

Copy 6 Dte Urdagel

MILIEUDIENST regio Eindhoven	
VESTIGING HELMOND	
ing. 29 NOV 2005	

**Custom Powders BV
Abatement of APFO**

Prepared by: 5.1.2e

June 2005



Background

Teflon MP1600 (See Appendix 1 Safety Data Sheet) has been dried at Custom Powders for a number of years and is a well-established process. The drying work has been undertaken for Dupont, Dordrecht. The process involves the removal of water and also the liberation of small amounts of APFO (see appendix 2 Safety Data Card) a surfactant used in the manufacture of the Teflon powder.

As part of their product stewardship Dupont have been reviewing the emissions of APFO globally. In reviewing the process at Custom Powders it has been identified that the level of APFO emission was significant and that it required investigation. The following is a review of the investigation and describes why Custom Powders wishes to discuss the emissions with the authorities.

Levels of APFO Emissions

Custom Powders BV dry Teflon MP1600 in the flash drying facility installed in unit 2 at the Helmond site. The plant is operated 8 or 12 hours a day. In 2003 the plant was drying the material for 112 days representing 935 hours. Theoretical calculation and actual measurements, undertaken by TNO (Netherlands Organisation for Applied Scientific Research TNO) have shown the levels of emission to be 448 grm/hr.

Emissions in Relation to the NeR, Netherlands Emission Guidelines for Air

Section 3.2.4 of the NeR guidelines were consulted and the attached flow chart is extracted from the guidelines (appendix 3)

The first criteria in the assessment process is to determine whether the APFO is carcinogenic. Dupont have stated that the material is not carcinogenic therefore APFO should be assessed using the next criteria which is the MAC value for APFO.

There is no MAC value published for APFO by any statutory bodies in Europe or the US. Ordinarily therefore, APFO would appear not have any special abatement requirements. A consultation process would be required with Infomill to agree a classification.

Never the less, Dupont being the specialists in Teflon manufacture, have some established knowledge relating to APFO.

Dupont operate with an internal MAC value of 0.01mg/m³ from studies principally undertaken in the USA. The Dupont internal MAC value of 0.01mg/m³ can be used in Section 3.2.4 of the NeR guidelines. It is known that the material is persistent but not bioaccumulative. Given this criteria the NeR guidelines classify the material as *Class gO.1*.

Furthermore Dupont handle APFO at their site in Dordrecht and have an Environmental Permit reference Besluit DWM/162352 of Gedeputeerde Staten of Zuid-Holland of September 24, 1998. In the public part of this permit, APFO is called "dispergeermiddel". APFO has an agreed classification of *Class gO.1*.

Using both these facts Custom Powders have been advised by Dupont that class *Class gO.1* is appropriate for this type of emission
The NeR guidelines can be used further to indicate whether abatement is necessary based on the following limits for gO.1 emissions.

1. 0.1kg/hr maximum
2. 20mg/m³ maximum
3. 50 kg/yr maximum

In the case for APFO emissions at Custom Powders, all of the above limits are exceeded. This has led Custom Powders and Dupont to review possible abatement methods.

Abatement Methods

The attached article 'Atmospheric Emissions Control Techniques for Industrial Applications' (Appendix 4) states the methods for removal of gaseous contaminants can be considered in three categories:-

LIQUID	Absorption into liquid	WET SCRUBBING
SOLID	Adsorption or reaction to produce a solid	DRY SCRUBBING ADSORPTION
GAS	Decomposition or Gas phase conversion	THERMAL OXIDATION

The technology of wet scrubbing is known to be a practical solution and is a technology employed by Dupont. However removal of the APFO in the air stream is not total and a further processing step of adsorption in a carbon bed is employed as a secondary means of APFO removal.

It is considered that utilising solely adsorption, using such technology such as a carbon bed is either not practical or too complex given the nature of the process.

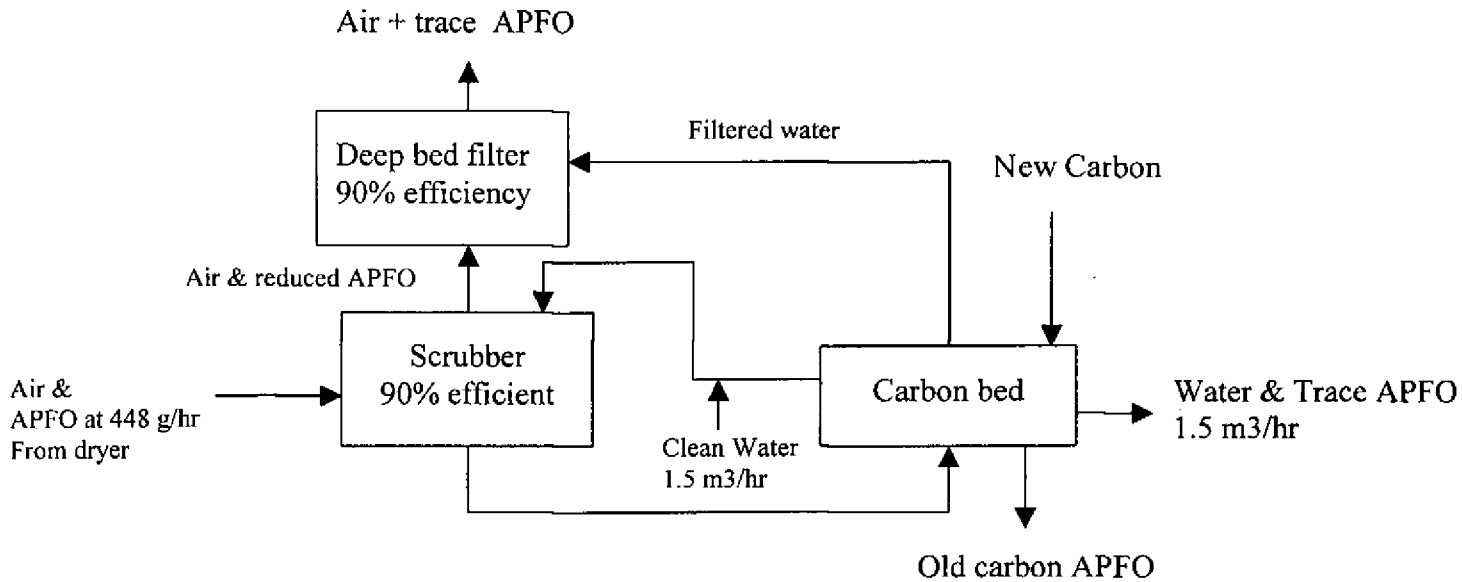
Thermal oxidation/thermal treatment is a technology that has been studied in theory by Dupont but the practicalities of installing and operating a system are unknown.

A more detailed review of the two feasible methods, water scrubbing followed by carbon bed adsorption and thermal treatment is described below.

1) Abatement Using Water Scrubbing and Carbon Bed Adsorption

Method

The air discharged from the dryer is scrubbed using water. The water containing APFO is then passed through a carbon bed filter to remove the APFO from the water. There are two water streams from the carbon bed filter. One stream is recycled to the scrubber. The other stream is an effluent containing trace levels of APFO. The air from the scrubber passes through a deep bed filter where further APFO is removed before the air is released to the atmosphere. The following is a flow diagram of the process.



Estimated Capital Cost

The following is estimated costs based on knowledge and size of equipment installed in facilities run by Dupont.

Design		x 1000 5.1.2f €
Equipment		
	Scrubber	
	Deep bed filter	
	Carbon bed	
	Pumps	
	Fan	
	Piping	
Electrical & Instrumentation		
Buildings & Civil Engineering		
Installation		
Contingency	10%	
Total Estimated Cost		

Effluent & Pollutants Generated

1. Carbon – material is incinerated approx 8.0te/yr containing 10% APFO
2. APFO in water 20 ppm at 1.5 m3/hr
3. APFO in air 2mg/m3

A disposal route is required for the water. An agreement has to be reached with the Waterschap for disposal into the sewage system or further treatment of waste water is required.

Running Cost

Based on changing carbon every 75 days estimated running costs are € 5.1.2f - 5.1.2f /day or around € 5.1.2f /year

The effluent disposal cost is estimated to be € 5.1.2f /year

Total running costs € 5.1.2f /yr

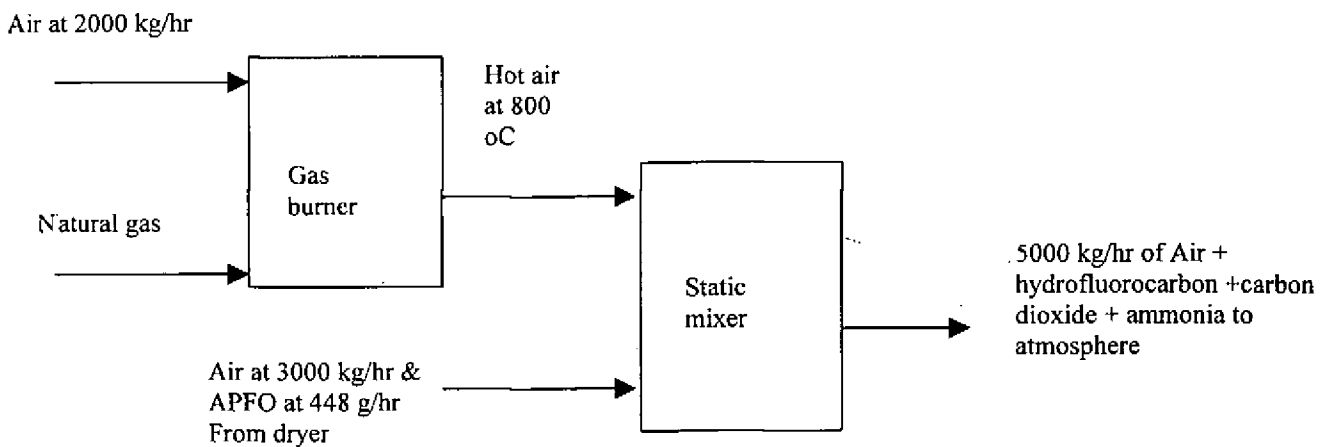
Comments

Dupont has proved the technology.
High operating & maintenance cost.

2) Abatement Using Thermal Treatment

Method

The air discharged from the dryer enters a static mixer where it comes into contact with hot gases delivered from a burner at 800oC. This converts the residual APFO into a hydrofluorocarbon, carbon dioxide and ammonia. The gases then leave the mixer and are emitted to atmosphere. The following is a flow diagram of the process.



Estimated Cost

Quotations have been received for the supply of thermal treatment equipment. In addition there will be the cost of buildings and installation.

Design
APFO thermal treatment equipment
Buildings & Civil Engineering

x 1000

5.1.2f

Custom Powders BV Abatement of APFO

June 2005

Installation
Contingency 10%

Total Estimated Cost

€

Effluent & Pollutants Generated

The APFO is broken down into the following components

1. 64 ppm of 1-hydroperfluoroheptane (see appendix 5)
2. 3 ppm of ammonia
3. 13 ppm of carbon dioxide

In addition there is 140 kg/hr of carbon dioxide generated from the combustion process

Running Cost

There will be the associated energy cost from motors and the maintenance of the equipment. Energy costs are estimated to be €^{5.1.2f}/year and maintenance cost €^{5.1.2f}/year giving a total cost of €^{5.1.2f}/year.

Comments

Thermal Treatment is a new and unproven technology for APFO. It is a known technology for treating flue gases containing other materials that require treatment prior to release to the atmosphere. The output of ammonia will be below the Dutch emission guidelines (30 ppm) and below that detectable by smell (20 ppm). It is believed that the hydrofluoroheptane will be low in toxicity with minimal impact on the environment. Dupont are working on the toxicity of the material and further data is expected at the end of 2005

Comparison of Costs for the Two Treatment Methods

A summary of the cost of the two feasible abatement methods is given in the table below.

	Capital Cost	Annual Running Cost
Water Scrubbing and Carbon Bed Adsorption	€ ^{5.1.2f} to	€ ^{5.1.2f}
Thermal Treatment	€ ^{5.1.2f}	

Review of Abatement Methods

The Thermal Treatment method is clearly the most economic. The disadvantage of this technology is that it is unproven on APFO. However the abatement technology is proven and there is every indication that it will work.

Guidance from the NeR in terms of the capital costs associated with an abatement installation is indicated as being not greater than €^{5.1.2f}/kg of emission over a 10 year period.

Assuming an element of growth in tonnage processed giving a running time of 1200 hours then the expected guidance expenditure to achieve abatement would be €^{5.1.2f}/kg x 0.448 kg/hr x 1200 hours/yr x 10 years = €^{5.1.2f} over a 10 year period

The lowest cost of abatement (thermal treatment) at €^{5.1.2f} and subsequent estimated running costs of €^{5.1.2f}/year are excessive in relation to the benefit. It is evident that in economic terms the cost of abatement is not viable. It is therefore argued that the present emissions are therefore *As Low As Reasonably Achievable*.

Substitution or Reduction of APFO

The choice of surfactants is limited by the technical criteria associated with producing MP1600. Over the last 30 years, DuPont has invested substantial resources to find an alternative to APFO but has been unsuccessful. Similarly extensive work has gone into reducing the amount of APFO used in the process by Dupont to the point where it is optimized. Dupont have informed Custom Powders that there is no prospect of either replacing or reducing the APFO used in the polymerization process.

Dispersion Model of Emissions by Dupont at Custom Powders Site

In a study Dupont have gathered the required data and applied it to a model that predicts the distribution of APFO concentration from the stack. The data input into the model included the height at which the APFO was discharged, the flow rates and temperatures, the quantity and the least favourable metrological conditions between the years 1997 and 2001.

The model predicted that the maximum annual average concentrations of APFO were located at a North Easterly point approximately 100 m from the point of emission. The level is predicted as 0.74ug/m³ and is shown in the attached diagram (see appendix 6)

In the US Dupont are using two criteria to assess whether action would be necessary if the plant was located in the USA. Firstly screening levels at plants in the US for permit compliance are 1.0ug/m³ at points outside the fence line of the plant. Secondly Community Exposure Guidelines have been established which for an industrial zone is given as a maximum of 0.9ug/m³ outside the fence line of the plant. The predicted level of 0.74 ug/m³ is below these two criteria.

In supporting Custom Powders, Dupont have therefore expressed a view that the emission is acceptable.

The above model was based on improvements in the stack configuration that have been implemented by Custom Powders following Dupont recommendations to improve the dispersion of APFO in the atmosphere. These recommended changes came from Dupont, following the initial model calculations.

Conclusion

Custom Powders is drying Teflon MP1600 for Dupont and in so doing is releasing APFO to atmosphere. Abatement techniques have been evaluated and the indications are that the costs of installing the technology are prohibitive. Dupont has considered substitution and reduction of APFO but neither is a practical option for the manufacture of MP1600

In preparing this review, Dupont have supported Custom Powders and have indicated that they believe the emission levels to be acceptable. Custom Powders therefore wishes to inform the authorities of the situation and seek permission to continue to process Teflon MP1600.

Appendix 1

This SDS adheres to the standards and regulatory requirements of the European Community and may not meet the regulatory requirements of other countries.

-- SAFETY DATA SHEET --

Ref. 074110000/N/NS
Page 1 of 3
Print date 2002-03-23
Revision date: 1997-01-10

In accordance with the legislation of the European community

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND THE COMPANY/UNDERTAKING

Chemical nature of the preparation: ZONYL* PTFE(R) fluoroadditive
Types: MP-1000, MP-1100, MP-1200, MP-1300, MP-1400, MP-1500, MP-1600, MP-1600 N

Supplier: Du Pont de Nemours International S.A.
2, Chemin du Pavillon
CH-1218 Le Grand-Saconnex / Geneva
Emergency telephone number +44-2871-861.313 (GB)

2. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical nature of the preparation: polytetrafluoroethylene (PTFE)

3. HAZARDS IDENTIFICATION

Most important hazards: None
Specific hazards: None

4. FIRST AID MEASURES

Inhalation: Move to fresh air in case of accidental inhalation of fumes from overheating or combustion. Consult a physician after significant exposure.
Skin contact: Cool skin rapidly with cold water after contact with molten polymer. Do not peel polymer from the skin. Obtain medical attention.
Eye contact: Rinse with water.

5. FIRE-FIGHTING MEASURES

Suitable extinguishing media: water, carbon dioxide (CO₂), foam, dry powder
Special protective equipment for firefighters: In the event of fire, wear a self contained breathing apparatus and a complete suit protecting against chemicals
Wear neoprene gloves when handling refuse from a fire involving ZONYL*

6. ACCIDENTAL RELEASE MEASURES

Personal precautions: None
Environmental precautions: None
Methods for cleaning up: Sweep-up to prevent slipping hazard.

In accordance with the legislation of the European community

Chemical nature of the preparation: ZONYL* PTFE(R) fluoroadditive
Types: MP-1000, MP-1100, MP-1200, MP-1300, MP-1400, MP-1500, MP-1600, MP-1600 N

7. HANDLING AND STORAGE

Handling
Technical measures/Precautions: None under normal processing. The solid polymer can be combusted only with difficulty.
Precautions: Provide appropriate exhaust ventilation at processing equipment
Safe handling advice:

Storage
Technical measures/Storage conditions: None
Storage conditions: None
Incompatible products: None
Packaging material: None

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Personal protective equipment
Respiratory protection:
Eye protection: safety glasses
Hand protection: heat insulating gloves
Hygiene measures: Do not contaminate tobacco products. Do not smoke. Wash hands before breaks and at the end of workday. General precaution for all plastics and elastomers: Do not breathe fumes evolved from hot polymer.

Control parameters
National occupational exposure limits
respirable dust: TLV-TWA = 3 mg/m³; ACGIH(1999)
Hydrogen fluoride: TLV-C(as F) = 3 ppm; ACGIH(1999)

9. PHYSICAL AND CHEMICAL PROPERTIES

Tested according to

Appearance
Form: powder
Colour: white
Odour: none

pH (°C): Not applicable
Melting point/range: 320-342 °C ASTM D1457
Decomposition temperature: > 260 °C
Flash point: Not applicable
Autoignition temperature: > 500 °C ASTM D1929
Explosive properties: Not applicable
Relative density (°C): from 2,20 g/cm³ ASTM D792
to 2,20 g/cm³
Bulk density: 500 kg/m³ ASTM D1457
Solubility
- water solubility (°C): insoluble

In accordance with the legislation of the European community

Chemical nature of the preparation: ZONYL® PTFE(R) fluoroadditive
Types: MP-1000, MP-1100, MP-1200, MP-1300, MP-1400, MP-1500, MP-1600,
MP-1600 N

10. STABILITY AND REACTIVITY

Conditions to avoid: Temperatures above 250 °C
Materials to avoid: Aluminium powder, halogenated compounds
Hazardous decomposition products: fluorinated olefins, carbonylfluoride, Hydrogen fluoride
Further information: Product resists ignition and does not promote flame spread. O2
Index - ASTM D2863: > 95 % ...

11. TOXICOLOGICAL INFORMATION

Acute toxicity: no data available
Local effects: The thermal decomposition vapours of fluorinated polymers may
cause polymer fume fever with flu-like symptoms in humans,

12. ECOLOGICAL INFORMATION

no data available

13. DISPOSAL CONSIDERATIONS

Waste from residues / unused products: Like most thermoplastic plastics the product can be recycled.
Where possible recycling is preferred to disposal or incineration.

Can be landfilled, when in compliance with local regulations. Can
be incinerated using a scrubber to remove hydrogen fluoride, when
in compliance with local regulations.

Contaminated packaging: Empty containers should be taken for local recycling, recovery or
waste disposal.

14. TRANSPORT INFORMATION

Not classified as dangerous in the meaning of transport regulations.

15. REGULATORY INFORMATION

According to EC-Dir. 67/548, as amended, the product does not need to be labelled.

16. OTHER INFORMATION

Before use read DuPont's safety information.

Recommended use: various

* DuPont's registered trademark

Do not use in medical applications involving permanent implantation in the human body. For other
medical applications see DuPont caution bulletin No. H-50102.

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and
belief at the date of its publication. The information given is designed only as a guidance for safe
handling, use, processing, storage, transportation, disposal and release and is not to be considered a
warranty or quality specification. The information relates only to the specific material designated and may
not be valid for such material used in combination with any other materials or in any process, unless
specified in the text.

Cat:
SBU:
Afd.:Categorie 1
DuPont Fluoroproducts
Fluoroproducts Teflon PTFECAS-nr.:
Interne code:

003825261 Synoniemen:

APFO
ammoniumperfluorooctanoaat
C-8EINECS:
Bruttoformule: CF₃(CF₂)₆COO

FYSISCHE EIGENSCHAPPEN		BELANGRIJKE GEGEVENS	
Kookpunt	°C	Witte tot geelbruin gekleurde vaste stof, die bij verhitting sublimiert tot damp. De verzadigde dampspanning van APFO bij 20 °C komt overeen met 70 ppb; dit is dus vele malen de blootstellingslimiet!	
Smeltpunt	184 °C	Reactiviteit: Bij inwerking van logen wordt ammoniak gevormd. De stof tast lichte metalen (oa. aluminium) aan.	
Vlampunt	°C	Stabilliteit: De stof ontdeedt bij verhitting (vanaf 200 °C) en bij brand onder vorming van giftige en bijtende dampen/gassen (oa. NH ₃ , NOx en HF).	
Zelfontbrandingstemperatuur	°C	MAC-TGG: ppm 0,01 mg/m ³ 15 min: ppm mg/m ³ Huidopname :Ja	
Soortelijke dichtheid (water = 1)	0,6	Bijzondere: AEL waarde: 0,56 ppb De stof is giftig bij inademen en tast de lever aan. Bij inslikken is het matig giftig.	
Dampdichtheid (lucht=1)			
Dampspanning (mbar)	0,009		
Wateroplosbaarheid	zeer goed		
Explosiegrens (Lang-Hoog)	Vol%		
Relatieve molecuulmassa	431		
pH-waarde			
Carcinogeen:	Nee		
AEL-waarde [ppm]	ppm		
AEL-waarde [mg/m ³]	0,01 mg/m ³		
BG-waarde [ppm]	ppm		
BG-waarde [mg/m ³]	mg/m ³		
RISIKO		PREVENTIE	
Brand Niet brandbaar.			
Inademen Irriterend, hoesten. Leverbeschadigingen bij hogere concentraties.	Inademen Gebruik bij het werken met APFO ALTIJD een comfo-masker met combinatie damp/stof-filter. Werk in zuurkast (lab.).		
Huid Wordt opgenomen; voorkom contact.	Huid Neopreen handschoenen, beschermende kleding.		
Ogen Roodheid, pijn.	Ogen Veiligheidsbril.		
Inslikken Matig giftig.			
			
OPRUIMING		EERSTE HULP	
Bij meer dan 50 liter gevarenzone ontruimen. Germorst produkt zorgvuldig op scheppen. Eventuele laatste resten wegspoelen met water. Spoelwater opvangen. (adembescherming). Mag niet in het riool-, oppervlakte- of grondwater terecht komen. Niet biologisch afbreekbaar.	Gescheiden van zuren. Verpakking hermetisch gesloten houden.	Brand Bij brand in directe omgeving: alle blusmiddelen toegestaan.	
		Inademen Frisse lucht, rust, arts waarschuwen.	
		Huid Verwijder verontreinigde kleding, wassen met water en zeep, arts waarschuwen.	
		Ogen Min. 15 minuten spoelen met water, arts waarschuwen.	
		Inslikken Water drinken, braken opwekken, arts raadplegen.	
		ETIKETTERING / VERVOER	
		R: 22 R: 37 S: 26 S: 37/39	R: 23 R: 41 S: 28 S: 45
	BAGA: Klasse C 1 KCA: Categorie IV	Annex-I nr.: z	Bijz. Aanduiding:
		ADR /VLG: /	
AANVULLENDE GEGEVENS			
Opmerkingen: De stof hoopt zich op in het lichaam en wordt daaruit slechts langzaam weer verwijderd. CEGw: 0,0063 mg/m ³ .			
Toxicologische gegevens: LD50 rat (oraal): 540 mg/kg ALC rat: 800 mg/m ³			
Ecotoxicologische gegevens:			

Opgesteld door: Admin
Revisie door: 5.1.2eAanmaakdatum: 14-02-2000
Revisie datum: 11/19/2002

Revisie nummer:

Other VOC reduction policies

In the area of the reduction of solvents there are other policy instruments that have precedence over the NaR.

- On the ground of the European Solvents Directive, separate standards apply for emissions of organic substances in specific industrial processes. This is included in the Solvents Decree conversion of EU-VOC Directive (*Oplasmiddelenbesluit omzetting EU-VOS richtlijn*). These standards have precedence over the NaR. And overview of the activities that relate to this is given in §2.8.2.
- In addition, many industries formulate VOC reduction plans that are focused on 30% reduction in 2010. The competent authority must take this into account.
- Some BREFs contain measures to reduce VOC emissions. The enforcement notes of the BREF specify how to deal with this.

In addition to the general standards, special regulations apply or other arrangements in other policy frameworks for a number of activities where organic substances are released. These are included in §3.4. In §2.8.4.6 it is indicated in which way they must be applied.

Clarification of the concepts
 (Suspected) carcinogen
 See Appendix 4.8

MAC
 Although the MAC value is established on other grounds besides health effects, the MAC value is, as yet, of particular importance in assessing the degree of environmental harmfulness.

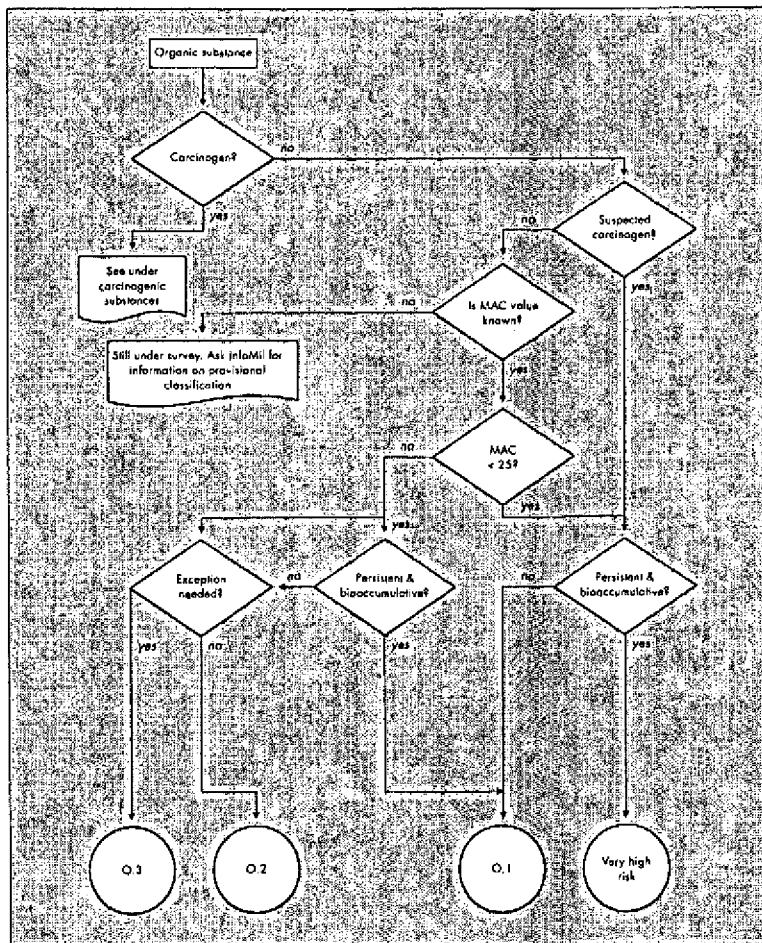
The following classification can be used:

Class	Toxicity	MAC value (mg/m ³)
0.1	high	< 25
0.2	moderate	≥ 25

For the classification of organic substances for which no MAC value has been established, for the time being refer to InfoMil.

Very toxic, persistent and bioaccumulative
 Organic substances with a very high risk for humans and the environment are classified into the group 'Very high risk substances' on the basis of toxicity, persistence and bioaccumulation. Examples of such substances are dioxins and PCBs.

Figure 1 Diagram of classification of organic substances



ATMOSPHERIC EMISSIONS CONTROL TECHNIQUES**FOR INDUSTRIAL APPLICATIONS**

Paper presented to the First International Conference on Environmental Management and Technologies, Cairo, Egypt, February 1997 by [REDACTED], Executive Director ACWa AIR ACWa Services Ltd, [REDACTED], Skipton, [REDACTED], England

SUMMARY

The techniques available for the removal of particulates and gaseous contaminants from industrial exhaust streams prior to emission to atmosphere are reviewed.

Consideration is given to the design parameters for a wide variety of equipment including Cyclones, Fabric Filters, Electro-Filters, Wet Scrubbing, Dry Scrubbing, Adsorption Systems, and Thermal Oxidation.

The relative advantages of each system is discussed and the criteria to be considered in the selection of the appropriate gas cleaning plant for specific applications. The applications covered includes the treatment of exhaust streams containing dust, fume, acid gases, odours and VOC's.

1. PARTICULATE REMOVAL

- 1.1 The most important parameter for the design of particulate removal equipment is the particle size analysis.

Particulates can be simply classified into three groups:-

GROUP	SIZE MICRONS	EXAMPLES
Grit	100 – 1000	Rain, Foundry Sand
Dust	1 -1 00	Flash, Cement Dust
Fume	0 – 1	Tobacco Smoke, Zinc Oxide Fume, Virus

The finer the dust the more difficult it is to remove. Expressed another way the finer the dust the higher the energy expended to remove it.

1.1 Continued

The main equipment types for particulate removal are:-

CYCLONES
WET SCRUBBERS
BAG FILTERS
ELECTROSTATIC PRECIPITATORS

1.2 CYCLONE COLLECTORS

In the cyclone, the forces acting on the dust particles are increased beyond the normal gravitational forces by causing the gas to spin or rotate in some manner.

The principle of the common cyclone is shown that gas enters the tangential inlet duct and spins around the periphery of the cyclone. Gas velocity increases as the diameter decreases improving particle separation. By locating the discharge centrally and at a particularly position in the head of the cyclone, the gas spiral is induced to reverse in direction thus depositing dust in the hopper below.

The parameters affecting the cyclone efficiency are:-

$$\text{Cyclone Efficiency} = \frac{k p d^2 V}{u D}$$

where	k	=	constant for a given cyclone geometry
	p	=	particle density
	d	=	particle diameter
	V	=	inlet gas velocity
	u	=	gas viscosity
	D	=	Cyclone diameter

Hence the smaller the cyclone diameter the higher is its separation efficiency related to particle size. Thus to give a greater efficiency especially when handling high volumes, a multiplicity of small diameter cyclone bodies can be enclosed in a signal chamber.

Cyclones can be used on dry dusts but are not suitable for sticky materials or for gases containing small particles.

It can be used however for cleaning gases at high temperatures up to 1200°C by application of refractory lining.

1.2 Continued

CYCLONES

Advantages	Disadvantages
Low Capital & Operating Costs Simple Construction Low Maintenance Accepts High Dust Loads Suitable for High Temperature	Inefficient for Small Particles Susceptible to Plugging Must operate above Dewpoint Can suffer from abrasion

1.3 WET SCRUBBERS

A large number of different types of wet scrubbers have been used over the years, so being developed for specific applications, other having a more general use. Details of a few of the common types are given below.

1.3.1 Venturi Scrubbers

The contaminated gas is accelerated in the converging section before entering the throat. Scrubbing liquor enters around the top of the converging section and completely flushes the wall. In addition liquor is entered through a spray to completely fill the throat with droplets.

In the venturi throat, the high velocity gas atomises the liquid droplets which trap the solid particles. The scrubbed gas and liquid droplets leaving the venturi throat pass through the diverging section where further agglomeration takes place producing larger droplets. The liquor droplets are then separated from the gas stream in a cyclonic entrainment separator.

To ensure high scrubbing efficiencies even with varying gas flows the throat can be made adjustable thus maintaining the required scrubber pressure drop even at reduced throughputs.

The liquor from the separator is recycled via pumps to the venturi scrubber with a small bleed being discharged to control the build up of solids in the circulating liquor.

1.3.2 Plate Scrubbers

In this type of scrubber the gas passes upwards through a number of small holes in one or more plates. Liquor enters on the top plate, flows across the plate and through a downcomer to the plate below. Intimate gas liquid contact is obtained as the gas bubbles through the liquid in the plate.

1.3.2 Continued

Many types of plate are available ranging from simple sieve trays to more complex valve and bubble cap tray, the majority have been developed for gas absorption and are generally prone to plugging if solids are present.

The target plate was developed for particulate removal. In this design a "target" baffle is located over each hole in the plate. As the gas passes through the perforations the momentum of the dust particles results in the impinging on the "targets" from which they are collected by the liquor.

For increased dust removal performance a venturi scrubber has been incorporated into a tray design in the form of a venturi slot plate. Because of tray sealing problems the pressure drop across a venturi slot plate is limited to about 400mm.

1.3.3 Spray Towers

In this type of scrubber the liquor is sprayed into the gas stream and the resulting spray droplets impact with the particulate matter. The bulk of the liquor is separated by gravity and collects in the base of the tower but mist eliminators are required to prevent excessive carryover of droplets with the clean gas.

Fine droplets are required for high efficiencies and these are obtained by the use of pressure atomised sprays, air atomised spray, or ultrasonic atomised spray units.

Because of the lack of internals, low pressure drops of 25 to 80mm W.C are possible and are effective for particle sizes in excess of 2 microns.

1.3.4 Packed Tower

This type of scrubber has been in use for over a hundred years for the cleaning of gases. The dirty gas enters at the bottom of the tower and passes up through the packing counter current to the liquor which is introduced at the top of the scrubber via a distributor.

The form of packing has varied from the traditional lumps of stone or coke, wooden grids, ceramic rings to the modern proprietary packings which are available in a profusion of intricate shapes and materials of construction.

The high contact surface area makes this form of scrubber most suitable for the absorption of gases into the liquor. Whilst packed towers can be used for removing particulates down to 2 micron they are prone to blockage by solids and hence are not usually used when solids are present.

1.3.5 Turbulent Contact Absorbers (TCA)

In the conventional packed towers the packing is static and is liable to plugging from solids.

In Turbulent Contact Absorbers the packing is fluidised in the gas stream and is thus self cleaning. The turbulence created by the moving packing gives enhanced mass transfer for the absorption of gases.

1.3.5 Continued

TCA's comprises one or more beds of hollow plastic packing (spheres or ellipsoids). The gas enters at the base of the tower, passes up through the beds counter currently to the liquor which is distributed onto the top bed.

It is not normally necessary to redistribute the liquor between beds though to prevent channelling of the gas, good gas distribution is necessary at the base of the tower.

As the performance of TCA's depends on the fluidising of the packing there is a minimum fluidisation velocity which limits turndown but with good design a turndown ratio of 3:1 can be achieved.

TCA's, especially those with ellipsoid packings, are remarkably effective for the absorption of contaminants from gas streams containing particulates:-

COMPARISONS OF DIFFERENT TYPES OF WET SCRUBBERS						
	SPRAY TOWER	VENTURI	TARGET PLATE	PACKED TOWER	TURBULENT CONTACT ABSORBER	
Typical pressure loss mm W.C.	25 to 80	300 to 1500	75 to 150	100 to 300	50 to 250	PARTICLE SIZE MICRONS
Typical Removal Efficiency %	98.5	99.99+	99.5	99	99.5	10
	95	99.99+	97.5	90	95	5
	57	99.6	80	35	50	1
	5	40	25	---	---	0.1
Absorption of gases	FAIR	POOR	GOOD	VERY GOOD	EXCELLENT	
Tolerance of solids	VERY GOOD	VERY GOOD	GOOD	POOR	GOOD	

WET SCRUBBERS	
ADVANTAGES	DISADVANTAGES
Low Capital Cost	Liquid Effluent Produced
Collects Gases and Particles	Corrosion Resistant Materials Required
Cools and Cleans Hot Gases	Stack Gases Wet and Cold
Minimal Explosion or Fire Hazard	High Energy Cost for Fine Particles
Can Handle Gases at or near Dewpoint	

1.4 FABRIC FILTERS

In fabric filters, fabric tubes up to 5-7 m long by 100 to 150 mm diameter are hung together in a box structure.

Dust laden gases are passed through the semi-porous medium of woven or felted cloth which retains the dust particles and allows the clean gases to pass through.

The efficiency of this type of filter is very high but is subject to temperature and chemical composition limits, in particular water vapour content.

For economic reasons the fabric material is expected to give a life of several years.

Whilst high efficiency of removal is obtained it has a high pressure loss (and hence energy consumption). The high fan power required to overcome the system resistance for large gas volumes can result in excessive operating costs.

In operation, the gas is filtered for a given period of time. A regeneration system then comes into effect (without taking the filter off line) and cleans the bags. This is done by reverse air, a pressure pulse or by vibrating (shaking) the bags.

A pulse jet filter is one of the most common types where the regeneration of the bags (or removal of the dust cake) is done by a short sharp blast of air (a pulse) onto the top of the open bag. The effect of this is to expand the bag thus breaking away any dust cake on the outside of the bag. The dislodged dust falls down into the hopper and the filter continues cleaning the gas.

The pulses are initiated to each row of bags in turn on a timed basis or on a cycle initiated by high pressure drop across the bag.

There are many fibre fabrics from which to choose for bag filters.

Whilst fabric filters are relatively mechanically simple, moisture and/or high temperatures can destroy the fabric quickly resulting in total breakdown of dust removal.

For high temperature applications ceramic fibre filters can be used.

FABRIC FILTERS	
ADVANTAGES	DISADVANTAGES
High Efficiency for Submicron sized dust Produces Dry Product Lower Cost than ESP	High Pressure Drop Bags damaged at High Temperature Dewpoint Problems at Low Temperature High Maintenance Costs

1.5 ELECTROSTATIC PRECIPITATOR

Electrostatic precipitators can be operated over a wide range of inlet conditions i.e. temperature, pressure, and dust burden and can collect dust in both the dry and wet states. Even when removing submicron dust the pressure loss across an electrostatic precipitator is almost negligible (-20 mm W.G.) and hence fan power (a major operating cost) is kept to a minimum.

Electrostatic precipitation combines high efficiency with low operation costs.

The principle of Electrostatic Precipitation is simply to pass the gas and dust through an electric field where the particles first become charged, then move under the influence of the electric field to be deposited on collector electrodes, from where they are subsequently removed.

In industrial applications there are generally two types of electrostatic precipitator, the horizontal flow plate type, where a series of parallel plates form the gas passages with electrodes hanging centrally between the plates; and the tube type of precipitator, where the gas passes through vertical tubes and the discharge electrodes takes the form of coaxial elements.

In practice the parallel plate precipitator, having horizontal gas flow has the ability to have several stages, or fields, in series and therefore an extremely high efficiency. This design has generally superseded the tube type of vertical flow precipitator, except for mist collection where the tube precipitator is ideally suited and gives high collection efficiency as a single field device.

In either the plate or tube precipitator, the discharge electrode is energised by a high negative potential which causes local ionisation of the gas molecules. The positive ions are immediately collected by the negatively energised discharge electrode and the negative ions escape into the space charge region.

As particles pass through into the space charge area they receive a negative charge either from gaseous ions or electrons escaping from the corona region and as a now charged particle, move under the influence of the electrical field to become deposited on the collecting surface.

For air cleaning applications the electrodes are usually positively energised to limit possible ozone production.

With industrial precipitators operating on dry particles, the plates are vibrated or rapped at intervals to remove the collected dust which is deposited into a hopper situated beneath the plates. In the wet precipitator the dust on the collector plates is removed by water washing, either from sprays situated above the electrode system or by a self irrigated plate. Unless the particulates are removed the deposits interfere with the electric field and reduce performance.

1.5 Continued

Electrostatic Precipitator Advantages

Collecting particles to less than 0.1 micron in diameter

Removing either liquid or solid particulates with very high efficiencies (99.9%+)

The particulates can be recovered in the same state as they arrive at the precipitator i.e. either dry or wet

Having extremely low pressure losses <20 mm WG

Operating from ambient temperature up to 750°C

Handling either vacuum or pressure conditions

Having relatively low maintenance costs

Electrostatic Precipitator Disadvantages

High capital cost

Large space requirement

2. **ELIMINATION OF GASEOUS CONTAMINANTS**

The methods for removal of gaseous contaminants can be considered in three categories depending on the final form the contaminant is removed:-

LIQUID	Absorption into liquid	WET SCRUBBING
SOLID	Adsorption or reaction to produce a solid	DRY SCRUBBING ADSORPTION
GAS	Decomposition or Gas phase conversion	THERMAL OXIDATION

2.1 WET SCRUBBING

Absorption of gases into liquids is conventional mass transfer technology. The choice of absorbent depends on the contaminant to be removed but the most usual absorbent is water or an aqueous solution.

Acids or Alkalis are often used to control the pH to the optimum level for absorption. Oxidising agents such as hydrogen peroxide or hypochlorite can be used to "fix" the contaminant i.e. reduce its vapour pressure over the absorbent solution.

2.1 Continued

The contaminants removed from the gas are now in a liquid phase and a portion of the circulating liquid has to be discharged to ensure the total dissolved salts concentration and/or suspended solids do not exceed permitted levels.

This blowdown liquor may require further processing in an effluent treatment plant before it is suitable for discharge.

Conventional mass transfer devices such as trays or random packed towers can be used but often in gas cleaning application the equipment has to be suitable to cope with solids. The equipment therefore is similar to that previously discussed for particulate removal.

2.2 SOLID SYSTEMS

There are many solid adsorbents are used for gas cleaning the most usual are:-

- Activated carbons for hydrocarbon removal

- Lime for acid gas removal

- Compost/biomeida for odour removal

- Molecular sieves for hydrocarbons and carbon dioxide

These can be used either as a static or moving bed or the solids can be entrained in the gas stream.

2.2.1 Solid Beds

Activated carbon is used to remove organic contaminants and odours from gas streams. In some cases i.e. solvents it is possible to regenerate the carbon beds by steam or hot gas stripping, the solvents are then either incinerated or recovered. Some carbon suppliers, offer a service where they regenerate the spent carbon off site. In other cases the spent carbon has to be disposed of by incineration or landfill.

Compost Beds are used to remove odours from vent air. The compost adsorbs the pollutant and bacteria "feed" on it. The bacteria need to acclimatise to particular pollutants. Temperature, moisture control together with reasonably steady concentration levels are required for efficient operation.

Limestone beds have been used for over 100 years for acid gas removal and are still used. To meet the fluoride emission requirements from brick kilns dolomitic limestone beds are being used to treat the flue gas.

For smaller systems static beds are used, the very small units having the adsorbent packed in replaceable containers. For VOC control, activated carbon units are available as modules that can be handled by fork lift trucks. When spent they are returned to the supplier who regenerates the spent carbon and are then re-used.

2.2.1 Continued

For larger systems fixed static beds are used and these are generally regenerated in situ by steam or hot gas stripping.

For very large systems a moving bed system can be used where the gas usually flows horizontally through the material. The fresh solid absorbent is added at the top and passes down through the bed, the flow rate being controlled by a mechanical means and the spent material is discharged at the base and is either disposed of or regenerated.

Another form of moving bed is the rotary wheel adsorber where the adsorbent (usually activated carbon) can be regenerated in situ. The gas flows horizontally through a cylindrical bed, typically 500 mm deep, which is slowly rotating. By means of seals the contaminated gas flows through 80 to 90% of the bed area whilst hot regenerating gas passes counter-currently through the remaining area, removing the adsorbed contaminants.

2.2.2 Solid Injection

Because of the physical size and pressure drop limitation on solid beds injection of the powdered solid adsorbent into the gas stream is coming into more general use.

The powdered solid adsorbs or reacts with, the contaminant in the gas stream. The solid together with the contaminant is then removed along with any other dust in a bag filter or ESP.

Alkalis such as lime or sodium bicarbonate are injected for the removal of acid gases such as SO_2 and HCl . Powdered Active Carbons can be injected to remove heavy metals and trace organic compounds such as dioxin.

When the gas temperature is high a lime slurry can be sprayed into the gas to quench the gas evaporating the water and producing a dry lime particle which then reacts with the acid gases and is removed by bag filter and ESP as before.

The efficiency of both the dry and semi-dry lime injection systems increases with the amount of lime injected and decreases with temperature. Hence for optimum conditions there is a balance between the amount of lime used (or recycled) and the achievement of a low operating temperature which is safely above the dewpoint to ensure there are not sticky solids and there is no corrosion.

2.3 GASEOUS SYSTEMS

Thermal oxidation either with or without a catalyst has been used for a long time for removal of odours and organic contaminants. These tended to have a high energy cost as the contaminants are generally at a low concentration.

Improvements have been made in the thermal efficiency by better heat exchange systems with the untreated and treated gases. This has resulted in the combustion chamber being a relatively small section between the heat exchangers for the feed

2.3 Continued

and product gases. These heat exchangers can be either the recuperator type (shell and tube) or the regenerative type using beds of ceramic balls.

Catalytic thermal oxidation makes use of a catalyst which promotes the oxidation of the pollutants at lower temperatures. Because of the use of efficient heat exchange systems catalytic units may not be more thermally efficient but in some cases can be more cost effective.

Other applications of catalyst units for emission control are the DeNO_x systems for flue gases and the catalytic converter fitted to car exhaust.

3. SELECTION OF GAS CLEANING SYSTEM

The essential requirement for selecting the gas cleaning process is a specification of the gas to be treated and the required emission standards. The following tables together with the table for wet scrubbers in section 1.3 can be used as a guide to suitable processes for specific applications.

For particulate removal the following table gives some of the factors relevant to the initial selection.

SELECTION PARAMETERS FOR PARTICULATE REMOVAL								
	PARTICLE SIZE microns			INLET GAS TEMPERATURE Celsius				DRY PRODUCT
	Above 10	1 to 10	sub- micron	Above 400	250 to 400	Dewpoint to 250	Near Dewpoint	
CYCLONE	*			*	*	*		*
TARGET SCRUBBER	*	*		*	*	*	*	
VENTURI SCRUBBER	*	*	*	*	*	*	*	
FABRIC FILTER	*	*	*			*		*
FIBRE FILTER	*	*	*	*	*	*		*
DRY ESP	*	*	*		*	*		*
WET ESP	*	*	*				*	

For gaseous contaminants the following guidelines can be used.

GAS TYPE	PROCESS
Organic Compounds	Scrubbing (Oil/Water) Condensation Carbon Adsorption Thermal Oxidation
Acid Gases	Wet Scrubbing Dry Scrubbing Semi-Dry Limestone Beds
Odour Removal	Wet Scrubbing Carbon Adsorption Thermal Oxidisers Compost Beds

It is not possible to give definite selection procedures as each case needs to be considered on its merits. For many applications it is now necessary to have a combination of gas cleaning stages in order to meet the emission regulations.

CONCLUSION

A wide range of gas cleaning options available to reduce atmospheric pollution. The technology exists to meet most of the proposed emission standards but they do require a carefully engineered solution often needing a number of gas cleaning stages.

For some applications it is possible to combine gas cleaning with produce or energy recovery but these tend to be project specific and need to be integrated into the overall process and not just an "end of pipe" emission control process.

ACKNOWLEDGEMENTS

The author would like to thank ACWa Services Ltd and his colleagues for their help and assistance in the preparation of this paper.

Appendix 5

DECOMPOSITION PRODUCT OF APFO: 1-HYDROPERFLUOROHEPTANE

Formula: $C_7F_{15}H$

Other names: pentadecafluoroheptane, C-7 fluorocarbon hydride.

CAS 375-83-7

Information is based on the linear molecule and the H-atom at the end of the molecule. According to Japanese patents it can be used as a dry cleaning agent.

At this moment no toxicity data is available for this product.

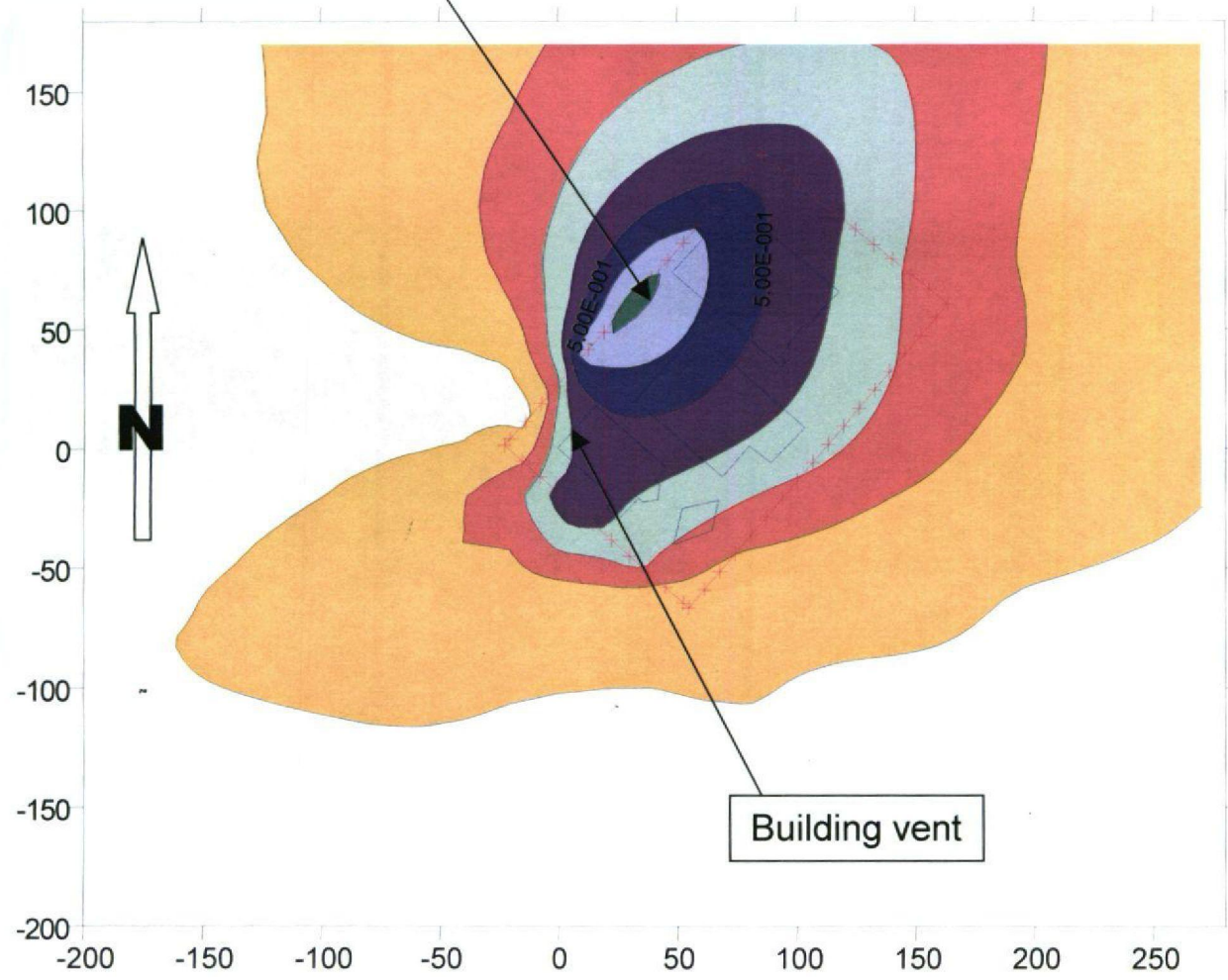
Based on the molecule structure it is estimated that the material will have:

- low toxicity
- low ODP (ozone depletion potential)
- low GWP (global warming potential)
- boiling point 95°C – 100 °C
- low vapor pressure; 0.1 atm.
- low solubility in water
- some solubility in alcohol

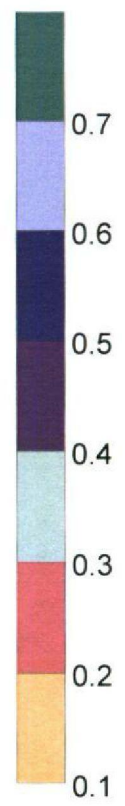
Further toxicity tests are underway and results may be expected by the end of 2005.

Annual Average Concentrations

Maximum Annual Average Concentration = 0.74 ug/m³



Scale in ug/m³



Building vent

Legenda toegepaste uitzonderingsgrondslagen

In dit document zijn gegevens geanonimiseerd op grond van:

Wet	Artikel	Omschrijving	Pagina's
Wet open overheid	Art. 5.1 lid 2 sub e	De eerbiediging van de persoonlijke levenssfeer	1, 12, 14
Wet open overheid	Art. 5.1 lid 2 sub f	De bescherming van andere dan in het eerste lid, onderdeel c, genoemde concurrentiegevoelige bedrijfs- en fabricagegegevens	4, 5, 6, 7