,101/						

Naphthalene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B-C/37,73/	(II)	50			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3,21

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
F		0.5-11.6/88/	
NL		1/112/	0.1/112/
FRG		0.3-0.6/141/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		2-8/85/	

Nitrobenzenes

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A /73/	I	5			3	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3

2-Nitro-p-cresol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I					

Nitrophenols

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/73/	I					

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	3,4

Nitrotoluenes

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/	II(I)	30				

Phenol

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,73/	I	19			2	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	3,4,7-11

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG		1.5/55/0.1-8/30/ 22-45/108/	
F		0.7-8.2/88/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG	6.8/55/near coke plants 25/30/near refineries	0-5/85/ 0-0.25/85/(Pentachlorophenol)	

Polychlorinated biphenyls (PCBs)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P	I(-)	1	B			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/(D)	2,3,11,23,27

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3		Rural Air ng/m^3
	0.1-1.0/87,123/ 0.003/124/,0.6-2.5/125/	5/149/		0.05/149/
NL			0.96/117/	

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
NL	3.05/117/		

n-Propylbenzene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/						

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3		Rural Air µg/m^3
NL		1/112/		0.6/112/
			1-0.5/117/	
GB		2-20/118/		
GR		8-13/119/		

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
GB	83/118/		7-80 airport/118/
GR	13/119/		

Pyridine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	15			2	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Styrene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,101/	II	420			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3,11

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG		0-6800/108/	
NL		0.4-1.6/111/,1.5/112/ 1.5-0.09/117/	0.2/112

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG	6800/108/	2-14/85/	

Thiocresols

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I					

Thiopheols

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I					

Toluene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	II	750			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	1,3,10,21,22

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	0.3/83/,2/54/,0.02/168/ 0.4/128/,0.8/162/		
FRG		8-31/54/,51/62/, 23-99/6/,2-16/107/, 11.5-102/141/, 4.4-27.5/116/,73.5/144/	5/62/
F		61-296/83/(Paris)	
GB		190/83/,13.5-(27)/62/, 15-280/118/,59.8/151/	1.3-2.8/62/,2/118/ 4.9/151/
NL		12-144(243)/83/,20-40/111/ 19/112/	4/112/
		19.1-3.6/117/	
I			2.5/127/
GR		43-143/119/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG	102/54/near coke plants	32-270/85/	102/54/,99/6/, 11/62/,2.1-(3.6)/62/
GB	280/118/		5-100/118/,10.4/151/
NL	243/83/		
F	296/83/		
GR	434/119/		

Toluenediisocyanate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I	0.07			3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L	2,3,5,11

Trimethylbenzenes

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37/	(II)					

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		7-19/111/,1.5-5/112/, 5.8-0.5/117/	0.4-2/112/
FRG		2.1-11.2/116/	
GB		0-70/118/	
I			0.1/127/
GR		52-104/119/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
GB	151/118/		0-25 airport/118/
GR	217/119/		

Trichlorophenols

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I					

Xylenes

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,73/	II	440			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/D	1-3,10,11,21

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
	0.1-0.08/168/		
FRG		2-227/54/,19/62/, 18-95/6/,26-57/107/ 8.8-77.4/141/ 4.2-28.7/116/,18/144/	1.4/54/,3/62/
NL		10.6-17.1/111/,3-6/112/ 6.2-0.4/117/	0.5-1.5/112/
GB		4.3-(9.3)/62/,5-290/118/, 13.6/151/	0.6-1.2/62/,2/118/, 3.1/151/
I			0.35-5.7/127/
GR		75-180/119/	
IRL			0.06-0.1/162/, 0.008/168/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG	227/54/	2-84/85/	53/54/,5.3/62/ 95/6/
GB	37.6/151/,290/118/		1.2-(1.9)/62/, 2-30 airport/118/, 5.7/151/
GR	416/119/		

Halogenated Hydrocarbons

2-Chloro-1,3-butadiene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II	36				

1,2 Dibromoethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/117/	II(III)		A2	1,6		

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,7(no longer allowed in the FRG)

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG		0.02/55/ 0.78-1.0/62/	
GB		0.03-(0.08)/62/, 0.1-0.7/118/, 0.23/151/	0.012-/0.03)/62/ 0.15/151/
NL		0.23-0.11/117/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG			0-2.0/62/
GB	1.26/118/		0.05(0.14)/62/, 0-0.22 airport/118/,
NL	1.6/117/		0.31/151/

1,2-Dichloroethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/117/	I	80	B			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,10

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
GB		0.2-(0.5)/62/,0.8/118/ 1.2/151/	0.02-0.05/62/ 0.08/151/
NL		1.2-0.2/117/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
GB	2.2/118/,3.5/151/		0.02-(0.05)/62/ 0.8/118/,0.08/151/ 0-0.22 airport /118/
NL	37/117/		

1,2-Dichloroethene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A-B/37/	I	790				

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		0.05-0.02/117/	

Chloroethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/37/	III	2600			1	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	30/86/		

Dichloromethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/37,73/	III	360			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/D	

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG	0.1/86/	2-6/6/,0.2-11.4/116/	
NL		14-1.4/117/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG		0-4000/85/	
NL	42/117/		

Tetrachloroethanes

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/117/	I	7	B			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L	3

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
NL		0.14-0.07/117/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
NL	0.7/117/		

Tetrachloroethene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/117/	III(II)	345			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	3-5,10,11,19,26,31

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
	0.14-0.6/60/,0.14/128/ 0.1/86/,0.19/106/		
FRG		8-28/6/,4.1-11.8/141/ 0-40/60/, 3.4-6.6/106/, 0.7-21.5/116/,1.1-6.1/121/	0.8-3/121/
NL		2.5-0.6/117/	0-9(40)/60/
I		29/122/sum of Tetra- and Trichlorethene	0.34/127/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		2.5-100/85/	
NL	40/117/		

Tetrachloromethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/99/	I	65	B		2	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/D	3,5,10,11,19,26

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
	0.56/106/,0.7/139/		
FRG		2-16/6/,0.6-0.8/106/ 0.6-0.9/116/,0.16-0.8/121/,	0.06-0.42/121/ 0.7/140/
[redacted]		2.9/140/	
NL		1.0-0.8/117/	
I		0.3/147/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		1-20/85/	
NL	3.2/117/		

1,1,1-Trichloroethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/102/	III(II)	1080			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	2-4,7,9,10,13,(31)

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG	0.7/57/,0.8/86/ 0.64/106/	3.5/57/,4-11/6/, 1.8-3.35/106/,1.0-1.8/121/, 0.9-25.2/116/	0.6/121/
NL		1.7-1.4/117/	
I		0.44/147/	0.6/127/

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		1-5/85/	
NL	41.6/117/		

1,1,2-Trichloroethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/102/	I	55	B		1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	2,3

Trichloroethene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/	II	260	B		1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/D	3-6,10,11,19,31

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	0.03/86/, 0.075/58/,	0.5/83/,0.3/139/, 0.1/106/	
FRG		4.6/55/,6-2/56/,0.4-2.7/121/, 4-24/6/,0-35/58/, 3.5-13.3/141/ 0.8-2.8/106/,0.5-2.4/116/	0.4-1.8/121/ 0.5-4.4/83/
F		9-33/83/	
NL		0.5-2.1/58/ 0.8-0.3/117/	
I			0.28/127/

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG	1100/83/	1.5-30/85/	
NL	16.7/117/		

near to production plants: normally less than 14
peak 76/138/
near to dry cleaners or other users: 108/138/

Trichloromethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/37,73/	II(I)	50	B		2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/D	3,5,10,11

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
	0.08/86/,0.08-0.13/139/, 0.14/106/		
FRG		0.08/55/,1.5-4/6/,0.1-0.5/121/, 0.27-0.68/106/	0.1/121/
NL		1.0-0.1/117/	
I		0.08/147/	

Count.	Peak Values $\mu g/m^3$	Indoor Concentrations $\mu g/m^3$	Near Traffic Concentrations $\mu g/m^3$
FRG		0-1.5/85/	
NL	37/117/		

Vinylchloride

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37,73/			A1	5-8	2	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
0	L/D	3,31

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
FRG	<0.001/59/	3.6/55/,11/30/, 0.2/59/,0.3-0.4/141/	

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG	252/30/		
NL	<10-500/59/ near industry		

Fluorochlorohydrocarbons

Fluorochlorohydrocarbons FCHC

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/99/		7600				

Dichloro-difluoromethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/137/	III				0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
0		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3		Rural Air µg/m^3
IRL/GB	1.1/136/,1.7/57,86/	1.1/134/	elder measurements 400-8000 m over sea level	
FRG		4.1/57/		
I		1.1/147/		

1,1-Difluoroethene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/99/			B			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	2

Hexafluoroethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/99/						

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	0.002/120/ Europe		

Monochlorodifluoromethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/99/			B		0	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
0	L/D	3

Monochlorotrifluoroethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/99/						

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	0.01/120/ Europe		

Tetrafluoromethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P/99/						

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	0.02-0.3/120/ Europe		

Trichlorofluoromethane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P						

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	1.0/57/,0.8/136/,1.1/139/		
FRG		0.6-8/6/,2.9/57/	
I		0.75/147/	0.74/127/

Ethers

Diethylether

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/105/	III	1200			1	0

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

1,4-Dioxane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II(I)	180	B		1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/D	3,5,6,10,11

Di-i-propylether

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/117/	III					

Tetrahydrofurane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37,105/	II	590			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Thioethers

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I					

Trioxane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II(-)					

Ketones

Acetone

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/37,73/	III	2400			1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	2.2/162/	15.5-42.3/141/	

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
	0.3/84/		

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG		2-12/85/	

Cyclohexanone

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II	200			3	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/D	3,4,10,11

Immissions:

Count.	Clean Air µg/m3	Urban Air µg/m3	Rural Air µg/m3
NL		3/112/	0.2/112/

Count.	Peak Values µg/m3	Indoor Concentrations µg/m3	Near Traffic Concentrations µg/m3
FRG		0-4/85/	

4-Hydroxy-4-methyl-2-pentanone

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
	III	240				

Methylethylketone

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
B/37/	III	590			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Methylbutylketone

Smogform. Class	Emi. Class	MAK mg/m3	Canc.	TRK mg/m3	Vapour Irrt.	Human Tox.
C/37est./	III(-)	700				

Methylcyclohexanone

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II	230				

Methylisobutylketone

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37/	III	21			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		0.5/112/	0.5/112/

Diisobutylketone

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/37est./		290			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Count.	Peak Values µg/m^3	Indoor Concentrations µg/m^3	Near Traffic Concentrations µg/m^3
FRG		0-3/85/	

Dibenzodioxins/furans

(2,3,7,8)-Tetrachlorodibenzodioxine

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
			A2			

Immissions:

Concentrations in exhaust from municipal waste incineration plants

flue gas µg/m^3	fly ash ppb
0.004-0.014/131/	41-81/130/

(2,3,7,8)-Tetrachlorodibenzofurans

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
			A2			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	3,17,27

Immissions:

Concentrations in exhaust from municipal waste incineration plants

flue gas µg/m^3	fly ash ppb
0.14/130/	50-147/130/
0.022-0.043/131	

PAH's

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
NL			0.2-2/112/
F		0-10/113/	
FRG		0.9-8/56/	0-3/56/
DK			0.01-2.6/114/
B		> 106 /169/	

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
NL	350/117/		
F	31/113/,70/129/		
FRG	18/56/		

Anthracen

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/73/						

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
NL		0.5-0.2/117/,	0.1/112/
F		0-0.2/113/,0.4-10/129/	0.04/129/
DK			0.2(0-0.7)/114/
FRG		0.7/115/	
B		0.9-13/164/(Anthracene + Phenanthrene)	

Benzo(a)pyrene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I		A2			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
FRG		2-5/56/,2.2/115/, 1-1.4/146/,1.7/150/, 6.0-40.4/161/,2.8-14/163/	1.8/56/,0-0.5/146/
GB		2.3-3.4/91/(suburban)	
NL		0.2/112/ 3-0.2/117/,0.4/112/	
F		0.02-4.6/113/, 0.25-15/150/	
DK			1(0.1-3.6)/114/
B		27/166/, 4.4/169/	11.4/166/
GR		2.3-5.7/119/	

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
FRG	11.6/56/,299/161/		3.7-69/163/
F	15/113/		
NL	120/117/		
GB	2200/150/		
B	64/166/		

Benzo(e)pyrene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
			A2			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
FRG		3-7.6/56/,2.9/115/	3/56/
GB		1.2-3.2/91/(suburban)	
NL		3- 1/117/,	0.6-20/112/
F		0.2-8.8/113/,0-12/129/	0.04/129/
DK			1.1(0.1-3.1)/114/
B		17.9/169/including Benzo(k)fluoranthene and Perylene	

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
FRG	17.3/56/		
F	27/113/		
NL	175/117/		

Benzo(a)anthracene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
			A2			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
FRG		8-17/56/,2.5/115/	2.1/56/
NL		3-0.6/117/,	0.5-0.6/112/
F		0.03-4.8/113/,0.9-53.7/129/	0.02/129/
DK			0.08(0.1-2.4)/114/
B		24.2/169/including Chrysene	

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
FRG	39/56/		
F	25/113/		
NL	100/117/		

Benzo(g,h,i) perylene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
			A2			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
FRG		2.7-4.9/56/,5.2/115/, 0.8-1.9/146/,3.8-16/163/	2.5/56/,0-0.6/146/
NL		0.8/112/ 2-0.8/117/,	0.4/112/
F		0.21-11.5/113/,1-27.4/129/	0.1/129/
DK			1.1(0.1-0.3)/114/
B		10/169/	

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
F	31/113/		
NL	100/117/		
FRG	63/163/		6.2-16/163/

Chrysene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
			A2			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
GB		2.5-6.7/91/(suburban)	
NL		0.6/112/ 3-<1/117/,	0.5/112/
F		0.22-8.9/113/,1.3-40.8/129/	0.06/129/
			<2.3(0.15-5.4)/114/
FRG		4-8/115/,2-10.5/146/	0.9-2/146/

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
F	29/113/		
NL	200/117/		

Coronene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
			A2			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
FRG		0.9-1.1/56/,2.4-5/115/, 0.3-1.4/146/,2.7-8.7/163/	1.5/56/,0-0.2/146/
GB		2.5-6.7/91/(suburban)	
NL		2-0.8/117/,	0.1/112/
F		0.1-1.8/113/,4.3-14.5/129/	0.13/129/
DK			0.6(0.03-3.6)/114/

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
FRG	10/56/,156/163/		3.4-8.7/163/
F	3.3/113/		
NL	20/117/		

Dibenzo(a,h)anthracene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II(I)		A			

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
FRG		1-2.1/56/,0.7/115/ 0.6-0.9/146/	0-0.4/146/
F		0.01-1/113/,0.6-13.5/129/	0.03/129/
DK			0.2(0-0.6)/114/
NL		1/117/	

Count.	Peak Values ng/m^3	Indoor Concentrations ng/m^3	Near Traffic Concentrations ng/m^3
F	2.8/113/		

Phenanthrene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/73/						

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L/D	1,3,21,22,27-30

Immissions:

Count.	Clean Air ng/m^3	Urban Air ng/m^3	Rural Air ng/m^3
DK			0.9(0.04-4.3)/114/
NL		10/117/	
F		0-38.2/129/	
FRG		0.5-1.5/146/	0-0.4/146/

Miscellaneous

Acetonitrile

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
P-A/37,73/		70			1	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1		

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG	0.017/90/	8.5-16.8/89/	3.8-10.3/89/

Acrylonitrile

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B-/37,73/	(III)		A2	7	3	4

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/(D)	3,5,7

Immissions:

Count.	Clean Air $\mu g/m^3$	Urban Air $\mu g/m^3$	Rural Air $\mu g/m^3$
FRG	$<$ 2 ng/m^3/61/	0-10.4/55/ 0.01-3/61/	

Carbondisulfide

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/73/	II	30			2	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Dimethylformamide

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/37/	II	60			2	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Dimethylsulfat

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II		A2	0.1-0.2	4	4

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3

Dimethylsulfide

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/73/	I				3	-

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L	3,21

Dimethylsulfoxide

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	III(-)				2	1

Epichlorhydrine (1-Chloro-2,3-epoxypropan)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	(III)		A2	12	3	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
3	L/(D)	3,7,11

1,2-Epoxypropane

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	(III)		A2			

Exhyleneoxide

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/73/	I(III)		A2		3	3

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2	L/(D)	3,6,9,11

Gasoline

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	II				1	1

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
2		

Hexamethylenediisocyanate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)	0.07				

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L	3

Methylmercaptan

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B-C/37,98/	(I)					

Mercaptans

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
C/98/*	(I)					

* aliphatic mercaptanes with less than 4 carbon atoms

Methylisocyanate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)	0.025				

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L	3

Phosgene

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)	0.4				

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	L	3

Immissions:

Count.	Clean Air µg/m^3	Urban Air µg/m^3	Rural Air µg/m^3
NL		< 0.08/117/	

Tetraethyllead

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
	I(-)	0.075				

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
	(L)/D	1,3

Triethylphosphate

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
A/37/						

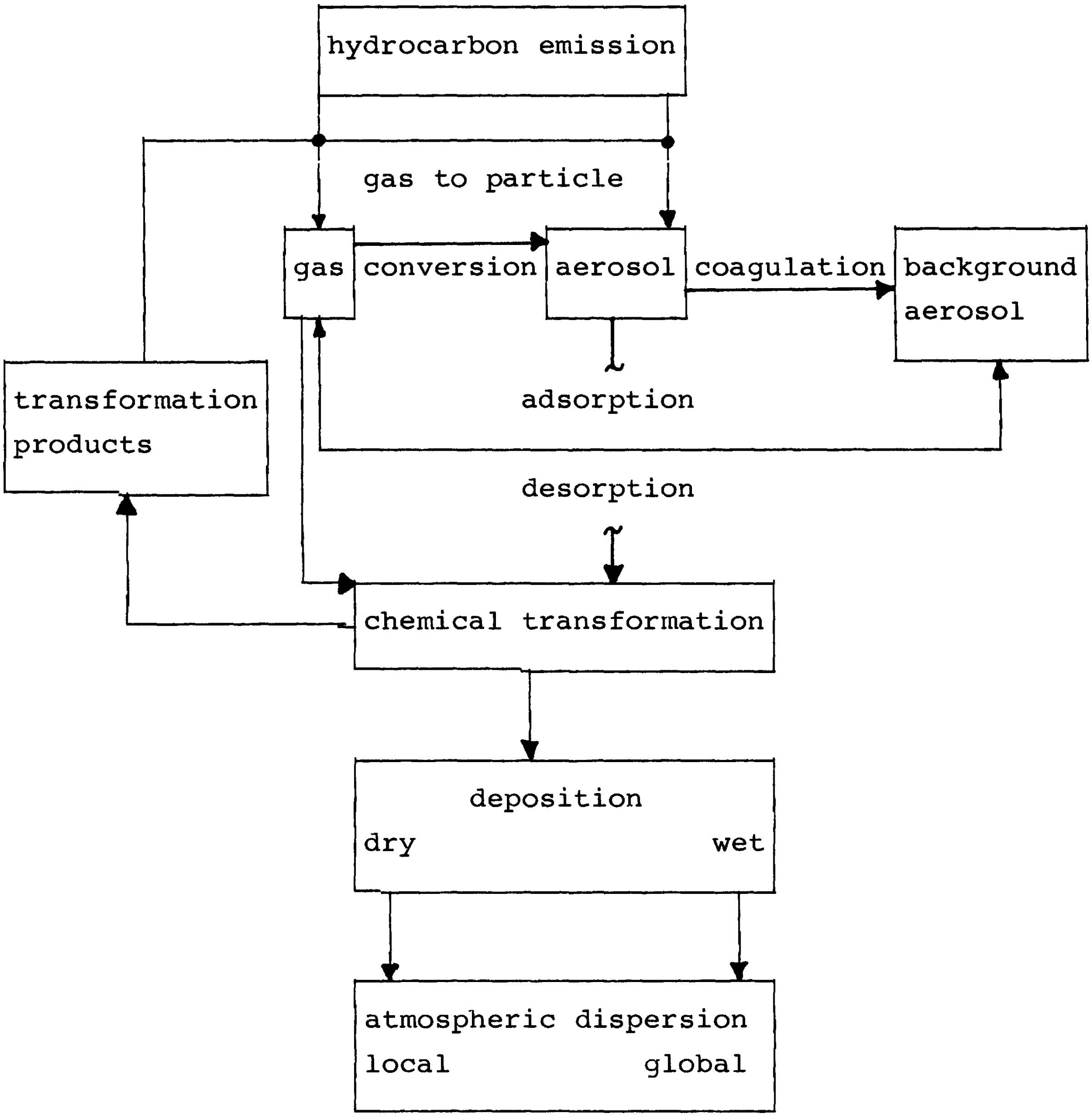
Prophyleneoxide (1,2-Epoxypropan)

Smogform. Class	Emi. Class	MAK mg/m^3	Canc.	TRK mg/m^3	Vapour Irrt.	Human Tox.
B/37/	II(III)		(A)		3	2

Aquat. Tox.	Emi. Loc./Dist.	Emi. Source
1	L	3,11

4.2 Atmospheric Transport and Distribution of Hydrocarbons

Hydrocarbons emitted into the atmosphere are transported by the general motion of the wind from the sources to remote areas. In course of the transport the plume is diluted by horizontal and vertical turbulent mixture. In the atmosphere the hydrocarbons will undergo physical and chemical transformations; the compounds or the transformation products are removed from the atmosphere by wet and dry deposition. A graphic scheme of the various atmospheric interactions is given in the figure below.



The atmospheric distribution and removal processes are strongly connected with each other. A suitable parameter for the description of the atmospheric behaviour of trace substances is the atmosperic half-life. The half-life is understood as the time during which the concentration decreases to 1/2 of the initial value.

The atmospheric half-life of the hydrocarbons is determined by the removal processes. These are

- chemical transformation
- physical transformation
- dry deposition
- wet deposition

The four processes have different significance for each trace substance. Therefore a general assessment of the atmospheric behaviour of hydrocarbons is not possible. Up to the present day there is still a lack of information about atmospheric half-life values especially of gaseous hydrocarbons.

Hydrocarbons which have short half-lives for example in the range of hours or even less will be transported by the windfield only over distances of few kilometers from the sources. The atmospheric dispersion for these compounds is restricted to the local and regional scale.
Hydrocarbons which have atmospheric half-lives in the range of days will be transported over distances of some 1000 km (long range pollutants). If the half-lives are even longer, the hydrocarbons are dispersed in hemispheric or even global scale. Typical examples for these group of chemicals are fluorochlorohydrocarbons.

The main aspects of the complex interactions between atmospheric distribution and deposition schemes are demonstrated in the next paragraphs.

The description of the chemical transformation is excluded as it is discussed in detail elsewhere.

4.2.1 Physical Transformations

Hydrocarbons are emitted into the atmosphere in form of gaseous compounds or/and in form of aerosol particles. The distribution of gaseous to aerosolbound compounds is in dynamic equilibrium. The distribution depends on the volatility, the temperature, the water solubility and the vapour pressure of each individual compound.

In the vicinity of the sources, in areas of high concentrations aerosol particles are formed by direct gas-to-particle conversion.

This initial distribution changes during the atmospheric transport process. As the plume is diluted by turbulent mixture, gaseous concentrations decrease. The equilibrium of gas to aerosolbound compounds is shifted to an increased gaseous phase.

In the atmosphere gaseous compounds adsorb onto soot and other organic particles of the background aerosol. Coagulation of hydrocarbon particles and background aerosols is another process which changes size distribution of the aerosols and influences deposition schemes.

Though the above mentioned physical transformations are not real removal processes which decrease the atmospheric load, they have to be regarded as removal processes at least for gaseous hydrocarbons, from the homogenous gas phase to other compartments.

Dry and wet deposition are the pathways through which gases and aerosol particles are transported to the ground and thus - at least temporarely - are removed from the atmosphere.

Dry deposition describes the direct pathway from the atmosphere to the surface of the earth. Wet deposition is the indirect pathway from the atmosphere to the surface of the earth. Wet deposition is the indirect pathway via clouds and precipitation.

The physical processes such as inertial impaction, diffusion and sedimentation are the same for both pathways. The main difference of dry and wet deposition is the location where the initial deposition takes place. Dry deposition is the removal onto stationary receptors in the atmospheric boundary layer. In contrast, wet deposition primarily is the removal of trace substances onto instationary precipitation element in the free atmosphere.

The significance of wet and dry deposition depends on a large number of parameters including

- chemical and physical characteristics of the hydrocarbons,
- vertical atmospheric concentrations,
- atmospheric conditions,
- chemical and physical composition of the receptor.

A detailed discussion of the parameters is given by Sehmel /155/.

Up to the present day very little is known about dry deposition of organic gases. Deposition of gases is determined by the resistance of the receptor. Receptors include water surfaces, ground, soils, plans, leafs etc. Each of these receptors has its own characteristics which has to be investigated in respect to the deposition of the hydrocarbon.

The polarity of the hydrocarbons is a key parameter which determines the water solubility. The incorporation of highly water-soluble hydrocarbons certainly increases dry deposition onto wet surfaces and wet deposition.

Dry deposition of organic aerosols is determined by the aerosol size distribution. Chemical composition is of minor importance. Atmospheric half-lifes of aerosols typically vary between 3 and 5 days under European meteorological conditions /152, 153/.

4.2.2 Chemical transformation

All substances emitted to the atmosphere can not only be removed by physical processes but also by chemical transformation reactions. Non persistent chemicals are transformed in the troposphere, persistent chemcials are transformed in the stratosphere. The most important persistent chemicals are the perhalogenated substances, especially fluorochlorohydrocarbons. These substances are photolyzed in the stratosphere. The primary photoproducts react with stratospheric ozone and in complex reaction pathways diminsh the ozone concentration in the stratosphere. The effect of a decreased ozone concentration would be an increased UV radiation on the earth's surface. Today there is no doubt that increased fluorochlorohydrocarbon emissions alone lead to a decreased ozone concentration in the stratosphere /132/. But as the effects on the stratospheric ozone concentration do depend also on the emission of other anthropogenic substances (e.g. CO_2) at the moment no exact prediction about the alteration of the stratospheric ozone concentration is possible /132/.

In the troposphere the most important chemical transformation of a substance S is the reaction with OH radicals. Usually the simplified reaction

$$OH + S \rightarrow \text{products}$$

is taken for the description of the transformation. The rate expression of this reaction is given by

$$d[S]/dt = -k_{OH}[OH][S]$$

where $[S]$ and $[OH]$ are the concentrations of the substance S and the OH radicals. Assuming steady state conditions for the tropospheric OH concentration the chemical lifetime of the substance is given by

$$\tau = 1/(k_{OH}[OH])$$

(The half-life of the substance can be obtained by multiplying with ln 2 or 0.7). In order to estimate the lifetimes of different substances not only their rate coefficients k_{OH} but also average values of atmospheric OH concentrations are necessary. For many substancies fairly exact values of k_{OH} are available. For the troposperic OH radical concentrations values between 1.5 10^5 and several 10^7 molecules per cm^3 were reported /73, 148/. For the FRG average noon-time concentrations of OH on sunny days during summer of $\sim 1.6\ 10^6\ cm^{-3}$ were reported /73/.

The tropospheric OH radicals mainly are formed as a result of ozone photolysis by UV light

$$O_3 \xrightarrow[\lambda \leq 310\ nm]{h\nu} O(^1D) + O_2$$

$$O(^1D) + H_2O \longrightarrow 2\ OH$$

$$OH + R \longrightarrow \text{products}$$

At steady-state the formation rate of OH is balanced by chemical consumption; were R is mainly CO, CH_4 and O_3. The OH radical concentration strongly depends on the irradiation intensity. Transformation reaction rates therefore should be higher in the southern member states of the EEC. The probability and intensity of photosmog formation therefore is also higher in the southern member states. In heavily polluted areas during smog situations Ozone and OH radical concentrations are enhanced. During night-time on the other hand no OH-radicals are produced. As an 24 h average value for the estimation of tropospheric lifetimes therefore we recommend 5 10^5 molecules per cm^3. Nevertheless it is felt that much more measurements of the OH radical concentration in the troposphere should be performed.

Another uncertainty is introduced to the estimation of tropospheric lifetimes by the temperature and pressure dependence of the k_{OH} rate coefficients. The published k_{OH} values normally were determined at room temperature. Due to the relatively strong temperature gradient in the troposphere (-6.5 K/km) the chemical transformation may be overestimated if the reactions show a significant activation energy. The same is true when the rate coefficients depend on the pressure or oxygen content of the troposphere.

The chemicals produced by these transformation reactions are called photooxidants. Ozone and peroxyacetylnitrate (PAN) most frequently are taken as representatives for these chemicals. The potential of a hydrocarbon to contribute to the formation of photooxidants may be classified by its k_{OH} rate coefficient. Chemicals with high k_{OH} values may be quickly transformed and therefore contribute to photochemical smog formation on a local or regional scale when the emissions and immissions are high. Substances with lower k_{OH} values normally do not lead to photochemical smog situations as they are more quickly diluted than transformed; only if the local immissions of these substances are very high, i.e. ten-to hundredfold that of substances from class C, they can contribute to smog situations. But of course these substances also may be transformed to toxic or irritant substances and therefore cannot be automatically regarded as substances which cause no environmental problems. In any case these substances contribute to the formation of photochemical oxidants, even at locations which are very distant from their emission sources.

According to a suggestion of the TNO which has been agreed by the European Commission during a working meeting /37/ the list of substances (chapter: Hydrocarbon immissions in the member states of the EEC) contains an item "smog formation class". The substances are classified by the quotient of the k_{OH} rate coefficient of the substance and methane. The following table shows the classification scheme which is a slight modification of the EPA classification /37/:

$\frac{k_{OH}(\text{substance})}{k_{OH}(\text{methane})}$	class TNO	lifetime (d)	distance (km)
10-100	A	30-300	$> 10^4$
$100-10^3$	B	3-30	10^3-10^4
$> 10^3$	C	3	< 1000

Additionally the table contains the estimated lifetimes (OH radical concentration 5 10^5 cm^{-3}) and the distancies which the substances can be transported during their lifetimes when a mean wind speed of 4 m s^{-1} is assumed. As already mentioned the OH concentrations during photochemical smog situations are higher, and the lifetimes of hydrocarbons in such situations therefore are lower than those given in the table.

In this classification system no other transformation reactions are taken into account. Further potential transformation pathways are e.g. reactions with ozone, direct photolysis or reactions of the substances which are adsorbed or absorbed to dry or wet aerosols. Reactions with ozone may contribute to the transformation when k_{ozone} is not much less than aproximately 10^{-5} that of k_{OH} /71/. Direct photolysis in the troposphere only occurs when the optical absorption coefficients of the substances are not equal to zero at wave length greater than approximately 290 nm. Reactions with OH radicals may be enhanced in wet aerosols as the OH radical concentration is higher - about 6 10^7 to 6 10^8 molecules/cm^3 - in the liquid phase of the aerosol than in the gas-phase /40/.

A further potential transformation process is the reaction with nitrating species /69, 70/. At the moment these reactions are not as well investigated as the other homogeneous gas phase reactions. But these reactions might be especially important for the transformation of aromatic and polycyclic aromatic compounds and during night time.

4.2.3 Smog formation potential of single classes of hydrocarbons

Acetates/Esters

As far as data are available the chemicals from this class in the list of substances belong to smog formation class B: the substances are not very rapidly transformed and that they contribute not very much to the formation of smog situations.

Acids

Only very limited information is available for this class of substances. Acetic acid is classified into class A. It may be estimated that acids with longer hydrocarbon chains belong to class B. In any case it seems not probable that acids can contribute to the formation of smog situations.

Alcohols

The limited data for alcohols show that alcohols with short hydrocarbon chains belong to class B whereas alcohols with longer hydrocarbon chains belong to class C. Therefore alcohols may contribute to local and regional smog situations if they are emitted in larger amounts. Unfortunatelly only limited data on alcohol immissions could be found. This might be due to their quick transformation or to the limited interest in alcohol immissions because they are believed to be of no environmental concern. The first would support the estimation that alcohols can contribute to smog formation, the second assumption needs further investigation, especially more immission measurements.

Aldehydes

The aldehydes from the list of substances belong to class B and C. This shows that aldehydes are rapidly transformed and that they many contribute to the formation of photochemical smog situations.

Alkanes, Alkenes, Alkines (without Methane)

Unbranched alkanes with less than 7 carbon atoms fall into class B, but most of the other substances belong to class C. If additionally the measured immission data are taken into account it becomes evident that this group of substances mainly contributes to the formation of photochemical smog. Alkenes additionally react with Ozone and therefore are even more rapidly transformed to photooxidants than estimated if only the reaction with OH radicals is taken into account.

Amines

Practically no information is available for amines. Further investigations are necessary.

Aromatics

Alkylated aromatics mostly belong to class C. When the immissions are taken into account it becomes evident, that these substances contribute to the formation of photosmog situations. Too little information is available for nitrated aromatics and sulphur containing derivatives. Halogenated aromatics become less reactive with increasing number of halogen substituents.

Halogenated hydrocarbons; Fluorochlorohydrocarbons

These substances belong to class A and B or are persistent in the troposphere. They do not contribute to the formation of photochemical smog.

Ethers

As far as data are available ethers belong to class C. Therefore these substances may contribute to photochemical smog situations. The importance of ethers for photochemical smog formation cannot be assessed as there are too little information an their immissions.

Ketones

Little information is available about ketones. Whereas acetone is relatively unreactive the other alkylketones belong to class B or C and therefore can contribute to photochemical smog formation. Information on ketone immissions is scarce. It is probable that ketones are important for photochemical smog formation in the vicinity of large varnish producing or consuming industries.

Dibenzodioxines/furans

These substances do not contribute to photochemical smog formation as they are released only in very small amounts and are not believed to react rapidly with OH.

PAH's

k_{OH} rate coefficients of most of the PAH's were not measured because of the low vapour pressure of the substances. As far as data are available PAH's belong to class C. However, taking the immission values into account it becomes evident that PAH's are not important for photochemical smog formation.

Miscellaneous substances

From these substances acrylonitrile might contribute to photochemical smog formation. For the other substances either k_{OH} or immission data are missing so that it is not possible to assess their potential to form photochemical smog.

4.2.4 Conclusions

According to the importance of their potential to contribute to photochemical smog formation the substances may be listed in the following sequence:

- alkanes, alkenes, alkylated aromatics
- alcohols, ketones
- acetates/esters, (ethers)
- other hydrocarbons from the list of substances

This sequence is rather rough and should be regarded as tentative since it is based on limited information only. Single compounds out of the various groups of substances may deviate from the sequence given above. For a more accurate assessment further k_{OH} values have to be determined in laboratory measurements, and immissions of single compounds and OH radical concentrations have to be measured in the various member states of the EEC.

4.3 Estimation of immissions

4.3.1 Estimation of immissions from point sources

The measurement of air concentrations for many organic pollutants is time consuming and requires experimental experience. Therefore the measurements may be relatively expensive. In order to avoid high costs methods were developed, which are suited to estimate immissions. Within the German legislation these methods are used to

- estimate the immission which a new or old emission source may cause in its neighbourhood,
- find out which measures are necessary in order to avoid dangerous or annoying immissions.

Two-dimensional gauss models are used to perform the necessary calculations /30, 63, 65/. German authorities also use these models for the estimation of the immission situation in heavily polluted areas of the FRG. The results of such estimations are published in the "Emissions Kataster" /20-22, 28, 30, 31, 55, 56/.

4.3.2 Estimation of immissions from road traffic

For the estimation of immissions near to roads, the road is treated as a line source. For the performance of calculations Gauss models and K-type models are used. The turbulence induced by the traffic itself changes the meteorological situations. This introduces special problems to the performance of the estimation. Various attempts are undertaken to overcome these problems. At the moment the Dutch Ministry of Housing, Physical Planning and Environment supports a long term experimental project which aims to measure emission, dispersion and deposition of automotive pollutants near to roads. Up to now only limited data are available from the project /64/.

4.3.3 Discussion of estimation methods

The estimation of immissions has several advantages relativ to measured data on ambient air concentrations:

- the contribution of various emission sources to the ambient air concentrations can be characterized
- geographical areas of high immissions can be identified
- a large number of substances can be taken into account

The disadvantages of estimation methods are

- most dispersion models employ several simplifying assumptions for environmental boundary conditions in order to save computing time (e.g. flat terrain, average meteorological conditions)
- immissions estimation is often extended to only short distances, 50 km are rarely exceeded.
- atmospheric chemical transformations of substances are not taken into account.
- the emission estimates used for the performance of the calculations often are incomplete and inaccurate.

4.4 Total hydrocarbon immission

4.4.1 Measurement of total hydrocarbon immission

The measurement of total hydrocarbons is relatively simple and inexpensive. The total hydrocarbon content of the air usually is determined by the silicagel method or with the aid of a flame ionisation detector (FID). In Germany official measurements have to be performed according to the methods described in the VDI-Handbook on Air Pollution Prevention /66/. These methods yield either the total amount of hydrocarbons in the air or the amount of hydrocarbons without methane (NMHC). As most of the methane is released from natural sources it is recommended to measure NMHC values because these values represent the anthropogenic immissions more accurate.

In the FRG total hydrocarbon immissions are measured within several monitoring networks routinely by automatic devices /42, 51, 53/. Part of the monitoring stations is equipped with devices for the measurement of NMHC immissions. In these instruments cooling traps (at -30°C) are used to separate methane and nonmethane hydrocarbons.

In Denmark no measurements of hydrocarbon immissions are performed by the environmental authorities. In Greece NMHC immissions are measured by eight stations in the Athens area; it is planned to install further eleven stations in the other industrialized zones (1985) /133/. In Greece devices with catalysts are used for the separation of methane and nonmethane hydrocarbons.

No information was available for the other member states

4.4.2 Measured data on total hydrocarbon immissions

Total hydrocarbon immissions are caused by natural - mostly methane - and anthropogenic emissions. In the FRG the amount of anthropogenic hydrocarbon emissions increased from 1966 to 1974 remained constant for 1978 and decreased for 1982 /82/. The data are given in the table below.

	1966	1970	1974	1978	1982
hydrocarbon emissions in 10^6 t a^{-1}:	1.4	1.7	1.8	1.8	1.6

Measured data of hydrocarbon immissions are not available for the whole area of the FRG. The following values therefore have to be taken as representatives. The table shows mean and peak values of total hydrocarbon immissions in Bavaria in mg/m^3 /52/.

	rural areas	small towns	large towns
mean	0.13-1.3	0.4-1.6	0.2-2
peak	1.6-4.3	1.6-6	2-10

The mean values are in the range of the natural total hc background the peak values in part exceed that level. A comparison of rural and urban values shows that anthropogenic hydrocarbons are released mainly in urban areas.

MNHC values for heavily polluted areas may be represented by the data reported in /31/ and /30/:

NMHC mg/m^3	Mainz-Budenheim	Ludwigshafen
mean	0.06-0.12	0.33-0.5
peak	4.3	2.3

The data for Mainz and Ludwigshafen confirm the values reported for Bavaria, although one has to take into account that the data from Bavaria include methane; the air concentration of methane caused by natural emissions can be as high as 2 mg/m^3.

The measured total hydrocarbon immissions show seasonal and diurnal variations. In cities day-time concentrations are twice as high as night-time concentrations, showing the importance of emissions from automobiles. During winter peak values at most sampling stations in Bavaria are higher than during summer. These maxima might be due to higher emissions - caused by domestic heating and/or higher fuel consumption by automobiles - or to the higher probability of meteorological inversion situations.

For Schleswig-Holstein (FRG) NMHC immissions for 1983 are reported to range between 0.01 and 0.1 ppm. 98 percentile values are 0.15 - 0.56 /109/. The concentrations were measured at rural and urban locations.

For Delmenhorst, a city in Niedersachsen (FRG) NMHC values from 0.47 to 0.64 mg/m^3 were reported /108/. Presumedly a varnish producing factory is responsible for the rather high values.

NMHC values in Greece; Athens area 1984 /119/

mean	peak
0.8 - 1.9 ppmv	94 ppmv
0.5 - 1.3 mg m^{-3} (as Methane)	6.3 mg m^{-3} (as Methane)

The higher values usually are observed during winter since air exchange is less effective in this season. During normal meteorological situations a quick air exchange takes place in the Athens area. The rather strong wind typical for these meteorological situations give rise to the lower NMHC concentrations observed during most time of the year.

The values themselves clearly exceed the values reported for the german heavily polluted areas. Presumedly most of the hydrocarbon immission is caused by vehicle emissions.

In France total hydrocarbon concentrations were measured during the years 1980-84 at roughly ten locations. The reported values are summarized in the table below /166/

location	concentration (µg/m^3)
Campagne	50 - 100
Urban air	1200 - 2000
City centre Carrefours	2000 - 5000
Industrial areas	1500 - 5000

In July 1985 measurements of total hydrocarbons and MNHC started at various locations. The measurements will last six months. Up to now no results are available /166/.

In Belgium NMHCs are continously measured at various urban and rural locations /167/. The reported values from 1981 to 1984 do not change significantly. Typical daily average values vary between 0,5 and 4,0 ppm. 95 percentile values vary between 1.2 and 9.6 ppm. The lower values may be taken as representative for rural areas whereas the upper values may be taken for urban

areas. Compared to the data reported for the other countries these values seem to be rather high.
According to the Danish environmental authorities no measurements are performed in Denmark.
In Portugal NMHC were measured at 3 locations (Monte Chao, Monte Velho, Sonega) between Jan and June 1983. Values between 0.6 and 0.93 were reported /168/.

For Great Britain only very limited values (0.2 - 1.6 ppm /118/) were available.

4.4.3 Correlations between total hydrocarbon immissions and single compounds immissions

Only limited data about simultaneous measurements of total hydrocarbons and single compounds immissions have been published. The measurements undertaken by the LIS /54/ show that NMHC immissions and single hydrocarbon immissions may be correlated. The correlation is fairly good when the number of pollutants is not too high. This result is interpreted by the authors in the following manner: When the immissions are caused by similar sources or mainly by one source a good correlation between NMHC and single hydrocarbon immissions may be expected. In the not heavily polluted areas investigated by LIS hydrocarbon immissions were mainly caused by automobile exhaust.

As these emission sources are rather similar a good correlation was found for these areas. For areas which were polluted by various sources no correlation between NMHC immissions and the immissions of the measured single hydrocarbons could be detected. The results in /54/ are supported by data from /62/. The authors of this publication /62/ revealed a correlation between traffic density and benzene, toluene and xylene immissions in urban areas.

If such correlations could be established they would allow to estimate single hydrocarbon immissions from inexpensive and easy to perform NMHC immission measurements. Although the first results mentioned are encouraging they should not be overstressed. The correlation coefficients of about 0.7 have to be improved and more measurements are necessary in order to evaluate the probable errors of the method.

Unfortunately, to our knowledge no similar attempts were performed in other member states of the EEC. Therefore it is not possible to judge the usefulness of such correlations for other countries.

4.4.4 Assessment of total hydrocarbon immissions

Like other screening values total hydrocarbon immissions contain only limited information. They are not suited to assess the health risk connected with a certain level of air pollution.

NMHC immission measurements are inexpensive and can be performed automatically. Therefore they can be used in monitoring networks. When the measurements are performed continuously sudden or permanent high values are detected. By this way various emission sources and their contributions to air pollution may be identified. E.g. correlation of hydrocarbon immission with traffic density can show the relative contribution of automobile emissions; seasonal correlations may reveal the contribution of domestic heating; or correlation with weekday and weekend values may help to clasify the importance of industrial emissions. Although these problems can not be solved by hydrocarbon immission measurements alone, such measurements can support the solution of that problems. At least they can be very useful in detecting areas which are heavily polluted by hydrocarbon immissions and for which further investigations should be performed.

Comparison of the NMHC data for the Athens area with data from other regions, e.g. shows that this area has to be regarded as heavily polluted by hydrocarbons. Taking the specific meteorological situation (normally quick air exchange) into account, it becomes clear that actions for the reduction of hydrocarbon emissions should be intensified.

4.5 Surveillance of single hydrocarbon immissions

4.5.1 Legal situation

According to § 44 of the BImschG /43/ in the FRG the various federal countries have to appoint heavily polluted areas and control the air quality in these areas. The law contains no information about the hydrocarbons for which immission measurements have to be performed. The immission measurements should be performed repeatedly within suited time intervals.

No comparable laws are active in Denmark or Greece.

4.5.2 Monitoring networks

Networks for monitoring air pollution should be capable to serve various purposes:

- At the various measuring stations it should be possible to measure meteorological and chemical analytical data.
- The immission measurements are needed in order to be able to raise a smog warning if necessary.
- The immission measurements are needed in order to be able to realize long-term trends in the immission situation and for the determination of possible emission sources.
- Immission measurements can be used in order to control the observance of emission limits by various sources.
- Immission measurements are necessary in order to control wether emission limits - directed by the authorities - satisfy the demands of air pollution prevention.
- Immission measurements should help to identify the transmission pathways of air pollutants.

- The capabilities given by the establishment of monitoring networks should support the performance of other measurements.

The location of the various measuring stations also should fulfil various demands:

- The measuring stations should form a regular network.

- The collection of the samples should not be influenced by local air circulations; the stations should not be situated at the bottom of local basins.

- The distance between the measuring station and buildings should be at least twice the height of the building.

- The air samples should be collected near to the ground.

- The measuring stations should not be situated in the close vicinity of emission sources like industrial plants or roads with dense traffic.

The last demand often is criticized because local air pollution problems by that way can be "solved". Therefore additional measurements have to be performed if housing areas are more closely situated to the emission sources than the measuring station.

The technical equipment of the measuring stations depends upon the analysis which have to be performed. For the measurement of many inorganic trace gases and total/nonmethane hydrocarbons in air automatically working devices are available. The immission measurement of single hydrocarbon species is more complicated and therefore normally not performed with automatic devices.

4.5.3 Existing monitoring networks

In the FRG Nordrhein-Westfalen (NRW) and Bayern (BY) have established monitoring networks which in part fulfil the demands described in the foregoing chapter /42, 51/. In NRW most of the measuring stations are situated within the heavily polluted areas; in BY the stations are situated in heavily polluted areas and in traditionally clean air areas.

Both networks mainly were established in order to measure inorganic trace gases like CO, O_3, NO_x, and meteorological data. Hydrocarbon immissions are only measured to a minor extend. In BY total or nonmethane hydrocarbon immissions (THC, NMHC) are measured routinely and continously. In NRW only single THC or NMHC measurements are performed. Immissions of single hydrocarbon compounds are measured only within additional projects.

The monitoring networks in the other federal countries of the FRG are less extensive. But all monitoring networks are still under construction and continuously improved. According to /67/ THC immissions were measured at 17 and NMHC immissions were measured at 72 stations continuously within the FRG. Measurements of single hydrocarbon immissions are performed in additional projects. These measurements are not performed continuously.

Another monitoring network in the FRG is operated by the Environmental Protection Agency (UBA, Berlin). Within this network only at the Frankfurt Pilot Station single hydrocarbon species immissions can be measured routinely, but no continuous measurements are performed. The task of that station mainly is to develope new methods for routine measurements /68/.

No monitoring network for hydrocarbon immissions exist in Denmark. PAH immissions repeatedly were measured by the National laboratory at Risø.

In Greece a monitoring network for the measurement of NMHC immissions is under construction. Single hydrocarbon immissions are measured within additional activities.

In France within a monitoring network at roughly ten locations total hydrocarbon concentrations are measured continously.

Beginning with July 1985 further total hydrocarbon and NMHC mesurements will be performed within a six months' period. Additionally the concentrations of seven groups of hydrocarbons but no single compounds will be determined. In door measurements of formaldehyde will be performed, too. The measurements were planned in order to get measured values which can be compared to data calculated with the EKMA model /166/.

In Belgium the monitoring network Belgisch Automatisch Meetnet voor Luchtverontreiniging was established. NMHCs are measured at 13 stations of that network. The stations of that network are situated in rural and urban areas. They belong to the zones Brussels, Antwerpen, Liege, Genf, and Charlroi /167/.

Little information was available for the other member states of the EEC. As it was possible to detect published data of single hydrocarbon immission for the other member states in scientific journals obviously such measurements were performed in these countries, too.

4.5.4 Presentation of data

When immissions are measured continuously methods for data reduction have to be applied. In order not to loose too much of information reports should contain at least the following data:

- sampling time
- mean values or medians
- 95 % percentile values
- peak values

The mean values can be given for hours, days, - preferably - weeks or months. An averaging time of a month should not be exceeded.

If immissions change frequently, the averaging time should be short enough, so that these changes are still represented by published data. Immission changes may be valuable for the determination of emission sources and therefore should not be removed by data reduction measures.

4.5.5 Methods for the measurement of hydrocarbon immissions

Most of the hydrocarbon pollutants are present in the air only in trace amounts. Prior to the analysis therefore, a sample enrichment has to be performed. For that purpose a specified volume of air is sucked through a trap which is filled with a suited adsorbing material, mostly silicagel, charcoal or Tenax. In order to remove most of the precipitable water sometimes the air probe is passed through traps which are filled with coarse-grained $MgSO_4$ before entering the silicagel-filled trap. To support adsorption of very volatile pollutants sometimes the adsorbing trap additionally is cooled to low temperatures. The amount of air sucked through the traps depends upon the concentration of the pollutants. The volumes vary between 5 and several tens of litres. The sampling time varies between several minutes and days. The sampling time is identical with the averaging time.

The desorption of the hydrocarbons may be performed by solvent extraction or heating. A convenient head space method for desorption and detection of halocarbons was developed by scientists at the Frankfurt Pilot Station of the German Environmental Protection Agency /78/. For the separation of the single compounds chromatographic methods - mostly gaschromatography - are employed. For the identification various detectors (FID; ECD, preferably for halocarbons; MS) are used.

Detailed descriptions of the methods are given in /6, 66/.

For official measurements the methods described in /66/ have to be used in the FRG.

4.5.6 Measured immissions values of single hydrocarbons

More than 1500 chemical substances have been identified in ambient air samples but only a small fraction of these substances was determined quantitatinely /77/. Immission measurements which were performed at specified locations over longer periods are very scarce.

Practically no such immission measurements are available which were performed within a monitoring network which was designed in order to obtain values which are really representative for a specified geographical area. Most of the immission measurements have been performed in isolated projects by single groups of scientists, which determined ambient air pollution concentrations at selected locations, mostly not too distant from the institution where they are working. For many substances no immission measurements were performed at all. The number of immission measurements performed in the member states of the EEC varies quite a lot. The available data on immission measurements are compiled in the list of substances. As immission measurements are rather rare, data were compiled not only for base year 1980 (1983), but the data cover the period from 1977 to 1985, a few values are older measurements.

In the following the groups of chemicals from the list of substances are discussed separately.

Acetates/Esters

These chemicals mainly are used as solvents and plasticizers. Therefore it can be expected that they are widespread air pollutants. However, immission measurements of these substances are very scarce. Phthalate esters can be determined in clean and polluted air, although their vapour pressure is rather low.

More immission measurements would be desirable, especially for phthalate esters.

Acids

Nearly no measured immission values are available. Measurements would be desirable at least for acids which belong to class 3 or 4 according to their vapour irritancy human, or aquatic toxicity (Acrylic and formic acid from the list of substances). Additionally it is recommended to look for dicarboxylic acids with short hydrocarbon chains. Although these substances are not believed to be emitted in large amounts they may be formed by chemical transformation processes in the atmosphere and contribute to air and general environmental pollution.

Alcohols

Practically no measured immission data are available. According to their potential to contribute to photosmog formation more immission measurements would be desirable.

Aldehydes

Too little immission measurements were performed for aldehydes. According to their toxic and environmental importance much more measurements should be performed.

Additionally it is recommended that immission measurements should be performed for glyoxal and similar aldehydes. Although these aldehydes are believed not to be emitted in larger amounts, they are produced by chemical transformation processes in the atmosphere and contribute to air pollution and other environmental problems.

Alkanes, alkenes, alkines (without methane)

Many of these substances are emitted by various vehicles. A fairly large number of immission measurements was published, although these data are not sufficient to estimate reliable mean exposure concentrations for the member states of the EEC. Immissions for alkanes in urban areas typically vary between 1 and 20 $\mu g/m^3$; values reported for near traffic locations are of the same magnitude. Peak values can be as high as 60 to 80 $\mu g/m^3$. The concentrations reported for rural areas vary between less than 1 and 5 $\mu g/m^3$.

Less data are available for alkenes. The values of ambient air concentrations of alkenes are similar to that of alkanes. Due to their higher reactivity peak values of alkenes only occur in the vicinity of very strong emission sources. The reported concentrations for ethine are also similar to that of the alkanes.

The reported data show that aliphatic hydrocarbons contribute a large fraction to NMHC immissions. A comparison of the immissions reported for urban and near traffic locations makes it probable that urban hydrocarbon immissions predominantly caused by motor vehicles.

The data base of aliphatic hydrocarbons immissions is not yet sufficient. Further measurements are recommended especially for alkenes.

No data were available for 1,3-butadiene immissions. As this substance is regarded as carcinogenic it is strongly felt that immission measurements should be performed in the near future.

Amines

No outdoor immission measurements were available for amines. As this group of chemicals contains several toxic and/or carcinogenic substances immission measurements are recommended. Some amines are easily detected by their characteristic odour. It is assumed that the emitted amounts of these amines are relatively small. Special attention therefore should be paid to less odorous amines which are additionally toxic.

Aromatics

A fairly large number of immission measurements are available for benzene and alkyl benzenes. For toluene and xylenes typical concentrations in urban air seem to vary between 1 and 100 $\mu g/m^3$. Typical values for benzene and other alkyl benzenes seem to vary between 1 and 80 $\mu g/m^3$. Immission values reported for near traffic locations are in the same concentration range. Peak values exceed the upper limits of that concentration ranges up to sevenfold. For rural areas values between less than 1 and 5 $\mu g/m^3$ were reported.

Very limited information is available for chlorobenzenes, PCBs, and phenols, no information is available for other benzene derivatives.

Benzene and alkyl benzenes mainly are emitted from motor vehicles. Toluene and Xylenes mainly are emitted from motor vehicles and varnishes. The reported immission values seem to represent this emission pattern, if the more rapid transformation of alkylbenzenes is taken into account. A comparison of the reported immission values for near traffic locations and urban air shows that urban air pollution to a large fraction is caused by emissions from motor vehicles. A comparison of the immission values of aromatic hydrocarbons with total NMHC immissions show, that aromatics also contribute a large fraction to NMHC immissions.

The reported immission data are not sufficient to estimate mean values for the aromatic hydrocarbon immissions in the member states of the EEC. Further measurements should be performed. Additionally it is recommended to measure immission values of other benzene deriatives. Special attention should be paid to nitrated benzene and phenol derivatives. These substances are not only emitted but they can also be produced by chemical transformation reactions in the atmosphere.

Halogenated hydrocarbons/Fluorochlorohydrocarbons

Only limited information is available for this group of substances; urban immissions of halogenated hydrocarbons vary between less than 1 and 40 $\mu g/m^3$. Values for rural air mostly are less than 1 $\mu g/m^3$ and similar to values reported for clean air. Indoor concentrations far exceed the outdoor concentrations. Insufficient information is available for fluorochlorohydrocarbons, too. The reported data show that high immission values are reached only in the vicinity of emission sources. The similarity of rural and clean air immissions reflects the chemical persistence of halogenated hydrocarbons.

Since there are only limited data available it is recommended to measure further immissions. Special attention should be paid to cancerogenic substances, especially to dibromo- and dichloromethane which are used as gasoline additives.

Ethers

No immission data are available for ethers. Immission values should be available especially for dioxane as this substance might be cancerogenic to humans. The ethers seem to be of no special importance for air pollution.

Ketones

Too little information is available for ketone immissions. It is recommended to measure immissions at least for those ketones which are widespread solvents in varnishes.

Dibenzodioxins/furans

Practically no measured immission values are available. Estimated immissions in the vicinity of a waste incineration plants are 2 10^{-15} g/m^3 /131/. Authorities, at least in the FRG, claim that there are no detectable TCDD immissions in the vicinity of waste incineration plants. Contrary to that K. Olie and J. Jager on behalf of the german television measured 2,3,7,8-TCDD immissions of 7.4 pg/m^3 in the vicinity of a waste incineration plant at Solingen, FRG.

It is recommended to further try to measure dioxin immissions in the vicinity of potential emission sources.

PAHs

Substances with vapour pressures greater than 10^{-4} Pa mainly occur in the gas phase /153/; the vapour pressures of PAHs are approximately 10^{-4} (Phenanthrene) or less. Tropospheric PAHs therefore occur in the gasphase and bound to aerosols as well.

For PAHs a relative large number of measurements is available. Reported total PAHs concentrations in urban areas vary between 0 and 10 ng/m^3; in rural areas the upper limit is approximately 3 ng/m^3. The reported data for single PAHs are in the same magnitude. Peak values can reach several hundreds of ng/m^3. Compared to the values reported for single PAHs the reportedvaluts for total PAHs seem to be too low.

The data show further that PAHs are widespread air pollutants which ocur in urban and rural locations in similar concentrations. Peak values are reached only near to emission sources. Immission measurements performed in Berlin revealed that PAHs immissions during winter are three times higher than during summer /163/. Domestic heating therefore seems to be a strong source for PAHs immissions.

From the compiled data it is not possible to estimate sufficient reliable exposure concentrations for humans. As many of the PAHs are regarded to be carcinogenic it is recommended to measure further PAHs immissions.

Miscellaneous

This group of substances contains nitriles, sulphur containing compounds, oxides and others. Only a few immission data were available, especially for nitriles.

It is recommended to measure further immissions especially for substances which are carcinogenic or toxic.

4.5.7 Discussion

Although emission limits are active for many substances /43/, too little data are available for hydrocarbon immissions in the member states of the EEC. Further measurements should be planned and performed in such a way that they will be suited to satisfy the following demands:

- The measurements should represent diurnal and seasonal immission variations.

- The measurements should be suited to detect longterm immission variations.
- The measurements should be performed within monitoring networks. These networks should have been designed in order to get immission data which are suited to determine exposure concentrations for specified geographical areas. Additionally the number of inhabitants living in these areas should be known so that the exposure of the population to certain chemicals can be estimated.
- The emission sources which contribute to the measured immissions should be known as far as possible

One advantage of such measurements would be that they can also be used to identify the main sources of hydrocarbon immissions. For example Bruckmann et al. measured 16 hydrocarbons in the ambient air of the Rhein/Ruhr area /54/. By using multivariate regression for the analysis of their data the authors were able to show that various emission sources can be described by the pattern of hydrocarbons which are released from that source. By extended utilization of that methods they were further able to show that 44 % of the stations within the NRW monitoring network mainly are influenced by automobile exhaust emissions. The investigations described in /54/ show, that multivariate regression methods can be a powerful tool for the identification of hydrocarbon immissions and the detection of the sources from which they were released.

A more straight forward but perhaps less significant tool for the identification of emission sources is the "finger-print" method /81/. If several hydrocarbons are released from a source the fractions of the single compounds often are constant. Therefore the ratios between the single hydrocarbons immissions remain constant during dilution if no atmospheric reactions occur. When the immissions measured at various locations in ambient air for two hydrocarbons are linearily correlated it is probable that both hydrocarbons were released from the same source. If the ratio of the immissions of these two hydrocarbons is identical with the known ratio for a specific emission source, it is probable that these hydrocarbons were released from such a source.

By applying that method to their measured immission data Neuber et al. were able to show that propane immissions in Frankfurt exceed the immissions which would be caused by automobile exhaust alone. The authors guess that additional propane is released from lecks in the municipal gas network. /81/ Applying the same method Müller et al. were able to show that the air pollution by aromatic hydrocarbons at the "Kleiner Feldberg" (a mountain near Frankfurt) mainly is caused by automobile exhaust released in the Frankfurt area /68/. The authors deduced this statement by taking into account further information about the reactivity of aromatic compounds in the air.

The application of both methods - multivariate regression and finger-print - is complicated by the chemical transformation and/or transmission of hydrocarbons in the air. Although the methods are not fully developed the cited examples show that further investigations should be undertaken. The methods seem especially suited for the investigation and descripton of short range transport phenomena.

In order to improve the possibilities to assess the hydrocarbon immissions in the member states of the EEC, it is recommended primarily to perform immission measurements for toxic and carcinogenic substances. Equal attention should be paid to substances which are emitted in large amounts. Immission measurements of potential photochemical transformation products should be performed in order to evaluate the amount of these products, again special attention should be paid to toxic and carcinogenic substances.

5 Hazard assessment of hydrocarbon immissions

5.1.1 General

Hydrocarbons which are emitted to the air may injure humans and other organisms. The injuries may be caused by the emitted substances themselves or by transformation products of these substances. Whereas the assessment of hydrocarbon immissions at the working place mainly has to take into account human toxic properties of the substances, assessment of hydrocarbon immissions in ambient air additionally has to take into account several other properties of the substances. Therefore at least the following aspects have to be dealt with:

- human toxicity and carcinogenic potential
- animal and plant toxicity
- potential of forming toxic transformation products
- persistance and distribution of the substance in the environment
- ecotoxicology

According to the complexity of the problem up to now the performance of hazard assessments can not take into account all mentioned aspects. Hazard assessment only can be performed for single compounds. Contrary to that a large number of different chemicals contribute to air pollution. Therefore it would be desirable that hazard assessment could take into account synergistic and antagonistic effects. Unfortunatelly this is impossible at the current state of knowledge.

5.1.2 Toxicity and carcinogenic potential

Information about the toxicity and carcinogenic potential of the selected hydrocarbons is included in the list of substances. These data and additional information will be used for the hazard assessment. Mainly birds and mammals besides humans might be directly affected by air pollutants. As it is believed that the adverse effects in animals will be less than that induced in humans, animals will not be taken into account during the hazard assessment.

Information about plant toxicity of hydrocarbon air pollutants is very scarce. Although forest decline became rather severe during the last years, it is not believed that hydrocarbon air pollutants directly are toxic to plants. Possible correlations between hydrocarbon immissions and forest decline are discussed elsewhere.

5.1.3 Toxic transformation products

Most hydrocarbons which are released to the air undergo transformation reactions in the troposphere. The main reaction pathway is oxidation. Aldehydes, alcohols, ketones and acids are known as main transformation products. Some of these transformation products are more toxic than the hydrocarbons initially released from the emission sources. Today, ozone and peroxyacetyl nitrate (PAN) are regarded as the most harmful transformation products of hydrocarbons /74/. Ozone is believed to contribute to forest decline. PAN and other hydrocarbon peroxynitrates also might contribute to forest decline /2/.

In addition to oxidations, nitrations can also occur as transformation reactions. Especially if aromatic hydrocarbons are transformed under tropospheric conditions, mono- and dinitrophenols and -cresols can be detected as reaction products /75/. Although these substances are produced only in minor (ca. 5 %) amounts, they could contribute to forest decline since these nitrophenols are effective phytotoxicants; dinitrophenolderivatives are used as herbicides. Within a BMFT project scientists at Battelle Frankfurt were able to detect mono- and dinitrophenols in rainwater. Although these research works are not completed there is strong evidence that the nitrophenol concentrations in rainwater may be high enough to cause chronic plant injuries /76/.

More general, substances containing aromatic ring systems easily undergo various substitution reactions without destruction of the aromatic system. The resulting substances may be more persistent and toxic than the precursors. Special attention therefore should be paid to aromatic hydrocarbon immissions /69, 70, 114/.

5.1.4 Persistence

Substances which are chemically inert in the troposphere may be globally distributed and reach fairly high concentrations. Therefore they can also reach compartments where they are no longer inert or where they may cause adverse health or environmental effects. Examples for such compounds are fluorochlorohydrocarbons or diethylhexyl phthalate.

It is known from experience that it is impossible to detect by laboratory tests all possible adverse effects a chemical can cause. Persistent chemicals may show effects yet unknown a long time after their first emission to the environment. When persistent chemicals are already distributed, it is impossible to remove them from the environment later on. Therefore it is recommended to reduce and restrict the emission of persistent chemicals as far as possible.

5.1.5 Ecotoxicology

Hydrocarbon immissions can be harmful not only to humans but to all living organisms. Hazard assessment therefore should take into account all organisms. To fulfil such a demand in a strict sense is obviously not possible. However, in order to be able to assess hydrocarbon immissions with respect to ecology a list of plants and animals which have to be taken into account should be available. Such a list should contain organisms which can be taken as representatives for various ecosystems. The list should be further divided into groups of organisms which exhibit different sensitivity against hydrocarbon immissions. No such list is available today, nor is it possible to establish such a list within a short time. For the compilation of such a list more information would be necessary about the impact of very small hydrocarbon immissions to organisms.

Today no experimental test is available to check the ecotoxicology of very small hydrocarbon immissions. On the other hand the rapid growth of forest decline in Europe reveals that complete ecosystems are heavily injured by air pollutants. Up to now the contribution of hydrocarbon immissions to forest decline is not clear. The possible importance of nitrophenols mentioned in the foregoing chapter shows that hydrocarbon immissions also may contribute rather directly to that phenomenon. Their contribution to the formation of photochemical oxidants like ozone also supports the suspicion that hydrocarbon immissions can contribute to forest decline.

Further investigations are necessary in order to be able to identify the importance of hydrocarbon immissions for the forest decline. If the importance of hydrocarbon immissions for forest decline can be shown many limit values for emissions and immissions would have to be lowered drastically.

5.2 Hazard assessment of single hydrocarbons

Maximum immission values (MIK) /66/

Analogous to the MAK values (threshold limit values at the working place, TLV) in Germany MIK values were developed. The procedures how to determine MIK values are given in /66/. MIK values have to be determined in such a way, that it becomes highly probable that no injuries will be observable in humans and in the environment if the MIK values are not exceeded in the ambient air. Therefore MIK values can not be determined for carcinogenics, because for these substances no threshold values can be defined. If MIK values can be determined two maximum immission concentrations are compiled for the substance. A mean value which should not be exceeded for long time periods and a (higher) short time value.

German MIK values were determined for inorganic trace gases and for several hydrocarbons. The MIK values for hydrocarbons were issued in 1966, therefore these values may be not up to date. Additionally it is recommended to use 1/20 MAK if no MIK has been determined for a substance.

Comparison of measured hydrocarbon immissions with MIK values reveals that direct adverse health effects have to be expected only from a few hydrocarbons. The urban immissions of acrolein can be as high as or even exceed the recommended MIK values. The MIK values recommended for formaldehyd can be exceeded by immissions in the vicinity of emission sources and - formaldeyhyde only - by indoor concentrations. A comparison of MIK values and measured values can not reveal all potentially hazardous substances as no MIK values exist for carcinogenic substances. A more detailed assessment will be given in the following text.

Acetates/Esters

This group contains no chemicals with high acute toxicity. Although there are only very limited immission data available it is expected that most of these chemicals will not cause direct health or environmental adverse effects. The high immission values reported from Belgium for dibutyl phthalate need further investigation.

Diethylhexyl phthalate turned out to be rather persistent in the environment. Additionally this chemical may be carcinogenic. Fiksel reports that an exposure level of 0.01 to 0.02 mg/day can induce 1 excess cancer per million population /157/. Assuming a daily air intake of 20 m^3 and using the reportet immission data the risk of excess cancer is less than 10^{-6} if only air exposure is taken into account. Further experiments to test the cancerogenic potential are under way /44/. The use and at least the emission of DEHP therefore should be reduced and/or restricted. It is recommended to perform further immission measurements and to investigate the importance of the air pathway for the distribution of DEHP.

It is expected that this group of chemicals contribute to ozone formation in photochemical smog and to the formation of oxygenated compounds like aldehydes, acids etc. In order to estimate their contribution to phototransformation products it is necessary to take the emitted amounts into account.

Acids

The data available are not sufficient to assess the hazard caused by this group of chemicals. Priority should be given to collect more data for acrylic, formic and halogenated acids, which are classified to be moderately toxic (class 3 NAS). Additionally it should be investigated to what extent mono- and diacids are produced by photochemical transformation reactions.

Alcohols

This group contains no chemicals which show moderate or high acute human toxicity. Although only a few immission measurements were available it is expected that alcoholic air pollutants can not cause direct adverse health or environmental effects.

As alcohols are rather quickly transformed in the troposphere this group contributes to ozone and photooxidants formation and by this mechanism indirectly can cause adverse health and environmental effects. The extend to which alcohols contribute to the photooxidants formation can be estimated when the emitted amounts are taken into account.

Aldehydes

Direct adverse effects have to be expected from acrolein and formaldehyde immissions, as the immission values reported for these two substances approximately are equal to the MIK values.

Not enough data are available to assess all chemicals from this group. In the FRG acetalaldehyde, acrolein and formaldehyde are suspected to be carcinogenic. The Commission of the EEC classifies formaldehyde to be carcinogenic.

For acrolein the US EPA estimated a daily unacceptable dose of 47.8 µg/man (70 kg body weight). Assuming a daily air intake of 20 m^3 and a 50 % resorption this value would be exceeded for humans living in German urban air. Although both values (unacceptable dose and immission) have to be regarded as tentative, the example shows again that acrolein immission could cause adverse health effects in humans. Further information on the toxicity and especially carcinogenicity have to become available and further immission measurements have to be performed for aldehydes. Priority should be given to acetaldehyde, acrolein and formaldehyde. Further it is recommended to investigate in what amounts these aldehydes are produced from other emitted air pollutants. The contribution of aldehydes to the formation of photooxidants seems to be of minor importance compared to their own potential to cause adverse effects.

Alkanes, alkenes, alkines /74/

Out of this group only 1,3-butadien is carcinogenic. A quantitative risk estimation is not possible as neither immission measurements nor dose risk correlations are available /44/. Immission measurements are strongly recommended.

None of the other chemicals in the list of substances shows moderate or higher toxicity. Hazard assessment of these substances mainly has to take into account their contribution to the formation of photooxidants. During smog situations the ozone concentration may become equally high as the NMHC concentration. In heavily polluted areas by this mechanisms ozone concentrations of 200 µg/m^3 can be exceeded. This concentration is a recommended tentative threshold limit value which should not be exceeded if direct adverse human health effects should be avoided. Direct plant damages can occur at even lower ozon concentrations. Additionally one has to bear in mind that these limit values do not consider any synergistic effects with other air pollutants. Other photooxidants especially PAN should also be taken into account. PAN concentrations in photosmog situations are approximately 5 % of the ozone concentration. It is not expected that direct adverse effects will be caused by this concentration. At the moment no methods are available to estimate the plant damages caused by lower concentrations. Also no methods are available to estimate the adverse effects caused by the synergistic action of various air pollutants and photooxidants. Too little information is available to estimate the "produced" amounts of the various photooxidants, especially that of other photooxidants than ozone and PAN.

Taking into account the high immissions of aliphatic hydrocarbons and the toxicity of their transformation products it becomes evident that this group of substances contributes a large fraction to adverse health and especially environmental effects. Measures to reduce the emission of aliphatic hydrocarbons therefore are strongly recommended. Additionally the emission of NO_x should be reduced. As NO_x accelerates the formation of ozone, the peak values of ozone could be lowered by this action. The total amount of photooxidants produced will not be affected by this action, the formation of photooxidants only can be lowered if less hydrocarbons are emitted.

The enhanced ozone immissions measured in clean air areas of Europe can not be correlated with local hydrocarbon sources. This experience shows that hydrocarbon emissions can cause air pollution problems in areas which are located very distant from the emission sources.

Form the USA damages to agricultural plants as high as 60 % were reported. The amount of damages caused by aliphatic hydrocarbon immissions in the various member states of the EEC can not be estimated quantitatively at the moment.

Amines

This group contains several toxic and carcinogenic chemicals. No hazard assessment can be performed as neither outdoor immissions nor other necessary data like smog formation potential are available. Further investigations to determine the importance of these chemicals for air pollution are recommended. Therefore investigations should be performed primarily for substances which are released in remarkable amounts, are carcinogenic and/ or toxic, and are transformed not to quickly. According to this criteria the lists of priority amines can be different for the various member states.

Aromatics

Aromatics besides aliphatic hydrocarbons contribute the largest fractions to air pollution. Everything what was stated about aliphatic phototransformation products is also true for aromatics. Additionally aromatics are easily transformed by substitution reactions. Substituted nitroaromatics produced by such mechanisms may be important for the forest decline (see also chapters toxic transformation products and ecotoxicology)

For several of the aromatics quantitative risk estimations can be performed:

Benzene: The US EPA estimates a life time risk for leucemia of 10^{-5} at a daily intake of 32 µg /156/. Assuming 20 m^3 air intake per day and a resorption ratio of 50 % leads to 10 excess leucemia cancers per million inhabitants at ambient air concentration of approximately 3 $\mu g/m^3$. Comparison of this value with reported immission data reveals that for people living in European cities the excess risk of leucemia caused by benzene immissions is greater than 10^{-5} at single locations even 10^{-4} can be exceeded. Immidiate actions to lower benzene immissions therefore are necessary in practically all member states of EEC. No information is available how many people live in the areas for which the high benzene immissions were reported. Therefore it is not possible to estimate how many excess leucemia cancers are expected to be caused by benzene immissions in the member states of the EEC.

Halogenated hydrocarbons

Quantitative health or cancer risks can be estimated for several of these chemicals. For the risk estimation 20 m^3 daily air intake and 50 % resorption are assumed:

1,2-Dichloroethane: 1.4 $\mu g/m^3$ correspond to a risk level of 10^{-5} /156/. According to /158/ an immission of 4.8 $\mu g/m^3$ corresponds to a risk level of 10^{-5}. The limited immission data reveal that people living in urban areas may be exposed to that risk. At heavily polluted locations even a risk level of 10^{-4} may be exceeded. Immidiate additional immission measurements are recommended.

Tetrachloroethene: 4.3 $\mu g/m^3$ corresponds to a risk level of 10^{-5} /156/. These concentrations are reached in urban air in Europe and in some locations exceeded so far that even risk levels of 10^{-4} are reached.

Tetrachloromethane: 6 $\mu g/m^3$ correspond to a risk level of 10^{-5} /156/. Only limited immission data are available. These data reveal, that people living in urban areas may be exposed to that risk level.

1,1,1-Trichloroethane: No adverse human health effects have to be expected by immissions of this substance.

Trichloroethene: 5.8 $\mu g/m^3$ correspond to a risk level of 10^{-5} /156/ Mean urban immissions are of the same magnitude. Reported peak values even correspond to risk levels greater than 10^{-3}.

Trichlormethane: 2.7 $\mu g/m^3$ correspond to a risk level of 10^{-5} /156/. Mean values in urban air are of the same magnitude; in heavily polluted areas even risk levels of 10^{-4} may be exceeded.

Vinylchloride: Direct adverse health affects have to be expected from vinylchloride immissions in the vicinity of industrial plants.

According to /156/ 44 µg/m^3, according to /59/ 0.35 µg/m^3 correspond to a risk level of 10^{-5}. As the data presented in /59/ are the more recent ones and in order to estimate conservative limit values it is recommended to use tentatively the figures from /59/. Therefore people living in urban areas in the FRG may be exposed to a risk level greater than 10^{-4}. Further immission measurements and research work is necessary in order to become able to estimate risks on a more reliable basis.

For the other chemicals of this group no risk estimations could be performed as either immission or toxicity data are missing. Nevertheless these chemicals can not be regarded as safe. Immission measurements and further research works are necessary in order to reveal their importance for air pollution.

According to the high health risk which is introduced by halogenated hydrocarbons further actions to reduce immissions are strongly recommended. Immidiate actions should be undertaken to reduce immissions of substances which correspond to a risk level of greater than 10^{-5}. For all other chemicals immidiate measures should be performed in order to evaluate their health risk level.

Fluorochlorohydrocarbons (FCKW)

There are no hints that these chemicals (except for monochlorodifluoromethane) will cause adverse health effects by direct exposure. The main health and environmental risk corresponding to these chemicals is their persistence under tropospheric conditions. The chemicals are transported to the stratosphere and will there reduce the ozone concentration. Lower ozone concentrations in the stratosphere will lead to increased UV radiation at the earth's surface. The risk of skin cancer and plant damages therefore would be increased. Although the alteration of the ozone concentration due to FCKW release may be small or even balanced by the effects caused by the release of other anthropogenic chemicals, the emission of fluorochlorohydrocarbons should be lowered and restricted as far as possible.

Ethers

No hazard assessment could be performed as too little data are available. Dioxane should be investigate primarely.

Ketones

No hazard assessment could be performed as not enough data are available. As this group contains no chemicals with high toxicity no adverse health effects are expected by direct exposure to these chemicals. But as these chemicals are used in large amounts in paint solvents they may cause adverse effects via their contribution to the formation of photooxidants.

Dibenzodioxins/furans

As no immission data are available it is not possible to assess the hazard which is caused by direct air exposure to these chemicals. If immission data are available an acceptable daily intake (ADI) of 1 pg/kg body weight is recommended /131/ for human health. Although it is felt that these chemicals do not directly cause air pollution problems, further immission measurements in the vicinity of potential emission sources are recommended. Health assessment of these chemicals has to take into account other routes of intake than direct air exposure. The distribution of these chemicals through the air seems to be the most severe problem connected with these chemicals.

PAHs

Hazard assessment of these chemicals has to take into account mainly their carcinogenity. Additionally PAHs are easily nitrated in the atmosphere. By that way for example Naphthalin is transformed to the strong procarcinogen 2-nitronaphthalene. Future immission measurements therefore should not only be performed for PAHs themselves but also for nitrated PAHs.

Assuming 20 m^3 daily air intake and 50 % resorption a tentative value of 2.5 ng/m^3 for a risk level of 10^{-5} can be derived from the data given in /156/ for benzo(a)pyrene. Estimating this value it was additionally assumed that health effects do no depend upon the kind of intake. As a conservative consumption it may be further assumed that all other carcinogenic PAHs are equally carcinogenic as BaP.

The reported immission data for PAHs reveal that risk levels of 10^{-4} frequently were exceeded for people living in urban areas. In heavily polluted areas even risk levels of 10^{-3} are exceeded.

Miscellaneous

Acrylonitrile: Acording to /61/ 0.37 $\mu g/m^3$, according to /156/ even lower concentrations correspond to a risk level of 10^{-5}. The very limited reported immission data reveal that risk levels of 10^{-4} can be reached in urban areas. Immidiate further immission measurements are recommended.

Neither sufficient immission nor toxicity data were available for the other carcinogenic chemicals in this group. Therefore no hazard assessment can be performed for these chemicals. Immission measurements are recommended at least for the carcinogenic substances.

5.3 Discussion

Whereas adverse health and/or environmental effects caused by anorganic emissions like SO_2 are well documented, little is known about hydrocarbon air pollutants. Adverse effects can be caused by the emitted hydrocarbons themselves or by their transformation products. Ozone, peroxyacetylnitrate and aldehydes at the moment are regarded as the most relevant transformation products. Additionally it is felt that nitrated transformation products will become more important in the future.

If hydrocarbon imissions and sun irradiance are high the air concentrations of these substances can become so high that they cause direct adverse health effects; such photosmog situations frequently occur in the Los Angeles area. In Europe photosmog situations are less important, the concentrations of the photooxidants do not reach so high concentrations that they create direct adverse health effects. But enhanced ozone concentrations measured in remote areas show that the yield of photooxidants is quite high in Europe, too, and that the photooxidants are distributed over large distances /74/. It seems that the formation of the total amount of photooxidants depends mainly on the emitted amounts of hydrocarbons and not on the rate of transformation. Therefore the emitted hydrocarbons and the photooxidants themselves and not the potential of hydrocarbons to contribute to photosmog situations has to be taken into account by hazard assessment.

Hazard assessment was performed only for hydrocarbons which are contained in the list of substances. Quantitative estimations were performed only if dose effect relations and immission data were available. Therefore if for a toxic and/or carcinogenic substance no such estimation was performed that does not mean that this substance cannot create severe adverse health effects. For the estimation of risk levels it was assumed that the exposure route inhalation is equivalent to other routes of intake. No attempts were made to estimate the additive risk caused by simultaneous exposure to various air pollutants. Higher risk levels valid for children or elder humans also were not taken into account. The reason for this neglect is that information about synergistic or antagonistic effects are not sufficient. No attempts were also made to estimate the real exposure of the populations. In order to perform such estimations indoor and outdoor immissions as well as information about the way of living of the population would be necessary. No attempts also were made to estimate the total number of additional cancers. For this estimation information about the geographical distributions of the hydrocarbon immissions and about the population density would be necessary.

The available data only show that local or regional hydrocarbon immissions in Europe are so high that people may be exposed to risk levels exceeding 10^{-4}. The risk levels estimated for the single hydrocarbons should be taken as rough indications of potential health and/or cancer risk. The ultimate aim of these estimations was to get criteria for priority setting. Taking these estimations into account we recommend the following measures:

1) Immidiate actions should be performed in order to reduce the emission of benzene, aliphatic and other aromatic hydrocarbons. Benzene occurs in the air of all European cities at such levels that many additional cancers are probably caused by that immissions. The other hydrocarbons are released in such high amounts that they are believed to contribute the largest part of direct air pollution and to the formation of toxic transformation products.

2) Immidiate actions should be performed in order to get better knowledge about the immission and toxicity of the following substances:

Formaldehyde
Acrolein
1,2-Dichloroethane
Trichloroethene
Tetrachloromethane
Acrylonitrile
Dichloroethene
1,1,2-Trichloroethane
1,2-Epoxypropane
Propyleneoxide
Vinylchlorid
1,2-Dibromoethane
Tetrachloroethene
Trichloromethane
Carcinogenic PAHs
Dichloromethane
Tetrachloroethane
Epichlorhydrine
Ethyleneoxide
Dibenzodioxins/furans

Additional actions in order to reduce the emissions should be performed if high amounts are emitted in single member states.

3) Further actions should be performed in order to get better knowledge about the immission and toxicity of the following substances:

Dibutyl phthalate
Acrylic acid
Acetaldehyde
Diethylhexyl phthalate
Formic acid
1,3-Butadiene

Carcinogenic Amines
Halogenated hydrocarbons if not mentioned under2)
Nitro-, chloro- and thioaromatics
1,4-Dioxane
Ketones

In the various member states priority can be given to different hydrocarbons. For priority setting the total emitted amounts in each country should be taken into account.

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6 - POSSIBLE TECHNIQUES FOR REDUCING THE EMISSIONS

6.1 - INTRODUCTION

The previous chapters have pointed out the large number of organic components and the complexity of the families of products involved. Contrarily to the other classical air pollutants such as SO_2, NOx, etc... for which the techniques of reduction are specific, for hydrocarbons the techniques are not specific : it can be only said that certain techniques are not well suited for some kind of products.

In the following of the chapter, the term "Volatile Organic Compounds" (VOC) will be used rather than "Hydrocarbons" because of the physical state of the products emitted into the air ; this physical state is essentially the gaseous one.

Different ways of reduction may be used :

a) Reduction of the use of Volatile Organic Compounds either in industrial processes or in household activities. The best example of this kind of actions is the lowering of the percentage of solvents in products such as paints or inks. For technical reasons, it is not always possible to reach the zero content of solvents.

b) Action on the process to avoid as far as possible the formation or the escape of VOC's. The best example is the case of firing hydrocarbon compounds (burners in boilers, internal combustion engines, etc...) ; a good combustion always reduces fuel consumption and the possibility of emitting unburnt compounds.

c) Fitting of devices on exhaust gases to separate and reuse or destroy VOC's. The most commun technologies are as follows :
   - Condensation is the transformation of a geseous phase into a liquid or solid phase followed by separation.
   - Adsorption uses a very porous substance such as activated carbon to separate specific molecules from the carrier gas.

- Absorption is the separation of specific molecules using the solvent properties of a liquid.
- Destruction of the molecules most often by action of oxygen :
  - . at low temperature : action of ozone
  - . at high temperature : combustion.

The choice of the best way of reducing the emissions of VOC's needs to know how these emissions occur in space and in time. We can distinguish two kinds of sources :

a) Channelled sources (pipes, stacks, etc...) on which it is theoretically possible to fit a device to separate VOC's before the dispersion into the atmosphere.

b) Diffuse and fugitive sources on which fitting such a device would be too difficult and for which a general means of reducing emissions is to reduce, as far as possible, the presence of VOC's in the process.

The present chapter presents the techniques used for separating and reusing or destroying VOC's. Some particular examples will be choosen in the oil industry in oder to make clear that even in difficult cases, solutions may be found and applied.

This chapter will not present the first way of reducing the emissions of VOC's, reduction of the use of organic compounds. Nevertheless one has to say that this mean is certainly the most satisfactory but the difficulties encountered explain that this solution is not at short term ; this solution can only be generalized progressively. For instance the decrease of the content of solvents in paints, or even the use of water-base solvents, bang against the resistance and the traditions of some professionals and of the public. In the printing industry, things are more complicated because the new formulations of inks with low content of solvents will oblige to modify the speed of printing and sometimes to change the machines themselves. Manufacturers of inks and paints have made great progresses during the last 15 years by developping new products ; they consider that, for the time beeing, the decrease of the mean content of solvents in their products is in average of some percent per year. A lot of work has yet to be done and a particular and difficult study would be necessary for evaluating precisely the ways of development and the chances of succeeding at the technical, economical and legal point of view

6.2 - COLLECTING, CONFINING AND REDUCING EMISSIONS

According to the type of source as defined above, it will be necessary firstly to collect emissions of VOC (if possible) and after to treat them in order to reduce the flux into the atmosphere. Sometimes, confining is substituted to collecting so as to avoid VOC's escape out of a storage.

In the field of VOC emissions, the main activities for which it is, or it would be, necessary to collect the emissions are as follows :

- Gasoline and diesel fuel handling and tank filling in service stations
- API separators on oil refinery water effluents
- Discharging of coke and leaks at the doors of coke ovens
- Degreasing and dry cleaning
- Coating of surfaces such as :
  - . painting
  - . printing
  - . manufacture of coated fabrics and calendered plastic sheets
- etc...

Collecting pollutants is not so easy as it seems. The geometrical shape of the machinery and the need for workers to physically reach the different parts of the system makes necessary the presence of large clear spaces between the machinery and the collection device. In these spaces, large amounts of air are circulated, but often the fans are undersized and VOC's escape out.

Many industrialized countries have published, mainly for occupational health reasons, documents to give advices to operators on good engineering practice for collecting diffuse and fugitive emissions by hoods, canopies, etc...

6.3 - CONDENSATION

Condensation is an operation in which one or more volatile components of a vapour mixture are separated from the remaining vapour by conversion to a liquid phase. Condensation is accomplished by reducing the temperature of the vapour mixture, by increasing pressure or both.

Figure 6.1 shows a classical condensation device. The absence of oxygen allows higher concentrations of VOC's than those allowed in a conventional thermal destruction. Gaseous nitrogen is used to provide inert atmosphere and liquid nitrogen is employed as a coolant.

The use of inert gas condensation obliges to operate with processes isolated as well as possible from outside air, dust and moisture. Sealing is generally accomplished by using nitrogen gas curtains. This sealing device limits the application of condensation control.

Condensation is technically limited to sources which emit waste gases with relatively high solvent concentrations [> 25 % L.E.L. (*)]. At low concentrations the condensation temperature required is unfeasibly low. Efficiencies as high as 90 to 99 % are achievable according to the kind of organic compound. Inert gas condensation saves energy because good sealings and high concentrations avoid handling and heating of large volume of dilution air.

Condensation is now a promising technology in many particular processes due to the improvement of heat exchangers and of cooling devices.

6.4 - CARBON ADSORPTION

Carbon adsorption removes VOC emissions from a waste gas stream by adsorption of the VOC's on the surface of activated carbon. The VOC's are subsequently desorbed. An order of magnitude of the capacity of adsorption is of 5 to 20 g of VOC's per 100 g of activated carbon.

There are two basic designs of carbon adsorbers : fixed beds and fluidized beds, but in simplified installations, it is possible to operate with non reusable carbon (elimination of very little concentrations of odorous compounds).

6.4.1 - FIXED-BED CARBON ADSORPTION (figure 6.2)

There are always at least two adsorbers. The adsorbers are cyclicly in and out of duty resulting in each adsorber operating in a batch mode. The modes include an adsorption cycle and a desorption or regeneration cycle.

During the adsorption cycle, as the capacity of the carbon bed to retain VOC's is depleted, the exiting VOC concentration begings to rise. This is called the "breakthrough point" and indicates that the carbon is at the limit of saturation ; then the flow is switched into the second adsorber.

The regenerative cycle is designed to desorb most of the retained VOC's and regenerate the carbon bed by :
- thermal regeneration,
- low pressure/vacuum regeneration.

(*) Low Explosivity Limit

Thermal regeneration may be accomplished using steam or another hot gas such as air. The steam and VOC mixture is routed to a recovery system where the steam/VOC mixture is condensed prior to separation.

Low pressure/vacuum regeneration is operated in adsorbers with an external jacket. Firstly, steam is directed through the vessel jackets to heat the carbon indirectly (at least 10 to 15°C above the VOC adsorption temperature). Vacuum is then applied to the hot carbon to remove VOC's which are then cooled and condensed with no further recovery treatment required.

Modern systems may achieve 99 % VOC removal efficiency with exit concentrations less than 20 ppm VOC's. However, as the carbon becomes older, the efficiency may decrease.

6.4.2 - FLUIDIZED-BED ADSORPTION (figure 6.3)

This is a continuous process. Adsorption and desorption occur simultaneously in a single vertical vessel. As the VOC waste gas flows upward in the adsorber, it contacts the activated carbon in the adsorption section and the VOC's are removed. The clean gas exits through the top of the vessel while the carbon beads containing VOC's continue down to the regeneration section where the carbon is indirectly heated with steam or other heating medium. The VOC's are then stripped off the carbon by direct contact with steam or another hot gas such as nitrogen. The VOC vapour mixture exits through the desorption section and is condensed. When nitrogen is used, no further VOC recovery treatment is needed.

The fluidized bed process offers a lower energy consumption than a fixed bed design, however the capital investment is higher.

Efficiencies are of the same order of magnitude as for the fixed bed.

6.5 - ABSORPTION

Gas absorption is an operation in which one or more components of a vapour mixture are separated from the vapour by intimate contact with a liquid absorbent. Phenomena involved are mainly physical ones, such as dissolving ; but sometimes, chemical reactions may be imagined, but it is rather rare. Solid absorbants do exist too ; they are different from activated carbon which operates by physical surface phenomena, whereas solid absorbents operate by volumic chemical phenomena.

A particular mention has to be made of the biological action. In F.R.G., U.K. and FRANCE particularly, studies were carried on the destruction of odours by biological action, biological washing (biowäscher in F.R.G.) or biological beds (solid absorbent made of fern and of heath).

The most developped technologies are liquid washers but, for the time beeing, there is not a big lot of accomplishments. The use of biological solid absorbent is still in the R and D phase but some realisations are in operation on particular processes (casting of pig iron or painting).

There are two basic designs of absorbers with liquid used for the control of VOC emissions :
- Packed columns (figure 6.4)
- Plate columns (figure 6.5).

The comparison to packed column and plate columns may be summarized as follows :

- Packed towers :
  - . less expansive than plate towers when materials of construction must be corrosion resistant.
  - . smaller pressure drop than plate towers.
  - . packed towers are preferred in sizes up to 2 feet in diameter if other conditions are nearly equal, except if particular conditions dictates another choice.
- Plate towers :
  - . plate towers are preferred when the liquid contains suspended solids since plate towers are more easily cleaned.
  - . they are more suitable when the process involves appreciable temperature variations ; expansions and contractions due to temperature changes may crush the tower packing.

The absorbent liquid is generally water but sometimes hydrocarbon oils can be used due to their ability to dissolve some VOC's. The desorption operations are not very simple because the residual organic concentration in the liquid must be extremely low for the reuse of this liquid.

6.6 - DESTRUCTION OF VOC MOLECULES BY OZONE

This technique consists on selectively oxidizing at ambiant temperature the VOC molecules in blend with components considered as less odorous or less noxious. There is no destruction of the molecule but only chemical transformation.

This technique is expensive and only used on small flow rates (less than some thousands of m^3/h) such as odorous emissions. The odour reduction is effective but we don't know exactly if this reduction is actually due to a chemical transformation or to the inhibition of olfactive cells.

The efficiency of ozone is much less critical in water phase where washers with injections of micro-bubbles of ozone have proven their interest in problems of odour.

6.7 - DESTRUCTION BY INCINERATION

Incineration is the oldest way for eliminating odorous or noxious molecules. Most of these molecules are constituted mainly by carbon and hydrogen which give carbon dioxide (CO_2) and water (H_2O) :

$$CmHn + (m + \frac{n}{4})O_2 \longrightarrow mCO_2 + \frac{n}{2} H_2O$$

Other molecules contain atoms such as S, P, O, N, etc... which, by burning, produce principally SO_2 and SO_3, P_2O_5, NO and NO_2 ; these molecules may be considered as secondary pollutants.

Three conditions are needed for obtaining a complete incineration :

a) The amount of oxygen has to be sufficient to achieve a total oxidation of VOC's. VOC's are more or less concentrated. One could believe that rich gases with high heat content are rare. In the reality, they are frequently encountered (oil and petrochemical industry, steel industry, etc...) and used in boilers (as non commercial fuels), as if they were regular fuels.

b) The oxidation reaction has to be started. Two solutions are possible :

- thermal combustion : the temperature of the mixture (VOC's + O_2) has to be at least equal to the auto-ignition temperature.
- catalytic combustion : catalysts are substances which can help the ignition of the mixture without being directly involved in the chemical reaction ; in catalytic combustions, catalysts contribute to decreasing the auto-ignition temperature.

c) The transformation has to be complete. The problem is to ensure a residence time compatible with the related temperature, so as to be sure to oxidize the totality of the combustible molecules.

6.7.1 - THERMAL INCINERATION

Technologists often distinguish rich gases, intermediate gases and poor gases at the heat content point of view.

Rich gases are those of which heat content is more than 20 MJ/m^3N ; combustion is possible without any additional fuel. Figure 6.6 presents a standard equipment for firing rich gases such as: H_2S, glycol, etc... The combustion head is surrounded by a mouth in refractory materials to stabilize the flame.

Intermediate gases (4 to 20 MJ/m^3N) may be burnt as rich ones but with special equipment. Figure 6.7 presents such a burner ; the mouth around the combustion head is much more elaborate than above to provide a good stability of the flame.

Poor gases (< 4 MJ/m^3N) : an additional fuel is always necessary. This fuel may be liquid or gaseous (figure 6.8) ; in this latter case, the mixing of the poor gas and of the rich gas can be obtained before being burned in a special device (figure 6.9).

In the case of gases with heat content less than 4 MJ/m^3N, VOC's can be considered as trace elements and the additional fuel becomes the main fuel used to increase the temperature of the gases up to the conditions of thermal destruction of the VOC's.

Gaseous effluents are always burned in devices equiped with heat recovery systems :

- boiler or other heat production system
- heat exchanger to increase the temperature of the incoming air to the burner.

But this heat recovery needs a constant or not too variable flow rate of the gaseous effluents. For instance oil industry produces rich gases of which flow rate is very variable ; heat recovery is sometimes not possible and incineration is operated in particular flares (low level flares) with natural induction of air (figure 6.10).

The incineration efficiency is defined as :

$$E = \frac{(Cvoc)inlet - [(Cvoc)outlet + (\Delta CO)]}{(Cvoc)inlet}$$

C = concentration of VOC's

ΔCO = difference of carbon monoxide concentrations between inlet and outlet.

This distinction is due to the fact that the chemical equilibrium :

$$CO_2 + C \rightleftharpoons 2\ CO$$

depends on the temperature ; if the temperature is not high enough, CO could be formed and the interest of the incineration could be greatly reduced.

The efficiency of a thermal incineration depends on three variables : temperature, turbulence and duration of the reaction (sometimes called "3 T" rule : Temperature-Turbulence-Time).

a) Temperature :

Figure 6.11 presents the relationship between destruction efficiency and temperature for five industrial cases :

- wire enamelling ovens (1 000 - 2 000 ppm hydrocarbons in inlet : residence time = 0,2 - 0,6 s).
- gum drying oven.
- plastic coating machine.
- coil coater (3 000 ppm hydrocarbons in inlet).
- metal coating oven (3 000 ppm hydrocarbons in inlet ; residence time = 0,3 s).

These high temperatures need, in most cases, well suited materials and result in high operating costs.

Figure 6.12 shows, for an hypothetical VOC, efficiency related to temperature. Naturally when we have a mixture of VOC's, the temperature of incineration has to be the one for which the most stable VOC is destructed.

b) Turbulence :

In order to get a maximum efficiency, it could be necessary to raise the temperature of all the VOC molecules of the gas to their auto-ignition temperature. Two ways are possible (figure 6.13) :

- to achieve a homogeneous distribution of the flame in all over the section of the combustion chamber.
- after a unique burner, to operate a strong mixing of the hot gases.

In these two cases the aim is to achieve a good homogeneïty of the temperature profile. Naturally, the mean temperature has to be higher than the auto-ignition one.

c) Time of residence :

The reaction of thermal destruction of VOC's is not immediate (fig. 6.12);

it generally needs duration as long as 0,5 to 1 second or more at the destruction temperature in a so called "reaction chamber". The speed of gases in this reaction chamber is often less than 12 m/s for a time of residence of 1,5 to 2 seconds (often recommended), the length has to be as great as 18 to 24 meters which is actually considerable and not always complied with.

Figure 6.14 presents the "ideal" incineration installation :
- homogeneïty of the temperature profile
- temperature compatible with the efficiency of destruction of the most "stable" VOC encountered
- long time of residence
- heat exchanger eventually designed in consideration of corrosion problems
- measurement of temperature at the end of the reaction chamber.

6.7.2 - CATALYTIC INCINERATION

As in thermal incineration, catalytic incineration is the more or less complete oxidation of hydrocarbons. The general feature of a catalytic incinerator includes the following devices :
- preheater burner
- mixing chamber
- catalyst bed
- heat recovery equipment

The incineration efficiency is defined as follows :

$$E = \frac{(\mathrm{Cvoc})\mathrm{inlet} - [(\mathrm{Cvoc})\mathrm{outlet} + (\Delta \mathrm{CO})]}{(\mathrm{Cvoc})\mathrm{inlet}}$$

The considerations on the formation of CO are the same as for the thermal incineration.

The efficiency of catalytic incineration depends on three variables : Temperature, Turbulence and Duration of the reaction (sometimes calles "3 T" rule : Temperature-Turbulence-Time) in the thermal incineration.

a) Temperature :

As for thermal incineration, temperature affects the performances of a catalytic incinerator. The following values give the temperature required for a 90 % conversion :

COMBUSTIBLE	IGNITION TEMPERATURE °C		LOWER L.E.L. (*)
	Thermal	Catalytic	
Benzene	580	302	1,2
Toluene	552	302	1,2
Xylene	496	302	1,7
Ethanol	392	302	3,5
MIBK (Methyl Isobutyl Ketone)	459	349	1,2
MEK (Methyl Ethyl Ketone)	515	349	1,8
Methane	632	500	5,3
Carbon monoxide	609	260	12,5
Hydrogen	574	121	4,0
Propane	481	260	2,4

(*) Lower Explosive Limits

These temperatures are well below those required for thermal incineration. Nevertheless a burner is required to reach this level of temperature. If VOC concentration is sufficient, heat combustion is used to maintain the adequate temperature : in this case the burner could be used only for starting the reaction of oxydation. However, plant safety regulations require waste gas combustions to be below 25 % of Lower Explosive Limits (L.E.L.) ; even with this constraint, low energy use and high VOC destruction efficiencies are achievable.

b) Turbulence :

The gases to be incinerated have to be regularly distributed all over the surface of the catalyst and at the adequate temperature. Creation of turbulence or a homogeneizing device is necessary between the burner and the catalyst. The techniques used are fairly the same as in the thermal incineration.

c) Duration of the reaction :

The time the gas spends in the catalyst bed also determines abatement efficiency. The volume of the catalyst in turn determines the physical size of the system and the pressure drop through it.

The relationship between percentage conversion fc, catalyst volume Vcat and gas flow rate Vgas at a fixed operation temperature can be obtained as follows :

$$- \ln(1 - fc) = K_e \frac{Vcat}{Vgas}$$

The constant $Ke(s^{-1})$ is somewhat complicated and combines the rates of a complex series of surface and diffusional processes.
The ratio Vgas/Vcat(s^{-1}) is called space velocity.

The conclusion is that the volume of catalyst is an important variable : 50 % more catalyst is required if removal efficiency has to be raised from 90 % to 97 % for the same flow rate.

d) Kind of catalyst :

The brief discussion above shows the need to derive maximum performance from each unit volume of catalyst which means increasing the available surface of active catalyst material.

Various types of catalyst exist :
- Metal strips
- Spherical pellets
- Ceramic rods
- Ceramic honeycomb
- Metal honeycomb

	ADVANTAGES	DISADVANTAGES
Metal strips	Low pressure drop High surface/volume	Less active than ceramic supported catalyst
Spherical pellets	Can be used in both fixed and fluidized beds	High pressure drop Attrition problem
Ceramic rods	Low pressure drop	Low surface/volume
Ceramic honeycomb	Low pressure drop High surface/volume	May have non-uniform catalyst coating
Metal honeycomb	Low pressure drop High surface/volume High mechanical strength	Less active than ceramic supported catalyst

Precious metals, typically platinum and palladium, are usually preferred over non precious metals because precious metals generally allow lower operating temperatures and higher space velocities for a given destruction efficiency.

The knowledge of the composition of the VOC waste gas stream is necessary in order to design the proper catalyst within the catalytic incineration system.

e) Poisoning of the catalyst :

The presence of particulates or catalyst poisons in the waste gas stream may have a severe effect on the catalyst and on its performances. It is generally recommended that the maximum particulate concentration does not exceed 0,1 mg/m^{3}N. The table 6.1 lists several poisons and masking substances and their effects.

The figure 6.15 presents the features of an "ideal" incineration installation :

- Homogeneity of the field of temperature before the catalyst
- Temperature at the inlet of the catalyst compatible with the efficiency of destruction of the most "stable" VOC encountered
- Sufficient volume of the catalyst
- Gas stream without particulate and poisons
- Heat exchanger
- Measurement of the temperature at the inlet and at the outlet of the catalyst.

6.8 - TECHNICAL COMPARISON (2)

Four points of view may be considered :
- environmental and energy considerations
- state of development
- applicability
- operation and maintenance requirements.

Only the three following technologies will be examined : carbon adsorption (fixed-bed), catalytic incineration and thermal incineration (with recovery and regenerative heat exchange). The remaining technologies do not present sufficient data for a good comparison.

6.8.1 - ENVIRONMENTAL AND ENERGY CONSIDERATIONS

Table 6.2 presents a summary of the four possible technologies. These technologies present identical overall potentials for VOC's removal of 95 % or more. They all prevent any possibility of secondary air pollution.

6.8.2 - STATE OF DEVELOPMENT

All these four technologies have been used to control VOC emissions in large number of industries. All are widely available on the commercial market.

6.8.3 - APPLICABILITY

We focus our attention on the limitations and technical constraints of each technology. Table 6.2 presents a summary of these considerations.

6.8.4 - OPERATING AND MAINTENANCE REQUIREMENTS (O/M)

O/M considerations include a variety of concerns relating to the day to day operation of a control device. These concerns are very numerous, such as :
- severity of duty (corrosion for instance)
- characteristics of the emission stream (particulates, poisons, etc...)
- availability of trained technical personnel familiar with O/M of the type of device installed
- use of preventive maintenance approach to O/M
- location of equipment (outside, etc...)
- quality of original equipment and spare parts.

Table 6.3 summarizes the O/M comparison for each of these categories.

6.9 - ECONOMIC COMPARISON

In the past, many studies were made on this subject. These studies generally suffer of the following shortcomings :
- lack of precision
- uncomplete definitions
- lack of information on the basic technical and economic data (gas flow rate, efficiency, cost of energy, cost of products, depreciation time, etc.)
- etc...

It actually seems that such a study is impossible, especially since all considerations on costs (capital costs, annualized capital charges and direct operating and maintenance costs) have to take into account other technical considerations (see § 6.8) which cannot be estimated at the economic point of view.

The most recent study has been made by VDI - Kommission Reinhaltung der Luft (Verein Deutscher Ingenieure) in DM of 1982. This study presents six cases which can be summarized as follows : (1)

FLUE GAS m^3/h	CAPITAL COST 10^6 DM	HOURLY COST DM/h	PROFIT DM/kg of solvant recovered	SPECIFIC COST DM/1 000 m^3
CASE A 3 600 Condensation	1,35	114	0,32	32
CASE B 5 000 50 000 Adsorpt. activ. carbon	0,20 0,59	35-40 115-175		7-8 2,3-3,5
CASE C 2 280 Adsorpt. activ. carbon			0,3	
CASE D 90 000 Absorption water	3		0,48	6,4
CASE E 130 000 Absorption Biological washer	2,02	220		1,69
CASE F 10 000 Thermal incineration	0,54	80-88		8,8

6.10 - SPECIAL TECHNOLOGIES

Among the activities emitting VOC's, some require particular technologies to reduce emissions, especially in oil industry.

Oil industry is characterized by channelled emissions (combustions) but also by diffuse and fugitive emissions :

- flares
- leakage in pipes

- storage of liquid hydrocarbons
- handling of liquid hydrocarbons
- API waste water separators

The vapour pressure of the liquids manufactured and handled in oil refineries and in commercial distribution networks are very different :

Iranian crude oil	# 0,5	bar at 37°C
Gasoline for vehicles	0,65	bar at 37°C (summer)
	0,8	bar at 37°C (winter)
Kerosene	0,05	bar at 37°C
House heating oil	< 0,001	bar at 37°C
Heavy fuel-oil	< 0,001	bar at 100°C

6.10.1 - LEAKAGE IN PIPES

The great number of valves (3 or 4 000) and of compressors and pumps (100 - 200) in a normal oil refinery needs a watchful survey and maintenance of the gaskets, not only for environmental reasons, but mainly for safety reasons, not forgetting energy conservation.

The main action to reduce these leakages is by following a regular procedure of survey (using portable hydrocarbon detectors) and of maintenance. Exhaust valves are connected to a collecting pipe directing gaseous hydrocarbons to the flare. Often these gases are compressed so as to be used as fuel in furnaces and boilers.

6.10.2 - STORAGE TANKS

In oil refineries, the storage of liquid products is made in cylindrical tanks of :

- 50 000 to 100 000 m^3 for crude oil
- 10 000 to 20 000 m^3 for light and middle distillates.

By emptying and filling fixed roof tanks, the inside air saturated of hydrocarbons is ejected outside. For instance, if a tank of 20 000 m^3 full of gasoline (0,8 bar at 37°C) is emptied, the hydrocarbon emission is approximately 50 t.

To avoid the presence of air saturated with hydrocarbons above the surface of the liquid, the tanks are of floating roof type ; the roof is a mobile disc floating on the surface. A good design of the seal system to secure a good tightness is necessary (figure 6.16).

Floating roofs are commonly used for crude oil and for gasoline.

For some products, such as kerosene, the floating roof is to be switched to an internal floating screen inside a fixed roof tank. These screens may be retrofitted to existing fixed roof tanks.

A good quality floating roof or floating screen may reduce emissions up to 80 to 85 % and even more with double seals on roofs.

Other improvements may be achieved for reduction of emissions by ensuring a good maintenance of valves and by painting tanks with light colours.

6.10.3 - GRAVITY SEPARATORS ON WASTE WATERS

Process waters used in an oil refinery are more or less polluted by liquid hydrocarbons. These waters are generally collected in a large settling pond where water and liquid hydrocarbons separate by gravity ; hydrocarbons are lighter than water, they gather on surface where they are in contact with the atmosphere on, sometimes, very important areas.

Emissions depend :
- on the volatility and on the quantity of hydrocarbons arriving in the pond,
- on the ambient temperature.

In the past this emission represented, may be, 25 % of the total emissions of the oil refineries. Three kinds of actions are able to reduce the emissions :

- treating water pollution before entering the pond (reduction of emission up to 80 %),
- covering with fixed roof with suction of hydrocarbon vapours and incineration ; the efficiency is of 60 to 70 % but the cost is very high,
- recovering of liquid hydrocarbons on the surface of water by different mechanical systems such as oleophilic rotating drums ; this technique offers the advantage of recovering oil with low percentage of water ; the investment cost is barely 25 % of the covering solution. The efficiency is of 70 to 90 % of reduction.

6.11 - CONTROL OF VOC's FROM VEHICLES

Motor vehicles are an important source of VOC's, mainly gasoline engines. The sources of VOC's are : crank case, exhaust emissions and evaporative emissions from the fuel tank and carburator.

Four kinds of actions may be applicable :

- improvement of conventional engines,
- motors with high compression ratio and high air/fuel ratio,
- stratified charge engines,
- catalytic post-combustion or thermal reactor.

This classification has been used by the E.R.G.A. working group on Air Pollution created in january 1982 by the Commission of the European Communities in order to establish the technical elements for the development of the regulations.

6.11.1 - IMPROVEMENT OF CONVENTIONAL ENGINES

Figure 6.17 presents the relative concentrations of pollutants related to the air/fuel ratio at a given rotation speed.

By operating at high air/fuel ratio in order to reduce the emissions of CO and of HC, the emissions of NOx are maximum. These emissions can be reduced by adjusting both air/fuel ratio and injection setting, but the effects are limited by problems of instability of combustion and increase of the fuel consumption. On the other hand, mechanical devices for carburizing and for ignition are subject to wear or out of tuning. Then it is necessary to act on other parameters, such as :

- geometrical characteristics of the engine :
  - reduction of the surface/volume ratio of the combustion chamber to avoid the tampering effect,
  - reduction of the compression ratio

- fuel filling of the cylinders :
  - improvement of carburettor (multiple bodies with simultaneous or differential openings, constant depression, etc...). Research is now in progress to electronically drive the air/fuel ratio.
  - mechanical or electronical injection of fuel are good solutions to reduce fuel consumption or emission of pollutants, but the cost is high.

- design and heating of the admission pipe.
- recirculation of exhaust gas (EGR) back into the intake system is used for the control of NOx through reduction of the peak combustion tempara-ture. The exhaust gas acts as an inert diluent. However to attain low enough NOx emission levels, loss of fuel economy is so great as to make the use of EGR alone unattractive.

- ignition device

More and more vehicles are now equiped with totally electronical ignition. Increasing the duration of the spark (1,5 to 3 m/s) produces a reduction of the NOx emissions and allows operating with higher air/fuel ratio. More recent researches have led to electronically driving both ignition and injection.

- "swedish concept"

This particular technology permits to comply with the swedish regulation (identical to the US regulation of 1973) without too much modifications, unjustified by the smallness of the market.

This technology involves heating of the admission air, accelerated idling, introduction of air in the exhaust pipe to burn HC and exhaust gas recirculation (EGR). Measured with the European cycle, emissions of HC and NOx are lower than the limits of the regulation but the emissions of CO are higher and the consumption of fuel is also increased.

The ERGA working group admitted that if this technology could be optimized with the European cycle, the emissions of the three pollutants could be lower than the actual regulation and the increase of the consumption lower than 4 %.

6.11.2 - MOTORS WITH HIGH COMPRESSION RATIO AND HIGH AIR/FUEL RATIO (H.C.L.B. (High Compression Lean Burn).

Recent researches showed that by using a compact combustion chamber in which turbulence is controlled, it is possible to provide a compression ratio of 13:1 without knock and an air/fuel ratio less than 0,8. The emissions of CO and NOx are reduced but the emissions of HC are increased.

This kind of engine needs a particularly high level of machine finishing and also needs the use of electronic ignition and optimization of carburettor, admission pipe and/or injection.

The consumption could be reduced by 15 %, but it seems unlikely that emissions of HC and NOx could be reduced enough ; a post-combustion system (thermal or catalytic) would be necessary.

This kind of engine needs high octane ratio gasoline.

6.11.3 - STRATIFIED CHARGE ENGINES

The stratified charge consists on using a low air/fuel ratio around spark-plug and a high air/fuel ratio in all other parts of the combustion chamber.

6.11.3.1 - Engine with prechamber

Instead of having a conventional spark-plug, the combustion chamber is equiped with a small chamber with its own spark-plug. The function of the "torch" shooting from the prechamber is to ignite a lean, homogeneous mixture in the main chamber. The prechamber mixture, which is usually fuel rich, may be formed by a separate carburettor or by fuel injection. The volume of the prechamber is usually 5 to 15 % of the total volume of the main chamber. These engines are also known as "small volume prechamber engines" (HONDA), "three-valves prechamber engines" and "jet-ignition engines" (figure 6.18).

The C.V.C.C. engine (C.V.C.C. = Compound Vortex Controlled Combustion), developped by HONDA met the US 1977 emission standards with a small lean thermal reactor but without catalytic reactors, air injection, or exhaust gas recirculation, with little deterioration at 80 000 km.

The reduction of the NOx emissions is due to the lowering of the temperature, however this lowering is limited in order to burn HC.

An Engine with direct injection in the prechamber has been studied by VOLKSWAGEN (prototype PASSAT).

6.11.3.2 - Engine with divided chamber

When the volume of the prechamber increases, the motor is named "divided chamber". The characteristics are those of an engine with prechamber and direct injection. This technique has been studied by FORD.

6.11.3.3 - Open-chamber engines

This kind of engine uses a single combustion chamber with a direct fuel injection. In many aspects, they are similar to diesel engines, but they are spark-ignited (FORD-PROCO and TEXACO-T.C.C.S.). The most notable feature of these engines is their superior fuel economy, which approaches that of diesel engines. Adequate control of hydrocarbon and carbon monoxide emissions requires the use of an oxidation catalyst.

6.11.4 - POST-COMBUSTION

When modifications of engine structure are not sufficient to comply with regulations, the use of external devices is necessary. Two kinds of techniques do exist :

- thermal reactor
- catalytic reactor

6.11.4.1 - Thermal reactor

Thermal reactors require excess oxygen and high temperatures (> 700°C) to ensure efficient oxidation of hydrocarbons and carbon monoxide.

When thermal reactors are on engines with low air/fuel ratio, air injection is necessary ; the high temperatures provide a good combustion efficiency (for instance 85 % with a temperature of 800°C).

Many lean-burn engines include a simple thermal reactor, often no more than a somewhat enlarged thermally insulated exhaust manifold. Because of the lower exhaust temperatures of lean-burn engines, thermal reactor performance is limited, but usually adequate to give approximately a 50 % reduction in HC's. Since the introduction of the oxidation catalyst, thermal reactors are now found primarily on rotary, lean-burn and stratified-charge engines.

6.11.4.2 - Catalytic reactor

There are four general catagories of catalytic reactors for emissions control :

- oxidation catalysts

  Noble-metal catalysts, which contain platinum, palladium, and/or rhodium supported on pellets or monolithic substrates, have been demonstrated to meet hydrocarbon standards (0,25 g/km) and CO standards (2,1 g/km) for 80 000 km.

Oxidation catalysts operate at lower temperature than thermal reactors and, therefore, effectively decouple emission control from engine performance, allowing the tuning of the engine for improved fuel economy.

Noble metal oxidation catalysts have demonstrated durability for at least 80 000 km under controlled test conditions. They are deactivated by the presence of compounds containing Pb, Br, P. Early problems with cracking, burnout and attrition, appear to have been minimized through improvements in ignition systems and catalyst packaging. Total ignition failure at speeds above about 80 km/h is likely to result in reactor temperatures sufficiently high to deactivate the catalysts permanently or to damage its substrate and/or container.

Oxidation catalysts essentially eliminate the emissions of polynuclear aromatics (PAH), olefins and partially oxidized compounds, such as phenols, aldehydes and mercaptans. These hydrocarbons are eliminated to a much greater extent than total hydrocarbons. By requiring the use of unleaded gasoline to prevent catalyst poisoning, there will be a decrease in particulate emissions attributable to lead.

- <u>Reduction catalysts</u>

Reduction catalysts wihich are usually simply copper or steel shavings require a fuel-rich mixture and, therefore, suffer a fuel economy penalty, although this may be minimized by operating only slightly to the fuel-rich side of stoichiometric. Therefore, reduction catalysts cannot be used for oxides of nitrogen control on engines that produce fuel-lean exhaust products (lean-burn, stratified-charge and diesel engines).

Air/fuel ratio must be controlled carefully for satisfactory operation of these catalysts. Reducing an atmosphere too much will lead to the formation of ammonia, and inadequately reducing an atmosphere will prevent the reduction of oxides of nitrogen. Excessively lean transients must be avoided when the catalyst is at operating temperature, as they lead to excessive temperatures and potential catalyst failure. In some systems an upstream oxidation catalyst or thermal reactor is employed to protect the reduction catalyst from escess oxygen.

- <u>Dual catalysts</u>

Dual catalysts also require precise air/fuel ratio control. In one configuration, a reduction catalyst followed by an oxidation catalyst is used.

In another, an additional small, noble-metal catalyst is provided upstream of the reduction catalyst. Still another system uses a rich thermal reactor followed by a reduction catalyst, which in turn is followed by a second thermal reactor. During start-up, air is injected upstream of the reduction catalyst, which, during start-up, acts as an oxidation catalyst.

- Three-Way catalysts

Simultaneous control of all three pollutants in a single catalytic converter is possible, but air/fuel ratio control precise to about 0,5 % and an oxygen-sensor feedback-control are required. Several manufacturers now have sensors which can be guaranteed for 20 000 km or more (80 000 km). Most three-way catalysts contain noble metals : platinum, rhodium and, possibly, ruthenium.

Prototype systems using a three-way catalyst, an oxygen-sensor feed-back-control and each of three different mixture-control systems : electronic fuel injection, mechanical fuel injection, and electronic carburation have shown good fuel economy and driveability. The most significant problem impeding this technology is the assurance of catalyst durability.

6.11.5 - CONTROL OF THE EMISSIONS OF DIESEL ENGINES

The limitation of particulates emissions needs using a trap filtering the engine exhaust. A honeycomb ceramic core is the heart of the trap. The core is treated with a special coating that acts as a catalyst and burns or oxidizes the particulate matter. Disadvantages appear to be the cost of the trap and the reduction of both power and fuel economy by about 8 %.

The best way for reducing the particulates emissions is the control of the injection and of the combustion. In the past regulation of the visible smoke became effective. The abatement of smoke has also a positive effects on the VOC emissions.

6.12 - DISCUSSION AND CONCLUSIONS

6.12.1 - STATIONARY SOURCES

Many abatement techniques are now available. Theoretically each technique could be used for any activity emitting VOC but it is interesting to precise the most commonly used techniques in the activities as listed in the chapter 3 on the emissions (table 3.1).

	Condensation	Activated carbon	Absorption	Thermal incineration	Catalytic incineration	Other techniques
Petroleum refineries				+		
Storage						Floating roofs
API (Gravity separators)						Recovering of liquid HC
Chemical and petrochemical industry	+	+	+	+	+	
Coke manufacturing						Well design and maintenance
Fermentation			+			
Industrial use of solvents	+	+	+	+(1)	+(1)	Decreasing of solvent content in the products
Non-industrial use of solvent						Decreasing of solvent content in the products
Fuel combustion						Good combustion
Waste disposal				+	+	Good combustion

(1) Except for chlorinated solvents.

6.12.2 - MOBILE SOURCES

Only two techniques are promizing :

- 3-way catalyst and feedback fuel dosage with a lambda-sonde,
- lean-burn engine and oxidation catalyst to reduce HC emissions.

The first system is popular nowadays in the USA. Expectedly it will be aplplied in Europe for larger engines. Especially when emission-limitation will proceed quickly, it can be expected that manufacturers will choose this principally well-known solution. The second system will be attractive for smaller engines in cheep automobiles. The introduction of this system will possibly need more time.

A possible interim-solution, nowadays in use for small vehicles in the USA and Japan, is NOx-reduction by application of a rich fuel-air mixture and

and HC (and CO) reduction with an oxidation catalyst. This solution has a higher fuel consumption as a consequence but might result in a HC-reduction comparable to the combination of a poor mixture (lean-burn engine) and an oxidation catalyst.

The following estimated emission factors can be given for the two systems mentioned by ERGA (g/km) :

	Oxidation catalyst		3-way catalyst
Urban	0,7	...	0,55
Local	0,1	...	0,2
High ways	0,1	...	0,2

It is taken into consideration that on the average the oxidation catalyst is less effective in urban traffic. The factors apply to actual emissions of series-vehicles. Conversion from test-conditions to in-use conditions is not necessary since the activity of the catalyst within the relevant range is hardly sensitive to the HC-concentration with which it is fed.

Another aspect is the possible increase of emissions by ageing of the vehicle. As far as ageing of the engine is concerned there will not be much effect. The feedback fuel dosage, applied with a 3-way catalyst, should prevent deviations from carburation. When an oxidation catalyst is applied, such a deviation can be expected within a certain range but will be eliminated by the catalyst. Ageing of the catalyst itself is a possible effect that cannot be reglected. Failure of the catalyst then is a greater risk. A recent prognosis in the USA of HC emissions of vehicles to become operative in 1990 assumes that by that time only vehicles with feed-back fuel dosage and a 3-way catalyst will be in use, some of them with an extra oxidation catalyst.

It is estimated that driving 100 000 miles (160 000 km) will increase HC-emissions from 0,45 g/km to 1,5 g/km. This is caused by ageing and failure of the catalyst, malfunctioning of the fuel-dosage system and illegal manipulations by vehicle owners ("tampering") : e.g. removal of the catalyst or poisoning of the catalyst by using leaded fuel.

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7 – GOVERNMENTAL MEASURES FOR VOC ABATEMENT

Most Member States are currently taking measures for reducing the emissions of VOC from individual industrial sources ; but only a few have a specific policy which allows at the national scale to have a coherent action on this category of sources.

Researches on this item have been made easier by using the informatized data bases AIRQUAL (Air Quality standards) and EMILIE (Emission Limits) in the Documentation Center of CITEPA-IFE.

DENMARK

DENMARK has only little problems with air pollution caused by hydrocarbon emissions. The land is flat and there is always a good air exchange.

DENMARK supports every measure which is undertaken by the EEC or by the FRG in order to abate hydrocarbon emissions from vehicle exhaust.

No emission standards for hydrocarbon emissions are on action which have to be fulfilled everywhere in the country. However, local authorities can set emission standards for single industrial plants. Normally the values from the German TA-Luft where taken for such purposes.

FEDERAL REPUBLIC OF GERMANY

1. The TA Luft (Technische Anleitung zur Reinhaltung der Luft - 28th of august 1974) proposes emission limits for some organic compounds independantly of the nature of the source of emissions.

   VOC's are splitted in three classes :
   CLASS I ... if output $\geqslant$ 0,1 kg/h = 20 mg/m^3
   CLASS II ... if output $\geqslant$ 3,0 " = 150 mg/m^3
   CLASS III ... if output $\geqslant$ 6,0 " = 300 mg/m^3

   The list of substances of the chapter 4 presents the classification for each ot them.

A draft of a new issue of the TA Luft, not yet definitely accepted, proposes (Kabinett beschuss - 24th of july 1985) :

CLASS I ... if output $\geqslant$ 0,1 kg/h = 20 mg/m^3
CLASS II ... if output $\geqslant$ 3,0 " = 100 mg/m^3
CLASS III ... if output $\geqslant$ 6,0 " = 150 mg/m^3

This draft proposes the following values for the cancerogenic substances :

CLASSE I ... if output $\geqslant$ 0,5 g/h = 0,1 mg/m^3
CLASSE II ... fi output $\geqslant$ 5,0 " = 1,0 mg/m^3
CLASSE III ... if output $\geqslant$ 25,0 " = 5,0 mg/m^3

2. The draft of TA Luft also proposes limits of emissions for some specific processes :
   - handling of liquid organic compounds
   - smelting of aluminium
   - smelting of non-ferrous metals
   - non-ferrous foundry
   - production of 1,2-Dichlorethane and of Vinylchloride ; production of Acrylonitrile
   - production of Maleic anhydride and of Ethylbenzene
   - production of Polyvinylchloride
   - production of Polyacrylonitrile
   - handling of pesticide and other products
   - oil refinery
   - production of carbon for electrochemistry
   - industrial painting of vehicles
   - printing installations
   - production of fiber glass
   - fabrication of wood panels
   - liquid waste disposal by incineration

   For general VOC's, the limit of the emission is of 50 mg/m^3. For specific VOC's, the limit of the emission may be less than 50 mg/m^3.

FRANCE

Long before knowing with certitude the responsability of VOC's in the decaying of forests, the french Environment Ministry has considered the reduction of the emissions of VOC as a priority.

Among the actions now in program at the national level, one may present :

- reduction of the emissions of oil industry storage (products of the B category) by using floating roof or equivalent techniques,
- reduction of the emissions from the printing industry (mainly offset),
- reduction of the emissions from painting :
  - . by elaborating a policy for the industrial painting installations
  - . by going on with the development and the use of paints with low content of solvents
  - . by standardizing the measurement techniques of the emissions of pollutants in painting installations
- agreement to the efforts of the EEC to propose the reduction of the automotive pollution,
- proposal for reducing the speed on roads at EEC level,
- engagement of reducing the emissions of hydrocarbons of 30 % between 1980 and 2000 (Council of Ministers of 23/10/85).

GREECE

No national laws which control the emissions are in action, but there are various drafts in preparation which should be active in the near future (1986). The directive of the EEC will be set to national law.

Larger industries have to be licenced by regional or governmental authorities. These authorities may demand emission limits ; emission limits are active for only one of the two ATHENS refineries.

No abatement technologies are developed in GREECE itself, technologies have to be imported. If technologies for the reduction of the emissions are used, the government pays 30 % of the installation costs if the plant is situated in the Athens area and 15-30 % for plants outside of this area.

The use of white spirit will be restricted in the near future. Tri-and tetra chloroethene will be used instead of.

NETHERLAND

Environmental law has presently not yet the possibility to practice directives for air quality standards. It is expected that in 1986. This law will be changed in such a way that standards can be made.

In the mean time provisional standards are established and reported in the yearly published IMP-L (Indicatief Meerjarenprogramma fer bestryding van de Luchtverontseiniging = Indicative Program for Air pollution abatement). In the IMP-L 1985-1989, provisional standards are given for formaldehyde, acroleïn, benzene, ethene and PAH's as far as VOC's are concerned. In the next three years more substances will be added.

Meanwhile, a more rapid approach has been adopted. Criteria documents are prepared for each priority substance. In these documents all relevant knowledge about measuring methods, emissions, air transport, immission concentrations, effects, abatement techniques, abatement costs and, of course, physical, chemical and toxicological properties are reported. Comment is given by the Health Council after which an interior air quality demand is reported in a draft IMP-L. The Central Council for Environmental Hygiene gives comment about this draft. Finally the interior demand is prepublished to allow anybody to formulate objections.

Future criteria documents will have an integral character, that is to say they will take into consideration environmental aspects of air, surface water and soil.

Up to now criteria documents have been published (as far as VOC's are concerned) for acrylonitrile, 1,2-dichloroethane, epichlorohydrin, tetrachloroethylene, trichloroethylene and vinylchloride. In progress are documents for ethylene oxide, propylene oxide, phenol, styrene, toluene, tetrachloromethane, benzene and methylene-chloride.

SPAIN

At the policy point of view, according to the Decree for implementing the Law for the ambient air protection (22nd of april 1975), hydrocarbons concentrations (expressed as hexane) are limited :

30 minutes average	280 mg/m^3
24 hours average	140 mg/m^3

For limiting the emissions of VOC by fixed installations, only the oil refineries are concerned ; it is recommanded to avoid the loss of VOC's from the storage tanks by using floating roofs or vapour recovering devices.

For vehicles, the limitations concern only the emissions of CO.

In the 22nd of April Decree, a list of organic compounds considered is given :

- Acetylene
- Aldehydes
- Amines
- Anhydride and maleic acid
- Anhydride and acetic acid
- Fumaric acid
- Anhydride and phtalic acid
- VOC's from sulfur (mercaptans and others)
- Organic compounds of chlorine
- Organic compounds of lead
- Pyridine and methylpirydine (picolines).

8 Final conlusions and recommendations

1. Emissions of road traffic and solvent consumption comprise ca. 80 % of VOC-emissions in the European Communities. The error of these emissions probably is not larger than an estimated 30 or 40 %. Therefore no emission data are present in the inventory that prohibit application of the data given in this study.

2. Insufficiently known or unknown emissions are from source types that contribute relatively small fractions of total VOC. This does not mean that research on VOC-inventorying has been completed. For inventorying VOC on a regional or local scale there still are many problems to be solved.

3. There is a fair agreement between the list of priority substances based on hazard assessment of organic substances and the substances about which emission data could be reported (complete or partly complete).

4. By comparison with a provisional list of priority substances of the EEC it appears that - exept methylbromide - in this study all these substances have been taken into account, too. (Application of methylbromide seems to be of importance only in areas with extensive horticulture and will be restricted in the future in the Netherlands and the FRG.)

5. This comparison shows further that the list of priority chemicals of the EEC comprises too few chemicals. At least at the present screening stage more substances should be taken into account. (For comparison: the EEC list of priority water pollutants contains 129 chemicals.)

   For further investigations we therefore recommend to use the list of substances given by Battelle. For concenience this list is repeatedly given in the following text:

   A) Benzene, aliphatic (saturated and unsaturated) and other aromatic hydrocarbons. Immidiate actions should be performed in order to reduce emissions.

B) Formaldehyde
Acrolein
1,2-Dichloroethane *
Trichloroethene *
Tetrachloromethane
Acrylonitrile
Dichloroethenes
1,1,2-Trichloroethane
1,2-Epoxypropane
Propyleneoxide
Vinylchlorid
1,2-Dibromoethane
Tetrachloroethene *
Trichloromethane
Carcinogenic PAHs
Dichloromethane *
Tetrachloroethanes
Epichlorhydrine
Ethyleneoxide
Dibenzodioxins/furans

Immidiate actions should be performed in order to get better knowledge about the immission, emission and toxicity of these substances.

Additional actions in order to reduce the emissions should be performed if high amounts are emitted in single member states. That is especially important for the substances marked by an asterisk (*).

C) Dibutyl phthalate
Acrylic acid
Acetaldehyde
Carcinogenic Amines
Halogenated hydrocarbons if not mentioned under B)
Diethylhexyl phthalate
Formic acid
1,3-Butadiene
Nitro-, chloro- and thioaromatics
1,4-Dioxane
Ketones

Actions should be performed on order to get better knowledge about the immission, emission and toxicity of these substances.

6. In the field of reducing the emissions the strategy can be the following:
The increase of the quality of the products seems to be well suited for reducing the emissions from the little and geographically dispersed sources, the use of abatment devices may be a good solution for reducing the emissions from large sources in which use of expensive products could be economically unfeasible.

The same principles may be followed for reducing the emission of VOC's into the atmosphere.

7. Small and geographically dispersed sources mainly comprise the use of paints, varnishes, and/or other products containing solvents in housekeeping activities and in little industries (painting, automobile repare, architectural painting, etc...). For these sources it is recommended to promote the development and the use of products with low content of solvents or if possible without solvents. Where single solvents are used (degreasing, dry cleaning, etc...) the recycling combined with good collecting devices seems to be the best way for energetical and economical reesons.

8. For large sources (automobile industry, offset printing, etc...) if use of products with low content of solvents is not possible, the use of well designed abatement devices has to be recommended. An effort has to be made to precise what is actually technically and economically feasible. An effort has to be made also to develop reliable and simple tools to check the good operating of the abatement systems.

TABLES

Table 3.1

Selected sources of volatic organic compounds

Petroleum refineries

Primary iron and steel industry

- coke manufacturing
- sinter plant
- rolling

Foundries

Chemical and petrochemical industry

a) selected bulk products:
- ethene
- 1,2-dichloroethane
- vinylchloride
- polyvinylchloride
- polyethylene (LD and HD)
- polystyrene
- SBR (styrene-butadiene rubber)
- carbon black

a) other production processes (dependant on available knowledge and data)

Fermentation processes

- bread manufacturing
- beer "
- wine "
- spritis "

Use of solvents

- industrial
- non-industrial

Waste elimination

- municipal waste incineration
- industrial waste incineration
- sewage sludge incineration
- sludge spreading

Stationary combustion sources

- power plants
- industrial
- residential
- other

Table 3.1 (cont'd)

Transport

- road transport
- gasoline powered vehicles, exhaust
- diesel " " , "
- LPG " " , "
- gasoline " " , evaporation
- navigation; harbours
- airports
- railroads

Gasoline distribution

Agriculture

- agricultural waste burning
- agricultural tractors and other machinery

Natural emissions

- forests
- forest fires

Table 3.2a

VOC emission factors for industrial sources

Source type	Unit	Lit. source	Emission factor						
			total VOC	product	specific substances	ethene	(other) paraffins	(other) olefins	(other) aromates
petroleum refineries	kg/t ref. intake	5	0.4(0.2-0.6)				0.35	0.04	0.01
prim. iron & steel industry									
coke manufacturing	kg/t coke	2, 11	0.3(0.2-0.9)		0.05 benzene	0.15	0.05		0.05
sinter plants	kg/t sinter	2, 12	0.05(0.03-0.1)		0.02 acetylene	0.01	0.01	0.01	
rolling	kg/t product	19	0.3(flat) 0.1(long)						
foundries (grey iron)	kg/t cast iron	2	2		0.1 aldehydes	0.9		1.0	
chemical industry									
a) selected bulk products									
ethene	kg/t product		0.8(0.5-4)	0.2		(0.2)	0.5	0.1	
1,2-dichloroethane	"	7	14 (2-15)	10				4	
vinylchloride	"	7	3.5+1.5	3.5	1.5 Cl-hydrocarbons	0.1-0.2			
polyvinylchloride	"	7	8.5		8.5 vinylchloride				
polyethylene-LD	"		1.5(1-10)			1.5			
polyethylene-HD	"		6(4.5-18)			0.3	5.2	0.5	
polystyrene	"	7, 13	4(0.5-6)		1 styrene; 3 n-pentane				
SBR-rubber	"	7, 13	5.3(1-10)		5 styrene; 0.3 1,3-butadiene				
SBR-latex	"	7, 13	1.3(0.3-2.5)		1 styrene; 0.3 1,3-butadiene				
carbon black	"	9, 14	2.5			1.5	1		
b) other chemicals									
ABS-resins	"	7, 13	5(0.7-10)		2(0.1-4) styrene ; 2(0.1-4) acrylonitrile			1(0.5-1.5)	
acetone (isopropanol)	"	13	0.1(0.02-0.2)	0.01-0.1	0.01-0.1 isopropanol				
acrylic acid	"	a.o. 14			10(5-15) acroleïn		50?	20?	
acrylonitrile	"	7, 13		0.5(0.2-3)	2(1-7) acetonitrile		50?	40?	
alkyd resins	"	13	6(0.5-12)				5(0.2-10)		1(0.3-2)
benzene	"			0.1(0.02-0.2)					
1,3-butadiene	"							0.5(0.2-2)	
caprolactam	"	13			0.07(0.05-0.1) benzene		0.05		
cumene	"	7		0.1(0.02-0.15)	0.02-0.2 benzene				
cyclohexane	"	7, 13	0.1(0.02-0.3)	0.1(01-0.1	0.01-0.2 benzene				
cyclohexanone	"	7(phenol), 13	0.07(0.04-0.11)		0.01-0.03 cyclohexane; 0.01-0.03 cyclohexanol; 0.02-0.05 phenol				
dimethylterephtalate	"	13	6(2-12)		1-1.5 xylenes; 1-5 methanol; 0.1-5 org. compounds				
ethyleneglycol									
ethyleneoxide	"	7	0.8	(0.8)	0.8 ethyleneoxide				
ethyanolamine					(factor for sum of products)				
ethylacetate	"	13	3.5	2-4	0.1-0.5 ethanol				
ethylbenzene	"	7	0.5(0.1-1)		0.05-0.2 benzene		0.02-0.3		0.03-0.5

Table 3.2a (concluded)

Source type	Unit	Lit. source	Emission factor						
			total VOC	product	specific substances	ethene	(other) paraffins	(other) olefins	(other) aromates
methylethylketone (butane)	kg/t product		7.5				5	2.5	
" (butanol)	"		1.5					1.5	
melamine-formaldehyde resins (for thermosetting products)	"	13	solvents		0.5-4 alif.alcohols;				1-2.5
methanol	"	13	2(with flares: 0.2)	0.2-0.8	< 2 dimethylether				
nitrile rubber	"	7, 13			3 acrylonitrile; 5-15 1,3-butadiene				
polyacrylonitrile (PAN)	"	7, 13			5 acrylonitrile; 10 solvents (e.g. DMF)				
polybutadiene	"				0.6(0.2-1) 1,3-butadiene				
polychloroprene			10					7 2	
polyester resins (application)	"	7	40		40(10-100) styrene				
polyetherpolyols	"	7			0.1 propyleneoxide				
polyurethane resins	"	13			< 3 solvents (MEK, et.acetate etc.)				
polypropylene	"	13			0.5-1.5 propene		5-10		
phenol (cumol)	"	7		0.16					
phenolic resins	"	7			0.3 phenol				
phtalic anhydnine	"	13	2-10		2-10 product + organic acids				
propyleneoxide	"	7		0.5(0.2-0.6)					
propyleneglycol	"	7			0.1 propyleneoxide				
styrene	"	7, 13		0.2					0.2 (0.05-0.5)
toluene	"		0.1	0.1(0.02-0.2)					
urea-formaldehyde resins	"	13	1.5-4		0.5-0.8 butanoles; 1-2.5 alif. or arom.				
<u>fermentation processes</u>									
bread	"	9, 13	6		6 ethanol				
beer	kg/10^3 l	9, 15	1		1 "				
wine	"	9, 15	5		5 "				
spirits	"	9, 15, 16	20		20 "				
<u>automobile manufacturing</u>									
solvent emissions from laquer									
automobiles	kg/veh.	9, 19	15						
utility vehicles	"	9, 19	30						
<u>municipal waste incineration</u>	kg/ton waste	9, 28	0.15						
<u>stationary combustion</u>									
coal and coal briquettes	kg/TJ	8, 9, 28	30		see table 3.5 (total VOC is incl. CH_4)				
coke	"	"	30						
dist. and res. oil	"	"	30						
refinery gas	"	"	10						

Table 3.2b

VOC-emission factors for non-industrial sources

Source type	Unit	lit. source	Emission factor					
			total VOC	saturates	unsaturates	aromates	oxygenates	unreactive
Stationary combustion [1]								
public service/commerce:								
coal and -briquettes	kg/TJ fuel	8, 9, 28	50	25	5	5	10	5
coke	"	"	40	20	4	4	8	4
dist. and res. oil	"	"	10	6.5	1	0.5	1	1
gaseous fuels	"	"	5	1	0.15	-	0.1	3.75
residential:								
coal	"	"	200	100	20	20	40	20
coal briquettes	"	"	400	200	40	40	80	40
coke	"	"	15	7.5	1.5	1.5	3	1.5
brown coal briquettes	"	"	150	75	15	15	30	15
dist. and res. oil	"	"	15	9.8	1.5	0.8	1.5	1.5
gaseous fuels	"	"	30	6	0.9	-	0.6	22.5
Mobile sources								
road transport		see Annex IV						
railroad	kg/TJ fuel	13, 51	250	126	54	26	34	10
inland navigation								
diesel oil	"	13, 51	120	60	26	13	16	5
residual oil	"	"	150	76	32	16	20	6
air transport	kg/LTO	9(8, 13)	15	7.6	3.2	1.6	2	0.6
agricultural tractors	kg/TJ fuel	9, 13	250	126	54	26	34	10
Gasoline distribution	kg/t gasoline	49	4.5	4	0.5			
Solvent use		see section 3.4.7, tables 3.3 and 3.4						
Natural sources		see section 3.4.14, fig. 3.1a and b						

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[1] stationary combustion sources incl. methane

Table 3.3

VOC-emissions from solvent use6)

	(18) FRG 1978-1980	(19) France 1979	(16) UK 1975	(2) Netherlands 1981	(20) Sweden 1984	(21) USA 1982	(22) Canada 1978	default value
INDUSTRIAL								
paint application	3.25			(2)2)	2.4	6.8		2
degreasing	2.31)	1.65	0.45		1.2	1.6	2.25	1.6
printing	1.15	0.65		0.55	0.85	1.3		1.0
chemical industry				1.3				
storage & handling				0.15				
metal products manuf.				0.7	0.35	4.1		
glues, adhesives	0.8							
other	0.3			2.4				
total from industry	7.8			5.1	4.8	13.8		
NON-INDUSTRIAL								
paint application	2.6		2.6	2.7	1.2	2.85		2.5
chemical cleaning	0.25	0.55	0.66	0.25	0.18	0.95	0.7	0.5
consumer products				3.5	3.83)	3.5	0.9	3.5
- a.w. aerosol cans				1.25				
total non-industrial				6.45	5.2	7.3		6.5
total emissions	13.7	13	5.5	11.6	10	21.1	5.6	12
total paint application	5.85	3.7		4.7	3.6	9.65		4.5
OECD-estimation 19754)	13.2	12.2	5.55)	11.4	12.1	29.5	10.0	
1985	18.8	17.5	7.4	15.3	16.1	40.4	13.5	

1) or 1.9
2) included in industrial emissions
3) OECD-figure
4) Ref. 5
5) from ref. 16
6) Source: ref. 17.

Table 3.4

Compositions of VOC-emissions from solvent use$^{3)}$
(wt. %)

	(23) FRG 1982	(19) France 1978	(15) OECD Europe$^{2)}$	(2) Netherlands 1981	(21) USA 1982	(24) Sydney	default value
sat. hydrocarbons C$_{4+}$	19.2	27	36.3	42.5	59.3	25.7	32
toluene	5.4		5.1	>6.6		18.4	6
xylenes	3.9		4.0	>3.1		10.6	4
other aromates	1.6			9.8	1.6	16.6	5
total aromates	10.9	24	9.1	19.5		45.6	
methylalcohol	3.8	>24$^{1)}$	1.2	1.3	5.0	13.7	2
ethylalchol	3.3		6.1	8.6	5.3		6
isopropylalcohol	1.4	(6)	6.7	3.8	2.6	1.3	5
butanoles	6.7		6.4		1.5		
cellosolves	5.3				4.7		
other alcohols					0.2		5
total alcohols	20.5		20.4	13.7	19.3	15.0	
acetone		(6)	6.1	2.3	3.2	1.6	4
methylethlketone			3.2		4.1	2.9	3
methylisobutylketone			2.1	2.0	1.0	1.0	2
other ketones					0.3		
total ketones	5.4		11.4	4.3	8.6	5.5	
acetates	7.1	9	5.1		2.8	2.6	6.5
other esters	0.5						
total esters	7.6		5.1	3.9	2.8	2.6	
ethers	11.9			1.9			2
methylene chloride	6.0		5.5	4.6		1.8	5
trichloroethylene	2.2		4.4	1.3	1.3	1.9	2.5
perchloroethylene	4.4		4.8	3.5	4.0	0.4	4
other Cl-hydrocarbons	4.9		3.0	1.0	1.6	1.5	2.5
total Cl-hydrocarbons	1.75	16	17.7	10.4	6.9	5.6	
Cl-F-hydrocarbons	3.8			3.6			3.5
other solvents	3.2			0.2	1.5		

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[1] Incl. ethers.

[2] Non-reactive compounds not included. Added for this study: 300 kt acetone, 60 kt methylalcohol, 270 kt methylene chloride, 150 kt trichloroethane.

[3] Source: ref. 17.

Table 3.7 Industrial VOC-emissions (10^3 ton/year)

	Belgium	Denmark	France	Federal Republic of Germany	Greece	Ireland	Italy	Luxemburg	Netherlands	Portugal	Spain	United Kingdom	EC
Petroleum refineries	9.2	2.8	45/32	35/37	6.4	0.5	33		17.5	3.3	18	31	200
Primary iron & steel industry													
coke manufacturing	1.5		2.4	20/17	0.02		2		0.7	0.06	1.0	2.5	30
sinter plants	0.5		0.6	1.3			0.7	0.25	0.13	0.02	0.3	0.5	5
rolling			3.5										(20)
Foundries			3.7	6.2	1.8				0.4				(30)
Chemical industry													
ethene	0.34		1.65/1.45	1.0/2.2	0.01		1.4		1.5	0.16	0.5	3/0.9	10
1,2-dichloroethane	6.3		15.4	13			17.2		0.45			9.1	61
vinyl chloride	3.2		2.3/3.4	11/1.6			3.2		0.7	0.06	0.85	1.1	25
polyvinylchoride	2.0	0.03	6.9/4.6	1/1.2	0.5		6.5		0.4	0.43	1.8	3.0	25
polyethylene-LD	0.6	0.005	1.2/1.6	1.2/1.0			1.0		1.0	0.35	0.55	0.3	5
polyethylene-HD	1.2	0.02	1.2/1.2	64/3.4			1.1		0.6	0.35	0.9	0.6	70/10
polystyrene	1.1	0.02	0.5/1.2	2.4/2.1			1.0		0.2		0.45	0.9	10
SBR	0.1		0.6/0.4	0.7			0.8				0.22	0.8	5
carbon black			0.6/0.4	0.7			0.3				0.05	0.35	5
other processes	3.0		>1.8/4	43/12			8			1	2	7.5	(80)
Industrial solvent use													
vegetable oil extraction	2	1	7.9/11	15/12	0.2	0.5	12	0.1	3.6	2	10	11	60
metal cleaning	15	7	90	141/110	0.8	4	90	0.5	10	8	50	85	500
printing	10	4	35/55	70/65	8	4	55	0.4	8	8	50	55	300
automobile industry(laquer)	4		28/50	60			25		1.5		15	20	160
other paint consumption	20	8	82/80	130	11	3	110	0.1	}48	10	70	140	620
other uses	15	1	25/70	>50/85	2	1	65			4	15	50	270
Fermentation processes													
beer	1.4	0.1	2.2	9.5	0.3	0.6	1.0	0.06	1.7	0.4		6	25
wine			34	6.5	2.4		41	0.1		4	15		100
spirits	0.15		12	6	0.8		6		0.8	0.2		11	35
bread	4.4	1.6	18	20	6.4	2	32	0.3	5	3	12	26	130
Waste elimination													
municipal waste incineration	0.1	0.1	0.9	1.0					0.4			}38 incl. agr. burning	(10)
industrial waste "			0.1										} (5)
sewage sludge "			0.2										
sludge spreading			6.3										(20)
Stationary combustion													
power plants	1.1			9.3	0.7					0.27		12	50
industrial boilers	1.9	1.0	4.3/8.2	16/14	1.9	0.7	7.2	0.3	1.2	1.4	5.5	4/8.8	50
Total	110	30	440	770/700	50	20	530	3	110	50	280	500	2800

Table 3.8 NON-industrial VOC-emissions (10^3 ton/year)

	Belgium	Denmark	France	Federal Republic of Germany	Greece	Ireland	Italy	Luxemburg	Netherlands	Portugal	Spain	United Kingdom	EC
Stationary combustion													
residential	9.9	3.0	50/30	36	0.7	6.6	5.2	0.35	4.0	0.1	4.1	59	160
other	0.5	0.5	3.5/0.5	5		0.3	0.8		0.5		0.4	4.9	15
Solvent use													
paint use (automobile repair)	4	1.7	10/20	}160 25	1.1	0.9	20	0.2	6.1	1.5	12	19	100
other paint use	20	11	140/130	135	19	7	90	0.8	32	18	100	110	680
chemical cleaning	5	2.5	20	15	3.5	2	20	0.2	3.5	5	15	20	110
other uses (consumer products)	35	19	235/200	200	20	10	170	1.3	48	20	100	190	1000
Road transport													
automobiles, gasoline, exhaust	54	27	600/350	432	}61 21	16.7	320	3.1	70	}17	}130	}497 401	}2000
utililyvehicles, gasoline,	3.4	2.6	125/41	17	10.6	1.6	13	0.13	4.4			37	
vehicles, gasoline, evaporation	14	6.5	102/92	118	7	4.4	93	0.7	19	6	45	82	490
automobiles, diesel	36	0.6	7/7.7	22	4/0.4	0.2	21	0.1	3.7	}12	}38	}41 3	}370
utility vehicles, diesel	7.6	5.3	67/69	60	14/12	1.4	50	0.3	10.1			45	
automobiles, LPG	2.0	-	-	-	1/-	-	2	-	18	-	-	-	25
motor cycles	8.4	2.2	204/35	47	25/8.1	0.4	50	0.18	10.4			17	400/250
off-highway vehicles	0.4		23	5.9	0.65								(50)
Other transport													
railroads	0.9	1.0	5.1/4.2	5.4/3.8	0.4	0.3	1.3		0.4		1.3	10/6	25
airports	0.5./0.4	0.4/0.7	6.1/2.8	2.9/3.2	0.5	0.3	1.2	0.07	0.8/0.8	4.5		2.4	30
internal navigation	1.0/0.8	1.1/1.2	0.7/0.6	4.2/3.0	2.9/1.8		0.9	0.005	2.4/10.5	2.9	6.9	4.5	40
harbours	1.0		2.2	1.5	1.0	0.1	2.0	-	1.5				20
Gasoline distribution	11.6	6.2	120/81	115/103	6.8	4.2	50	1.3	16	3.4	26	88	450/400
Agriculture													
agricultural waste burning		9.6	41									see Annex I	(200)
tractors,oth.agr. machinery	0.2/1.7	0.25/4.8	23/18	0.8/10	12/5.7	0.4	11.7	0.003	0.2/1.8	2.8	17	6.6	80
Natural emissions													
forests	35	14/45	982	242/495	3 72/130	70		6	25			185	(2700)
forest fires		0.07	16	0.9					0.1				
Total (anthropogenic)	190	110	1800/1200	1300	170/120	60	1000	10	250	100	600	1200	6800/6100

Table 3.9

Summary of VOC-emissions

Emissions per source category in the European Communities (10^3 ton/year)

Source category	Total	%	Unsaturated	%	Unreactive	%	Other	%
Industrial sources								
Petroleum refinenes	200	2	20	2			180	3
Prim.iron & steel ind.; foundries	(90)	1	(35)	3.5	(5)	0.5	(50)	1
Chemical industry	(260)	3	(80)	8.5	(80)	7	(100)	1.5
Solvent use	1900	21			670 1)	61	3130 1)	45
Fermentation processes	300	3.5					300	4
Waste elimination	(40)	0.5	(10)	1	(5)	0.5	(25)	0.5
Stationary combustion sources	100	1	30	3			70	1
Subtotal ind.sources	2900	32						
Non-industrial sources								
Stationary combustion sources	180	2	50	5			130	2
Solvent use	1900	21						
Road transport	3200	36	600	62	300	28	2300	33
Other transport	120	1	25	2.5	10	1	85	1
Gasoline distribution	400	4.5	45	4.5			335	5
Agriculture	(300)	3.5	(80)	8	(20)	2	(200)	3
Subtotal non-ind.sources	6100	68						
Total anthropogenic sources	9000	100	1000	100	1100	100	6900	100
Natural sources	(2700)		(2700)					

TABLE 6.1 : **SUBSTANCES THAT INFLUENCE CATALYST ACTIVITY** (Réf. 2)

Type of Inhibitor	Effect
Fast Acting Inhibitors	
Phosphorus, Bismuth, Lead, Arsenic, Antimony, Mercury	Irreversible reduction of catalyst activity at rate dependent on concentration and temperature.
Slow Acting Inhibitors	
Iron, Tin, Silicon	Irreversible reduction of catalyst activity. Higher concentrations than those of fast acting catalyst inhibitors may be tolerated.
Reversible Inhibitors	
Sulfur, Halogens, Zinc	Reversible surface coating of catalyst active area at rate dependent on concentration and temperature.
Surface Maskers	
Organic Solids	Reversible surface coating of catalyst active area. Removed by increasing catalyst temperature.
Surface Eroders and Maskers	
Inert Particulate	Surface coating of catalyst active area. Also errosion of catalyst surface at rate dependent on particle size, grain loading and gas stream velocity.

TABLE 6.2 : GENERAL APPLICABILITY OF CONTROL DEVICES

100°F = 38°C
900°F = 482°C

Control Device	Waste Gas Temperature Requirements (1)	Susceptibility to Contaminants (2)	Sensitivity to VOC species (3)	Sensitivity to Varying VOC Concentrations (4)	Size and Space Requirements (5)	Emission Stream and Process Data Requirements (6)
Carbon Adsorption	Stream must usually be less than 100°F. Cooler may be required.	Carbon is susceptible to fouling by high boiling point compounds such as resins	Streams containing multiple VOC's will be more difficult to recover. VOC's miscible with water could require complex recovery treatment (i.e. distillation).	Recovery efficency may vary.	Size is dependent on complexity of recovery system. Typical system requires as much or more land as thermal incinerator.	Requires more exetensive data than other devices.
Catalytic Incinerator	Essentially none. Very high temparature streams (greater than 900°F) are unsuitable.	Catalyst is susceptible to erosion, masking and poisoning from particulate and catalyst poisons.	operating temperature may be adjusted to achieve desired performance.	Little or none.	Smaller than thermal units. Can be used typically for roof installation	Requires general process information, VOC waste fas stream charracteristics, (including presence of poisons and/or maskers).
Thermal Incineration (Recuperative)	None.	Corrosion can be a problem with certain contaminents.	Operating temperature may be adjusted to achieve desired performance.	Little or none.	Typically equivalent or higher than catalytic.	Minimal.
Thermal Incineration (Regenerative)	None.	Corrosion can be a problem with certain contaminents.	Operating temperature may be adjusted to achieve desired performance.	Variability could affect energy use.	Typically not used for roof installations. Greater than conventional thermal system.	Minimal.

TABLE 6.3 : OPERATION AND MAINTENANCE REQUIREMENTS

Control Device	Overall Equipment Life (1)	Overall Reliability (2)	Operation Labor Requirements (3)	Maintenance Labor and Materials Requirements (4)	Startup/ Shutdown Procedure (5)	Potential for Equipment Damage (6)
Carbon Adsorption	Approximately 10 years (except for carbon beds)	Potentially lower than incineration systems due to complexity.	Potentially high especially if distillation system used. Skilled personnel may be required.	Potentially high with replacement of carbon beds at infrequent intervals.	Fairly complex depending on installation, however, very quick startup.	Somewhat greater than incinerators, especially if stream is hot and cooling used.
Catalytic Incineration	Approximately 10 years (except for catalyst beds)	Approximately equivalent to thermal incineration systems except on dirty streams.	Low.	Low, unless emission stream dirty. Cleanings or replacement of catalyst at infrequent intervals.	Simple ; need to bring temperatures up at controlled rate.	Somewhat greater potential than thermal.
Thermal Incineration (Recuperative)	Approximately 10 years.	Potentially highest due to simplicity ; breackdown of refractory and insulation may be a problem due to high temperature.	Low.	Low unless corrosive species present.	Simple ; need to bring temperatures up at controlled rate.	Low unless corrosive species present.
Thermal Incineration (Regenerative)	Approximately 10 years.	Potentially lowest of incineration systems due to complexity.	Somewhat higher than other incineration systems, especially with fluctuating VOC loadings.	Low, however maintenance of valves, dampers, and flappers can be high systems.	Fairly simple, however, procedures may be more complex than recuperative.	Low.

TABLE 6.4 : ENVIRONMENTAL AND ENERGY CONSIDERATIONS

Control Device	Potential Overall VOC Removal (%) (1)	VOC Removal Variability (2)	Secondary Air Pollution Generation (3)	Water Pollution Generation (4)	Solid Water Pollution Generation (5)	Supplemental Energy Use (6)
Carbon Adsorption	95 +	Potential for VOC removal efficiency to decrease with time. Efficiency depends on concentration.	Small amounts of particulate matter SO_2 and NOx from boiler used to generate steam.	VOC recovery process (i.e. decantation, distillation, extraction) create waste water containing VOC's. credit.	Spent carbon must be either reactivated or disposed.	Depends on energy credit for recovered VOC's. Potentially very low or net
Catalytic Incineration	95 +	Potential for VOC removal efficiency to decrease with time	Impurities such as nitrogen and sulfur in waste stream may cause emissions	None.	Old catalyst support must be either reused or disposed.	Typically less than thermal incineration with recuperative heat exchange.
Thermal Incineration (Recuperative)	95 + (Potentially greater than both catalytic incineration and adsorption).	Performance generally does not degrade with time	Impurities such as nitrogen and sulfur in waste stream may cause emissions.	None.	None.	Potential highest depending on amount of heat recovery equipment used in the system.
Thermal Incineration (Regenerative)	95 + (Potentially greater than both catalytic incineration and adsorption).	Performance generally does not degrade with time	Impurities such as nitrogen and sulfur in waste stream may cause emissions	None.	None.	Typically less than thermal incineration with recuperative heat exchange.

FIGURES

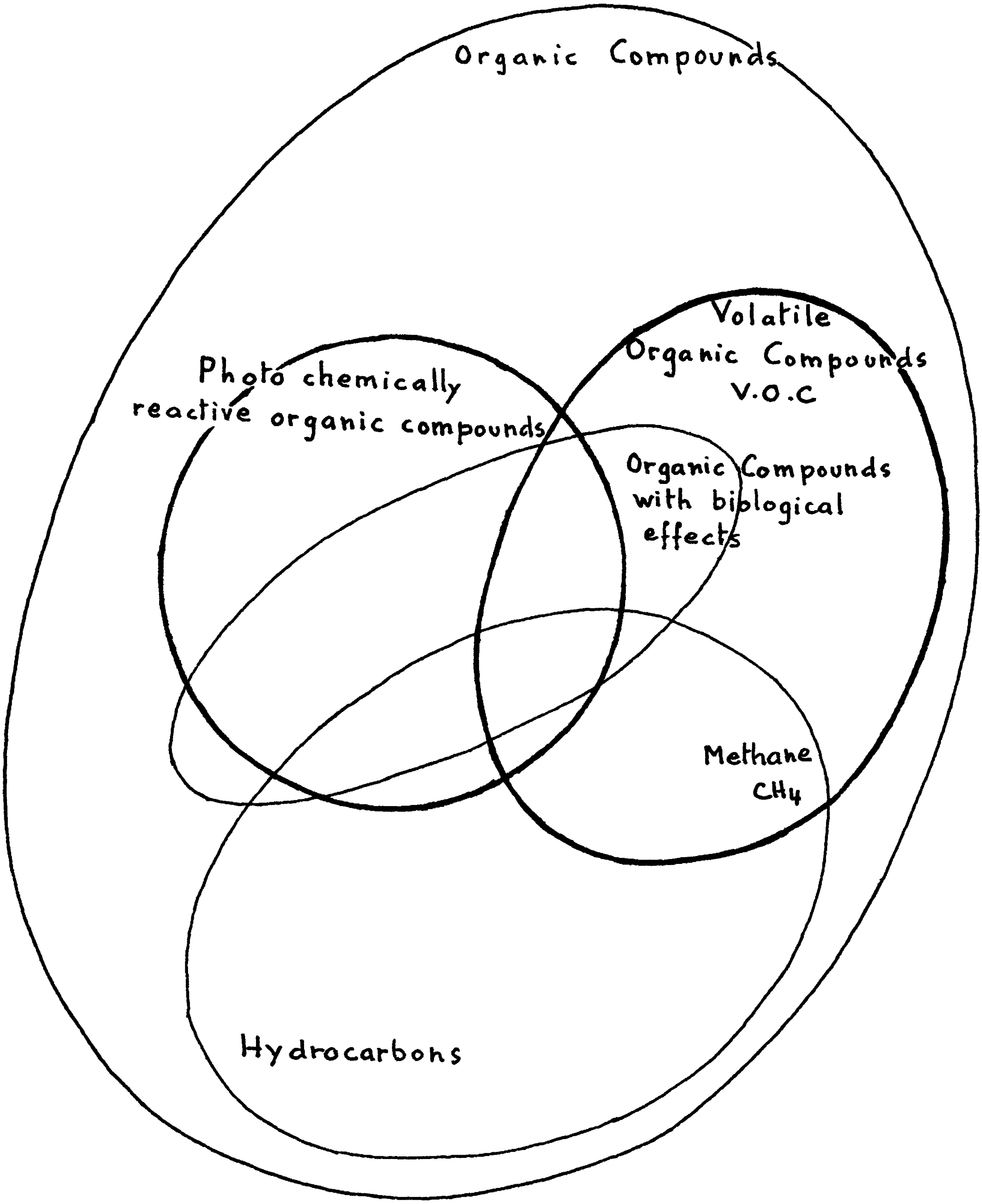


Figure 2.1 - Classification of some Organic Compounds

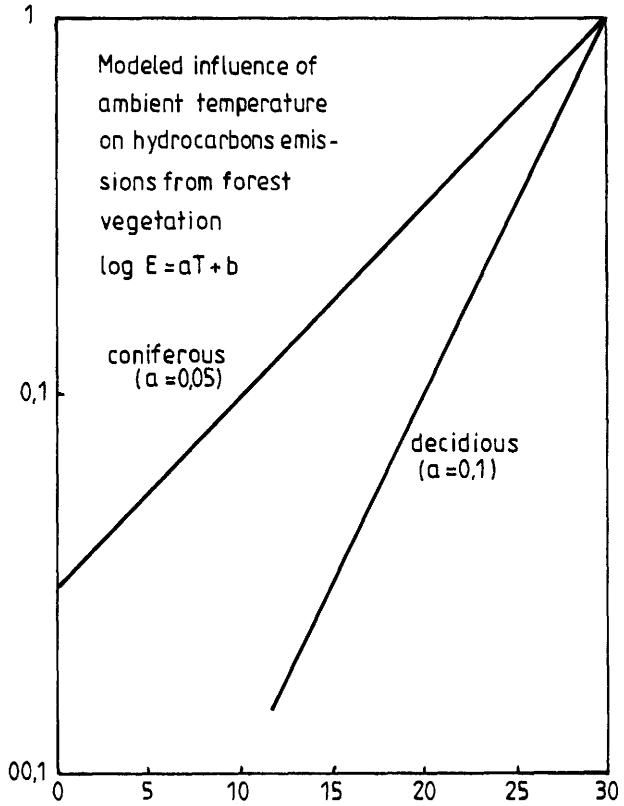


Fig. 3.1 a

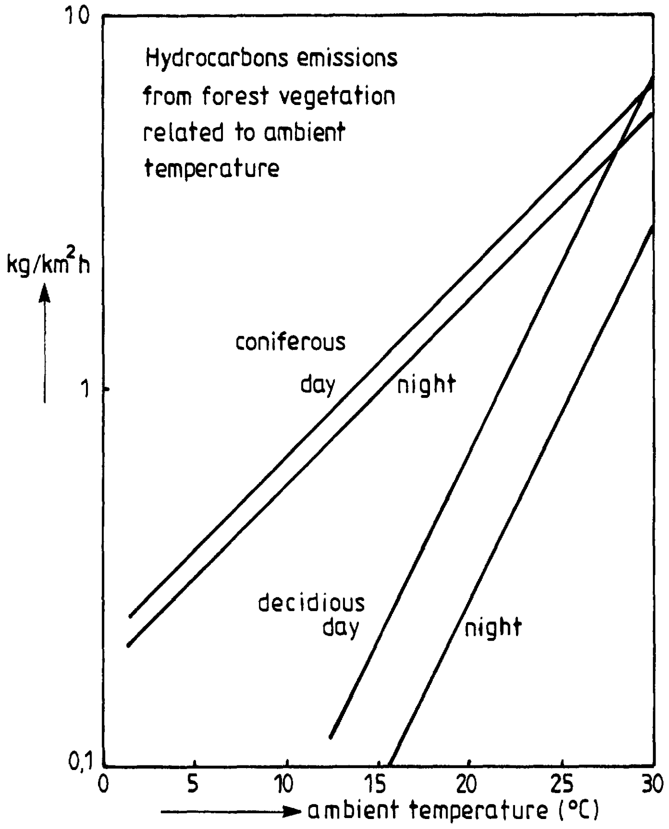


Fig. 3.1 b

MT_TNO
13014
Fig. 3.1a en 3.1b

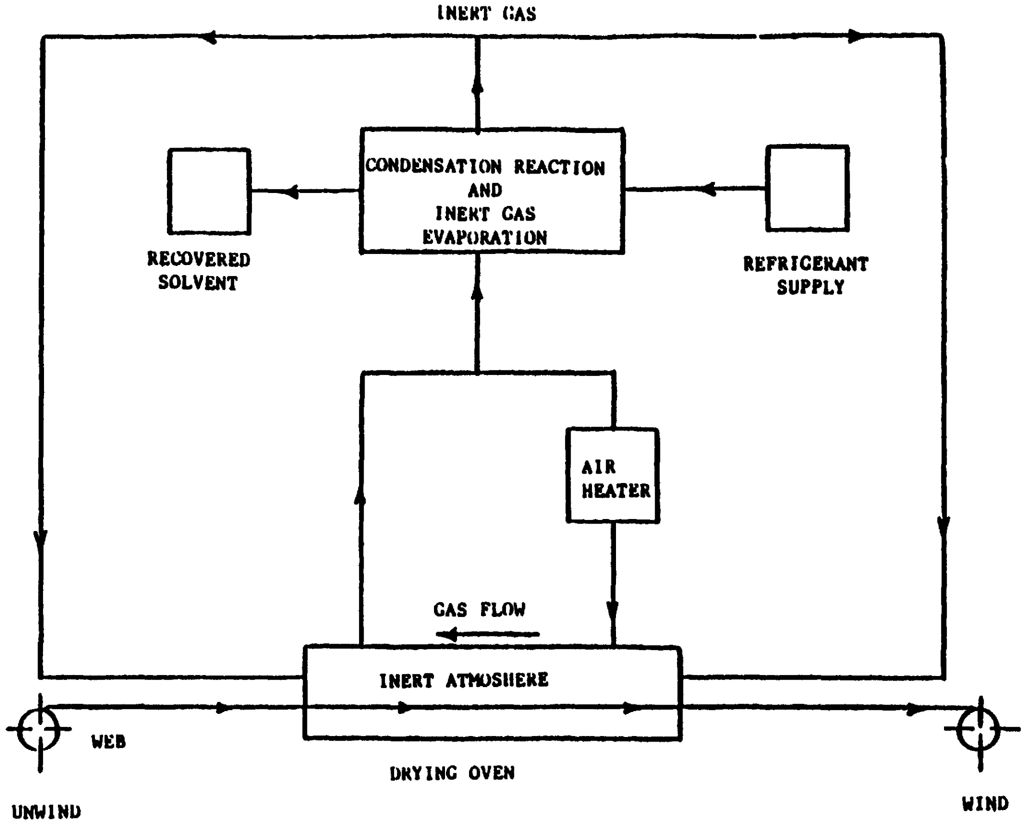


FIGURE 6.1 : Diagram of an inert gas condenstaion solvent recovery system. (Réf. 7)

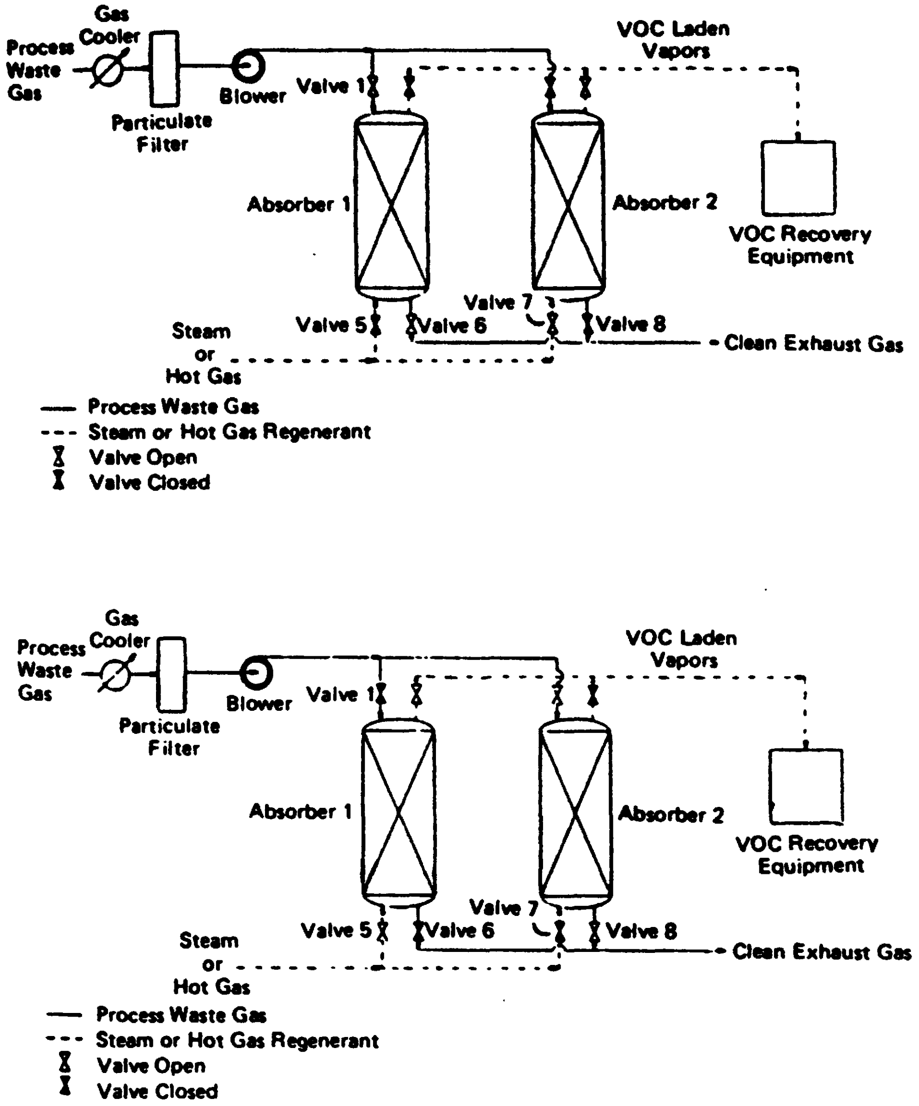


FIGURE 6.2 : **Fixed-Bed Carbon Adsorption System.** (Ref. 2)

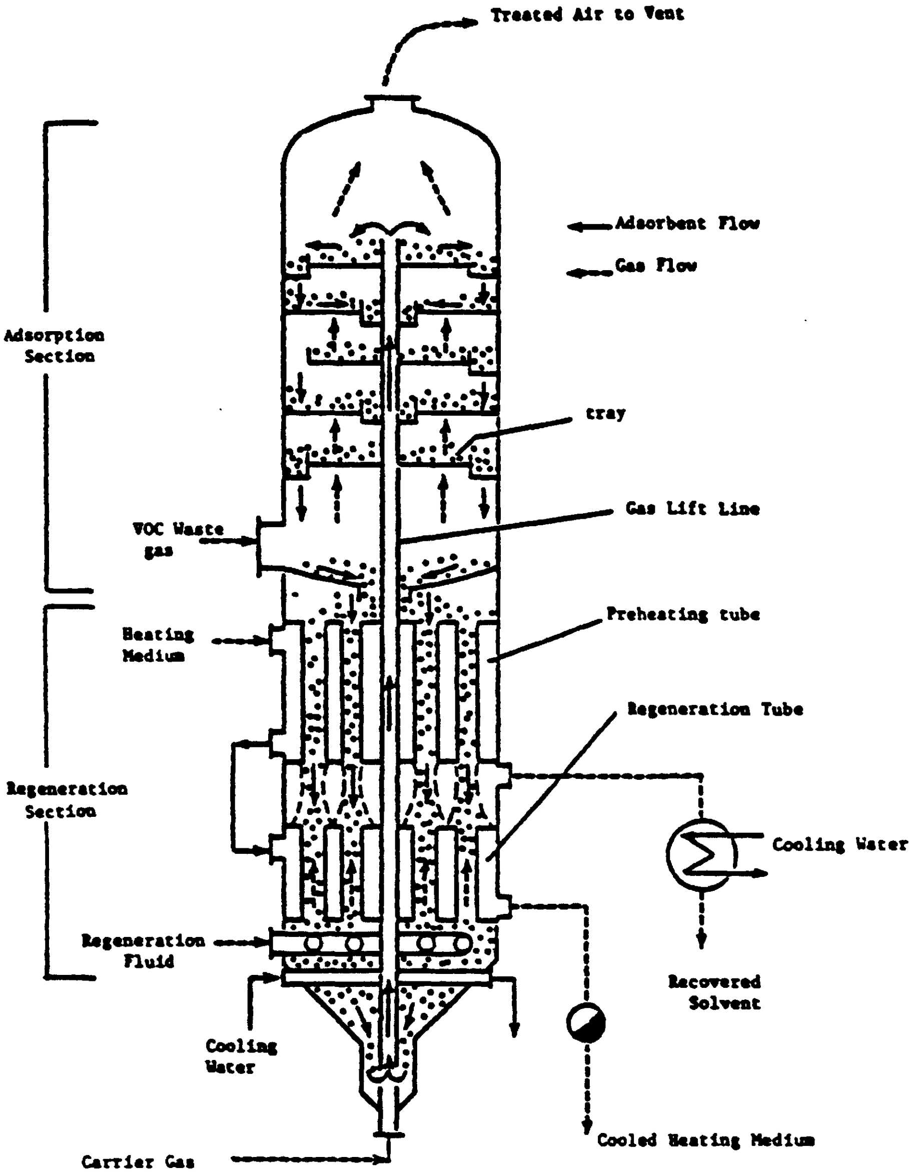


FIGURE 6.3 : Schematic diagram of fluidized-bed carbon adsorption system. (Ref. 2)

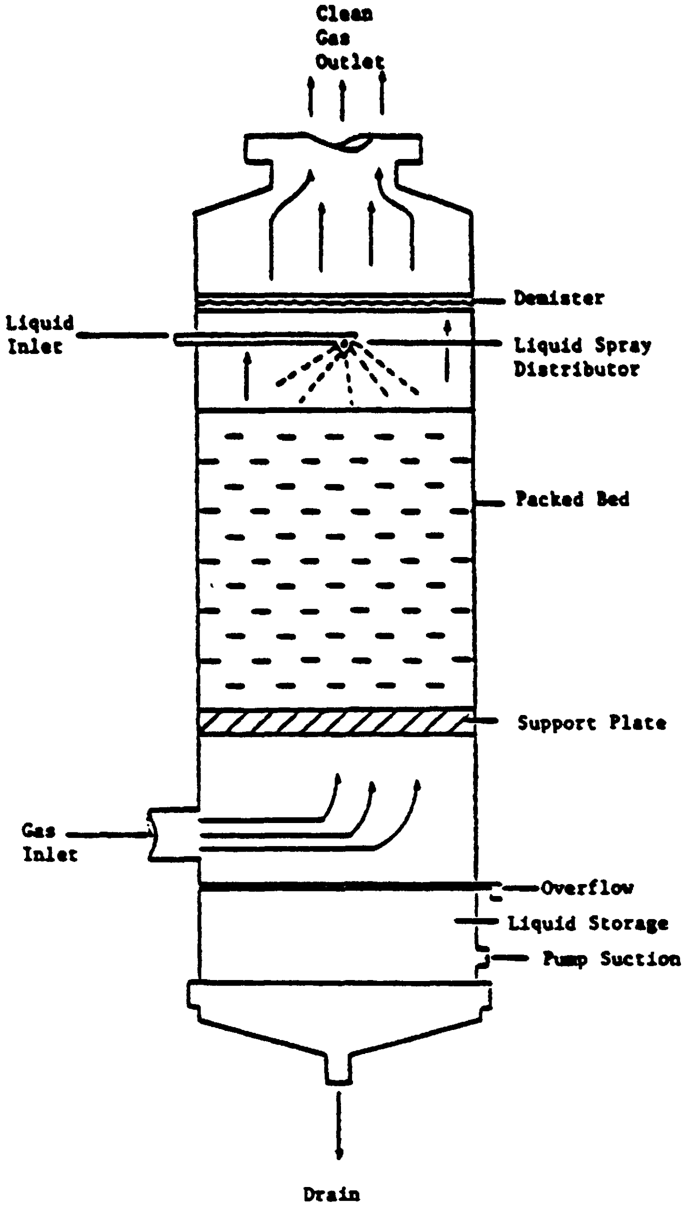


FIGURE 6.4 : Typical packed absorption column. (Ref. 2)

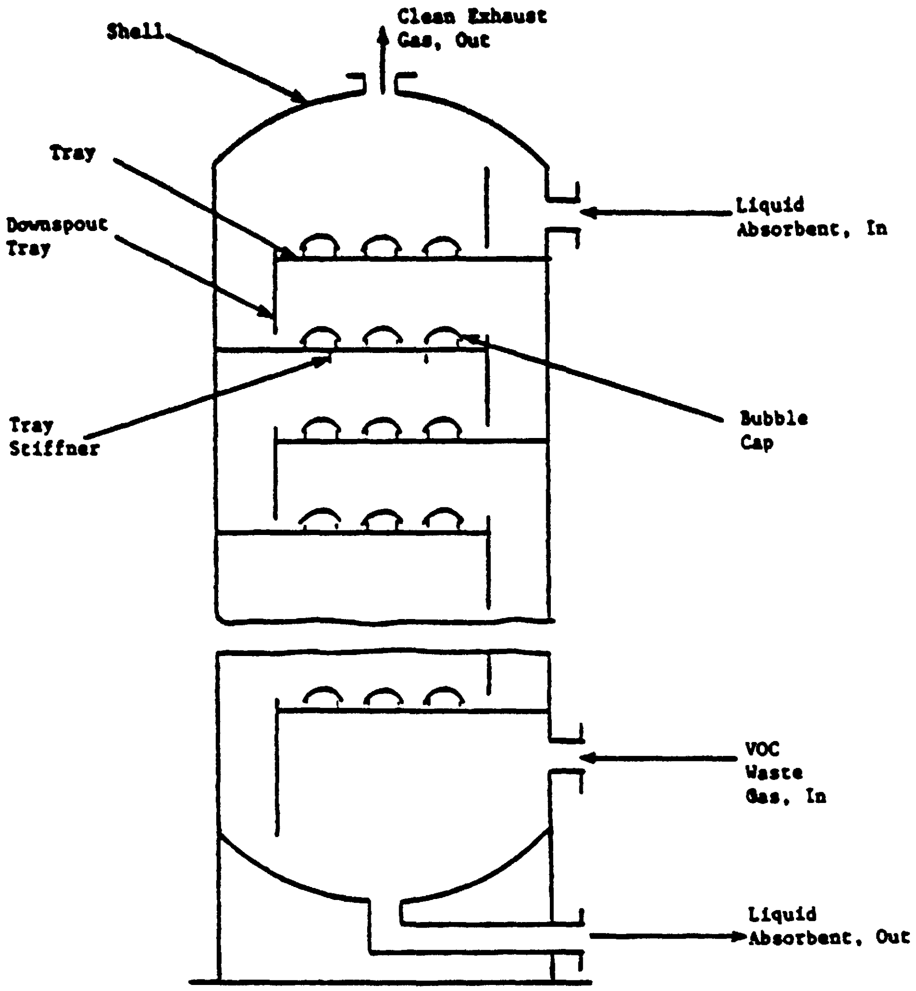
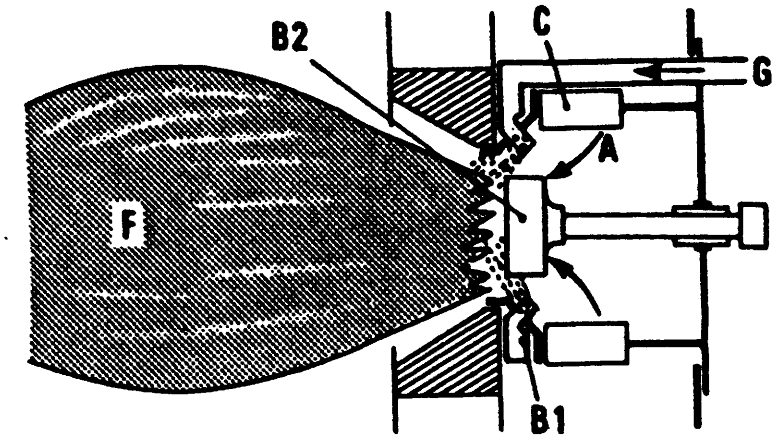


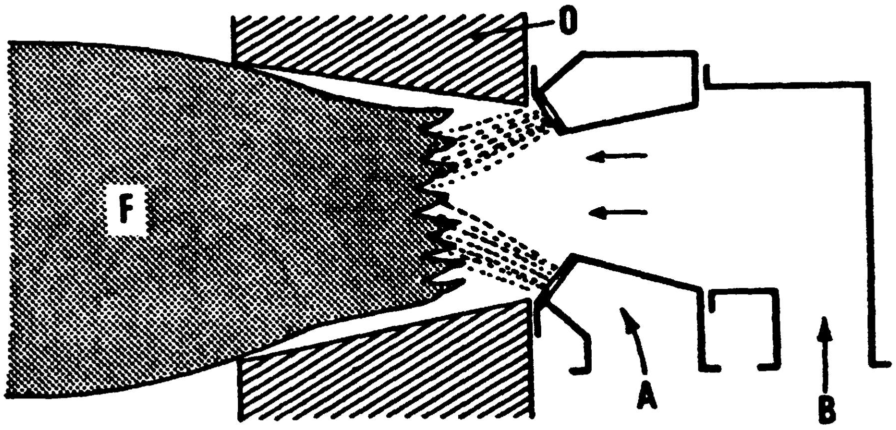
FIGURE 6.5 : Bubble cap absorption column. (Ref. 2)



A - Combustion air
B1 - Gas burner

F - Flame
G - Gas arrival

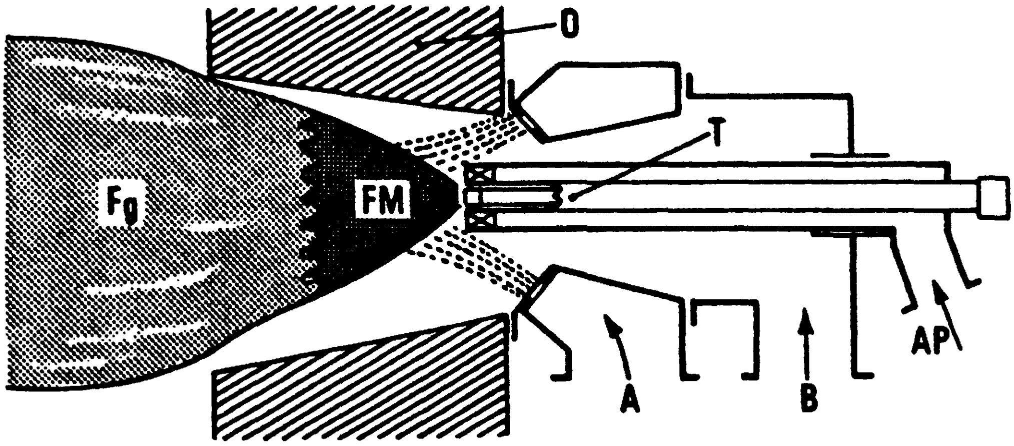
FIGURE 6.6 : Burner for rich gas



A - Combustion air
B - Arrival of gas

F - Flame
O - Refractory

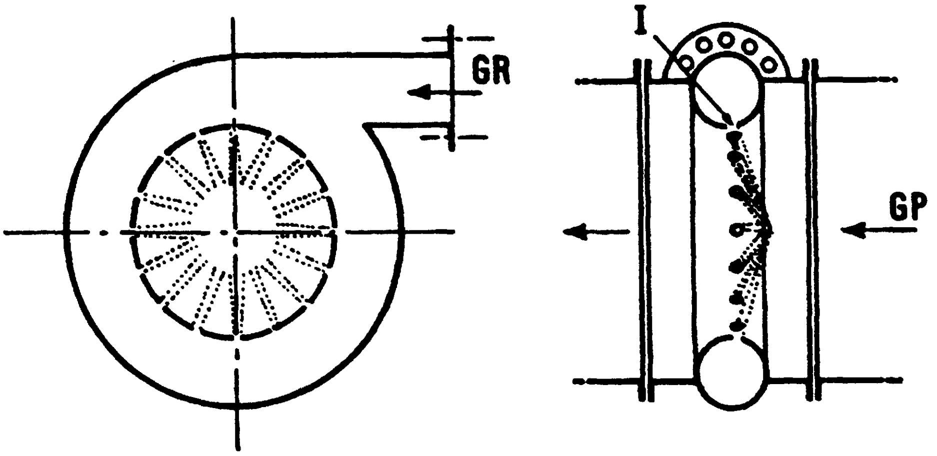
FIGURE 6.7 : Burner for intermediate gas



A - Combustion air
B - Poor gas
Fg - Flame of gas

Fm - Flame of additional fuel
0 - Refractory

FIGURE 6.8 : Burner for poor gas



GR - Rich Gas

GP - Poor Gas

FIGURE 6.9 : **Injection device of rich gas in poor gas**

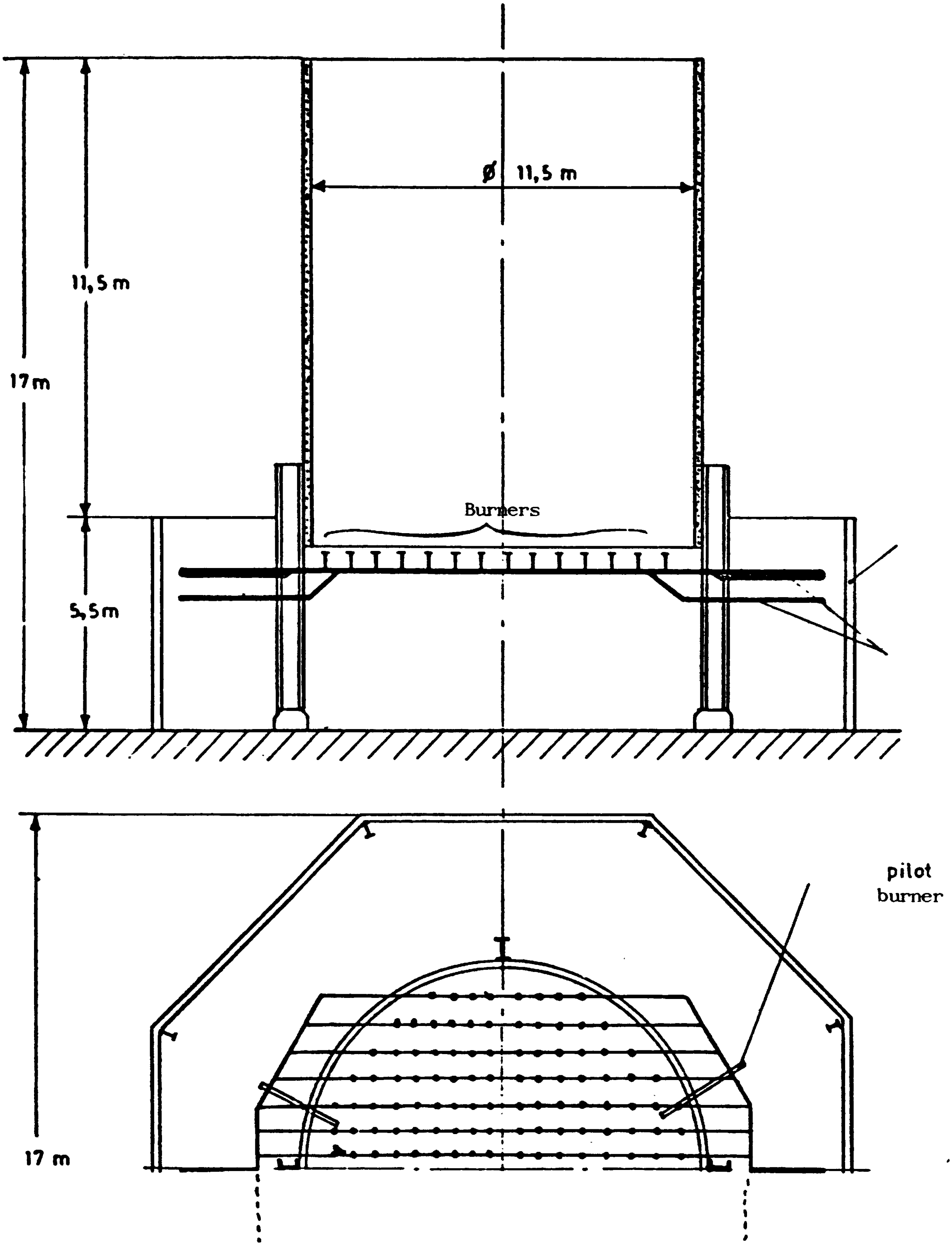


FIGURE 6.10 : Low level flare used in oil industry

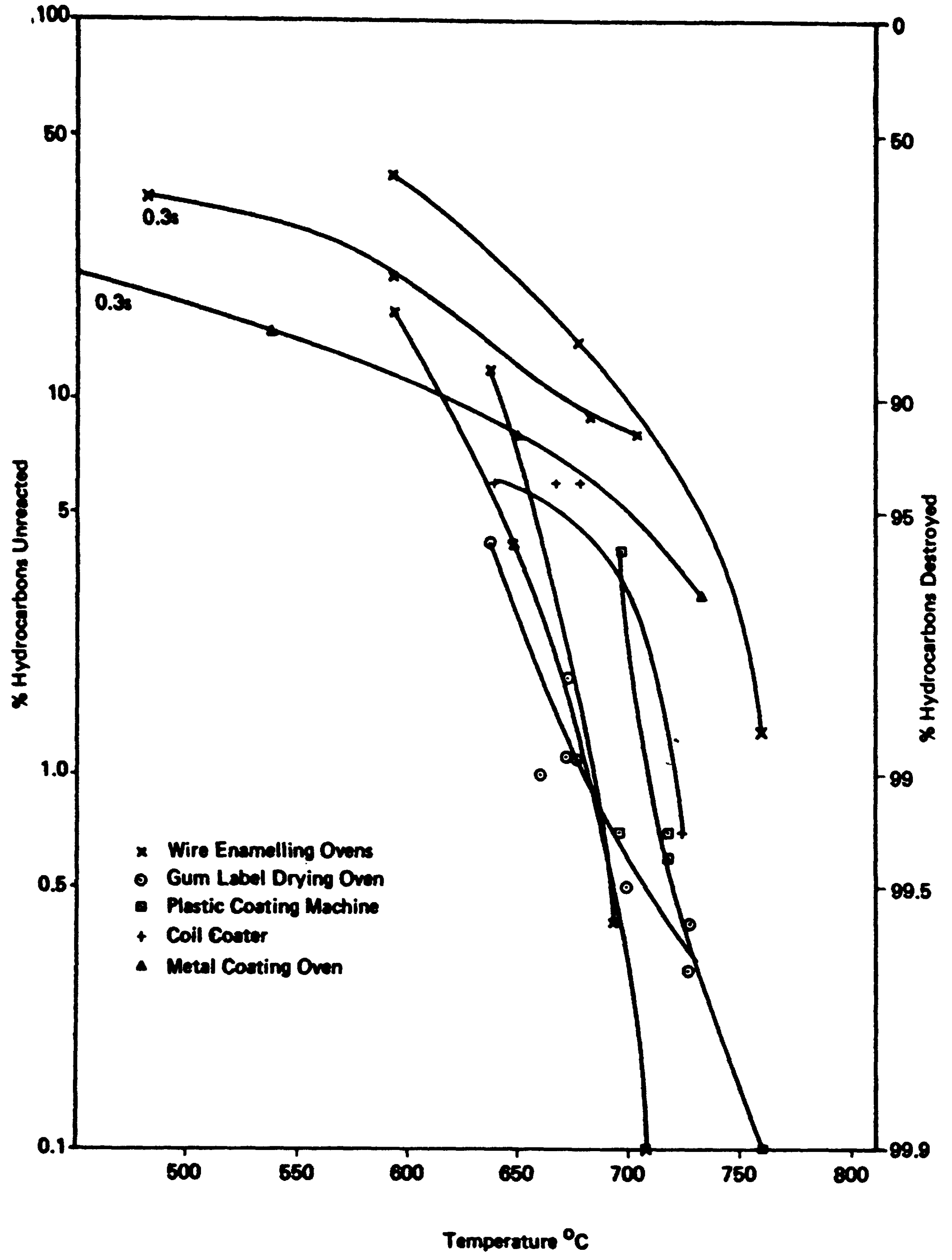


FIGURE 6.11 : *Efficiency of Destruction of Hydrocarbons in Industrial Incinerators* (Ref. 4)

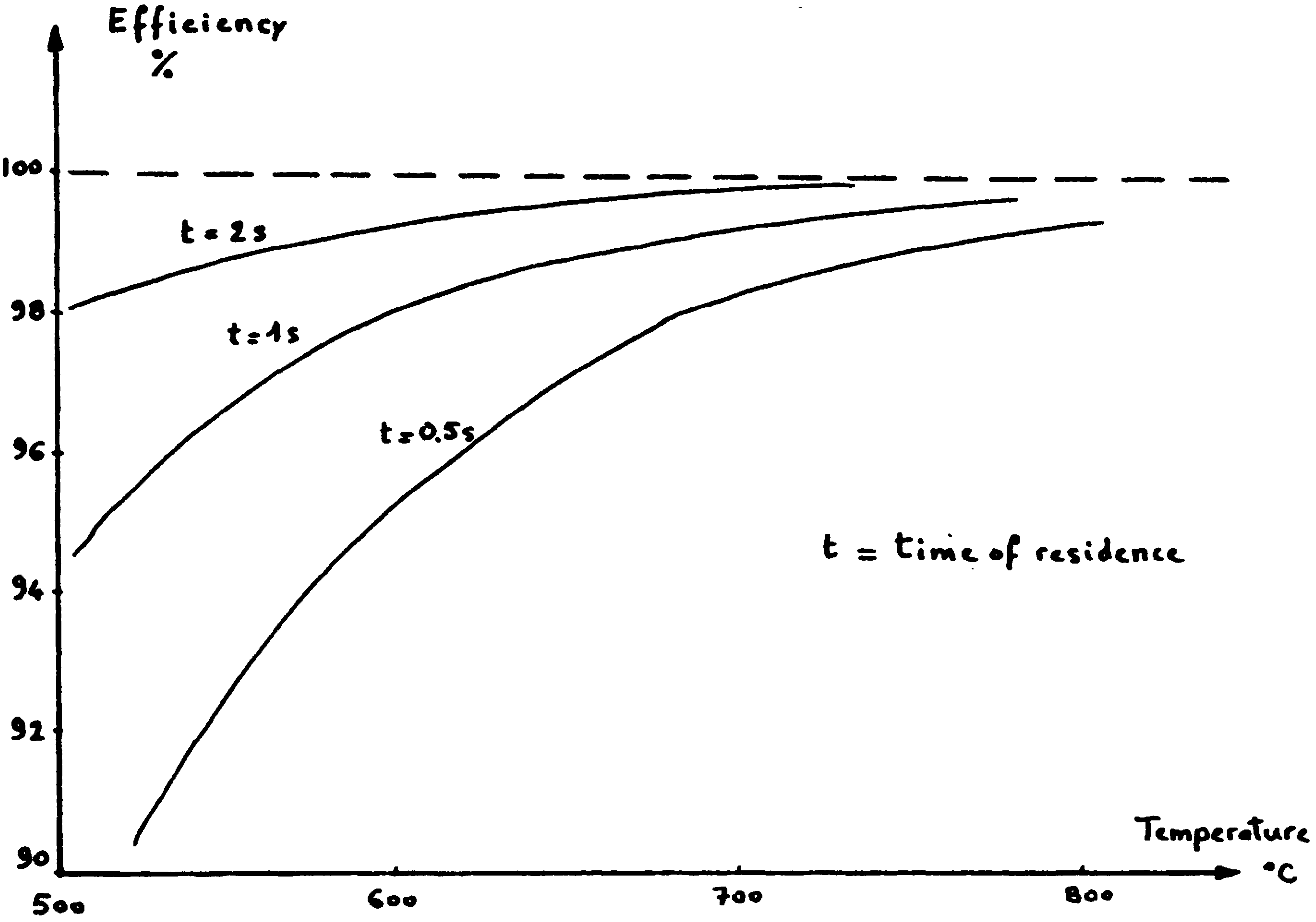


FIGURE 6.12 : Efficiency of incineration related to temperature and time of residence (theoretical case)

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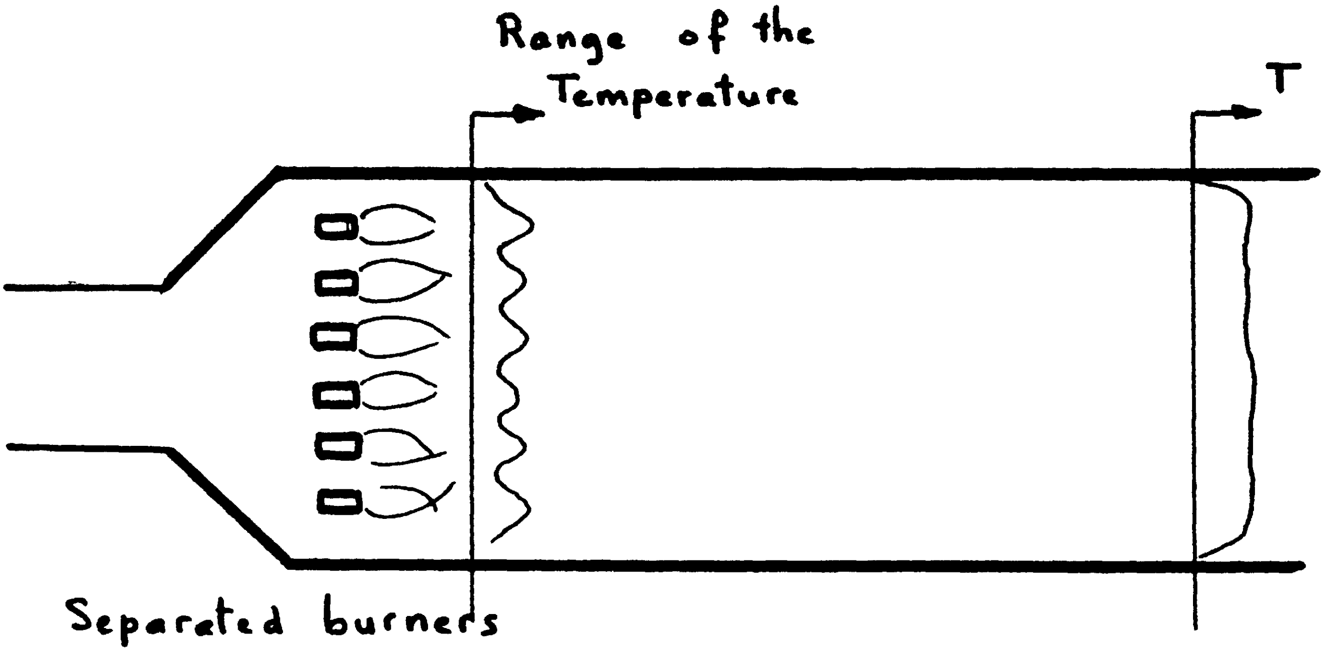
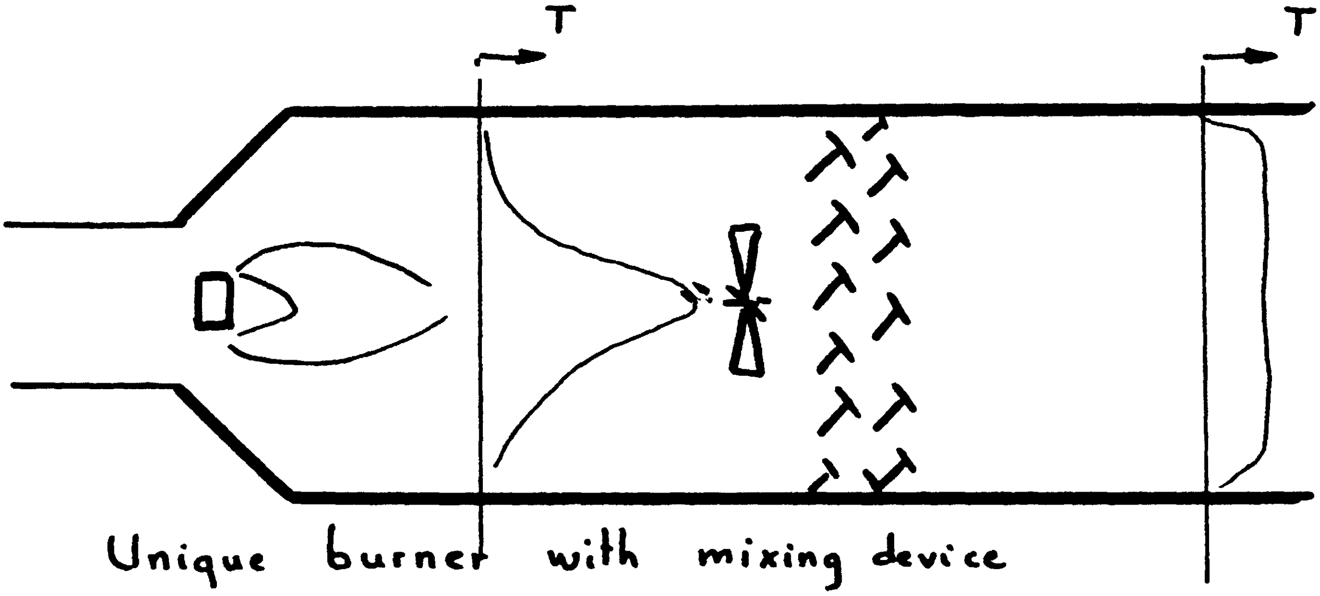


Separated burners



Unique burner with mixing device

FIGURE 6.13 : **Homogeneization of the distribution of the temperature**

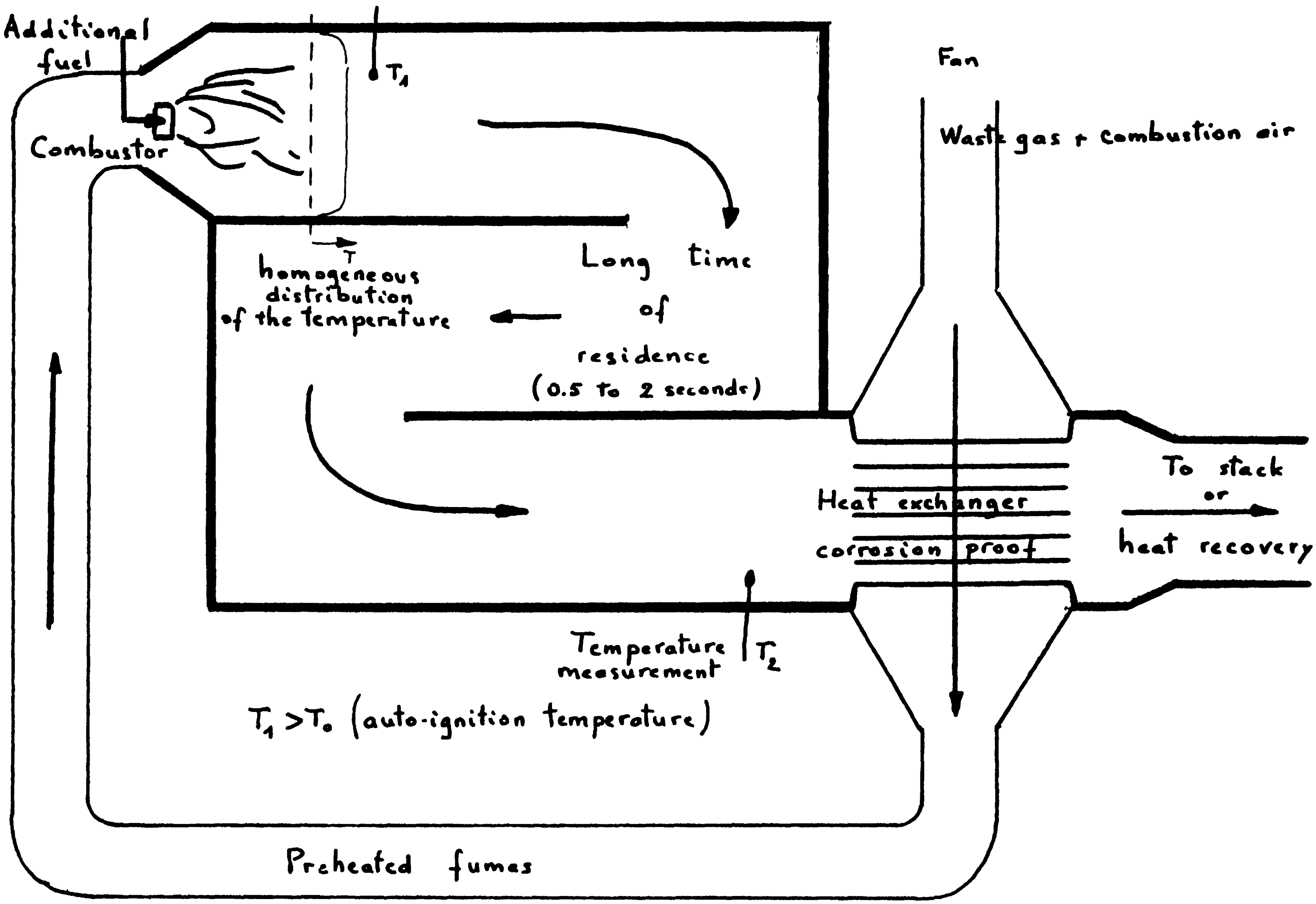


FIGURE 6.14 : Ideal thermal incineration

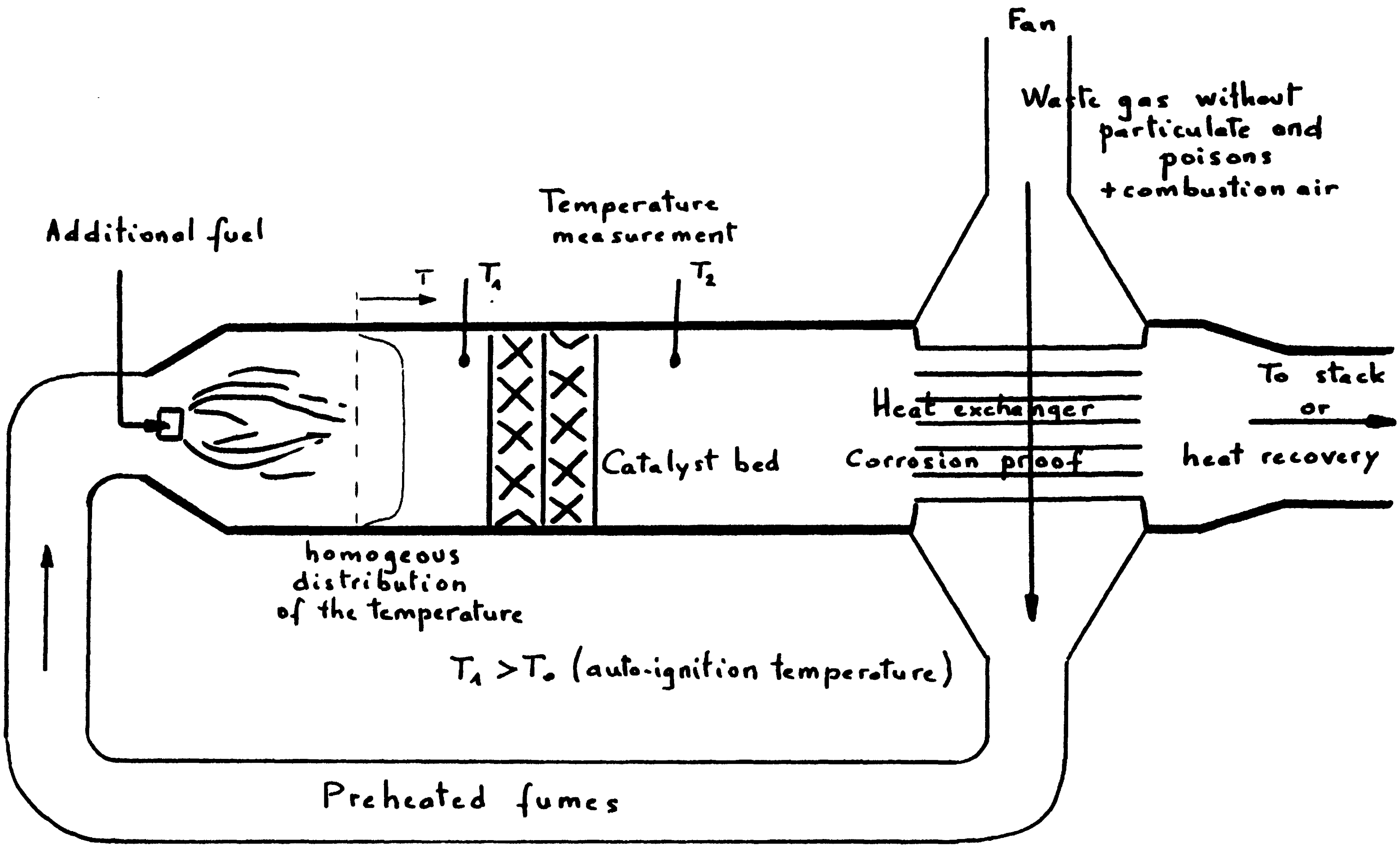


FIGURE 6.15 : Ideal catalytic incineration

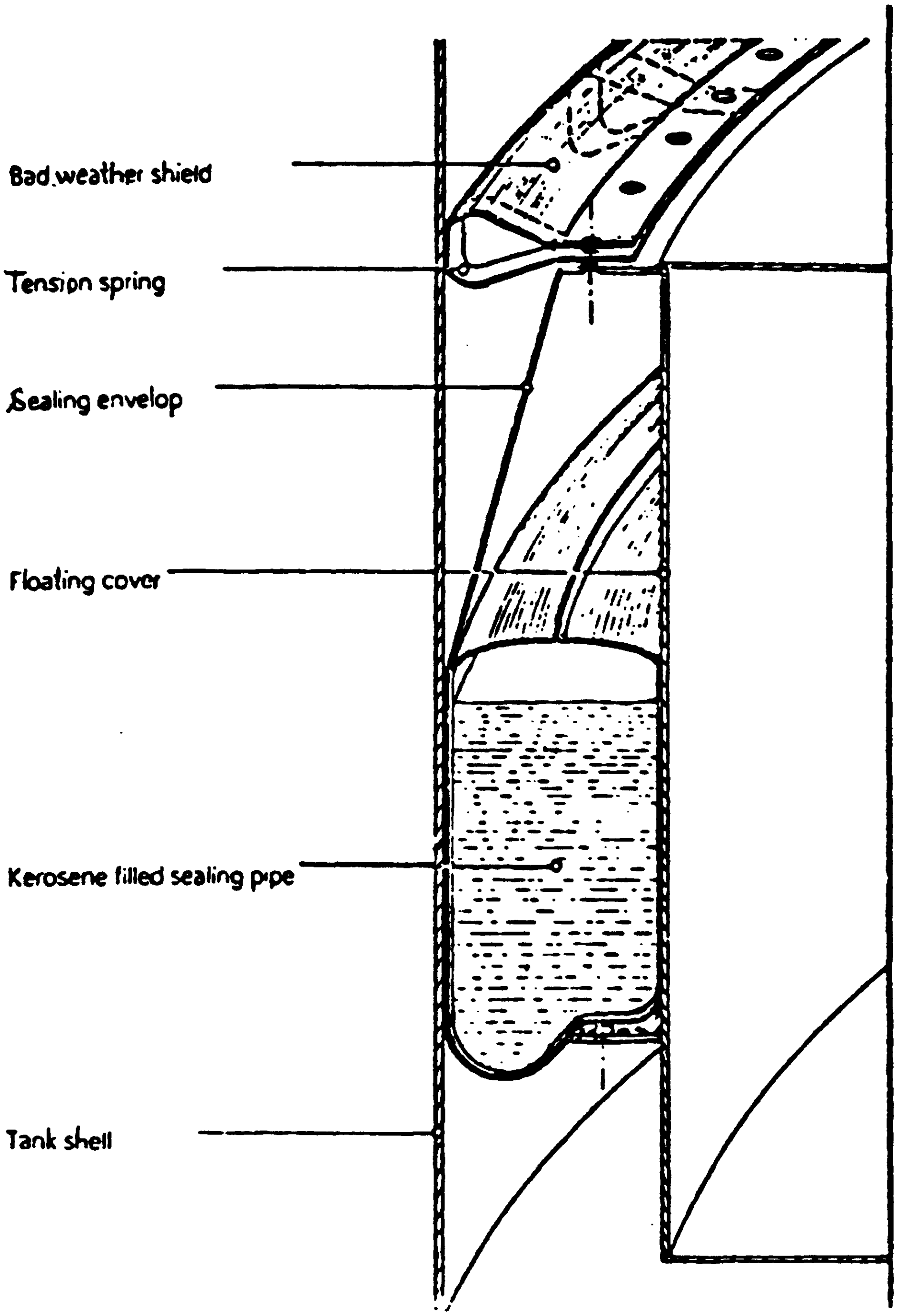


FIGURE 6.16 : **Example of seal system**

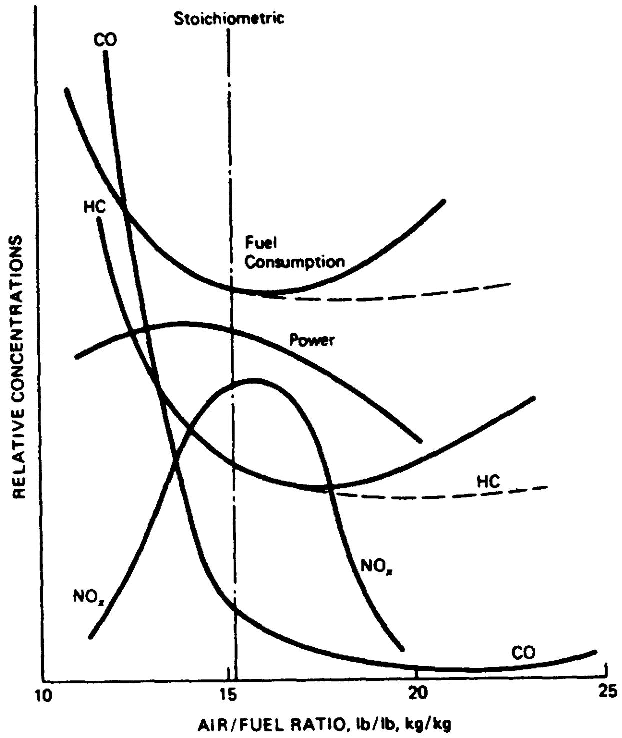
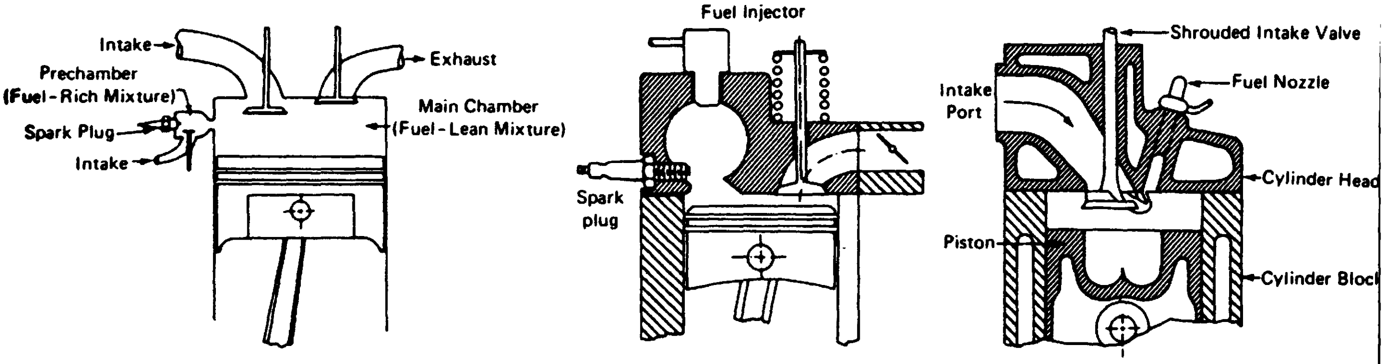


FIGURE 6.17 : Relationship of typical engine emission and performance to air/fuel ratio.

Solid line : conventional engine

Dashed line : lean-burn engine



Small Volume Prechamber
(Torch Ignition)
Honda CVCC

Divided Chamber
Ford

Open Chamber
Texaco TCCS

FIGURE 6.18 : **Stratified-charge engine configurations**

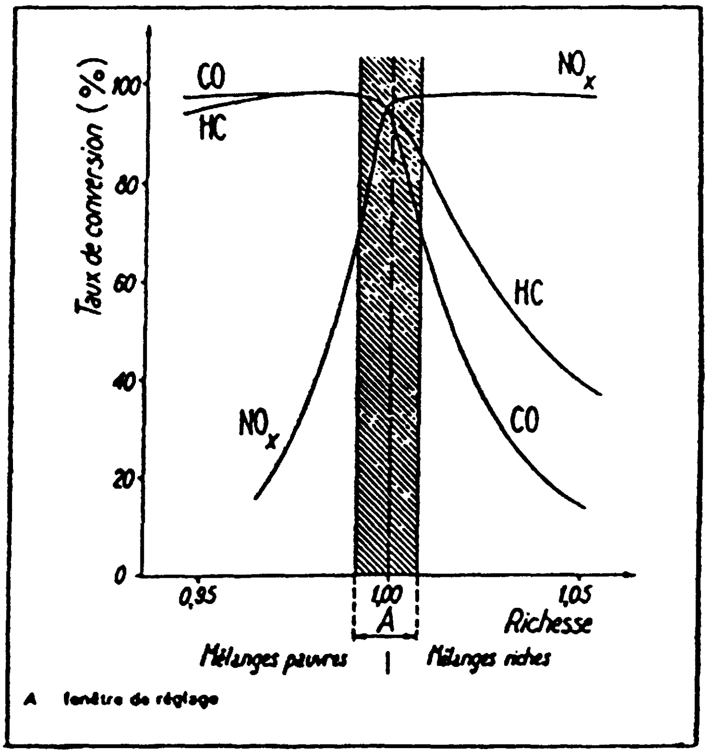


FIGURE 6.19 : Conversion efficiency of a three-way catalyst according to the air/fuel ratio

ANNEXES

ANNEX I

VOC EMISSIONS PER COUNTRY

VOC-emissions in Belgium

Source type	Activity rate	Emission (10^3 ton/year) total	unsaturated	unreactive	other
petroleum refineries	23 Mt/y refinery intake	9.2	1.0		8.2
prim. iron & steel industry					
coke manufacturing	5.000 kt/y coke	1.5	0.75	0.25	0.5
sinter plants	10.000 kt/y sinter	0.5	0.2	0.2	0.1
rolling	kt/y rolled products				
foundries	kt/y cast iron				
chemical industry					
ethene	420 kt/y ethene	0.34	0.13		0.21
1,2-dichloroethane	450 kt/y dce	6.3	1.8	4.5	
vinyl chloride	640 kt/y VC	6.8/3.2	2.2	1.0	
polyvinylchloride	235 kt/y PVC	2.6/2.0	2.0		
polyethylene-LD	380 kt/y PE-LD	0.9/0.57	0.57		
polyethylene-HD	190 kt/y PE-HD	1.2/1.5	0.15		1.0
polystyrene	280 kt/y PS	0.3/1.1			1.1
SBR	30 kt/y SBR	0.1			0.1
carbon black	- kt/y carbon black	-			
other processes		3	0.5	0.5	2
industrial solvent use					
vegetable oil extraction	0.2 kg/cap.year	2			2
metal cleaning	1.5 kg/cap.year	15			
printing	1.0 kg/cap.year	10			
automobile industry (laquer)	$200x10^3$ automob.; $30x10^3$ ut.veh.	4			
other paint consumption	2.0 kg/cap.year	20			
other uses	1.5 kg/cap.year	15			
fermentation processes	1420,7,730, kt/y beer spirits and bread resp.	6			6
waste elimination					
municipal waste incineration	kt/y waste	0.1			
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants					
industrial		1.9	0.5		1.4
residential		9.9	3.0		6.9
other		0.5	0.1		0.4
non-industrial solvent use	6.5 kg/cap.year	64			
road transport					
gasoline, exhaust	see Annex IV	65	12	7.4	46
gasoline, evaporation		14	2	-	12
diesel, exhaust		11.2	3.4	0.7	7.1
LPG, exhaust		2.0	0.6	1.3	0.1
railroads		0.9	0.2	0.1	0.6
air transport	$41x10^3$ LTO/year	0.4	0.1		0.3
navigation, inland		0.8	0.2	0.1	0.5
harbours		1.0	0.3	0.1	0.6
gasoline distribution	2575 kt/y gasoline	11.6	1.3		10.3
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles		1.7	0.5	0.1	1.1
natural emissions					
forests	2900 km² coniferous forest	28	28		
	5000 km² deciduous forest	7	7		
forest fires	km²/y				
Total, anthropogenic		290	35	40	215
, natural		35	35		

VOC-emissions in Denmark

		Emission (10^3 ton/year)			
Source type	Activity rate	total	unsaturated	unreactive	other
petroleum refineries	7 Mt/y refinery intake	2.8	0.3		2.5
prim. iron & steel industry					
coke manufacturing	kt/y coke	-			
sinter plants	kt/y sinter	-			
rolling	kt/y rolled products				
foundries	kt/y cast iron				
chemical industry					
ethene	kt/y ethene				
1,2-dichloroethane	kt/y dce				
vinyl chloride	kt/y VC				
polyvinylchloride	kt/y PVC	0.03	0.03		
polyethylene-LD	kt/y PE-LD	0.005	0.005		
polyethylene-HD	kt/y PE-HD	0.02	0.003		0.017
polystyrene	kt/y PS	0.02			0.02
SBR	kt/y SBR				
carbon black	kt/y carbon black				
other processes					
industrial solvent use					
vegetable oil extraction	0.2 kg/cap.year	1			1
metal cleaning	1.4 kg/cap.year	7			
printing	0.8 kg/cap.year	4			
automobile industry (laquer)	$x10^3$ automob.; $x10^3$ ut.veh.				
other paint consumption	1.6 kg/cap.year	8			
other uses	0.2 kg/cap.year	1			
fermentation processes	87, 260 kt/y beer and bread resp.	1.7			1.7
waste elimination					
municipal waste incineration	1500 kt/y waste	0.1			
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants		1.1			
industrial		1.0	0.2		0.8
residential		3.0	0.8		2.2
other		0.5	0.1		0.4
non-industrial solvent use	6.7 kg/cap.year	34			
road transport					
gasoline, exhaust	see Annex IV	32	5.5	3.8	22.7
gasoline, evaporation		6.5	0.7	-	5.8
diesel, exhaust		5.9	1.75	0.35	3.8
LPG, exhaust					
railroads		1.0	0.2	0.1	0.7
air transport	$70x10^3$ LTO/year	0.7	0.15	0.05	0.5
navigation, inland		1.2	0.3	0.1	0.8
harbours					
gasoline distribution	1368 kt/y gasoline	6.2	0.7		5.5
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles		4.8	1.3	0.3	3.2
natural emissions					
forests	4300 km² coniferous forest	40	40		
	3800 km² deciduous forest	5	5		
forest fires	km²/y				
Total, anthropogenic		125	12	13	100
, natural		45	45		

VOC-emissions in France

		Emission (10^3 ton/year)			
Source type	Activity rate	total	unsaturated	unreactive	other
petroleum refineries	80 Mt/y refinery intake	45/32	5		40
prim. iron & steel industry					
coke manufacturing	8.300 kt/y coke	2.4/2.5	1.2	0.4	0.8
sinter plants	kt/y sinter	0.6	0.25	0.25	0.1
rolling	kt/y rolled products	3.5	1.5		2
foundries	kt/y cast iron	3.7	0.2		3.5
chemical industry					
ethene	1780 kt/y ethene	1.65/1.45	0.65		1.0
1,2-dichloroethane	1100 kt/y dce	15.4	4.4	11.0	
vinyl chloride	690 kt/y VC	2.3/3.4	2.4	1.0	
polyvinylchloride	540 kt/y PVC	6.9/4.6	6.9		
polyethylene-LD	1050 kt/y PE-LD	1.2/1.6	1.2		
polyethylene-HD	190 kt/y PE-HD	1.2/1.15	0.2		1.0
polystyrene	240 kt/y PS	0.5/1.2			1.9
SBR	160 kt/y SBR	0.63/0.55	0.03		0.6
carbon black	130 kt/y carbon black	0.55/0.35	0.3		0.2
other processes		>18/4	1.5	0.5	2.0
industrial solvent use					
vegetable oil extraction	(0.2 kg/cap.year)	7.9/11			7.9
metal cleaning	(1.6 kg/cap.year)	90/90			
printing	(1.0 kg/cap.year)	35/55			
automobile industry (laquer)	x10^3 automob.; x10^3 ut.veh.	28/50			
other paint consumption	(0.9 kg/cap.year)	82/80			
other uses	(1.3 kg/cap.year)	25/70			
fermentation processes	2180,6810,260,3940 kt/y beer, wine spirits and bread resp.	66/65			66
waste elimination					
municipal waste incineration	kt/y waste	0.9			
industrial waste incineration	kt/y waste	0.1			
sewage sludge incineration	kt/y sludge	0.2			
sludge spreading		6.3			
stationary combustion sources					
power plants					
industrial		4.3/8.2	1.1		3.2
residential		50/30	17		33
other		3.5/05	0.7		2.8
non-industrial solvent use	7.0 kg/cap.year	385/370			
road transport					
gasoline, exhaust	see Annex IV	725/425	78	52	295
gasoline, evaporation		102/92	10	-	82
diesel, exhaust		74/77	23	5	49
LPG, exhaust		-			
railroads		5.1/4.2	1.1	0.3	2.8
air transport	280x10^3 LTO/year	6.1/2.8	0.6	0.1	2.1
navigation, inland		0.7/0.6	0.15	0.05	0.4
harbours		2.2	0.4	0.1	1.7
gasoline distribution	17995 kt/y gasoline	120/81	13		107
agriculture					
agric. waste burning	kt/y waste	41			
off-highway vehicles		23/18	6.5	1.5	15
natural emissions					
forests	km² coniferous forest km² deciduous forest	982	982		
forest fires	km²/y	16			
Total, anthropogenic		2000/1700	250/200	250/200	1500/1300
, natural		1000	1000		

VOC-emissions in the Federal Republic of Germany

		Emission (10^3 ton/year)			
Source type	Activity rate	total	unsaturated	unreactive	other
petroleum refineries	Mt/y refinery intake	35/37	4		31
prim. iron & steel industry					
coke manufacturing	kt/y coke	20/7	10	3.5	6.5
sinter plants	kt/y sinter	1.3	0.5	0.5	0.3
rolling	kt/y rolled products				
foundries	kt/y cast iron	6.2	0.3		5.9
chemical industry					
ethene	2700 kt/y ethene	1.0/2.2	0.4/0.8		0.6/1.4
1,2-dichloroethane	900 kt/y dce	13	3.5	9.5	
vinyl chloride	1000 kt/y VC	16/1.6	11 /0.05	5 /1.5	
polyvinylchloride	800 kt/y PVC	1/1.2	1 /1.2		
polyethylene-LD	650 kt/y PE-LD	1.2/1.0	1.2/1.0		
polyethylene-HD	600 kt/y PE-HD	64/3.4	8/0.5		56/2.9
polystyrene	500 kt/y PS	2.4/2.1			2.4/2.1
SBR	200 kt/y SBR	0.7	0.1		0.6
carbon black	250 kt/y carbon black	0.7	0.4		0.3
other processes		43/12	1.0	2.5	8.5
industrial solvent use					
vegetable oil extraction	(0.25 kg/cap.year)	15/12			15
metal cleaning	(2.4 kg/cap.year)	141/110			
printing	(1.2 kg/cap.year	70/65			
automobile industry (laquer)	3600x10^3 automob.;300x10^3 ut.veh.	60			
other paint consumption	2.2 kg/cap.year	130			
other uses	1.5 kg/cap.year	> 50/85			
fermentation processes	9500,1300,310,3390 kt/y beer, wine, spirits and bread resp.	42			42
waste elimination					
municipal waste incineration	kt/y waste	1.0			
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants		9.3			
industrial		13 /14	3.7		9.3
residential		79 /36	10		26
other		5	1		4
non-industrial solvent use	6.2 kg/cap.year	360			
road transport					
gasoline, exhaust	see Annex IV	497	77	59	361
gasoline, evaporation		118	13		105
diesel, exhaust		83	25	5	53
LPG, exhaust		-			
railroads		3.8	1.0	0.3	2.5
air transport	320 x10^3 LTO/year	3.2	0.6	0.2	2.4
navigation, inland		3.0	0.8	0.2	2.0
harbours		1.5	0.3	0.1	1.1
gasoline distribution	22850 kt/y gasoline	115/103	13		102
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles		10	2.5	0.5	7
natural emissions					
forests	48000 km^2 coniferous forest	242 450	450		
	33000 km^2 deciduous forest	45	45		
forest fires	km^2/y	0.9			
Total, anthropogenic		1900	200	250	1450
, natural		240/500	240/500		

VOC-emissions in Greece

Source type	Activity rate	Emission (10^3 ton/year) total	unsaturated	unreactive	other
<u>petroleum refineries</u>	14 Mt/y refinery intake	6.4	0.7		5.7
<u>prim. iron & steel industry</u>					
coke manufacturing	kt/y coke	0.02	0.01		0.01
sinter plants	kt/y sinter				
rolling	kt/y rolled products				
<u>foundries</u>	kt/y cast iron	1.8	0.1		1.7
<u>chemical industry</u>					
ethene	kt/y ethene	0.01	0.004		0.006
1,2-dichloroethane	kt/y dce				
vinyl chloride	kt/y VC				
polyvinylchloride	kt/y PVC	0.5	0.5		
polyethylene-LD	kt/y PE-LD				
polyethylene-HD	kt/y PE-HD				
polystyrene	kt/y PS				
SBR	kt/y SBR				
carbon black	kt/y carbon black				
other processes					
<u>industrial solvent use</u>					
vegetable oil extraction	0.2 kg/cap.year	0.2/ 2			
metal cleaning	0.9 kg/cap.year	0.8/ 9			
printing	0.8 kg/cap.year	8			
automobile industry (laquer)	$x10^3$ automob.; $x10^3$ ut.veh.				
other paint consumption	1.1 kg/cap.year	11			
other uses	0.2 kg/cap.year	2			
fermentation processes	290,470,40,1060 kt/y beer, wine spirits and bread resp.	10			10
<u>waste elimination</u>					
municipal waste incineration	kt/y waste				
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
<u>stationary combustion sources</u>					
power plants		0.7			
industrial		1.9		0.5	1.4
residential		0.7		0.2	0.5
other					
<u>non-industrial solvent use</u>	4.4 kg/cap.year	44			
<u>road transport</u>					
gasoline, exhaust	see Annex IV	40	7.6	4.8	27.6
gasoline, evaporation		7.0	0.8	-	6.2
diesel, exhaust		12	3.7	0.8	7.9
LPG, exhaust		-			
<u>railroads</u>		0.4	0.1		0.3
<u>air transport</u>	50 $x10^3$ LTO/year	0.5	0.1		0.4
<u>navigation</u>, inland		1.8	0.5	0.1	1.2
harbours		1.0	0.2	0.1	0.7
<u>gasoline distribution</u>	1515 kt/y gasoline	6.8	0.7		6.1
<u>agriculture</u>					
agric. waste burning	kt/y waste				
off-highway vehicles		5.7	1.5	0.4	3.8
<u>natural emissions</u>					
forests	12000? km² coniferous forest	}372 110	}372 110		
	13000? km² deciduous forest	20	20		
forest fires	km²/y				
Total, anthropogenic		170	35	10	125
, natural		372/130	372/130		

VOC-emissions in Ireland

Source type	Activity rate	Emission (10^3 ton/year)			
		total	unsaturated	unreactive	other
petroleum refineries	1.3 Mt/y refinery intake	0.5	0.05		0.45
prim. iron & steel industry					
coke manufacturing	kt/y coke	-			
sinter plants	kt/y sinter	-			
rolling	kt/y rolled products				
foundries	kt/y cast iron				
chemical industry					
ethene	kt/y ethene				
1,2-dichloroethane	kt/y dce				
vinyl chloride	kt/y VC				
polyvinylchloride	kt/y PVC				
polyethylene-LD	kt/y PE-LD				
polyethylene-HD	kt/y PE-HD				
polystyrene	kt/y PS				
SBR	kt/y SBR				
carbon black	kt/y carbon black				
other processes					
industrial solvent use					
vegetable oil extraction	0.15 kg/cap.year	0.5			0.5
metal cleaning	1.1 kg/cap.year	4			
printing	1.1 kg/cap.year	4			
automobile industry (laquer)	x10^3 automob.; x10^3 ut.veh.				
other paint consumption	0.9 kg/cap.year	3			
other uses	0.3 kg/cap.year	1			
fermentation processes	590,330 kt/y beer and bread resp.	2.6			2.6
waste elimination					
municipal waste incineration	kt/y waste				
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants					
industrial		0.7	0.2		0.6
residential		6.6	2.2		4.4
other		0.3	0.1		0.2
non-industrial solvent use	5.7 kg/cap.year	20			
road transport					
gasoline, exhaust	see Annex IV	18.7	3.2	2.3	13.2
gasoline, evaporation		4.4	0.5		3.9
diesel, exhaust		1.6	0.5	0.1	1.0
LPG, exhaust		-			
railroads		0.3	0.1		0.2
air transport	27 x10^3 LTO/year	0.3	0.1		0.2
navigation, inland					
harbours		0.1			0.1
gasoline distribution	930 kt/y gasoline	4.2	0.5		3.7
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles		0.4	0.1		0.3
natural emissions					
forests	7300 km² coniferous forest	69.5	69.5		
	300 km² deciduous forest	0.5	0.5		
forest fires	km²/y				
Total, anthropogenic		75	8	8	59
, natural		70	70		

VOC-emissions in Italy

Source type	Activity rate	Emission (10^3 ton/year)			
		total	unsaturated	unreactive	other
petroleum refineries	82 Mt/y refinery intake	33	3.5		29.5
prim. iron & steel industry					
coke manufacturing	6500 kt/y coke	2	1	0.3	0.7
sinter plants	14000 kt/y sinter	0.7	0.3	0.3	0.1
rolling	kt/y rolled products				
foundries	kt/y cast iron				
chemical industry					
ethene	1740 kt/y ethene	1.4	0.5		0.9
1,2-dichloroethane	1230 kt/y dce	17.2	4.9	12.3	
vinyl chloride	640 kt/y VC	3.2	2.2	1.0	
polyvinylchloride	770 kt/y PVC	6.5	6.5		
polyethylene-LD	690 kt/y PE-LD	1.0	1.0		
polyethylene-HD	200 kt/y PE-HD	1.1	0.1		1.0
polystyrene	250 kt/y PS	1.0			1.0
SBR	200 kt/y SBR	0.8	0.1		0.7
carbon black	120 kt/y carbon black	0.3	0.2		0.1
other processes		8	1	2	5
industrial solvent use					
vegetable oil extraction	0.2 kg/cap.year	12			12
metal cleaning	1.6 kg/cap.year	90			
printing	1.0 kg/cap.year	55			
automobile industry (laquer)	1200 x10^3 automob.; 200 x10^3 ut.veh.	25			
other paint consumption	1.9 kg/cap.year	110			
other uses	1.1 kg/cap.year	65			
fermentation processes	1010,8220,300,5300 kt/y beer, wine spirits and bread resp.	80			80
waste elimination					
municipal waste incineration	kt/y waste				
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants					
industrial		7.2	1.8		5.4
residential		5.2	2.2		3.0
other		0.8	0.2		0.6
non-industrial solvent use	5.3 kg/cap.year	300			
road transport					
gasoline, exhaust	see Annex IV	383	77	47	259
gasoline, evaporation		93	10	-	83
diesel, exhaust		71	22	4.4	45
LPG, exhaust		1.8	1.2	0.5	0.1
railroads		1.3	0.4	0.1	0.8
air transport	120 x10^3 LTO/year	1.2	0.2	0.1	0.9
navigation, inland		0.9	0.2	0.1	0.6
harbours		2	0.4	0.1	1.5
gasoline distribution	11020 kt/y gasoline	50	5		45
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles		11.7	3.1	0.8	7.8
natural emissions					
forests	km^2 coniferous forest km^2 deciduous forest				
forest fires	km^2/y				
Total, anthropogenic		1450	150	200	1100
, natural					

VOC-emissions in Luxemburg

		Emission (10^3 ton/year)			
Source type	Activity rate	total	unsaturated	unreactive	other
petroleum refineries	Mt/y refinery intake	-			
prim. iron & steel industry					
coke manufacturing	kt/y coke				
sinter plants	4500 kt/y sinter	0.25	0.1	0.1	0.05
rolling	kt/y rolled products				
foundries	kt/y cast iron				
chemical industry					
ethene	kt/y ethene				
1,2-dichloroethane	kt/y dce				
vinyl chloride	kt/y VC				
polyvinylchloride	kt/y PVC				
polyethylene-LD	kt/y PE-LD				
polyethylene-HD	kt/y PE-HD				
polystyrene	kt/y PS				
SBR	kt/y SBR				
carbon black	kt/y carbon black				
other processes					
industrial solvent use					
vegetable oil extraction	0.25 kg/cap.year	0.1			0.1
metal cleaning	1.4 kg/cap.year	0.5			
printing	1.1 kg/cap.year	0.4			
automobile industry (laquer)	x10^3 automob.; x10^3 ut.veh.				
other paint consumption	0.25 kg/cap.year	0.1			
other uses	kg/cap.year				
fermentation processes	60, 20, 50 kt/y beer, wine and bread resp.	0.45			0.45
waste elimination					
municipal waste incineration	kt/y waste				
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants					
industrial		0.3	0.05		0.25
residential		0.35	0.1		0.25
other					
non-industrial solvent use	6,8 kg/cap.year	2.5			
road transport					
gasoline, exhaust	see Annex IV	3.4	0.64	0.42	2.3
gasoline, evaporation		0.7	0.1	-	0.6
diesel, exhaust		0.4	0.12	0.02	0.26
LPG, exhaust		-			
railroads					
air transport	x10^3 LTO/year				
navigation, inland					
harbours					
gasoline distribution	296 kt/y gasoline	1.3	0.15		1.15
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles					
natural emissions					
forests	500 km^2 coniferous forest	4.5	4.5		
	km^2 deciduous forest	1.5	1.5		
forest fires	km^2/y				
Total, anthropogenic		11	2	0.6	8.4
, natural		6	6		

VOC-emissions in the Netherlands

		Emission (10^3 ton/year)			
Source type	Activity rate	total	unsaturated	unreactive	other
petroleum refineries	Mt/y refinery intake	13.4	1.5		11.9
prim. iron & steel industry					
coke manufacturing	kt/y coke	0.7	0.35	0.1	0.25
sinter plants	kt/y sinter	0.13	0.05	0.05	0.03
rolling	kt/y rolled products				
foundries	kt/y cast iron	0.4	0.02		0.38
chemical industry					
ethene	kt/y ethene	1.5	0.5		1.0
1,2-dichloroethane	kt/y dce	0.45		0.45	
vinyl chloride	kt/y VC	0.7	0.5	0.2	
polyvinylchloride	kt/y PVC	0.4	0.4		
polyethylene-LD	kt/y PE-LD	1.0	1.0		
polyethylene-HD	kt/y PE-HD	0.6	0.1		0.5
polystyrene	kt/y PS	0.2			0.2
SBR	kt/y SBR				
carbon black	kt/y carbon black				
other processes		3.3	0.4	0.3	2.6
industrial solvent use					
vegetable oil extraction	kg/cap.year	3.6			36
metal cleaning	kg/cap.year	10			
printing	kg/cap.year	8			
automobile industry (laquer)	80x10^3 automob.;10x10^3 ut.veh.	1.5			
other paint consumption	kg/cap.year	68			
other uses	kg/cap.year				
fermentation processes	1730,40,830 kt/y beer, spirits and bread resp.	7.5			7.5
waste elimination					
municipal waste incineration	kt/y waste	0.4			
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants					
industrial		2.4/1.2	0.3		0.9
residential		4.0	0.8		3.2
other		0.5	0.1		0.4
non-industrial solvent use	kg/cap.year	90			
road transport					
gasoline, exhaust	see Annex IV	85	14	10	60
gasoline, evaporation		19	2	-	17
diesel, exhaust		14	4.2	0.9	8.7
LPG, exhaust		18	5.5	12	0.5
railroads		0.4	0.1		0.3
air transport	x10^3 LTO/year	0.8	0.2		0.6
navigation, inland		10.5	2.8	0.7	7
harbours		1.5	0.3	0.1	1.1
gasoline distribution	3588 kt/y gasoline	16	2		14
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles		1.8	0.5	0.1	1.2
natural emissions					
forests	2450 km^2 coniferous forest	23	23		
	1050 km^2 deciduous forest	2	2		
forest fires	km^2/y	0.1			
Total, anthropogenic		400	40	60	300
, natural		25	25		

VOC-emissions in Portugal

Source type	Activity rate	Emission (10^3 ton/year)			
		total	unsaturated	unreactive	other
petroleum refineries	Mt/y refinery intake	3.3	0.3		3
prim. iron & steel industry					
coke manufacturing	kt/y coke	0.06	0.03	0.01	0.02
sinter plants	kt/y sinter	0.02	0.01	0.01	
rolling	kt/y rolled products				
foundries	kt/y cast iron				
chemical industry					
ethene	200 kt/y ethene	0.16	0.06		0.1
1,2-dichloroethane	kt/y dce				
vinyl chloride	10 kt/y VC	0.04/0.06	0.04	0.02	
polyvinylchloride	50 kt/y PVC	0.43/0.4	0.43		
polyethylene-LD	120 kt/y PE-LD	0.35/0.2	0.35		
polyethylene-HD	60 kt/y PE-HD	0.35	0.05		0.3
polystyrene	kt/y PS				
SBR	kt/y SBR				
carbon black	kt/y carbon black				
other processes		1	0.4	0.1	0.5
industrial solvent use					
vegetable oil extraction	0.2 kg/cap.year	2			
metal cleaning	0.8 kg/cap.year	8			
printing	0.8 kg/cap.year	8			
automobile industry (laquer)	x10^3 automob.; x10^3 ut.veh.				
other paint consumption	1.0 kg/cap.year	10			
other uses	0.4 kg/cap.year	4			
fermentation processes	380,830,10,500 kt/y beer, wine spirits and bread resp.	7.6			7.6
waste elimination					
municipal waste incineration	kt/y waste				
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants		0.27			
industrial		1.4	0.4		1.0
residential		0.1			
other					
non-industrial solvent use	4.6 kg/cap.year	45			
road transport					
gasoline, exhaust	see Annex IV	7	3.0	2.0	11.6
gasoline, evaporation		6	0.7	-	5.3
diesel, exhaust		12	3.5	0.7	7.3
LPG, exhaust					
railroads					
air transport	x10^3 LTO/year	4.5			
navigation, inland		2.9			
harbours					
gasoline distribution	750 kt/y gasoline	3.4	0.4		3.0
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles		2.8	0.7	0.2	1.9
natural emissions					
forests	km² coniferous forest km² deciduous forest				
forest fires	km²/y				
Total, anthropogenic		140	12	18	110
, natural					

VOC-emissions in Spain

		Emission (10^3 ton/year)			
Source type	Activity rate	total	unsaturated	unreactive	other
petroleum refineries	Mt/y refinery intake	18	2		16
prim. iron & steel industry					
coke manufacturing	3500 kt/y coke	1.0	0.5	0.15	0.35
sinter plants	kt/y sinter	0.3	0.15	0.15	
rolling	kt/y rolled products				
foundries	kt/y cast iron				
chemical industry					
ethene	610 kt/y ethene	0.5	0.2		0.3
1,2-dichloroethane	kt/y dce				
vinyl chloride	170 kt/y VC	0.85	0.6	0.25	
polyvinylchloride	210 kt/y PVC	1.8	1.8		
polyethylene-LD	370 kt/y PE-LD	0.55	0.55		
polyethylene-HD	150 kt/y PE-HD	0.9	0.1		0.8
polystyrene	110 kt/y PS	0.45			0.45
SBR	70 kt/y SBR	0.22	0.02		0.2
carbon black	20 kt/y carbon black	0.05	0.03		0.02
other processes		2	0.4	0.4	1.2
industrial solvent use					
vegetable oil extraction	0.2 kg/cap.year	10			10
metal cleaning	1.0 kg/cap.year	50			
printing	1.0 kg/cap.year	50			
automobile industry (laquer)	800 x10^3 automob.; 130x10^3 ut.veh.	15			
other paint consumption	1.4 kg/cap.year	70			
other uses	0.3 kg/cap.year	15			
fermentation processes	3030, 2000 kt/y wine and bread resp.	27			27
waste elimination					
municipal waste incineration	kt/y waste				
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants					
industrial		5.5	1.5		4
residential		4.1	1.3		2.8
other		0.4	0.1		0.3
non-industrial solvent use	4.7 kg/cap.year	230			
road transport					
gasoline, exhaust	see Annex IV	129	25	16	88
gasoline, evaporation		45	5	-	40
diesel, exhaust		38	12	2.4	24
LPG, exhaust		-			
railroads		1.3	0.3	0.1	0.9
air transport	x10^3 LTO/year				
navigation, inland harbours		6.9	1.8	0.5	4.6
gasoline distribution	5720 kt/y gasoline	26	3		23
agriculture					
agric. waste burning	kt/y waste				
off-highway vehicles		17	5	1	11
natural emissions					
forests	km² coniferous forest km² deciduous forest				
forest fires	km²/y				
Total, anthropogenic , natural		770	70	100	600

VOC-emissions in the United Kingdom

Source type	Activity rate	Emission (10^3 ton/year) total	unsaturated	unreactive	other
petroleum refineries	Mt/y refinery intake	31	3.5		27.5
prim. iron & steel industry					
coke manufacturing	8500 kt/y coke	2.5	1.2	0.4	0.9
sinter plants	8800 kt/y sinter	0.45	0.2	0.2	0.05
rolling	kt/y rolled products				
foundries	kt/y cast iron				
chemical industry					
ethene	1100 kt/y ethene	3/ 0.9	0.35		0.55
1,2-dichloroethane	650 kt/y dce	9.1	2.6	6.5	
vinyl chloride	220 kt/y VC	1.1	0.75	0.35	
polyvinylchloride	350 kt/y PVC	3.0	3.0		
polyethylene-LD	200 kt/y PE-LD	0.3	0.3		
polyethylene-HD	100 kt/y PE-HD	0.6	0.1		0.5
polystyrene	230 kt/y PS	0.9			0.9
SBR	240 kt/y SBR	0.8	0.1		0.7
carbon black	150 kt/y carbon black	0.35	0.2		0.15
other processes		7.5	1	2	4.5
industrial solvent use					
vegetable oil extraction	0.2 kg/cap.year	11			11
metal cleaning	1.5 kg/cap.year	85			
printing	1.0 kg/cap.year	55			
automobile industry (laquer)	950 x10^3 automob.; 200x10^3 ut.veh.	20			
other paint consumption	2.5 kg/cap.year	140			
other uses	0.9 kg/cap.year	50			
fermentation processes	6030,530,4360 kt/y beer spirits and bread resp.	43			43
waste elimination					
municipal waste incineration	kt/y waste	} 38			
industrial waste incineration	kt/y waste				
sewage sludge incineration	kt/y sludge				
sludge spreading					
stationary combustion sources					
power plants					
industrial		8.8	2.5		6.4
residential		59	19		40
other		4.9	1.4		3.5
non-industrial solvent use	6.1 kg/cap.year	340			
road transport					
gasoline, exhaust	} see Annex IV	} 497 / 455	91	56	308
gasoline, evaporation		82	9	-	73
diesel, exhaust		41/48	15	3	30
LPG, exhaust		-			
railroads		6	1.5	0.5	4
air transport	240 x10^3 LTO/year	2.4	0.5	0.1	1.8
navigation, inland harbours	see Annex	4.5	1.2	0.3	3.0
gasoline distribution	19570 kt/y gasoline	88	10		78
agriculture					
agric. waste burning	kt/y waste	see waste elimination			
off-highway vehicles		6.6	1.8	0.4	4.4
natural emissions					
forests	17500 km² coniferous forest	165	165		
	15000 km² deciduous forest	20	20		
forest fires	km²/y				
Total, anthropogenic		1600	200	200	1200
, natural		185	185		

ANNEX II

EMISSIONS OF SPECIFIC COMPOUNDS PER COUNTRY

Emissions of specific compounds in Belgium
(10^3 ton/year)

	solvent use	road gasoline	traffic diesel	chemical industry	other sources
ethene		4.7	1.3	1.0	0.9
1,3-butadiene		0.4		0.02	
other olefins (ethyne excluded)		6.9	0.9	3.2	5.6
benzene		5[1]/2.9	0.3	0.8/0.1	0.3
toluene	8	7.0		0.1	
xylenes	5	5.6		0.1	
styrene		0.5/0.25		0.75/0.4	
acetaldehyde		0.15	0.23		
acroleïn		0.07	0.06		
dichloromethane (methylene chloride)	7				
trichloromethane (chloroform)	0.06				0.01
tetrachloromethane (carbon tetrachloride)	0.4			0.06	
1,2-dichloroethane				4.5	
trichloroethylene	3.0/3.3				
tetrachloroethylene	3.2/5				
vinylchloride				3.1/4.2	
Cl-F-hydrocarbons	4.5				
epichlorohydrin					
ethyleneoxide				0.41	
acrylonitrile				0.1	
phenol				0.01	0.16

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[1] incl. diesel

Emissions of specific compounds in Denmark

(10^3 ton/year)

	solvent use	road traffic gasoline		chemical industry	other sources
			diesel		
ethene		2.0	0.7		
1,3-butadiene		0.15			
other olefins (ethyne excluded)		2.8	0.5		2.8
benzene		2.6 1) 1.8	0.15		0.4
toluene	3.5	4.3			
xylenes	2.2	3.3			
styrene		0.28/0.15			
acetaldehyde		0.07	0.13		
acroleïn		0.03	0.03		
dichloromethane (methylene chloride)	2.8				
trichloromethane (chloroform)					
tetrachloromethane (carbon tetrachloride)	0.15				
1,2-dichloroethane					
trichloroethylene	2.1/1.4				
tetrachloroethylene	1.8/2.2				
vinylchloride					
Cl-F-hydrocarbons	2				
epichlorohydrin					
ethyleneoxide					
acrylonitrile					
phenol				0.08	

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1) incl. diesel

Emissions of specific compounds in the Federal Republic of Germany
(10^3 ton/year)

	solvent use	road traffic gasoline		chemical industry	other sources
		gasoline	diesel		
ethene		27	9.5	2.2	11
1,3-butadiene		2.3		0.5	
other olefins (ethyne excluded)		39	6.5	5	19
benzene		62[1]/29	2.2	11	
toluene	45	70			
xylenes	32	55			
styrene		2.9/2.4		3.4	
acetaldehyde		1.1	1.7		
acroleïn		0.55	0.45		
dichloromethane (methylene chloride)	49				
trichloromethane (chloroform)	0.24				0.08
tetrachloromethane (carbon tetrachloride)	1.5			0.19	
1,2-dichloroethane				15.9/13	
trichloroethylene	18/40				
tetrachloroethylene	36/82				
vinylchloride				12/1.3	
Cl-F-hydrocarbons	30				
epichlorohydrin				0.17	
ethyleneoxide				0.8	0.45
acrylonitrile				1.45	
phenol				0.11	0.92

[1] incl. diesel

Emissions of specific compounds in France

(10^3 ton/year)

	solvent use	road traffic		chemical industry	other sources
		gasoline	diesel		
ethene		28	8.8	2.5	1
1,3-butadiene		2.4		1.1	
other olefins (ethyne excluded)		41	6.0	10	21
benzene		30 1)/22	2.0	4.2	0.5
toluene	40	52			
xylenes	30	41			
styrene		2.9/1.8		3.4	
acetaldehyde		0.9	1.6		
acroleïn		0.45	0.4		
dichloromethane (methylene chloride)	35				
trichloromethane (chloroform)	0.22			0.05	
tetrachloromethane (carbon tetrachloride)	1.4			0.22	
1,2-dichloroethane				11	
trichloroethylene	44/20				
tetrachloroethylene	19/30				
vinylchloride				8.5/7	
Cl-F-hydrocarbons	25				
epichlorohydrin				0.12	
ethyleneoxide				0.40	
acrylonitrile				0.54	
phenol				0.05	0.8

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1) incl. diesel

Emissions of specific compounds in Greece
(10^3 ton/year)

	solvent use	road traffic gasoline	road traffic diesel	chemical industry	other sources
ethene		2.8	1.4		0.01
1,3-butadiene		0.2			
other olefins (ethyne excluded)		4.1	1.0		2.8
benzene		4.7[1]/1.9	0.3	0.7	
toluene	4.6	4.7			
xylenes	3.0	3.8			
styrene		0.5/0.15			
acetaldehyde		0.08	0.25		
acroleïn		0.04	0.07		
dichloromethane (methylene chloride)	3.8				
trichloromethane (chloroform)					
tetrachloromethane (carbon tetrachloride)	0.2				
1,2-dichloroethane					
trichloroethylene	2.0				
tetrachloroethylene	3.3 /3.0				
vinylchloride					
Cl-F-hydrocarbons	2.5				
epichlorohydrin					
ethyleneoxide					
acrylonitrile					
phenol					0.15

[1] incl. diesel

Emissions of specific compounds in Ireland
(10^3 ton/year)

	solvent use	road traffic		chemical industry	other sources
		gasoline	diesel		
ethene		1.3	0.2		
1,3-butadiene		0.1			
other olefins (ethyne excluded)		1.9	0.1		2.5
benzene		1.65 1)/0.9	0.04		0.2
toluene	2.0	2.2			
xylenes	1.3	1.7			
styrene		0.19/0.08			
acetaldehyde		0.04	0.03		
acroleïn		0.02	0.01		
dichloromethane (methylene chloride)	1.6				
trichloromethane (chloroform)					
tetrachloromethane (carbon tetrachloride)					0.07
1,2-dichloroethane					
trichloroethylene	1.4/0.8				
tetrachloroethylene	1.2/1.3				
vinylchloride					
Cl-F-hydrocarbons	1				
epichlorohydrin					
ethyleneoxide					
acrylonitrile					
phenol					0.05

1) incl. diesel

Emissions of specific compounds in Italy

(10^3 ton/year)

	solvent use	road traffic		chemical industry	other sources
		gasoline	diesel		
ethene		28	8.1	2	1
1,3-butadiene		2.4		0.4	
other olefins (ethyne excluded)		40	5.6	8	13
benzene		29[1]/17	1.9	4.4/0.2	
toluene	44	42			
xylenes	30	33			
styrene		3.0/1.5		3.5	
acetaldehyde		0.9	1.5		
acroleïn		0.4	0.4		
dichloromethane (methylene chloride)	37				
trichloromethane (chloroform)	0.22				0.045
tetrachloromethane (carbon tetrachloride)	1.4				0.17
1,2-dichloroethane				11/12.3	
trichloroethylene	28/18				
tetrachloroethylene	19/29				
vinylchloride				6.1/8.7	
Cl-F-hydrocarbons	25				
epichlorohydrin				0.015	
ethyleneoxide				0.5	0.28
acrylonitrile				1.2	
phenol				0.06	0.85

[1] incl. diesel

Emissions of specific compounds in Luxemburg
(10³ ton/year)

	solvent use	road traffic		chemical industry	other sources
		gasoline	diesel		
ethene		0.23	0.05		
1,3-butadiene		0.02			
other olefins (ethyne excluded)		0.34	0.03		0.15
benzene		0.5[1]/0.17	0.01		
toluene	0.2	0.40			
xylenes	0.15	0.32			
styrene		0.02/0.015			0.03
acetaldehyde		0.007	0.008		
acroleïn		0.004	0.002		
dichloromethane (methylene chloride)	0.2				
trichloromethane (chloroform)					
tetrachloromethane (carbon tetrachloride)					0.01
1,2-dichloroethane					
trichloroethylene	0.11/0.09				
tetrachloroethylene	0.11/0.14				
vinylchloride					
Cl-F-hydrocarbons	0.13				
epichlorohydrin					
ethyleneoxide					
acrylonitrile					
phenol					0.005

[1] incl. diesel

Emissions of specific compounds in the Netherlands

(10^3 ton/year)

	solvent use	road traffic		chemical industry	other sources
		gasoline	diesel		
ethene		5.1	1.6	2.6	3.1[2]
1,3-butadiene		0.45		0.4	
other olefins (ethyne excluded)		7.5	1.1	5.5	6.1[3]
benzene		7.3[1]/4.7	0.35	1.2	
toluene	13	11.3			
xylenes	5	8.9			
styrene		0.7 /0.4		1.45	
acetaldehyde		0.18	0.29	0.08	0.2[4]
acroleïn		0.09	0.07	0.03	
dichloromethane (methylene chloride)	7.5				
trichloromethane (chloroform)	0.2			0.02	
tetrachloromethane (carbon tetrachloride)	0.37			0.04	
1,2-dichloroethane				0.45	
trichloroethylene	2.9				
tetrachloroethylene	5.7				
vinylchloride				0.7	
Cl-F-hydrocarbons	5.9				
epichlorohydrin				0.06	
ethyleneoxide				0.2	0.23
acrylonitrile				0.23	
phenol				0.03	0.21

[1] incl. diesel

[2] o.w. 2.6 from LPG-powered vehicles

[3] o.w. 1.6 " " " "

[4] from LPG-powered vehicles

Emissions of specific compounds in Portugal
(10^3 ton/year)

	solvent use	road traffic		chemical industry	other sources
		gasoline	diesel		
ethene		1.1	1.3	0.3	0.1
1,3-butadiene		0.09			
other olefins (ethyne excluded)		1.6	0.9	0.8	1.3
benzene		1.4[1]/0.9	0.3		
toluene	4.5	2.1			
xylenes	3	1.7			
styrene		0.5 /0.07		0.3	
acetaldehyde		0.035	0.25		
acroleïn		0.02	0.06		
dichloromethane (methylene chloride)	3.8				
trichloromethane (chloroform)					
tetrachloromethane (carbon tetrachloride)	0.15				
1,2-dichloroethane				0.2	
trichloroethylene	1.0/1.9				
tetrachloroethylene	3.3/3				
vinylchloride				0.45	
Cl-F-hydrocarbons	2.5				
epichlorohydrin					
ethyleneoxide					
acrylonitrile				0.075	
phenol					0.14

[1] diesel included

Emissions of specific compounds in Spain

(10^3 ton/year)

	solvent use	road	traffic	chemical industry	other sources
		gasoline	diesel		
ethene		8.9	4.4	1	0.8
1,3-butadiene		0.8		0.05	
other olefins (ethyne excluded)		13	3.0	3.7	12
benzene		10[1]/6.3	1.0		
toluene	20	15			
xylenes	14	12			
styrene		2.0/0.5		1.2	
acetaldehyde		0.28	0.8		
acroleïn		0.14	0.2		
dichloromethane (methylene chloride)	17				
trichloromethane (chloroform)					
tetrachloromethane (carbon tetrachloride)	0.9				
1,2-dichloroethane				3.0	
trichloroethylene	19/ 9				
tetrachloroethylene	17/14				
vinylchloride				2.4	
Cl-F-hydrocarbons	12				
epichlorohydrin				0.012	
ethyleneoxide				0.12	
acrylonitrile				0.43	
phenol					0.7

[1] incl. diesel

Emissions of specific compounds in the United Kingdom
(10^3 ton/year)

	solvent use	road gasoline	traffic diesel	chemical industry	other sources
ethene		33	5.5	1	1.5
1,3-butadiene		2.8		0.3	
other olefins (ethyne excluded)		48	3.8	7	36
benzene		29[1]/21	1.3	4.3/0.5	
toluene	40	50			
xylenes	28	39			
styrene		3.0/1.7		3.7	
acetaldehyde		1.0	1.0		
acroleïn		0.5	0.25		
dichloromethane (methylene chloride)	35				
trichloromethane (chloroform)	0.22				0.06
tetrachloromethane (carbon tetrachloride)	1.4				0.17
1,2-dichloroethane				6	
trichloroethylene	50/18				
tetrachloroethylene	19/28				
vinylchloride				3.6/3.8	
Cl-F-hydrocarbons	25				
epichlorohydrin				0.03	
ethyleneoxide				0.41	
acrylonitrile				0.88	
phenol				0.04	0.84

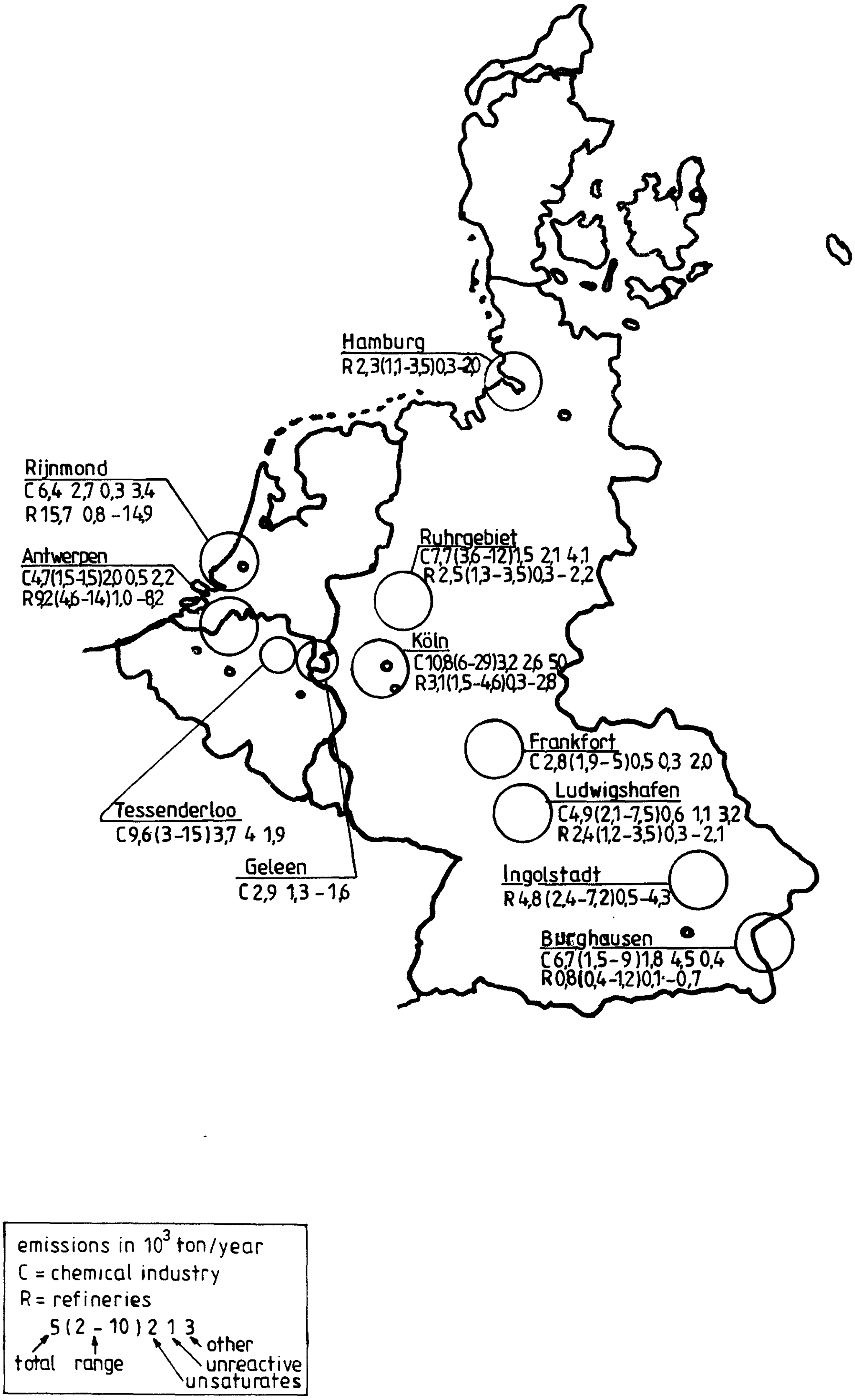
[1] incl. diesel

Emissions of specific compounds in the European Communities
(10^3 ton/year)

	solvent use	road gasoline	traffic diesel	chemical industry	other sources
ethene		145	45	13	20
1,3-butadiene		12		3	
other olefins (ethyne excluded)		210	30	45	125
benzene		180/110	10	10	27
toluene	225	260			
xylenes	155	205			
styrene		16/ 9		18	
acetaldehyde		5	8		
acroleïn		2.5	2		
dichloromethane (methylene chloride)	200				
trichloromethane (chloroform)	1.2			0.1	0.2
tetrachloromethane (carbon tetrachloride)	8			0.5	0.4
1,2-dichloroethane				50	
trichloroethylene	170/120				
tetrachloroethylene	130/200				
vinylchloride				35	
Cl-F-hydrocarbons	135				
epichlorohydrin				0.4	
ethyleneoxide				3	
acrylonitrile				5	
phenol				0.4	5

ANNEX III

LOCAL CONCENTRATIONS OF VOC EMISSIONS PER COUNTRY



Local concentrations of VOC-emissions in Belgium, the Federal Republic of Germany and the Netherlands

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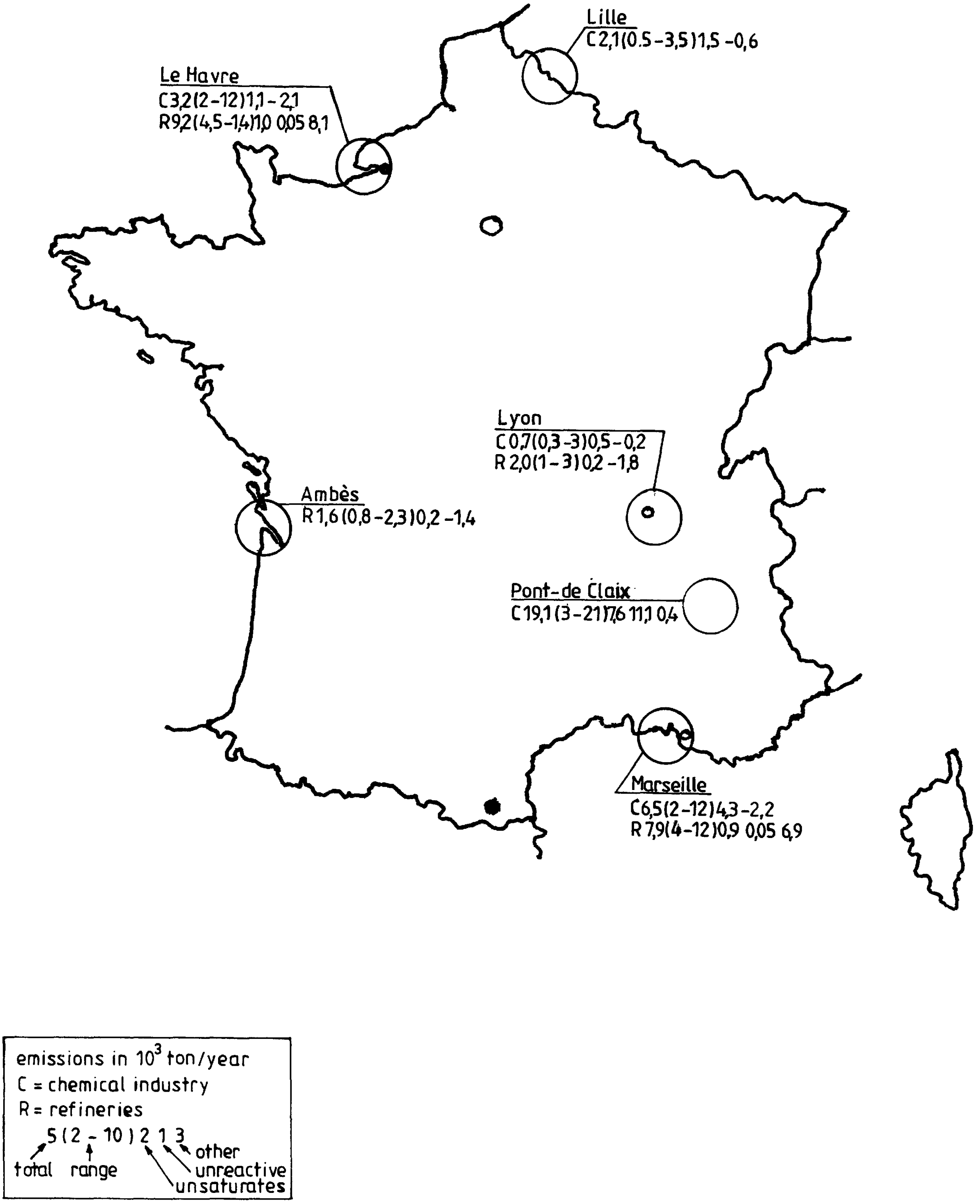
Fig. III. 1



Local concentrations of VOC-emissions in France

MT_TNO
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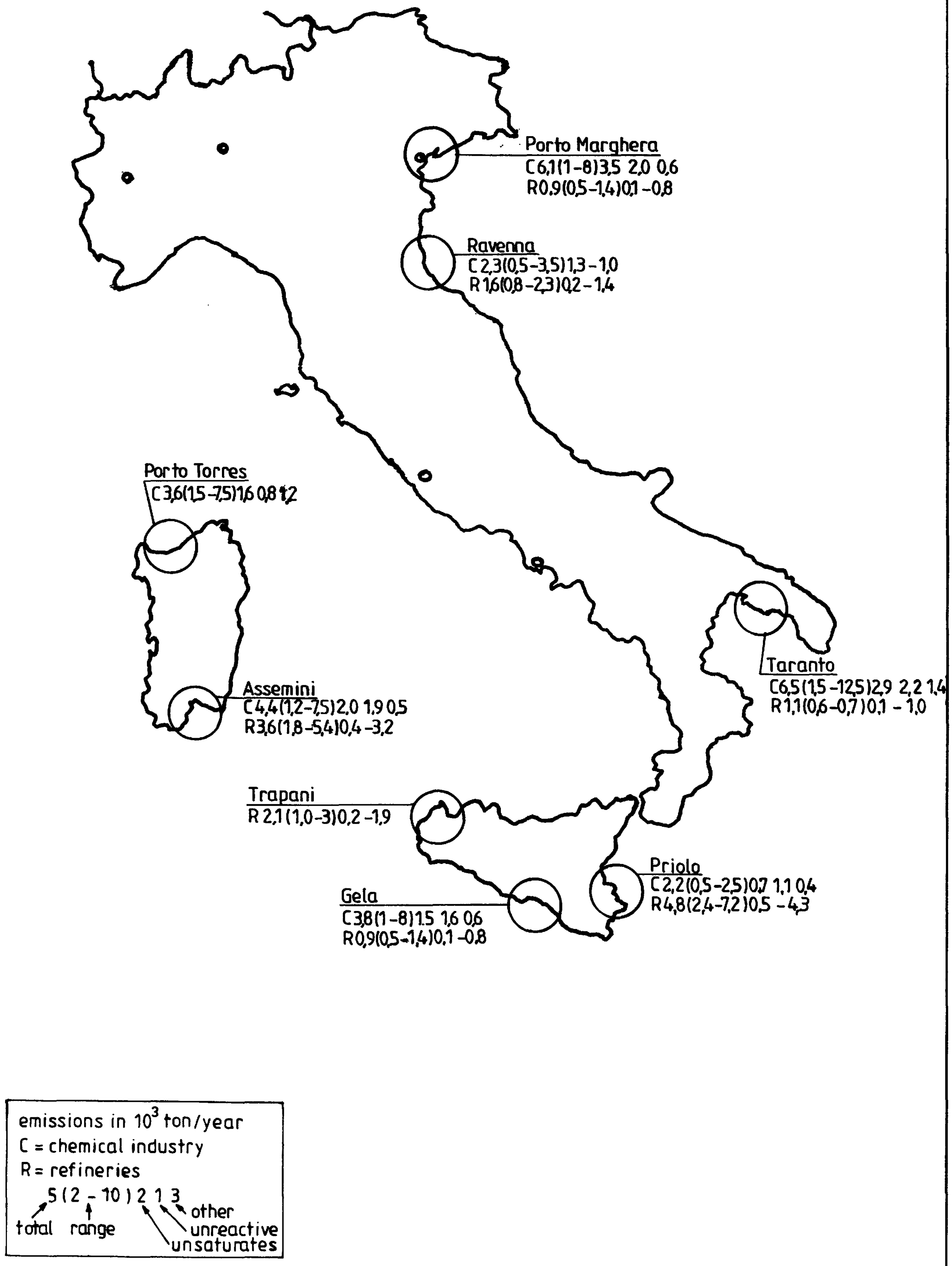
Fig. III.2

emissions in 10^3 ton/year
C = chemical industry
R = refineries
5 (2 - 10) 2 1 3
total range
other
unreactive
unsaturates

Local concentrations of VOC-emissions in Greece

MT_TNO
13014
Fig. III.3



Local concentratrations of VOC-emissions in Italy

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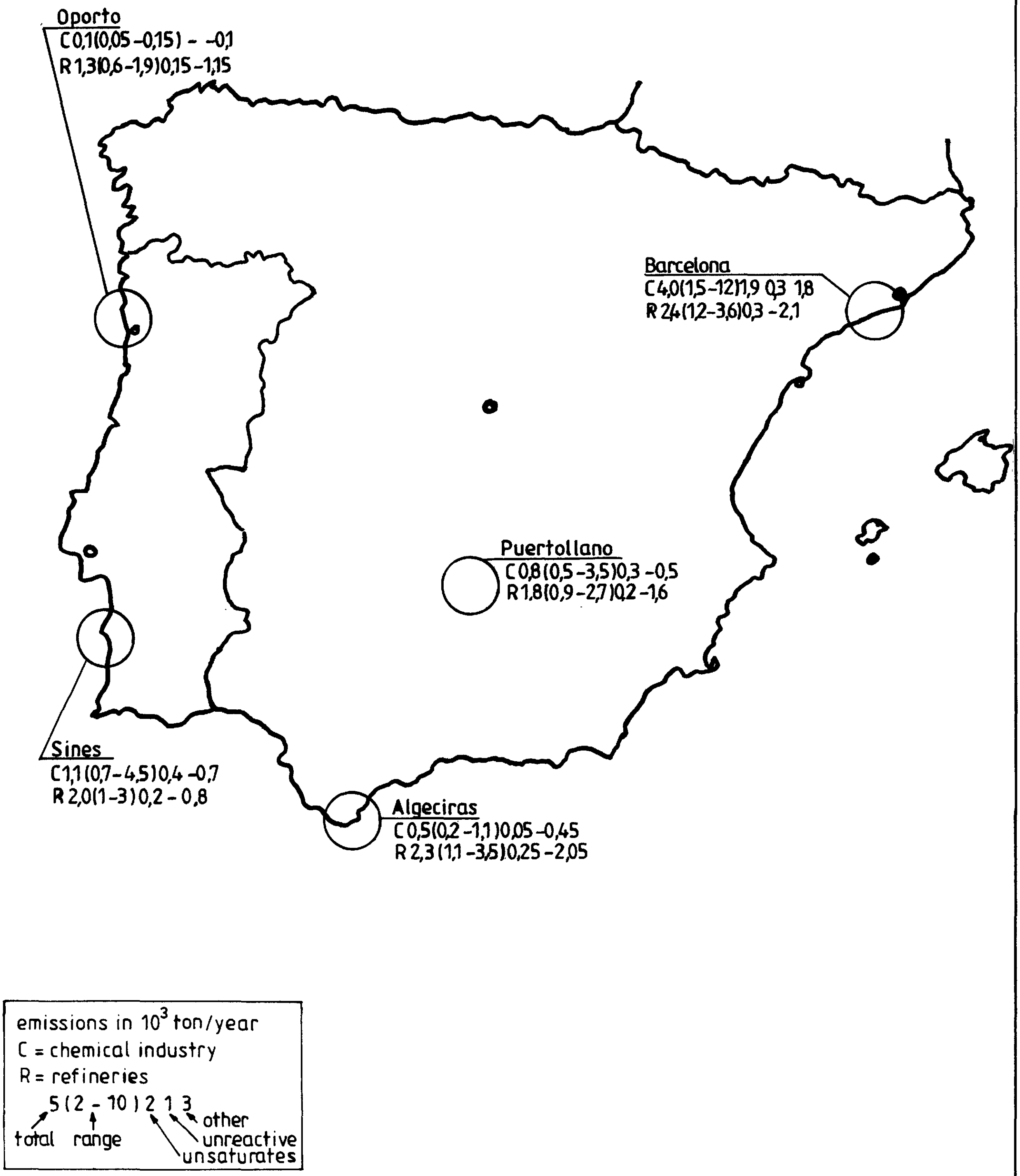
Fig.III.4



Local concentrations of VOC-emmissions in Portugal and Spain

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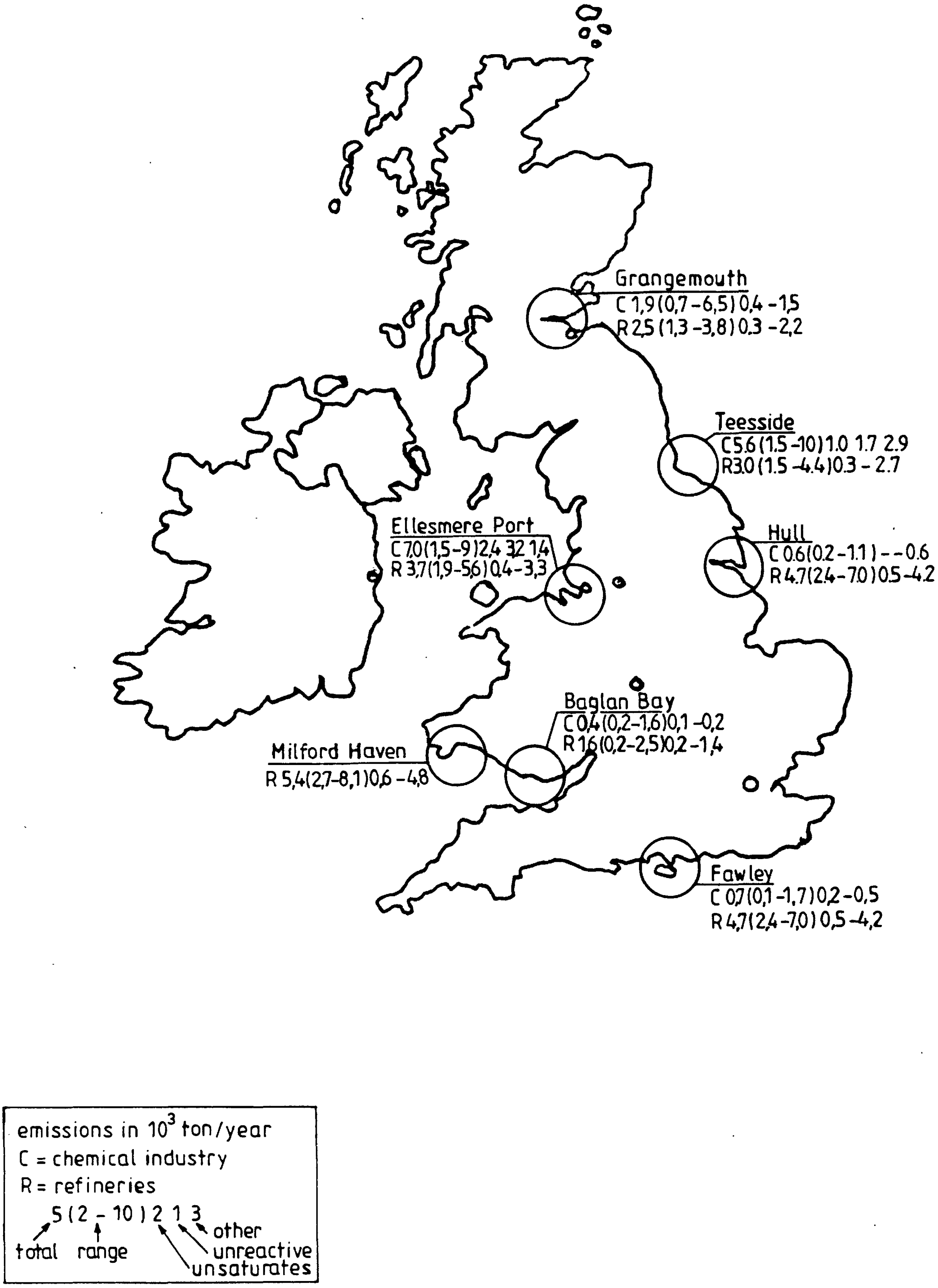
Fig. III.5



Local concentrations of VOC-emissions in the United Kingdom

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13014
Fig.III.6

ANNEX IV

VOC-EMISSIONS FROM ROAD TRAFFIC

VOC-EMISSIONS FROM ROAD TRAFFIC

In the sections 3.4.10 and 3.5 the methodology of road traffic emissions estimation has been described. In this annex details are reported.

1. MASS EMISSIONS

1.1 Vehicle data

From national statistics and from data collected by the ad-hoc working party "Motor Vehicle Emissions" of the EC numbers of vehicles per member country were estimated for the year 1985. Obtainable data varied with respect to base year from 1981 to 1985 and, since harmonization was anyhow necessary it was felt that the choice of a recent base year would be advantageous. The estimated error in vehicle categories was considered to be small. Subdivisions within a category, however, could for some countries only be made by rough estimations based upon comparisons. Considering the LPG-consumption in member countries LPG-powered vehicles were assumed to be influencing emissions only in Belgium, Italy and the Netherlands.
In tables IV-1 and IV-2 the parc data are presented. For Portugal and Spain no realistic subdivisions were possible. The numbers of the main vehicle types only allowed rough emission estimations to be made.

1.2 Emission factors

In section 3.4.10 has been reported how emission factors were obtained. Fig. IV-1 shows the measured data. In table IV-3 the emission factors deduced from these data are given. The factor for evaporative emissions also is given for reasons of completeness.

1.3 Emissions

Exhaust emissions, obtained by multiplication of mileage per vehicle (sub) type and per mode and the accompanying emission factor are presented in table IV-4. Evaporative emissions were calculated from all gasoline-powered vehicles. The emission factor for motorcycles was assumed to be 30% of the factor for automobiles, based on tank geometry and place of the tank.

All data (numbers of vehicles, mileages, emission factors and emissions) are, for all member countries, presented in separate tables in this Annex. These emissions do not take into account differences in automobile parc age. The working-party of the EC reported average ages for the vehicle-parcs in most of the member countries. An average age can be deduced from these figures with the exception of Belgium (one year younger), Denmark (one year older) and Italy (two years older). For Greece no data were available and it was assumed that the parc's age for this country is comparable to Italy. To correct for differences in age the emission factors for gasoline-powered automobiles may be taken 4% higher or lower per year increase or decrease of average parc age.

The corrected exhaust emissions are given in table IV-4 as well as in all other places in this report where road traffic emissions are presented.

In table IV-5 exhaust and evaporative emissions are given as a percentage per road class.

2. COMPOSITION

The composition of VOC exhaust emissions used in this study was taken from (17). The following text has been extracted from that paper. Literature references in it are given in a separate list at the end of this Annex.

For gasoline-powered vehicles the literature was searched for test data satisfying the following demands: a) test vehicle(s) without exhaust control, b) VOC-analysis comprising at least main components, c) complete (or nearly complete) mass balance. Eleven investigations answered these demands (table IV-6).

All data were converted to % by weight to facilitate combination with mass emission factors. As could be expected, averaging absolute fractions was not of much use. Therefore composition profiles were calculated for saturates, unsaturates and aromates. These resulted in applicable averages (tables IV-7a and b).

Next the profiles had to be integrated to one average composition. Only for aromates a useful correlation between fuel- and exhaust composition appeared to exist (fig. IV-2). It has been shown, however (12, 13), that there is a relation between fuel aromates and exhaust olefines (fig. IV-3). With this, exhaust composition can be estimated by the aromatic content of the fuel (fig. IV-4). Finally, a correction for oxygenates is needed. Oxygenate content and composition as well as diesel- and LPG-exhaust composition were estimated from literature data satisfying the same above-mentioned demands (tables IV-8 to 10). In contrast with gasoline-exhaust composion useful material was scarce; for diesel fuel only six more or less incomplete date-sets were found, for LPG only two (20, 22). Since only one report about field measurements was found that could be used as a comparison (21), an average road traffic exhaust composition was calculated for that purpose (Netherlands, 1978; table IV-11). In this table a comparison based on a reactivity scheme has been added because this is what ultimately is of interest.

The results have been used to estimate mass emissions of some VOC-species present in vehicle exhaust that are in the list of chosen substances (Section 3.2). For that purpose the aromatic content of gasoline is needed. Yearly average data for 1983 for member countries were taken from (52). No data were given for Greece, Ireland and Luxemburg. For these countries 40 wt. % was assumed. The aromatic contents used are:

Belgium	: 36 wt. %
Denmark	: 45
France	: 42
Fed. Rep. of Germany	: 49
Greece	: 40
Ireland	: 40
Italy	: 36
Luxemburg	: 40
Netherlands	: 46
Portugal	: 43
Spain	: 40
United Kingdom	: 36

3. DISCUSSION

Assessing exhaust emissions from road traffic by completing a mileage-emission factor matrix per country, taking into account all parameters that are recognized as relevant has already been proposed and worked out into detail by experts from TÜV-Rheinland (Cologne). Attempts to make this method operational for EEC-member countries resulted in data-sets for only a few countries that disposed of the necessary data.

The emission estimation reported here should be considered as an attempt to make the most of all information available at present. It was realized of course that many data are missing, and, replaced as they are by default values, results are expectedly disputable. However, it was also realized that even a rough picture might have the spin-off effect of a discussion that might result into improvements.

Road transport emissions reported by member countries allow provisional comparisons to be made. Results for the Federal Republic of Germany are ca. 10% too low. This can be explained in the first place by the methane content and next by the difference in base years. Those for the United Kingdom are ca. 10% too high and emissions from France are only half of those, reported by CITEPA. This large difference is being discussed. Reported emissions from Belgium, Denmark, Greece, Ireland and the Netherlands are all considerably higher than those estimated for this study. The differences probably are caused by the factors applied, apart from the difference between total VOC and NMVOC.

If emissions from gasoline-powered vehicles are combined with - in dependent - gasoline consumption data, the average emission factor for seven countries is 22.8 ± 1.3 kg VOC/ton gasoline. Exceptions are Belgium (26.7), Italy (36.5) and Luxemburg (11.7) (see table IV-4, also for similar factors for diesel oil). For the time being this should not be considered as proof for the reliability of the method used in this study. Discussion should be concentrated on emission factors in the first place.

Another cause of differences may be the effects of cold start and the successive warming-up on emissions. These are, in all probability, not incorporated in the measured data that are the basis of the emission factors used. The magnitude of the effects depend on climatological conditions. This, together with the fraction of the millage driven in urban traffic (where the effects are restricted to) determined the increase of emissions. The yearly average result may vary between 10 and 25% per country.

Considering the combined effects of subtraction of methane, differences in base years and the effect of cold start, the emissions presented in table IV-4 could be 25 - 45% higher for the base year 1983.

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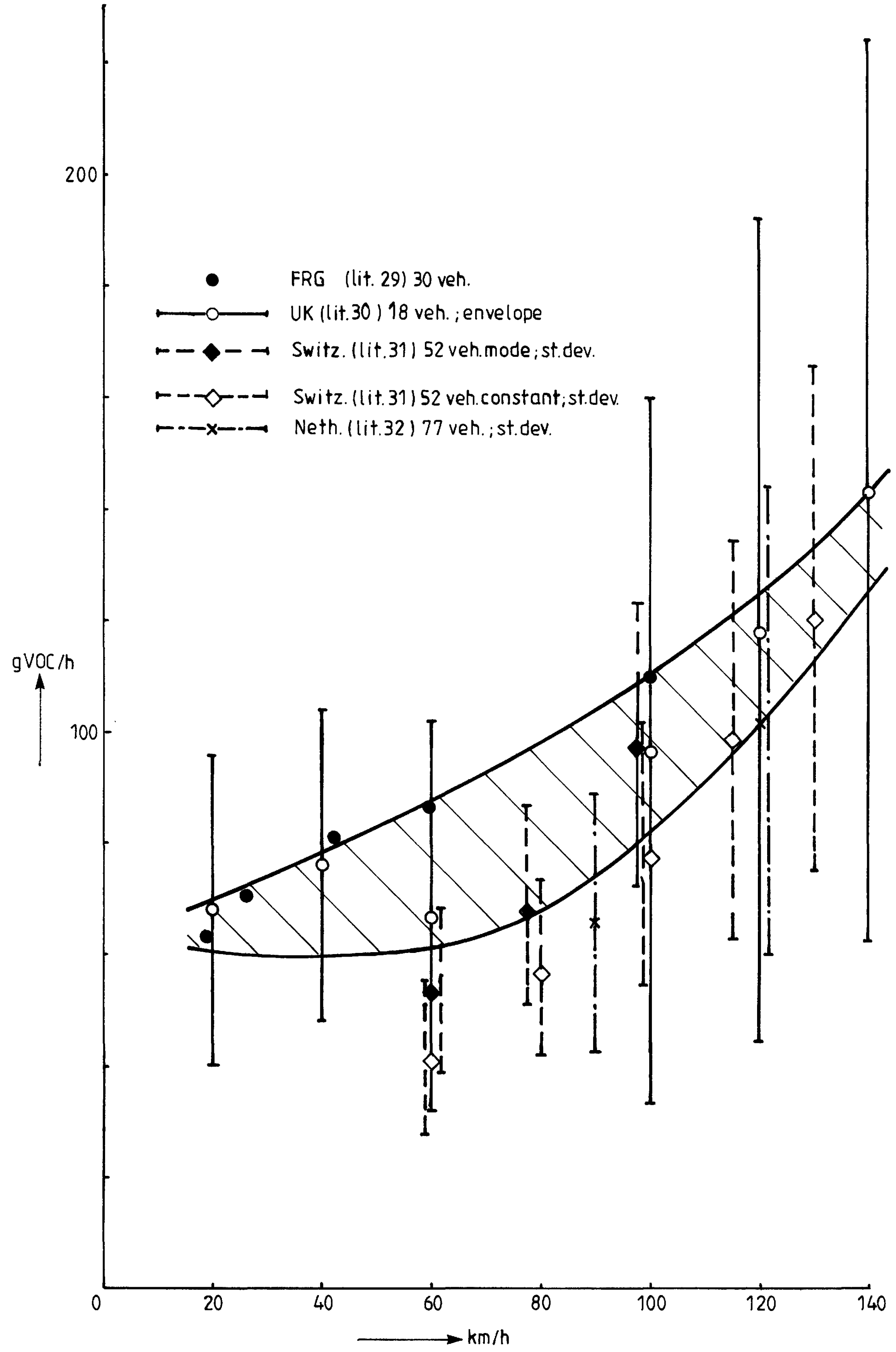

VOC-exhaust emissions of gasoline-powered automobiles

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Fig. IV.1

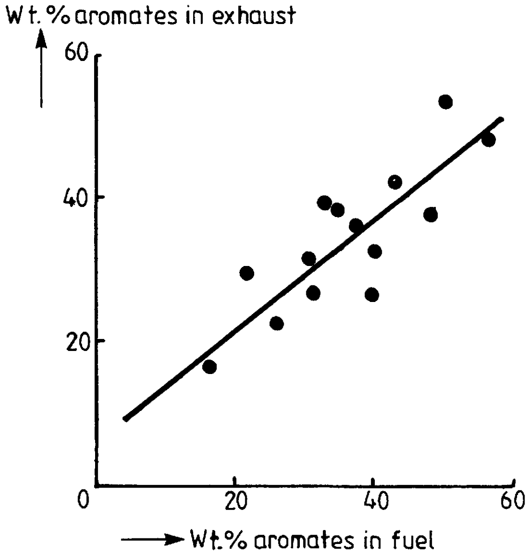

Fig. IV -2

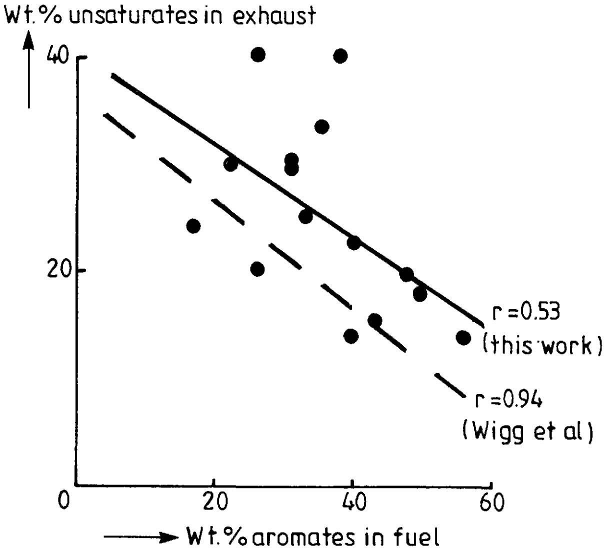

Fig. IV -3

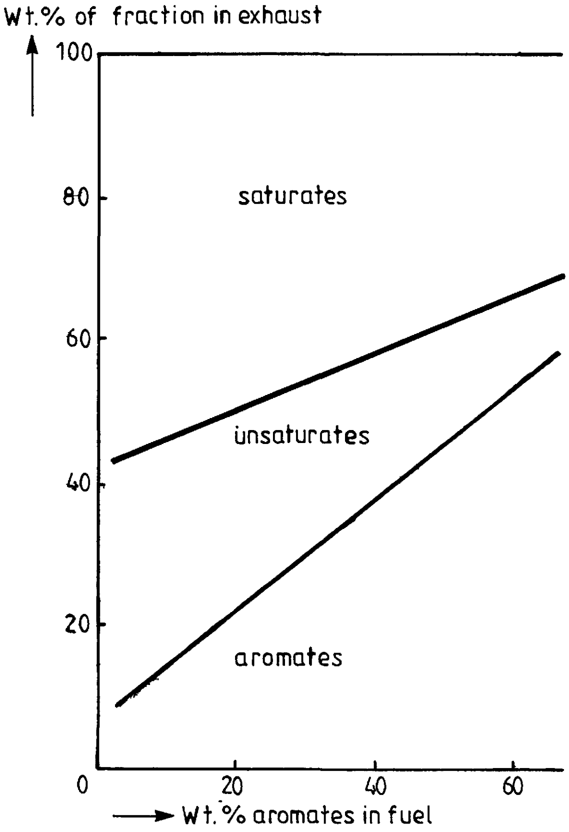

Fig. IV-4

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Fig. IV -2-3-4

Table IV-1 Vehicle parc (1985) ($\times 10^3$)

	Belgium	Denmark	France	Federal Republic of Germany	Greece	Ireland	Italy	Luxemburg	Netherlands	Portugal	Spain	United Kingdom
Automobiles, gasoline, < 1.4 l	1600	640	12100	9700	1030	530	15700	75	2300			8100
1.4 - 2 l	810	540	5300	11400	110	300	3000	56	1300			6600
> 2 l	290	90	600	2900	10	50	300	16	300			1200
gasoline, total	2700	1270	18000	24000	1150	880	19000	147	3900			15900
, diesel	510	80	1100	1800	50	20	3000	13	320			400
, LPG	100						100		650			
automobiles, total	3310	1350	19100	25800	1200	900	22100	160	4870	1300	9000	16300
Light commercial vans (< 3.5 t GVW)												
gasoline	83	60	900	300	230	40	200	3.3	130			940
diesel	62	100	1500	330	300	10	1300	2.5	95			160
LPG	3								22			
lcv's, total	148	160	2400	630	530	50	1500	5.8	247			1100
Trucks + road tractors												
gasoline	5	10	100	70	35	2	70	0.2	2.4			50
diesel, 3.5 - 5.5 t GVW	17	20	300	160	50	7	200	0.7	4			100
5.5 - 12	32	15	140	240	45	6	100	1.3	57			85
12 - 15	17	10	90	180	15	4	60	0.7	24.8			40
> 15	35	15	190	260	20	4	120	1.1	16.8			225
trucks + road tractors, total	106	70	820	910	165	23	550	4	105.			500
Autobuses, diesel	18	8.3	50	69	18	3	80	0.7	11.7	10	45	65
Special service vehicles												
gasoline	15	7	80	120	8	3	60	1	13			120
diesel	22	16	120	190	12	6	100	2	19			180
spec. serv. veh. total	37	17	200	310	20	9	160	3	32			300
Motorcycles												
≥ 50 cm^3	135	38	900	1407	135	15	950	2	130			900
< 50 cm^3	358	180	2200	2000	650	15	3500	12	600			500
motorcycles, total	493	218	3100	3407	785	30	4450	14	730			1400
Light comm. vans + trucks + road tractors	254	230	3220	1540	695	73	2050	9.8	352	360	1400	1600

Table IV-2 Vehicle parcs ; comparative data (1985)

	Belgium	Denmark	France	Federal Republic of Germany	Greece	Ireland	Italy	Luxemburg	Netherlands	Portugal	Spain	United Kingdom
Vehicles per 10^3 inh. :												
automobiles, gasoline <1.4 ℓ	162	125	221	166	105	151	276	205	159			146
1.4-2 ℓ	82	106	97	195	11	86	53	153	90			119
>2 ℓ	29	18	11	50	1	14	5.3	44	21			22
gasoline, total	274	248	329	410	117	251	334	403	269			286
diesel	52	16	20	31	5.1	5.7	53	36	22			7.2
LPG	10						1.8		45			
automobiles, total	336	264	349	441	122	257	389	438	336	136	189	293
light commercial vans (<3.5 t GVW)	15	31	44	11	54	14	26	16	17			20
trucks + road tractors												
gasoline	0.51	2.0	1.8	1.2	3.6	0.57	1.2	0.55	0.17			0.90
diesel 3.5-5.5 t GVW	1.7	3.9	5.5	2.7	5.1	2.0	3.5	1.9	0.28			1.8
5.5-12	3.2	2.9	2.6	4.1	4.6	1.7	1.8	3.6	3.9			1.5
12 - 15	1.7	2.0	1.6	3.1	1.5	1.15	1.1	1.9	1.7			0.72
>15	3.6	2.9	3.5	4.4	2.0	1.15	2.1	3.0	1.2			4.1
trucks + road tractors, total	10.8	13.7	15.0	15.6	16.8	6.6	9.7	11.0	7.2	38	29	9.0
autobuses	1.8	1.6	0.91	1.2	1.8	0.86	1.4	1.9	0.81	1.0	0.9	1.2
special service vehicles	3.8	3.3	3.7	5.3	2.0	2.6	2.8	8.2	2.2			5.4
motorcycles ≥ 50 cm^3	14	7.4	16	24	14	4.3	17	5.5	9.0			16
< 50 cm^3	36	35	40	34	66	4.3	62	33	41			9.0
automobiles / light comm. vans + trucks + road tractors	13	5.9	5.9	17	1.7	12	11	16	14			10
automobiles, gasoline : % <1.4 ℓ	59	50	68	40	89.5	60	82.6	51	59			51
1.4-2 ℓ	30	43	29	48	9.6	34	15.8	38	33			41.5
>2 ℓ	11	7	3	12	0.9	6	1.6	11	8			7.5
automobiles : % diesel	15	5.9	5.8	7.0	4.2	2.2	14	8.1	6.6			25
% LPG	3						0.5		13.3			

Table IV - 3

VOC-emission factors for road vehicles (g/km) (methane included)

	urban	local	high-ways
automobiles, gasoline, <1.4 l	2.5	1.0	0.8
1.4 - 2 l	3	1.1	1.0
>2 l	3.5	1.2	1.1
, diesel	0.8	0.3	0.3
. LPG	1.4	1.0	0.9
light commercial vans (<3.5 t GVW), gasoline	3	1.5	1.0
, diesel	1.2	0.5	0.3
. LPG	1.9	1.3	1.1
trucks and road tractors, gasoline	7	4	3
, diesel, 3.5 - 5.5 t GVW	1.8	1.0	0.7
5.5 - 12 t "	2.5	1.3	0.9
12 - 15 t "	3.0	1.5	1.1
>15 t "	3.5	1.8	1.2
autobuses, diesel	3	1.5	1.1
special service vehicles, gasoline	5		
, diesel	2		
motorcycles, ≥ 50 cm^3	6	6	3
< 50 cm^3	5	5	
gasoline-powered vehicles, evaporation (g/veh.day)	13		

Table IV-4 NMVOC emissions from road traffic (1985) (10^3 ton/year)

	Belgium	Denmark	France	Federal Republic of Germany	Greece	Ireland	Italy	Luxemburg	Netherlands	Portugal	Spain	United Kingdom
Exhaust emissions												
Automobiles, gasoline	53.5	27.1	350	432	20.5	16.7	320	3.09	70.0			401
, diesel	3.7	0.6	7.7	22.1	0.45	0.2	20.7	0.10	3.7			2.9
, LPG	2.0						1.5		16.5			
total	61.8	27.7	358	454	21	16.9	342	3.2	90			403
Light commercial vans, gasoline	3.0	1.9	31.5	10.7	7.5	1.4	7.1	0.12	4.2			30.5
, diesel	1.1	1.8	26.7	5.8	5.2	0.2	22.9	0.05	2.4			4.0
, LPG	0.1								1.2			
total	4.2	3.7	58	16.5	12.7	1.6	30	0.17	7.8			35
Trucks + road tractors, gasoline	0.3	0.6	8.7	6.0	3.0	0.2	6.0	0.01	0.2			5.6
, diesel	4.4	2.6	36.3	45.8	4.8	0.8	18.4	0.16	6.3			32.5
total	4.7	3.2	45	52	7.8	1.0	24	0.17	6.5			38
Autobuses, diesel	1.8	0.8	5.0	6.9	1.8	0.3	7.9	0.07	1.2			6.7
Special service vehicles	0.3	0.2	1.6	2.4	0.2	0.1	1.3	0.03	0.2			2.3
Motorcycles	8.4	2.2	34.6	47.3	8.1	0.4	50	0.18	10.4			17.4
Gasoline-powered vehicles, total	65.3	31.9	425	497	39.2	18.7	383	3.4	84.8	17?	130?	455
Diesel - " " "	11.2	5.8	77	82	12.4	1.5	71	0.39	13.8	10?	36?	48
LPG - " " "	2.1								17.7			
Fuel consumption (10^3 t/y), gasoline	2450	1400	18100	23500	1600	870	10500	290	3520	750	5700	20300
, diesel	2300	900	10200	11300	1180	360	9300	155	2400	1400	5200	6800
Emissions (kg/ton fuel), gasoline	26.7	22.8	23.4	21.1	24.5	21.5	36.5	11.7	24.1	23?	23?	22.4
diesel	4.9	6.4	7.5	7.3	10.5	4.2	7.6	2.5	5.8	7?	7?	7.0
Average emission factor (g/km): (methane included)												
- automobiles, gasoline	1.73	1.75	1.69	1.62	1.74	1.66	1.71	1.72	1.51			1.90
- trucks + road tractors	1.61	1.65	1.72	1.65	1.98	1.75	1.72	1.54	1.55			1.78
Evaporative emissions	14	6.5	92	118	7	4.4	93	0.7	19	6	45	82

Table IV-5 NMVOC emissions from road traffic (1985) per road class (wt.%)

	Belgium	Denmark	France	Federal Republic of Germany	Greece	Ireland	Italy	Luxemburg	Netherlands	United Kingdom
Automobiles , urban	69	70	70	64	77	68	73	69	58	76
, local	23	22	26	23	19	25	21	23	26	20
, highways	8	8	4	13	4	7	6	8	16	4
Light duty + heavy duty vehicles										
, urban	60	60	65	49	64	69	64	61	64	55
, local	27	29	24	31	28	23	25	27	25	33
, highways	13	11	11	20	8	8	11	12	11	12
Motorcycles , urban	77	83	82	79	80.5	72	82.5	81	79.5	71
, local	20	16	16	18	18	24	15.5	17	18	24.5
, highways	3	1	2	3	1.5	4	2	2	2.5	4.5
All vehicles , urban	68	68	69	64	72	69	73	75	60	72
, local	23	24	25	23	23	24	21	23	26	22
, highways	9	8	6	13	5	7	6	8	14	6

Table IV-6

Investigations of automotive exhaust; gasoline powered vehicles; experimental data.

Lit. nr.	Test vehicle(s)	Test procedure	Gasoline composition (wt.%)			Approx. year of investig.
			sat.	unsat.	arom.	
1	no data					1967
2	0.63 l single cyl. motor; compression ratio = 8.9/1		55	10	35	1967
3	1 of 4 cyl. of 1.3 l motor; compression ratio = 8.5/1		46	16	38	1970
4	Automobile without control system		59	10	31	1968
5	No data; "representative composition"					1971
6	"62 privately owned and operated automobiles". Composition of one of these is given.	Calif. cycle				1970
7	1969 Valiant; 3.8 l	7-mode Calif. cycle. Each fuel: rich, resp. lean; with, resp. without vacuum spark advance	a) 63.5 b) 57 c) 48	14.5 10 2	22 33 50	1971
8	"pre-emission controlled car with retrofit device of retarding ignition timing"	Hot 10-mode, 6 cycles	a) 51 b) 71 c) 62 d) 59.5 e) 41 f) 40 g) 33	6 12 12 0.6 19 12 11	43 17 26 40 40 48 56	1975
9	1963 Chevrolet 283 V8	FTP	69	5	26	1979
10	67 automobiles representative for Sydney fleet. Ages: < '72 - > '78. Weighed average composition given.	1975 FTP	63.5	6	30.5	1980
11	Opel Ascona 1.6 S (1983)	EEC-cycle, rich and optimal; 90 km/h opt. 120 km/h opt.				1984

Table IV-7a Investigations of automotive exhaust; gasoline powered vehicles. Hydrocarbon analyses (wt.%)

Hydrocarbon	1	2	3	4	5	6	7			8							9 3)	10 4)	11
							a	b	c	a	b	c	d	e	f	g			
saturated																			
methane	22.0	16.0	20.1	12.8	23.7	19.1	14.8	12.9	15.7	14.6	22.9	22.4	28.0	40.3	28.6	31.1	28.5	14.8	21.7
ethane	2.8	4.0	4.7	2.7	3.6	1.7	1.6	1.5	1.5								5.4	2.8	4.3
propane	-									0.2	0.3	0.4	0.5	0.3	0.4	0.5		0.2	0.3
butanes	4.7	5.1	12.0	10.3		11.0	5.7	6.0	11.6	3.7	4.6	3.9	2.6	4.7	4.1	2.7	10.7	7.7	6.1
pentanes	13.3	14.9	19.8	16.0		14.0	12.7	16.9	13.7	22.7	10.7	13.6	15.1	18.2	18.4	19.6	9.0	21.1	25.2
hexanes	9.4	12.4	17.4	19.1		16.3	24.8	19.5	11.9	35.4	15.0	18.5	22.8	19.8	27.6	26.2	14.8	22.0	2.0
heptanes	7.5	9.4	13.5	13.4		12.3	14.7	10.4	11.6	8.7	10.3	6.2	7.4	6.8	9.5	10.0	9.7	11.7	9.7
octanes	40.3	35.9	10.5	}25.7		20.8	10.7	9.3	21.4	10.2	34.1	30.3	20.8	5.1	6.4	6.3	16.7	10.1	27.2
C $\geq$ 9 saturates		2.2	2.0			4.8	15.0	23.6	12.6	4.5	2.1	4.7	2.8	4.8	5.0	3.6	5.2	9.6	3.5
wt. % abs.	30.8	27.8	23.2	42.8	34.5	44.4	40.3	35.0	28.0	41.7	58.8	56.8	53.4	50.6	42.1	37.4	37.3	38.8	27.0
unsaturated																			
ethylene	21.5	18.3	33.6	29.9	22.4	25.5	29.3	24.6	22.8	33.2	30.7	32.9	39.1	31.9	36.2	39.0	34.4	31.2	28.2
acetylene	15.9	13.1	24.5	19.6	25.8	35.7	22.4	21.4	27.8	24.9	25.4	28.1	24.3	23.8	39.7	29.4	24.6	27.5	42.4
propylene	12.6	15.8	13.1	18.5	17.5	11.8	11.3	10.4	15.4	13.1	23.5	15.8	13.8	16.7	8.9	11.6	14.8	13.6	13.9
propadiene		2.6	3.6		2.3	0.5	0.7	0.5	1.0								0.8		1.3
methylacetylene	1.8					1.0	1.2	1.3	2.1								1.9	1.2	
1-butenes	12.5	16.0	8.5	10.6	12.9	5.7	4.2	3.5	6.4	3.7	4.0	3.7	3.7	4.1	3.1	2.6	6.4	6.2	12.2
1,3-butadiene							2.8	2.5	1.6								4.3		1.3
2-butenes	2.5	3.8	3.7			2.9	2.0	2.8	3.4	2.4	2.5	2.8	1.9	6.2	1.3	1.6	2.1	3.1	0.7
1-pentenes	3.1	3.5	3.7			3.6	2.8	4.2	2.5	5.1	3.4	3.7	1.6	3.3	1.4	2.3	6.0	1.5	
2-pentenes	7.0	6.9	4.6	21.4		7.9	4.2	5.9	5.2	10.3	4.0	4.4	3.8	7.6	2.1	3.0	2.0	3.4	
1-hexenes	4.7	4.2	1.4			1.2	3.6	2.9	4.2	3.5	1.3	2.0	4.0	1.6	2.1	2.6	1.4		
2- and 3-hexenes	3.8	3.6	1.8			2.7	3.3	4.3	1.5	3.8	1.6	2.5	1.3	2.5	1.6	2.9	1.1	12.3	
C $\geq$ 7 unsaturates	14.6	12.2	1.5			1.5	12.2	15.7	6.1		3.6	4.1	6.5	2.3	3.6	5.0	0.2		
wt. % abs.	32.0	33.7	40.6	30.3	37.1	24.9	30.2	25.3	18.0	15.5	24.6	20.4	14.1	22.8	19.9	13.9	40.3	29.5	25.3
aromatic																			
benzene	8.2	7.2	11.3	11.0	12.5	8.3	5.7	2.6	2.9	14.9	14.7	15.0	12.3	16.2	14.8	46.2	17.6	14.0	10.3
toluene	47.2	46.7	20.1	32.5	40.8	20.8	14.5	10.0	34.7	32.0	26.3	27.3	32.3	31.1	36.2	21.5	22.7	29.2	23.9
xylenes	11.2	11.0	23.2	22.5	14.0 2)	21.4	18.5	19.6	25.7	23.7	23.5	24.0	22.2	24.4	24.3	15.8	26.6	25.5	34.5
ethylbenzene	3.0	3.5	5.4	7.5	4.0	4.3	3.6	3.5	5.8	5.4	6.3	5.8	6.1	6.5	7.1	4.1	5.2	5.4	10.1
styrene							1.3	0.9	0.9										2.8
1,2,4-trimethylbenzene		7.8 1)	9.8	8.5		8.3	9.8	9.6	7.5	5.4	5.6	4.5	4.4	2.4	3.6	2.7	10.7	6.0	
1,3,5-trimethylbenzene	1.2	1.5	2.9			2.5	2.3	1.9	1.5	2.2	2.5		1.3	1.8	1.0	0.7	4.2	2.3	8.1
1,2,3-trimethylbenzene			1.3	18.0		0.7	11.4	11.9	10.6	3.9	1.5	2.0		1.0	1.1	1.5	10.4	9.7	
other Cg-aromates	29.2	8.6	12.0			11.5				6.4	8.6	6.8	7.0	5.3	6.7	3.8			7.2
C $\geq$ 10 aromates		13.7	14.0			22.2	32.9	40.0	10.4	6.1	11.0	14.6	14.4	11.3	5.2	3.7	2.6	7.9	0.3 5)
wt. % abs.	37.2	38.5	36.2	26.9	28.4	30.7	29.5	39.7	54.0	42.8	16.6	22.8	32.5	26.6	38.0	48.7	22.4	31.7	47.7

1) + C_{10} arom.
2) + styrene
3) some peaks interpreted with results of 7
4) 6% methane and 4% unsat. C_6 + assumed
5) naphtalene

Table IV-7b

Investigations of automotive exhaust; gasoline powered vehicles

Average values (wt. %)

Hydrocarbon	average	%σ	average (excl. 2σ)	%σ	n	adopted average
saturated						
methane	21.6 ± 7.3	34	20.5 ± 5.9	29	18	19
ethane	3.1 ± 1.3	44	3.1 ± 1.3	44	12	3
propane	0.3 ± 0.1	33	0.3 ± 0.1	33	9	0.5
butanes	6.5 ± 3.2	49	6.5 ± 3.2	49	18	
pentanes	16.4 ± 4.2	26	15.9 ± 3.7	23	17	
hexanes	18.6 ± 7.5	41	18.6 ± 5.2	28	16	
heptanes	10.2 ± 2.4	23	10.2 ± 2.4	23	18	
octanes	18.6 ± 11.4	61	18.6 ± 11.4	61	18	
C9 + saturates	6.2 ± 5.9	95	5.5 ± 3.9	70	15	
	101.5		99.2			
C_4 + saturates	76.7 ± 7.3	9	77.6 ± 6.1	8	17	77.5
						100
unsaturated ethylene						
ethylene	29.7 ± 5.9	20	29.7 ± 5.9	20	19	29.5
acetylene	26.1 ± 7.2	28	25.2 ± 6.2	25	18	25
propylene	14.3 ± 3.3	23	13.8 ± 2.5	18	18	14
propadiene	1.2 ± 0.8	67	1.2 ± 0.8	67	8	1
methylacetylene	1.6 ± 0.5	31	1.6 ± 0.5	31	7	1.5
1-butenes	5.3 ± 2.8	52	4.9 ± 2.1	43	14	6
2-butenes	2.7 ± 1.2	46	2.5 ± 0.9	35	16	2.5
1,3-butadiene	2.5 ± 1.2	47	2.5 ± 1.2	47	5	2.5
1-pentenes	3.2 ± 1.2	39	3.0 ± 1.0	34	15	3
2-pentenes	5.1 ± 2.3	45	4.8 ± 1.9	40	15	4
1-hexenes	2.7 ± 1.2	46	2.7 ± 1.2	46	15	2.5
2- and 3-hexenes	2.6 ± 1.0	41	2.6 ± 1.0	41	15	2.5
C_{7+} unsaturates	6.4 ± 5.2	81	6.4 ± 5.2	81	14	6
	103.4		100.9			100
aromatic						
benzene	12.9 ± 9.1	71	11.1 ± 4.5	40	18	12
toluene	28.9 ± 9.9	34	28.9 ± 9.9	34	19	29
xylenes	23.1 ± 6.8	29	22.5 ± 6.1	27	19	23
ethylbenzene	5.8 ± 2.1	37	5.3 ± 1.6	30	19	5
styrene			1		4	1
1,2,4-trime.-benzene	6.6 ± 2.8	42	6.6 ± 2.8	42	15	6.5
1,3,5-trime.-benzene	2.0 ± 0.9	44	1.8 ± 0.7	36	14	2
1,2,3-trime.-benzene	1.6 ± 1.0	61	1.3 ± 0.4	32	7	1.5
other C9 aromates	7.6 ± 2.3	30	7.6 ± 2.3	30	11	8
C_{10+} aromates	14.0 ± 10.5	75	12.1 ± 7.9	65	15	12
	102.6		98.3			100

Table IV-8

Oxygenates in automotive exhaust; gasoline-powered vehicles (wt. %)

Component	14			15	16	17		18	19		20		average (excl. 2σ)	%σ	adopted average
	a	b	c			a	b		a	b	a	b			
formaldehyde		86	74.2	48.7	48.5	36.9	42.0	53.0	53.9	49.3	50.0	46.0	50.3 ± 9.8	20	50
acetaldehyde		13.5	19.6	9.3	7.3	12.9	6.7	9.1	9.2	13.4			11.2 ± 4.0	36	10
acetone			5.2	}22.2	0.5	8.2	0.8	3.0	9.0	23.0			4.5(0.5-9)		5
propionaldehyde															
acroleïn				5.0	12.7		3.0	8.7					8.1(3-12.7)		
butylaldehydes					0.7	4.4	1.5	3.0	3.0	2.0			2.4 ± 1.3	54	
hexanaldehyde			1.2												
benzaldehyde				12.4	20.8	7.2	11.6	11.1	11.2	10.2			12.1 ± 4.2	35	10
tolualdehyde				12.3		14.5	7.5						11.4(7.5-14.5)		10
other aldehydes				0.9	9.5	15.9	26.9	12.1	13.7	2.1					15
total oxygenates	2.0	5.8	1.9								2.3	1.6	2.7 ± 1.7	64	2

See list of references for experimental data

Table IV-9

Composition of diesel exhaust

Component	average	adopted average
methane	3.7 ± 1.5	4
ethane	0.5	0.5
saturates $C_{\overline{13}}$	50	50
ethylene	11.0 ± 3.4	11
acetylene	3.2 ± 1.6	3
propylene	3.4 ± 1.0	3.5
1-butenes	1.5 ± 0.5	1.5
pentenes	0.7	0.5
unsaturates $C_{\overline{13}}$	2	2
benzene	2.6 ± 1.1	2.5
aromates $C_{\overline{12}}$	8	8
formaldehyde	5.9 ± 2.5	6
aliph. aldehydes $C_{\overline{4}}$	4	4
unsat. aldehydes $C_{\overline{3}}$	0.5	0.5
acetone	2 (0.6-3.6)	2
organic acids $C_{\overline{2}}$	1	1

Table IV-10

Composition of LPG-exhaust

Component	average	adopted average
methane	8.9 (1.3-16.4)	9
ethane	2.7 ± 0.8	3
propane	34.5 ± 6.0	35
ethylene	15.6 ± 4.9	15
acetylene	21,8 ± 5.7	22
propylene	7.6 ± 2.1	8
benzene	0.15(0.03-0.4)	
toluene	0.3 (0.06-0.5)	
xylenes	1.5 (0.06-3.5)	1.5
formaldehyde	3.4 ± 1.5	4
acetaldehyde	0.6	1
organic acids	1.7 ± 1.0	1.5

Table IV-11

Road traffic exhaust composition (wt. % and mole/kg[2])

	calculated [1]	measured (21)
methane	8.0	7.2
ethane	1.3	0.6
propane	1.2	0.6
C_4-C_{10} saturates	29.8	32.3
C_{11+} saturates	5.5	2.2
ethylene	7.9	6.6
acetylene	6.3	4.8
propylene	3.6	2.6
propadiene	0.2	
methylacetylene	0.3	
1-butenes	1.4	1.0
1,3-butadiene	0.5	
2-butenes	0.5	0.4
1-pentenes	0.7	1.2
2-pentenes	0.9	1.3
1-hexenes	0.5	2.4
2- and 3-hexenes	0.5	
C_{7+} unsaturates	1.5	0.7
benzene	3.2	3.9
toluene	7.2	9.9
xylenes	5.7	6.4
ethylbenzene	1.2	2.3
styrene	0.3	0.8
1,2,4-trime.-benzene	1.6	2.3
1,2,5-trime.-benzene	0.5	1.3
1,2,3-trime.-benzene	0.4	0.6
other C_9-aromates	2.0	2.8
C_{10+} aromates	3.9	3.7
formaldehyde	1.6	1.1
other oxygenates	1.8	1.0
OLE	1.4	1.1
PAR	32.7	31.1
TOL	0.9	1.3
XYL	1.2	1.4
FORM	1.5	0.7
ALD	0.6	1.0
ETH	2.8	2.4
UNR	11.1	10.0

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1) 30% aromates in gasoline, gasoline exhaust: 86%, diesel exhaust: 11%, LPG exhaust 3% (Dutch 1978 average).

2) Chemical bond species (CBM-X, SAI)

VOC-emissions from road traffic in Belgium (1985) (methane included)

	vehicles	mileage per vehicle	total mileage	mileage distribution %			total mileage per mode 10^9 km			emission factor g/km			emission 10^3 ton			
	x 10^3	10^3 km	10^9 km	urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	1600	11.9	18.9	48	42	10	9.1	8.0	1.8	2.5	1.0	0.8	22.8	8.0	1.4	32.2
1.4-2 l	810	14.1	11.4	36	45	19	4.1	5.1	2.2	3.0	1.1	1.0	12.3	5.6	2.2	20.1
> 2 l	290	16.7	4.8	25	44	31	1.2	2.1	1.5	3.5	1.2	1.1	4.2	2.5	1.7	8.4
total	2700	13	35.1	41	43	16	14.4	15.2	5.5	2.7	1.05	1.0	39.3	16.1	5.3	60.7
, diesel	510	18	9.2	25	45	30	2.3	4.1	2.8	0.8	0.3	0.3	1.8	1.2	0.84	3.8
, LPG	100	20	2.0	25	45	30	0.5	0.9	0.6	1.4	1.0	0.9	0.70	0.90	0.54	2.1
automobiles, total	3310	14	46.3	37	44	19	17.2	20.2	8.9				41.8	18.2	6.7	66.6
Light commercial vans, gasoline	83	15	1.25	75	10	15	0.93	0.13	0.19	3	1.5	1	2.8	0.20	0.19	3.2
, diesel	62	20	1.25	65	15	20	0.81	0.19	0.25	1.2	0.5	0.3	1.0	0.10	0.08	1.2
, LPG	3	20	0.06	65	15	20	0.04	0.01	0.01	1.9	1.3	1.1	0.08	0.01	0.01	0.10
total	148	17.3	2.56	70	13	17	1.78	0.33	0.45				3.9	0.31	0.28	4.5
Trucks, gasoline	5	15	0.08	30	45	25	0.025	0.035	0.020	7	4	3	0.18	0.14	0.06	0.38
, diesel, 3.5-5.5 t GVW	17	20	0.34	25	50	25	0.085	0.17	0.085	1.8	1.0	0.7	0.14	0.17	0.06	0.37
5.5-12 t "	32	30	0.96	20	55	25	0.19	0.53	0.24	2.5	1.3	0.9	0.48	0.69	0.22	1.4
12-15 t "	17	40	0.68	10	50	40	0.068	0.34	0.27	3.0	1.5	1.1	0.20	0.51	0.30	1.0
> 15 t "	35	30	1.05	10	45	45	0.11	0.47	0.47	3.5	1.8	1.2	0.39	0.85	0.56	1.8
total	106	29.2	3.1	15	50	35	0.48	1.55	1.09				1.4	2.4	1.2	5.0
Autobuses, diesel	18	50	0.9	40	50	10	0.36	0.45	0.09	3	1.5	1.1	1.1	0.68	0.10	1.9
Special service vehicles																
, gasoline	15	1	0.015	100			0.015			5			0.075			0.075
, diesel	22	5	0.11	100			0.11			2			0.22			0.22
total	37	3.4	0.125	100			0.125						0.30			0.30
Motorcycles, > 50 cm³	135	7	0.95	65	25	10	0.62	0.24	0.09	6	6	3	3.7	1.4	0.27	5.4
< 50 cm³	358	2	0.72	90	10		0.65	0.07	-	5	5		3.3	0.35	-	3.7
total	493	3.4	1.7				1.3	0.31	0.09				7.0	1.8	0.27	9.1
Gasoline powered vehicles													49.4	18.2	5.8	73.4
Diesel powered vehicles													5.3	4.2	2.2	11.7
LPG powered vehicles													0.78	0.91	0.55	2.2
All vehicles													55.5	23.2	8.6	87.3
Evaporative emissions	2848									13 g/veh.day			13.5			13.5

VOC-emissions from road traffic in Denmark (1985) (methane included)

	vehicles	mileage per vehicle	total mileage	mileage distribution			total mileage per mode			emission factor			emission			
				%			10^9 km			g/km			10^3 ton			
	x 10^3	10^3 km	10^9 km	urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	640	11	7	50	40	10	3.5	2.8	0.70	2.5	1.0	0.8	8.8	2.8	0.56	12.2
1.4-2 l	540	14	7.5	35	45	20	2.6	3.4	1.5	3.0	1.1	1.0	7.9	3.7	1.5	13.1
> 2 l	90	18	1.6	25	45	30	0.40	0.72	0.48	3.5	1.2	1.1	1.4	0.86	0.53	2.8
total	1270	12.7	16.1	41	43	16	6.5	6.9	2.7	2.8	1.1	1.0	18.0	7.4	2.6	28
, diesel	80	20	1.6	25	45	30	0.40	0.72	0.48	0.8	0.3	0.3	0.32	0.22	0.14	0.7
, LPG	-									1.4	1.0	0.9				
automobiles, total	1350	13.1	17.7	39	43	18	6.9	7.6	3.2				18.4	7.6	2.7	29
Light commercial vans, gasoline	60	15	0.90	65	20	15	0.58	0.18	0.14	3	1.5	1	1.7	0.27	0.14	2.1
, diesel	100	20	2	65	20	15	1.3	0.40	0.30	1.2	0.5	0.3	1.6	0.20	0.09	1.9
, LPG	-		-							1.9	1.3	1.1				
total	160	18.1	2.9	65	20	15	1.9	0.58	0.44				3.3	0.47	0.23	4.0
Trucks, gasoline	10	15	0.15	25	55	20	0.04	0.08	0.03	7	4	3	0.28	0.32	0.09	0.69
, diesel, 3.5-5.5 t GVW	20	20	0.40	20	60	20	0.08	0.24	0.08	1.8	1.0	0.7	0.14	0.24	0.06	0.44
5.5-12 t "	15	30	0.45	20	55	25	0.09	0.25	0.11	2.5	1.3	0.9	0.23	0.33	0.10	0.66
12-15 t "	10	40	0.40	15	55	30	0.06	0.22	0.12	3.0	1.5	1.1	0.18	0.33	0.13	0.64
> 15 t "	15	40	0.60	10	50	40	0.06	0.30	0.24	3.5	1.8	1.2	0.21	0.54	0.29	1.0
total	70	28.6	2.0	17	55	28	0.33	1.1	0.58				1.0	1.8	0.67	3.5
Autobuses, diesel	83	50	0.42	40	50	10	0.17	0.21	0.042	3	1.5	1.1	1.51	0.32	0.05	0.88
Special service vehicles																
, gasoline	7	1	0.01	100			0.01			5			0.05			0.05
, diesel	10	5	0.05	100			0.05			2			0.10			0.10
total	17	3.5	0.06	100									0.15			0.15
Motorcycles, > 50 cm^3	38	3	0.11	65	25	10	0.07	0.03	0.01	6	6	3	0.42	0.18	0.03	0.63
< 50 cm^3	180	2	0.36	90	10		0.32	0.04		5	5		1.6	0.20		1.8
total	218	2.2	0.47				0.39	0.07	0.01				2.0	0.38	0.03	2.4
Gasoline powered vehicles													22	8.4	2.9	33
Diesel powered vehicles													3.3	2.2	0.86	6.4
LPG powered vehicles													-	-	-	-
All vehicles													25	11	3.8	39
Evaporative emissions	1360									13 g/veh.day			6.5			6.5

VOC-emissions from road traffic in France (1985) (methane included)

	vehicles	mileage per vehicle	total mileage	mileage distribution %			total mileage per mode 10^9 km			emission factor g/km			emission 10^3 ton			
	x 10^3	10^3 km	10^9 km	urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	12100	11.0	133	46	46	8	61	61	11	2.5	1.0	0.8	152	61	8.8	222
1.4-2 l	5300	15.1	80	34	55	11	27	44	9	3.0	1.1	1.0	81	48	9.0	138
> 2 l	600	18.3	11	18	64	18	2	7	2	3.5	1.2	1.1	7.0	8.4	2.2	18
total	18000	12.4	224	40	50	10	90	112	22	2.7	1.1	0.9	240	118	20	378
, diesel	1100	18.5	20	20	55	25	4	11	5	0.8	0.3	0.3	3.2	3.3	1.5	8
, LPG	-	-	-							1.4	1.0	0.9				
automobiles, total	19100	12.8	244	39	50	11	94	123	27				243	121	22	386
Light commercial vans, gasoline	900	15	13.5	75	10	15	10	1.4	2.0	3	1.5	1	30	2.0	2.0	34
, diesel	1500	20	30	65	15	20	20	4.5	6.0	1.2	0.5	0.3	23	2.3	1.8	28
, LPG	-	-	-							1.9	1.3	1.1				
total	2400	18.1	43.5	68	14	18	30	5.9	8.0				54	4.3	3.8	62
Trucks, gasoline	100	20	2.0	30	50	20	0.6	1.0	0.4	7	4	3	4.2	4.0	1.2	9.4
, diesel, 3.5-5.5 t GVW	300	25	7.5	25	55	20	1.9	4.1	1.5	1.8	1.0	0.7	3.4	4.1	1.1	8.6
5.5-12 t "	140	35	4.9	20	55	25	1.0	2.7	1.2	2.5	1.3	0.9	2.5	3.5	1.1	7.1
12-15 t "	90	45	4.1	10	55	35	0.4	2.2	1.4	3.0	1.5	1.1	1.2	3.3	1.6	6.1
> 15 t "	190	50	9.5	10	45	45	1.0	4.3	4.3	3.5	1.8	1.2	3.3	7.7	5.1	16
total	820	34.1	28	17	51	32	4.8	14.3	8.8				15	23	10	47
Autobuses, diesel	50	50	2.5	40	50	10	1.0	1.25	0.25	3	1.5	1.1	3.0	1.9	0.28	5.2
Special service vehicles																
, gasoline	80	1	0.08	100			0.08			5			0.40			0.40
, diesel	120	5	0,60	100			0.60			2			1.2			1.2
total	200	3.4	0.68	100			0.68						1.6			1.6
Motorcycles, > 50 cm^3	900	3	2.7	65	25	10	1.8	0.68	0.27	6	6	3	11	4.1	0.81	16
< 50 cm^3	2200	2	4.4	90	10		4.0	0.40	-	5	5		20	2.0	-	22
total	3100	2.3	7.1				5.8	1.1	0.27				31	6.1	0.81	38
Gasoline powered vehicles													306	130	24	460
Diesel powered vehicles													41	27	12	80
LPG powered vehicles													-	-	-	-
All vehicles													347	157	36	540
Evaporative emissions	19380									13 g/vh.day			92			92

VOC-emissions from road traffic in the Federal Republic of Germany (1985) (methane included)

	vehicles x 10^3	mileage per vehicle 10^3 km	total mileage 10^9 km	mileage distribution %			total mileage per mode 10^9 km			emission factor g/km			emission 10^3 ton			
				urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	9700	10.7	103.8	38	42	20	39.4	43.6	20.8	2.5	1.0	0.8	99	44	17	159
1.4-2 l	11400	12.6	143.6	31	42	27	44.5	60.3	38.8	3.0	1.1	1.0	134	66	39	239
> 2 l	2900	14.2	41.2	23	41	36	9.5	16.9	14.8	3.5	1.2	1.1	33	20	16	70
total	24000	12,0	289	32	42	26	93.4	120.8	74.4	2.8	1.1	1.0	265	130	72	467
, diesel	1800	30	54	25	45	30	13.5	24.3	16.2	0.8	0.3	0.3	11	7.3	4.9	23
, LPG	-									1.4	1.0	0.9				
automobiles, total	25800	13.3	343	31	42	26	106.9	145.1	90.6				276	137	77	490
Light commercial vans, gasoline	300	15	4.5	75	10	15	3.38	0.45	0.68	3	1.5	1	10.1	0.68	0.68	11.5
, diesel	330	20	6.6	65	15	20	4.29	1.0	1.32	1.2	0.5	0.3	5.1	0.50	0.40	6
, LPG	-									1.9	1.3	1.1				
total	630	17.6	11.1	69	13	18	7.67	1.45	2.0				15	1.2	1.1	17
Trucks, gasoline	70	20	1.4	30	45	25	0.42	0.63	0.35	7	4	3	2.9	2.5	1.1	6.5
, diesel, 3.5-5.5 t GVW	160	20	3.2	25	50	25	0.80	1.6	0.80	1.8	1.0	0.7	1.4	1.6	0.56	3.6
5.5-12 t "	240	30	7.2	20	45	35	1.44	3.24	2.52	2.5	1.3	0.9	3.6	4.2	2.3	10.1
12-15 t "	180	45	8.1	10	45	45	0.81	3.65	3.64	3.0	1.5	1.1	2.4	5.5	4.0	11.9
> 15 t "	260	50	13.0	10	40	50	1.3	5.2	6.5	3.5	1.8	1.2	4.6	9.4	7.8	21.8
total	910	36.2	32.9	14	44	42	4.8	14.3	13.8				15	23	16	54
Autobuses, diesel	69.4	50	3.5	40	50	10	1.4	1.7	0.4	3	1.5	1.1	4.2	2.6	0.44	7.2
Special service vehicles																
, gasoline	120	1	0.12	100			0.12			5			0.60			0.60
, diesel	190	5	0.95	100			0.95			2			1.9			1.9
total	310	3.5	1.07	100			1.07						2.5			2.5
Motorcycles, > 50 cm³	1407	3.2	4.5	65	25	10	2.9	1.2	0.4	6	6	3	17.6	6.7	1.4	26
< 50 cm³	2000	2.5	5.0	90	10		4.5	0.5		5	5		22.5	2.5		25
total	3407	2.8	9.5				7.4	1.7	0.4				40	9.2	1.4	51
Gasoline powered vehicles													319	142	75	536
Diesel powered vehicles													34	31	21	86
LPG powered vehicles													-	-	-	
All vehicles													353	173	96	622
Evaporative emissions	24960												118			118

VOC-emissions from road traffic in Greece (1985) (methane included)

	vehicles	mileage per vehicle	total mileage	mileage distribution			total mileage per mode			emission factor			emission			
				%			10^9 km			g/km			10^3 ton			
	x 10^3	10^3 km	10^9 km	urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	1030	10	10.3	50	40	10	5.15	4.12	1.03	2.5	1.0	0.8	12.9	4.1	0.82	17.8
1.4-2 l	110	12	1.32	40	45	15	0.53	0.59	0.20	3.0	1.1	1.0	1.6	0.65	0.20	2.5
> 2 l	10	16	0.16	35	45	20	0.06	0.07	0.03	3.5	1.2	1.1	0.21	0.08	0.03	0.3
total	1150	10.2	11.8	48	41	11	5.74	4.78	1.26	2.6	1.0	0.8	14.7	4.8	1.1	20.6
, diesel	50	18	0.90	35	45	20	0.31	0.41	0.18	0.8	0.3	0.3	0.25	0.12	0.11	0.48
, LPG	-									1.4	1.0	0.9				
automobiles, total	1200	10.6	12.7	48	41	11	6.1	5.2	1.45				15	5.0	1.2	21
Light commercial vans, gasoline	230	15	3.45	60	30	10	2.06	1.04	0.35	3	1.5	1	6.2	1.6	0.35	8.1
, diesel	300	20	6.0	60	30	10	3.6	1.8	0.60	1.2	0.5	0.3	4.3	0.90	0.18	5.4
, LPG	-									1.9	1.3	1.1				
total	530	17.8	9.45	60	30	10	5.7	2.8	1.0				10.5	2.5	0.53	13.5
Trucks, gasoline	35	20	0.70	25	55	20	0.18	0.39	0.14	7	4	3	1.23	1.54	0.42	3.2
, diesel, 3.5-5.5 t GVW	50	20	1.0	20	60	20	0.20	0.60	0.20	1.8	1.0	0.7	0.36	0.60	0.14	1.1
5.5-12 t "	45	25	1.13	20	55	25	0.23	0.62	0.28	2.5	1.3	0.9	0.58	0.81	0.25	1.6
12-15 t "	15	35	0.52	15	55	30	0.08	0.29	0.16	3.0	1.5	1.1	0.24	0.44	0.17	0.9
> 15 t "	20	40	0.80	10	10	40	0.08	0.40	0.32	3.5	1.8	1.2	0.28	0.72	0.38	1.4
total	165	25	4.15	18	55	27	0.77	2.3	1.1				2.7	4.1	1.4	8.2
Autobuses, diesel	18	50	0.90	40	50	10	0.36	0.45	0.09	3	1.5	1.1	1.1	0.68	0.10	1.9
Special service vehicles																
, gasoline	8	1	0.01	100			0.01			5			0.05			0.05
, diesel	12	5	0.06	100			0.06			2			0.12			0.12
total	20	3.5	0.07	100			0.07						0.17			0.17
Motorcycles, > 50 cm^3	135	3	0.41	65	25	10	0.26	0.10	0.04	6	6	3	1.6	0.60	0.12	2.3
< 50 cm^3	650	2	1.3	90	10		1.1	0.13		5	5		5.5	1.0		6.5
total	785	2.2	1.7				1.4	0.23	0.04				7.1	1.6	0.12	8.8
Gasoline powered vehicles													29.3	9.5	2.0	41
Diesel powered vehicles													7.2	4.3	1.4	13
LPG powered vehicles													-	-	-	-
All vehicles													36.5	13.8	3.4	54
Evaporative emissions	1468												7.0			7.0

VOC-emissions from road traffic in Ireland (1985) (methane included)

	vehicles	mileage per vehicle	total mileage	mileage distribution %			total mileage per mode 10^9 km			emission factor g/km			emission 10^3 ton			
	x 10^3	10^3 km	10^9 km	urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	530	11	5.83	40	50	10	2.32	2.92	0.58	2.5	1.0	0.8	5.8	2.9	0.46	9.2
1.4-2 l	300	14	4.20	35	45	20	1.47	1.89	0.84	3.0	1.1	1.0	4.4	2.1	0.84	7.3
> 2 l	50	18	0.90	25	45	30	0.23	0.40	0.27	3.5	1.2	1.1	0.81	0.48	0.30	1.6
total	880	12.4	10.93	37	48	15	4.03	5.21	1.69	2.7	1.1	0.9	11.0	5.5	1.6	18.1
, diesel	20	20	0.40	25	45	30	0.10	0.18	0.12	0.8	0.3	0.3	0.08	0.05	0.04	0.17
, LPG	—		—				—	—	—	1.4	1.0	0.9	—	—	—	—
automobiles, total	900	12.6	11.33	36	48	16	4.13	5.39	1.81				11.1	5.6	1.6	18.3
Light commercial vans, gasoline	40	15	0.60	70	20	10	0.42	0.12	0.06	3	1.5	1	1.26	0.18	0.06	1.5
, diesel	10	20	0.20	70	20	10	0.14	0.04	0.02	1.2	0.5	0.3	0.17	0.02	0.01	0.20
, LPG	-		—				—	—	—	1.9	1.3	1.1	—	—	—	—
total	50	16	0.80	70	20	10	0.56	0.16	0.08				1.43	0.20	0.07	1.7
Trucks, gasoline	2	20	0.04	35	45	20	0.014	0.018	0.008	7	4	3	0.10	0.07	0.02	0.19
, diesel, 3.5-5.5 t GVW	7	20	0.14	35	45	20	0.049	0.063	0.028	1.8	1.0	0.7	0.09	0.06	0.02	0.17
5.5-12 t "	6	25	0.15	20	55	25	0.030	0.083	0.038	2.5	1.3	0.9	0.08	0.11	0.03	0.22
12-15 t "	4	25	0.10	20	50	30	0.020	0.050	0.030	3.0	1.5	1.1	0.06	0.08	0.03	0.17
> 15 t "	4	35	0.14	10	45	45	0.014	0.063	0.063	3.5	1.8	1.2	0.05	0.11	0.08	0.24
total	23	24.8	0.57	22	49	29	0.13	0.28	0.17				0.38	0.43	0.18	1.0
Autobuses, diesel	3	50	0.15	40	50	10	0.060	0.075	0.015	3	1.5	1.1	0.18	0.11	0.02	0.31
Special service vehicles																
, gasoline	3	1	0.003	100			0.003			5			0.015			0.015
, diesel	6	5	0.030	100			0.030			2			0.06			0.06
total	9	3.7	0.033	100			0.033						0.08			0.08
Motorcycles, > 50 cm^3	15	3	0.045	65	25	10	0.029	0.011	0.005	6	6	3	0.17	0.07	0.02	0.26
< 50 cm^3	15	2	0.03	90	10		0.027	0.003	—	5	5		0.14	0.02	—	0.16
total	30	2.5	0.075				0.056	0.014					0.31	0.09	0.02	0.42
Gasoline powered vehicles													12.7	5.8	1.7	20.2
Diesel powered vehicles													0.8	0.55	0.23	1.6
LPG powered vehicles													-	-	—	—
All vehicles													13.5	6.35	1.9	21.8
Evaporative emissions	930												4.4			4.4

VOC-emissions from road traffic in Italy (1985) (methane included)

	vehicles	mileage per vehicle	total mileage	mileage distribution %			total mileage per mode 10^9 km			emission factor g/km			emission 10^3 ton			
	x 10^3	10^3 km	10^9 km	urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	15700	9.5	149	50	40	10	74.5	59.6	14.9	2.5	1.0	0.8	186.3	59.6	11.9	258
1.4-2 l	3000	12.0	36	28	47	25	10.1	16.9	9.0	3.0	1.1	1.0	30.3	18.6	9.0	58
> 2 l	300	16.0	4.8	19	50	31	0.9	2.4	1.5	3.5	1.2	1.1	3.2	2.9	1.7	7.8
total	19000	10.0	190	45	42	13	85.5	78.9	25.4	2.6	1.0	0.9	220	81	23	324
, diesel	3000	18	54	20	50	30	10.8	27.0	16.2	0.8	0.3	0.3	8.6	8.1	4.9	21.6
, LPG	100	18	1.8	20	50	30	0.4	0.9	0.5	1.4	1.0	0.9	0.56	0.90	0.45	1.9
automobiles, total	22100	11.1	246	39	44	17	96.7	106.8	42.1				229	90	28	348
Light commercial vans, gasoline	200	15	3	75	10	15	2.25	0.3	0.45	3	1.5	1	6.8	0.45	0.45	7.7
, diesel	1300	20	26	65	15	20	16.9	3.9	5.2	1.2	0.5	0.3	20.3	2.0	1.6	24
, LPG	-									1.9	1.3	1.1				
total	1500	19.3	29	66	15	19	19.2	4.2	5.7				27	2.5	2.0	31.6
Trucks, gasoline	70	20	1.4	30	50	20	0.42	0.70	0.28	7	4	3	2.9	2.8	0.84	6.5
, diesel, 3.5-5.5 t GVW	200	20	4	25	55	20	1.0	2.2	0.80	1.8	1.0	0.7	1.8	2.2	0.56	4.6
5.5-12 t "	100	25	2.5	20	55	25	0.50	1.38	0.63	2.5	1.3	0.9	1.3	1.8	0.57	3.7
12-15 t "	60	30	1.8	10	55	35	0.18	0.99	0.63	3.0	1.5	1.1	0.54	1.5	0.69	2.7
> 15 t "	120	40	4.8	10	45	45	0.48	2.16	2.16	3.5	1.8	1.2	1.7	3.9	2.6	2.8
total	550	26.4	14.5	18	51	31	2.6	7.4	4.5				8.2	12.2	5.3	26
Autobuses, diesel	80	50	4	40	50	10	1.6	2.0	0.40	3	1.5	1.1	4.8	3.0	0.44	8.2
Special service vehicles																
, gasoline	60	1	0.06	100			0.06			5			0.30			0.3
, diesel	100	5	0.50	100			0.50			2			1.0			1.0
total	160	3.5	0.56	100			0.56						1.3			1.3
Motorcycles, > 50 cm^3	950	3.5	3.3	65	25	10	2.15	0.83	0.32	6	6	3	12.9	5.0	1.0	19
< 50 cm^3	3500	2	7	90	10		6.3	0.70		5	5		31.5	3.5		35
total	4450	2.3	10.3				8.45	1.53	0.32				44.4	8.5	1.0	54
Gasoline powered vehicles													274	93	25	392
Diesel powered vehicles													40	23	11	74
LPG powered vehicles													0.6	1	0.5	2
All vehicles													315	117	37	468
Evaporative emissions	19650												93			93

VOC-emissions from road traffic in Luxemburg (1985) (methane included)

	vehicles x 10^3	mileage per vehicle 10^3 km	total mileage 10^9 km	mileage distribution % urb.	loc.	hi.w.	total mileage per mode 10^9 km urb.	loc.	hi.w.	emission factor g/km urban	loc.	hi.w.	emission 10^3 ton urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	75	12	0.90	45	45	10	0.41	0.41	0.08	2.5	1.0	0.8	1.03	0.41	0.06	1.50
1.4-2 l	56	14	0.78	35	45	20	0.27	0.35	0.16	3.0	1.1	1.0	0.81	0.39	0.16	1.36
> 2 l	16	16	0.26	25	45	30	0.07	0.12	0.08	3.5	1.2	1.1	0.25	0.14	0.09	0.48
total	147	13.2	1.94	39	45	16	0.75	0.88	0.32	2.8	1.1	1.0	2.09	0.94	0.31	3.34
, diesel	13	18	0.23	25	45	30	0.06	0.10	0.07	0.8	0.3	0.3	0.05	0.03	0.02	0.10
, LPG	-									1.4	1.0	0.9				
automobiles, total	160	13.6	2.17	37	45	18	0.81	0.98	0.39				2.14	0.97	0.33	3.44
Light commercial vans, gasoline	3.3	15	0.05	75	10	15	0.038	0.005	0.007	3	1.5	1	0.114	0.008	0.007	0.13
, diesel	2.5	20	0.05	65	15	20	0.033	0.007	0.010	1.2	0.5	0.3	0.040	0.004	0.003	0.05
, LPG	-									1.9	1.3	1.1				
total	5.8	17.2	0.10				0.071	0.012	0.017				0.15	0.01	0.01	0.18
Trucks, gasoline	0.2	15	0.003	30	45	25	0.0009	0.0014	0.0008	7	4	3	0.006	0.006	0.002	0.01
, diesel, 3.5-5.5 t GVW	0.7	20	0.014	25	50	25	0.0035	0.0070	0.0035	1.8	1.0	0.7	0.006	0.007	0.002	0.015
5.5-12 t "	1.3	30	0.039	20	55	25	0.0078	0.022	0.0098	2.5	1.3	0.9	0.020	0.028	0.009	0.057
12-15 t "	0.7	40	0.028	10	50	40	0.0028	0.014	0.011	3.0	1.5	1.1	0.008	0.021	0.012	0.041
> 15 t "	1.1	30	0.033	10	45	45	0.0033	0.015	0.015	3.5	1.8	1.2	0.012	0.027	0.018	0.057
total	4.0	29.3	0.117	16	50	34	0.018	0.059	0.040				0.05	0.09	0.04	0.18
Autobuses, diesel	0.7	50	0.035	40	50	10	0.014	0.018	0.0035	3	1.5	1.1	0.042	0.026	0.004	0.07
Special service vehicles																
, gasoline	1	1	0.001	100			0.001			5			0.005			0.005
, diesel	2	5	0.010	100			0.010			2			0.020			0.020
total	3	3.7	0.011	100			0.011						0.025			0.025
Motorcycles, > 50 cm^3	2	7	0.014	65	25	10	0.009	0.0035	0.0014	6	6	3	0.054	0.021	0.004	0.08
< 50 cm^3	12	2	0.024	90	10		0.022	0.0024		5	5		0.11	0.012		0.12
total	14	2.7	0.038				0.031	0.0069	0.0014				0.16	0.033	0.004	0.20
Gasoline powered vehicles													2.38	0.99	0.32	3.69
Diesel powered vehicles													0.20	0.14	0.065	0.41
LPG powered vehicles																
All vehicles													2.58	1.13	0.39	4.10
Evaporative emissions	152									13 g/veh.day			0.72			0.72

VOC-emissions from road traffic in the Netherlands (1985) (methane included)

	vehicles	mileage per vehicle	total mileage	mileage distribution %			total mileage per mode 10^9 km			emission factor g/km			emission 10^3 ton			
	x 10^3	10^3 km	10^9 km	urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	2300	11.1	25.5	32	39	29	8.1	10.0	7.4	2.5	1.0	0.8	20.3	10.0	5.9	36.2
1.4-2 l	1300	14.8	19.3	28	42	30	5.4	8.1	5.8	3.0	1.1	1.0	16.2	8.9	5.8	30.9
> 2 l	300	17.3	5.2	19	46	35	1.0	2.4	1.8	3.5	1.2	1.1	3.5	2.9	2.0	8.4
total	3900	12.8	50	28	42	30	14.5	20.5	15.0	2.9	1.0	0.9	40.0	21.8	13.7	75.5
, diesel	320	29	9.3	25	45	30	2.3	4.2	2.8	0.8	0.3	0.3	1.8	1.3	0.84	3.9
, LPG	650	26	16.9	25	45	30	4.2	7.6	5.1	1.4	1.0	0.9	5.9	7.6	4.6	18.1
automobiles, total	4870	15.6	76.2	27	43	30	20.5	32.8	22.9				47.7	30.7	19.1	98
Light commercial vans, gasoline	130	13.2	1.72	75	15	10	1.29	0.26	0.17	3	1.5	1	3.9	0.39	0.17	4.5
, diesel	95	26	2.47	75	15	10	1.85	0.37	0.25	1.2	0.5	0.3	2.2	0.19	0.08	2.5
, LPG	22	35	0.77	75	15	10	0.58	0.12	0.07	1.9	1.3	1.1	1.1	0.16	0.08	1.3
total	247	20	4.96	75	15	10	3.72	0.75	0.49				7.2	0.74	0.33	8.3
Trucks, gasoline	2.4	16	0.04	30	45	25	0.012	0.018	0.010	7	4	3	0.08	0.07	0.03	0.18
, diesel, 3.5-5.5 t GVW	4	16	0.06	20	45	25	0.012	0.027	0.015	1.8	1.0	0.7	0.02	0.03	0.01	0.06
5.5-12 t "	57	37	2.11	20	55	25	0.42	1.16	0.53	2.5	1.3	0.9	1.1	1.5	0.48	3.1
12-15 t "	24.8	52	1.29	10	50	40	0.13	0.65	0.51	3.0	1.5	1.1	0.39	1.0	0.56	2.0
> 15 t "	16.8	48	0.81	10	45	45	0.08	0.37	0.37	3.5	1.8	1.2	0.28	0.67	0.44	1.4
total	105	41	4.31	16	53	31	0.65	2.23	1.44				1.9	3.3	1.5	6.7
Autobuses, diesel	11.7	55	0.64	40	40	20	0.26	0.26	0.12	3	1.5	1.1	0.78	0.39	0.13	1.3
Special service vehicles																
, gasoline	13	0.7	0.01	100			0.01			5			0.05			0.05
, diesel	19	4.5	0.09	100			0.09			2			0.18			0.18
total	32	3.0	0.10	100			0.10						0.23			0.23
Motorcycles, > 50 cm³	130	7	0.91	65	25	10	0.59	0.23	0.09	6	6	3	3.5	1.4	0.27	5.2
< 50 cm³	600	2	1.2	90	10		1.08	0.12		5	5		5.4	0.60		6.0
total	730	2.9	2.11				1.7	0.35	0.09				8.9	2.0	0.27	11.2
Gasoline powered vehicles													52.9	24.3	14.2	91.4
Diesel powered vehicles													6.8	5.1	2.5	14.4
LPG powered vehicles													7.0	7.8	4.7	19.5
All vehicles													66.7	37.2	21.4	125
Evaporative emissions	4090												19.4			19.4

VOC-emissions from road traffic in the United Kingdom (1985) (methane included)

	vehicles	mileage per vehicle	total mileage	mileage distribution %			total mileage per mode 10^9 km			emission factor g/km			emission 10^3 ton			
	x 10^3	10^3 km	10^9 km	urb.	loc.	hi.w.	urb.	loc.	hi.w.	urban	loc.	hi.w.	urban	local	hi.w.	total
Automobiles, gasoline, < 1.4 l	8100	12.6	102	60	34	6	60.5	35	6.5	2.5	1.0	0.8	151	35	5.2	192
1.4-2 l	6600	15.8	104	44	45	11	45.5	47	11.5	3.0	1.1	1.0	137	52	11.5	200
> 2 l	1200	20.4	24.5	29	57	14	7.1	14	3.4	3.5	1.2	1.1	25	17	3.9	45
total	15900	14.5	230.5	49	42	9	113	96	21.5	2.8	1.1	1.0	313	104	20.6	437
, diesel	400	18.8	7.5	20	53	27	1.5	4.0	2.0	0.8	0.3	0.3	1.2	1.2	0.60	3
, LPG	-									1.4	1.0	0.9				
automobiles, total	16300	14.6	238	48	42	10	114.5	100	23.5				314	105	21	440
Light commercial vans, gasoline	940	16	15	50	40	10	7.5	6.0	1.5	3	1.5	1	22.5	9.0	1.5	33
, diesel	160	31	5.0	50	40	10	2.5	2.0	0.5	1.2	0.5	0.3	3.0	1.0	0.15	4.2
, LPG	-									1.9	1.3	1.1				
total	1100	18.2	20	50	40	10	10	8.0	2.0				25.5	10.0	1.65	37
Trucks, gasoline	50	25	1.25	35	45	20	0.44	0.56	0.25	7	4	3	3.1	2.2	0.75	6.1
, diesel, 3.5-5.5 t GVW	100	30	3.0	35	45	20	1.05	1.35	0.60	1.8	1.0	0.7	1.9	1.4	0.42	3.7
5.5-12 t "	85	40	3.4	20	55	25	0.68	1.87	0.85	2.5	1.3	0.9	1.7	2.4	0.77	4.9
12-15 t "	40	60	2.4	20	50	30	0.48	1.20	0.72	3.0	1.5	1.1	1.4	1.8	0.79	4.0
> 15 t "	225	55	12.4	10	45	45	1.24	5.6	5.6	3.5	1.8	1.2	4.3	10.1	6.7	21.1
total	500	45	22.5	23	46	28	3.9	10.6	8.0				12.4	17.9	9.4	40
Autobuses, diesel	65	51	3.3	40	50	10	1.3	1.7	0.33	3	1.5	1.1	3.9	2.6	0.36	7
Special service vehicles																
, gasoline	120	1	0.12	100			0.12			5			0.60			0.6
, diesel	180	5	0.90	100			0.90			2			1.8			1.8
total	300	3.4	1.02	100			1.02						2.4			2.4
Motorcycles, > 50 cm³	900	3	2.7	65	25	10	1.7	0.68	0.27	6	6	3	10.2	4.1	0.81	15.1
< 50 cm³	500	1.6	0.80	90	10		0.72	0.08		5	5		3.6	0.4		4
total	1400	2.5	3.5				2.42	0.76	0.27				13.8	4.5	0.81	19
Gasoline powered vehicles													353	120	24	497
Diesel powered vehicles													19	21	10	50
LPG powered vehicles																
All vehicles													372	141	34	547
Evaporative emissions	17310												82			82

European Communities — Commission

EUR 10646 — Hydrocarbons — Identification of air quality problems in Member States of the European Communities

R. Bouscaren, R. Frank, C. Veldt

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Three European consultants, under contract by the Commission, have studied the problem tied to hydrocarbons in the atmosphere of the European Member States. For the first time, a very detailed emission inventory was made in each country (including Spain and Portugal). These emission inventories confirm that the two main producers of hydrocarbons are solvent consumption and road traffic (approximately 40 % each). A list of substances which are involved in this problem of air pollution (toxicity, chemical reactivity, etc.) has been established with their main characteristics. By enquiring in the Member States, information on the orders of magnitude of hydrocarbon concentrations (total non-methanic or sometimes single species) in the ambient air has been collected. These data show for some substances, and taking into account our present knowledge, the possibility of effects on human health or on ecosystems. Finally a review of the governmental actions already underway confirmed that, probably due to the difficulty of the problem, little coherent effort has been made from the legal point of view; however abatement techniques for hydrocarbon emissions do exist (for stationary sources as well as for mobile sources). But, because of the lack of serious assessments of the problems and of good plant designs, these techniques have often been considered as deceptive and inadequate.

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