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HYDROGEN FLUORIDE

CAS-no.: 7664-39-3

EINECS-no.: 231-634-8

Summary Risk Assessment Report

2001

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SUMMARY RISK ASSESSMENT REPORT

Final report, October 2001

The Netherlands

Rapporteur for the risk evaluation of Hydrogen Fluoride is the Ministry of Housing, Spatial Planning and the Environment (VROM) in consultation with the Ministry of Social Affairs and Employment (SZW) and the Ministry of Public Health, Welfare and Sport (VWS). Responsible for the risk evaluation and subsequently for the contents of this report, is the rapporteur.

The scientific work on this report has been prepared by the Netherlands Organisation for Applied Scientific Research (TNO) and the National Institute of Public Health and the Environment (RIVM), by order of the rapporteur.

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PREFACE

This report provides a short summary with conclusions of the risk assessment report of the substance Hydrogen Fluoride that has been prepared by the Netherlands in the context of Council Regulation (EEC) No. 793/93 on the evaluation and control of existing substances. For detailed information on the risk assessment principles and procedures followed, the underlying data and the literature references the reader is referred to the original risk assessment report that can be obtained from European Chemicals Bureau[1]. The present summary report should preferably not be used for citation purposes.

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[1] European Chemicals Bureau – Existing Chemicals - http://ecb.ei.jrc.it

CONTENTS

1 GENERAL SUBSTANCE INFORMATION

Identification of the substance

CAS-No.:	7664-39-3
EINECS-No.:	231-634-8
IUPAC name:	hydrogen fluoride
Molecular formula:	HF
Structural formula:	H - F
Molecular weight:	20.01
Synonyms:	hydrofluoric acid anhydrous hydrofluoric acid

Purity/impurities, additives

Purity:	>99.9% (w/w)
Impurity:	<1% water
Additives:	none

Physico-chemical properties

Table 1.1 List of physico-chemical properties is provided

Property	Result	Comment
Physical state	liquid/gas	
Melting point	- 83°C	
Boiling point	°C at 1013 hPa	
Relative density	1.016 g/cm^3 at 0°C (liquid) 0.901 g/cm^3 at 22°C (liquid)	
Vapour pressure	1033 hPa at 20°C	
Water solubility	miscible in all proportions	
Partition coefficient n-octanol/water (log value)	- 1.4	
Flammability	non-flammable	see text
Explosive properties	non-explosive	see text
Oxidising properties	not oxidising in the sense of reaction with oxygen	see text
Odour (threshold air)	30µg/m^3	
Conversion factors (at 20°C)	1 mg/m^3 = 1.22. ppm (101 kPa, 25°C) 1 ppm = 0.82 mg/m^3 (101 kPa, 25°C)	

All relevant physicochemical data were provided. Although most of the data arise from data-bases and the underlying reports were lacking, the physico-chemical properties could be interpreted with sufficient certainty to a range that is within an acceptable accuracy. Therefore, further testing of these properties is considered superfluous. It is concluded, that the data submitted are acceptable with respect to the basic requirements as specified in Annex VIIA of

Directive 67/548/EC.

HF with concentrations of less than about 65% reacts with metals (e.g., iron from steel drums or from reactors) under formation of H_2. Mixtures of H_2 in air can be explosive. High heat of dilution may cause violent behaviour upon dilution of concentrated HF with water. There are no R- and S- phrases appropriate for the properties as mentioned above. Therefore, it is recommended to include these remarks in the Material Safety Data Sheets.

Classification

Classification according to Annex I: T+, C; R-26/27/28-35; S-7/9-26-36/37/39-45.

Proposal of the rapporteur: agreement with Annex I (see above) with the addition of R54 (Toxic to plants). It must be noted that HF is very toxic to plants and is a possible candidate for R54 (toxic to plants). Since no criteria have been established yet this R-phrase cannot be assigned yet.

2 GENERAL INFORMATION ON EXPOSURE

2.1 PRODUCTION

The production of HF (>1,000 t/a) is located at different sites in the European Union. The maximum total production of HF in the European Union for 1994 is 245,000 tonnes. There are no import or export data available.

The raw material for the production of HF is the mineral fluorspar (30-60% CaF_2), which is treated with acids to the so-called acid spar quality (about 97% CaF_2). HF is produced by the conversion of dried acid spar with concentrated sulphuric acid at elevated temperatures. The volatile HF formed is condensed and purified by distillation (VDI 1987).

2.2 USE PATTERN

Table 2.2 shows the industrial and use categories of HF. Anhydrous HF and hydrofluoric acid is used for the production of organofluor compounds and inorganic fluorides, as well as a catalyst of alkylation reactions in the petrochemical industry. It is also used for etching of glass and pickling of stainless steel. The two main types of use categories for HF can be characterised as use in closed systems and non dispersive use.

The quantitative estimate currently available for the industrial and use category distribution of HF is 60% for the synthesis of organofluor compounds, 30% as intermediate in chemical synthesis of inorganic fluorides, 4% as pickling agent of metal surfaces, 3% for etching of glass surfaces, and 2% as catalyst in alkylation reactions in the petrochemical industry (CTEF 1995).

Table 2.2 Industrial and use categories of HF

Industrial category	EC No.	Use category	EC No.
Chemical industry: basic chemicals	2		
Chemical industry: used in synthesis	3	Intermediates	33
Mineral oil and fuel industry	9	Process regulators (catalysts)	43
Metal extraction, refining and processing	8	Others: descaling and pickling of steel	55
Others: mining industry	15	Other: special metal extraction	55
Others: electrotechnical industry	15	electroplating agents	17
Others: Glass industry	15	Others: frosting, etching and polishing	55

3 ENVIRONMENT

3.1 EXPOSURE

3.1.1 General

HF may enter the environment from both natural (volcanoes, weathering of minerals and marine aerosols) and anthropogenic sources. The latter includes production of HF itself, but HF is also formed as a by-product during other industrial processes (phosphate fertiliser, aluminium and steel production, ceramic industry etc.).

Once released in the environment HF is unlikely to remain in its original form for very long. In air, water and soil HF is transformed to a variety of other F-compounds.

3.1.2 PECs at production and use

For all production and end-use plants site-specific emission data were available. According to industry the submitted emission data are assumed to cover 85% of the total emissions of HF from HF producers and users. The release data are used to calculate the Predicted Environmental Concentrations (PECs) in water, soil and air. The PECs in water, based on the most recent release data for each site, range from 0.2 to 9mg/l. For air this range is 0.07 to 3.3 µg/m^3. All PECs in soil are assumed to be below 1.5mg/kg.

3.1.3 Releases from other (unintentional) sources

The fluoride emissions from the HF-industry are compared to those from other industrial sources. It can be concluded that the European fluoride emission from the HF industry only amounts to about 2% of the total industrial fluoride emission to surface water. The atmospheric emission of the HF industry accounts for less than 0.1% of the total European emission.

3.2 EFFECTS

3.2.1 Aquatic compartment

Both short and long term toxicity data (NaF) are available for fish, crustaceans, algae and micro-organisms.

The PNEC for the freshwater compartment is extrapolated from the calculated mean NOEC-value for *Daphnia magna* (8.9 mg/l) using an extrapolation factor of 10. The extrapolation leads to a PNEC for the freshwater environment of **0.9 mg/l ($PNEC_{aqua}$)**. The set of aquatic ecotoxicity data consists of test results based on both actual and nominal concentrations. The assumption is made that this PNEC already includes a background fluoride level. One should further realise that the PNEC of 0.9 mg/l is based on daphnid tests carried out under hard water conditions. Given the clear relation between toxicity and water hardness, this PNEC may underestimate soft water conditions. There are no long-term daphnid tests in soft water, but there is one very soft water test (12 mg/l $CaCO_3$) with *Oncorhynchus mykiss*. Using this fish test and applying an assessment factor of 10 would result in a PNEC of 0.4 mg/l for soft water conditions.

Another important issue in this context is that natural background fluoride levels may vary substantially within the EU. Under natural conditions elevated natural background F levels can be encountered in certain regions. This means that the above-mentioned PNEC is therefore not directly applicable to those regions with high natural F-levels.

From the available data on micro-organisms the results of the activated sludge test (510 mg/l) are used for deriving the $\mathbf{PNEC_{microorganisms}}$ of **51 mg/l** .

3.2.2 Terrestrial compartment

Long-term ecotoxicity data with fluoride for terrestrial organisms, including microbial processes, are available. The lowest available NOEC, i.e. 106 mg/kg for nitrification, was selected for deriving the PNEC for the terrestrial compartment. Applying an assessment factor of 10 gives a PNEC of 11 mg/kg. The factor 10 was chosen because long-term data are available for three trophic levels.

The background F concentrations in the above-mentioned test systems were very low. So, theoretically, the PNEC of 11mg/kg is a concentration that must be added to the natural background concentration in soil. However, the PNEC is negligible (less than 10 percent) compared to the average natural background F concentrations in soil.

3.2.3 Atmospheric compartment

Many experiments are available in which all kinds of plants (bean, barley, corn, garden flowers, strawberries, pine, shrubs, grass, rice etc.) are exposed to HF in fumigation experiments. Sensitive species are tulip, gladiolus, fruit crops, conifers and grasses, which are affected at concentrations ranging from 0.4 to 1.0$\mu g/m^3$ after exposure for several days.

On the basis of a large number of fumigation experiments with plants (ornamental crops, fruit crops and conifers) exposed to HF, a relationship was derived between the no-effect-concentration and exposure time (Slooff *et al.* 1988). The lowest NOEC-value (0.2$\mu g/m^{3)}$ for 7-month exposure of highly sensitive plant species will be taken into consideration for the derivation of the PNEC for the atmospheric compartment. Because of the size and diversity of the data set and the character of the experimental set-up (ecosystem-like; 7 months exposure) the application of an extrapolation factor is considered not to be necessary. The $\mathbf{PNEC_{plant,\ air}}$ is therefore $\mathbf{0.2\ \mu g/m^3}$.

3.2.4 Non compartment specific effects relevant to the food chain

Livestock

Cattle were shown to be the most sensitive of domestic animals to dietary fluoride, particularly young animals. Observed effects all eventually lead to a loss of body weight and diminished meat and milk production. Atmospheric NOECs for livestock (and plants) of 0.8 µg and 0.3 $\mu g/m^3$ (daily averages) were calculated for the grazing season and winter season, respectively. These NOEC values have been derived from the relationship between F content of animal feed and (the absence of) effects on the one hand, and from the relationship between F contents of feed (grass) and atmospheric F concentrations on the other. Both values are based on a maximum acceptable F level in feed of 55mg/kg dry weight. In the Netherlands a limit concentration of 2mg fluoride per litre has been set for drinking water for ruminants and poultry.

Wild-life

It is concluded that wild herbivores are or may be more susceptible to fluoride toxicity than domestic live stock, on a dietary F content basis. Thus the atmospheric NOECs derived for livestock may provide an insufficient guarantee for the protection of wild fauna.

3.3 RISK CHARACTERISATION

It is clear that not only the HF industry, but also other industrial and natural sources contribute to regional and continental fluoride emissions (see also 3.1.3) At these regional and continental levels the fluoride emissions from HF industry are small compared to other sources. They cannot be considered to contribute significantly to the fluoride concentrations in the aquatic, terrestrial or atmospheric compartment at a larger scale. For this reason the environmental exposure assessment was restricted to local levels close to HF producing and end-use plants. As a consequence, also the risk characterisation is only performed for the local situation. Additional information on the whole range of other F release sources in the European Union (e.g. NaF industry) is needed for an in-depth risk evaluation of fluorides.

For two plants the local aquatic PEC/PNEC values were larger than 1 **(conclusion iii**). For the remaining plants the PECs in water do not exceed the PNEC **(conclusion ii)**.

For two HF producing plants and one HF using plant the calculated PEC in the atmosphere exceeds the PNEC. The results of recent monitoring programmes have not changed these conclusions **(conclusion iii)**.

Maximal local PEC values for the terrestrial compartment were calculated from deposition of HF.

Levels were found to be negligible compared to background concentrations **(conclusion ii)**.

For a few plants the fluoride surface water concentrations exceed the Dutch drinking water limit concentration of 2 mg/l for ruminants and poultry (see paragraph 3.2.4). Local air concentrations around a number of plants exceed the atmospheric NOECs for livestock of 0.8µg and 0.3µg/m^3 for the grazing season and winter season, respectively **(conclusion iii)**. It is emphasised that wild-life is probably more susceptible to fluorides than livestock.

4 HUMAN HEALTH

4.1 EXPOSURE

4.1.1 Workplace exposure

Exposure of workers to HF is possible in HF production facilities, in chemical industry using HF for further synthesis, in facilities using HF solutions or products containing HF and indirect, due to the formation of HF from other compounds. Occupational exposure levels are estimated using measured data and modelling by EASE with relevant assumptions.

A major part of the produced HF is used by the producers in further synthesis. Exposure in production and further use in the chemical industry is mainly due to fugitive emissions, since production and use is done in strictly closed conditions. Some peak exposure activities are possible when systems have to be opened for tasks such as quality checks. The reasonable worst-case full shift inhalation exposure is estimated to be 0.5 mg/m^3 with short-term exposure levels (up to 2 hours) of 2.5 mg/m^3. Typical exposures are very low and have not been estimated. Dermal exposure in this scenario occurs only accidentally.

The use of HF solutions for etching purposes leads to evaporation of HF and to possibilities for dermal contact in the preparation and cleaning of baths. The reasonable worst case full shift inhalation exposure level is estimated to be 2.4mg/m^3, with a typical level of 1.2 mg/m^3 and short term exposure levels (2-3 hours) of up to 6mg/m^3. A single day dermal exposure of 0.5 mg/day is estimated. Due to the corrosive nature of HF and the process in which it is used repeated dermal exposure is not expected in this situation.

The use of HF in cleaning and polishing products is expected to lead to lower exposure levels than the use for etching. Exposure is also possible due to the use of facade cleaning products (pastes) containing HF. The inhalation exposure is due to evaporation from the product and due to aerosol formation when the product is removed from the facade using low pressure water spraying. Inhalation levels for this use of HF may be substantial, but depend on the amount of free, unreacted HF at the moment of removing of the product from the facade and cannot be estimated with available information and methods. Dermal exposure has been reported to occur relatively frequently and is estimated to be 110mg/day for single day exposure and 0.2 mg/day for repeated exposure. The latter value is considered to be an upper bound level that probably overestimates true repeated exposure levels.

In several industries indirect exposure to HF, not related to the use of the substance, occurs.

Examples are the fertiliser production, the aluminium industry, magnesium foundries and fire fighting. The exposure is due to formation of HF from fluorine compounds. These indirect exposure situations can lead to exposure levels that are higher than the reasonable worst cases estimated for situations where HF is handled. The reasonable worst-case full shift inhalation exposure levels for the mentioned situations are estimated to be between <1 and 10 mg/m^3. Further estimates have not been made, but dermal exposure levels are expected to be clearly lower than dermal exposure due to the use of HF containing products.

Table 4.1 Conclusions of the occupational exposure assessment (Dermal)

Scenario	Activity	Frequency (days/year)	Duration (hr)	Reasonable worst case		Typical concentration		Dermal	
				(mg/m^3)	method	(mg/m^3)	method	mg/cm^2/ day	dose (mg/day)
1. Chemical industry	general peak activities	100-200 100-200	6-8 1-2	very low 2.5	EASE, meas. meas.	n.e.		accidental	accidental
	full shift [1]		6-8	0.5	calc.				
2. Use of HF solutions	etching [a]	50-100	2-3	6.0	meas., EASE, exp [2]			not estimated	0.5 (single day)
	full shift [1]	50-100	6-8	2.4		1.2	exp [2]		
	manual cleaning/ facade; full shift	50-100	6-8	n.e. [3]		n.e.		n.e.	110 (single day) 0.2 (repeated[4])
3. Indirect exposure	several	100-200	6-8	<1-ca.10 [5]	meas.	n.e.			cannot be estimated [5]

n.e.= not estimated
meas.= measured
exp.= expert

[a] etching: preparing and cleaning baths

[1] Full shift exposure calculated from 1.6 hour at 2.5 mg/m^3 and negligible exposure during the remaining 6.4 hours. In practice the background exposure may be higher, but for compensation the duration of high exposure may be lower

[2] Expert judgement based on stationary measurements and on measured data that are probably short-term data

[3] The inhalation exposure for manual cleaning and polishing is probably below the level of etching, due to the low volumes handled. The inhalation exposure due to facade cleaning cannot be estimated with the available information and methods

[4] The repeated exposure is an upper bound estimate that probably (severely) overestimates true exposure levels

[5] These are rough estimates based on measured data that were limited in quantity and quality and are only presented for comparison with the other 2 scenarios

[6] Cannot be estimated, but are considered to be clearly below the levels in scenario 2

4.1.2 Consumer exposure

The producers of HF stated that there is no consumer exposure since the historic uses for aqueous hydrogen fluoride e.g. rust cleaning agents have been discontinued. It appeared that consumer use only occurs in accidental cases e.g. workers use industrial products in private life or HF containing products are reformulated and/or marketed as consumer products. However, recent information obtained from the Anti-poison centre in Belgium shows that the use of aqueous hydrogen fluoride in rust cleaning and stone and wood cleaning agents, all available and marketed to consumers, is still common practice in Belgium (SZV&W, 1999). A significant number of accidents through the use of these products have been reported.

4.1.3 Man exposed indirectly via the environment

Hydrogen fluoride may enter the environment from both natural and anthropogenic sources. The contribution of HF emissions from the HF producing and processing industry is limited compared to those from other industrial sources. In air, water and soil HF is transformed to a variety of other fluoride anion containing compounds.

Local fluoride concentrations are calculated for the atmospheric compartment for 13 HF-producing and 5 end use plants. In addition to the calculated atmospheric HF concentrations monitoring data are available for some plants.

The measured data range from 0.05 - 2.4 μg/m^3. The calculated local atmospheric HF concentrations for each production and end use plant range from 0 – 3.2μg/m^3. Based on these data, estimates of the actual inhaled amount in μg/day have been calculated assuming an average respiration rate in an adult person of about 20 m^3 per day. These estimates range from 1 to 48 μg/day for the measured concentrations and from 0.076 to 64 μg/day for the calculated local concentrations (in the latter case these estimates are strictly related to local plant sites and are exclusive the background concentration). An exposure level of 50 μg F/day can be considered as a realistic worst case situation of inhalatory exposure to fluoride of the population at large.

To get an impression of the relevance of the actual additional intake of fluoride via air these exposure estimates (in μg/day) have been compared to fluoride intake food and drinking water. With respect to the intake via food and water the highest value of 5640μg F/day has been taken into account as a worst case situation. Human intake of fluoride may also include iatrogenic sources such as dental products. It has been estimated that from this use a daily fluoride ingestion of 300μg F/day can be reached. When all sources are taken together, it can be calculated that exposure to fluoride via air in the form of HF is about 1% of the total daily exposure, which is considered negligible.

4.2 EFFECTS

The human population may be exposed to hydrogen fluoride, and indirectly to fluoride, predominantly at the workplace and indirectly via the environment.

In the data set for HF animal as well as human studies were available. With respect to reproduction toxicity (base set requirement), mutagenicity and carcinogenicity data from studies carried out with sodium fluoride have been taken into account, since these studies provide insight Sensitisation studies with HF are not available. Although such a test is a base-set requirement it in the possible hazard of fluoride and thus HF as has been explained in the sections on toxicokinetics.

Inhaled gaseous hydrogen fluoride is virtually completely absorbed in the upper airways. Fluoride circulates in the body as F^- and in association with proteins and lipids and its distribution and elimination do not depend on its place of entry into the body. Fluoride can be found in all tissues in the body and sequestration takes place in bone tissue in which about half of the absorbed fluoride is deposited. Secretion is mainly via the urine. In humans half-lives are in the range of 2 to 9 hr and in the range of 8 to 20 years for fluoride in plasma and bone deposits, respectively.

HF is very toxic by inhalation, in contact with skin and if swallowed. According to the EU guidelines HF is classified as Very Toxic (T^+).

When applied to skin and eye HF produces severe lesions, even at low concentrations. According to EU guidelines HF is classified as corrosive (C).

It was agreed that based on the physico-chemical properties of HF and F^-, it is reasonable to assume that the substance has no sensitising properties.

Signs of acute fluoride intoxication in humans resemble those observed in animals. Dermal contact with HF either as liquid or as gas produces severe dermal lesions. Dermal contact with HF may result in systemic (cardiac) effects including death. Inhalatory exposure is highly damaging to the respiratory tract. Exposure to HF in a concentration of 1.16 mg/m^3 will possibly result in some irritation. Prolonged oral intake of excess fluoride results in skeletal fluorosis, an effect for which indications were also found after inhalatory exposure.

The available animal data set for HF permits the derivation of a NOAEL for repeated subchronic inhalatory exposure. No suitable studies are available to derive a NOAEL for HF for other routes of exposure. In a study with rats, changes in body and organ weights as well as haematological and clinical signs and death were seen at actual concentrations of 7.52 mg/m^3; 6hr/d; 5d/w for 90 days. This value is equal to a duration corrected value (DCV[2]) of 1340 µg/m^3. Based on actual exposure levels a NOAEL of 0.72 mg/m^3 is established. Because at higher dose levels apart from irritation also systemic effects occur, a duration corrected equivalent of this NOAEL is calculated. This duration corrected value (NOAEL) amounts to 128 µg/m^3.

In epidemiological studies with workers exposed to 0.48mg total fluoride/m^3 (of which 0.2mg gaseous fluoride) no fluorosis was observed. This level can be considered as an inhalatory NOAEL for fluoride in humans. At this level slight respiratory effects were observed, but these effects were not attributable to HF, because simultaneously, exposure to other air-way irritants occurred.

It is concluded that fluoride does not induce chromosomal damage *in vivo*. However, genetic damage is observed in *in vitro* studies.

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[2] DCV: calculated as: $C(air) \cdot h / 24 \cdot d / 7$; in which h and d are hours of exposure per day (=6) and number of days of exposure per week (=5), respectively

Carcinogenic studies with HF are not available[3]. From studies with sodium fluoride in rats and mice it is concluded that fluoride is not considered to be carcinogenic in animals.

Reproduction studies with HF are not available. In some incomplete studies fluoride (as NaF) has elicited effects on male fertility in mice, rats and rabbits. The LOAEL for these effects was 2.26mg F^-/kg b.w./d. In a two-generation study (leading to a NOAEL of 250mg NaF/l; equivalent to 11 mg/kg b.w./d) and in an intratesticular injection study, fluoride did not induce any sign of impaired testicular functioning. There are very strong indications from the two-generation study that fluoride does not affect male or female fertility. This cannot be stated with certainty because the study has not been fully reported, yet. Despite this limitation, the NOAEL of about 10mg/kg b.w./d derived from the two-generation study will be used in the risk assessment.

From three well-performed embryo- and developmental toxicity studies with NaF an overall NOAEL for maternal toxicity and developmental effects of 11.12mg F^-/kg b.w./d can be derived.

The duration corrected NOAEL of 128µg/m^3 from the 90 days rat study will be used for the characterisation of the risk of human inhalatory exposure for the population at large.

The NOAEL of 0.48mg total F/m^3 for systemic effects which was found in an epidemiological study is used as starting point for the occupational risk assessment.

It should be noted that in most studies background exposure to fluoride (e.g. control diet or/and drinking water fluoride level) has not been determined. This is especially problematic in oral studies in which systemic effects were investigated. Basically it would be correct to take this background exposure into account in the risk assessment for fluoride. An appropriate correction can only be carried out when sufficient data on bioavailability and concentrations in animal feed and drinking water are available. Animal feed for routine toxicity testing may contain as much as 20 mg fluoride/kg diet (approx. 1 mg/kg b.w./d). On the other hand, human diet will contain fluoride from natural sources as well. The risk-evaluation for the workers and population at large for systemic effects reflects only the additional risk resulting from exposure to fluoride above oral background. In this approach it is assumed that oral effects of fluoride in the diet are equally likely to occur in humans and in experimental animals.

4.3 RISK CHARACTERISATION

4.3.1 Workplace

Assuming that oral exposure is prevented by personal hygienic measures, the risk characterisation for workers is limited to the dermal and respiratory routes of exposure. Furthermore, it is assumed that adequate risk reduction measures are taken to prevent accidental exposure.

For risk characterisation, local effects of HF and systemic effects of the fluoride-ion after uptake of HF should be distinguished. Actually, for risk regarding systemic effects the total intake of F^- should be taken into account, i.e. F^--uptake via food and drinking water and the F^--uptake

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[3] IARC (164) has evaluated the carcinogenicity of mists of strong inorganic acids. From this IARC evaluation no conclusion can be drawn with respect to the inhalatory carcinogenicity of HF

due to occupational exposure to HF. Data on background levels in the toxicity studies are not always reported. For occupational risk characterisation it is assumed that the impact of oral background uptake of F^- in the studies and for workers are comparable. Therefore, the estimated risk with regard to systemic effects reflects only the additional risk resulting from exposure to HF above oral background levels, unless data are available which allow a refinement (see 4.2). If applicable, quantitative risk characterisation is performed by calculation of the MOS (ratio between NOAEL/LOAEL and exposure levels) and comparison of this value with the minimal MOS. This minimal MOS is established via assessment factors, taking into account inter- and intraspecies differences, differences between experimental conditions and the exposure pattern of the worker, type of critical effects, dose-response relationship, confidence of the database and correction for route-to-route extrapolation. A risk is indicated when the MOS is lower than the minimal MOS.

Given the LC_{50}-values (1 hr values 280-1900 mg/m^3) and the estimated short-term exposure levels (2.5-10 mg/m^3) it is concluded that there is no need for risk reduction measures additionally to those already taken to prevent accidental exposure (**conclusion ii**).

Exposure to HF is possible by dermal contact, and via the respiratory tract and the eyes. The occupational risk for local effects is characterised for exposure via the skin, the respiratory tract and the eyes, both to liquid and to gaseous HF, and account is made for single as well as repeated exposure. It is noted that local effects to the skin might be caused by simultaneous exposure to gaseous and liquid HF. Skin contact with liquids in scenario 1 is limited to accidental events. Despite the fact that risk reduction measures are taken to prevent accidental exposure, contact to the skin cannot be excluded in scenarios 2 and 3. Because of the strong corrosive properties, it is concluded that additional risk reduction measures to avoid local effects due to skin contact with liquids are indicated for these scenarios (**conclusion iii**). The data available do not allow a risk estimation for local skin effects after single exposure to gaseous HF. Respiratory effects due to single exposure to gaseous HF have been described in case reports (accidental exposure) and in volunteer studies. Exposure to levels >2.5 mg/m^3 for 60 minutes resulted in subjective symptoms of the upper airways. Because of the estimated short-term occupational exposure levels (2.5 mg/m^3 in scenario 1, 6 mg/m^3 in scenario 2, up to circa 10mg/m^3 in scenario 3) a risk cannot be excluded and risk reduction measures, additional to those already taken to prevent accidental exposure, are indicated (**conclusion iii**). Repeated inhalation exposure to liquid HF is not expected. Given the MOSs (0.2-1.2) between the LOAEL for local effects on the skin and nasal mucosa in a human volunteer study with repeated exposure to gaseous HF (1.16 mg/m^3) and the inhalation occupational exposure levels (2.5-10 mg/m^3) it is concluded that workers are at risk with regard these effects in all exposure scenarios (minimal MOS 2) (**conclusion iii**). Exposure to the eyes is possible via vapours (all scenarios) or accidentally by splashing of HF (solutions) in scenarios 2 and 3. However, eye protection is obligatory for activities where direct handling of HF occurs. If the required protection is strictly adhered to, exposure to liquid HF will occur only accidentally in scenarios 2 and 3, so **conclusion (ii)** is justifiable. Given the effects observed in the acute eye irritation studies (exposure to HF solutions) and in human volunteer studies (repeated exposure to vapours gives slight irritation at 1.16mg/m^3), it is concluded that HF is of concern for workers with regard to eye irritation after repeated exposure to vapours, and risk reduction measures are indicated for these scenarios (**conclusion iii**). It is noted that workers are not at risk for adverse eye effects after single exposure to gaseous HF, based on a human volunteer study, in which no effects on eyes were observed after 60 minutes exposure to concentrations up to 5.2 mg/m^3. According to the information submitted by industry extensive risk reduction measures have been taken in industrial premises producing and/or using HF (scenario 1 and 2). It is noted that exposure levels in scenarios 1 and 2 are estimated for situations with protective measures and it is possible that in some industrial premises adequate risk reductions measures are already applied to avoid irritation.

Despite the lack of a sensitisation study with HF, it is concluded that there is no concern for workers with respect to this endpoint given the physico-chemical properties of HF and F^- (**conclusion ii**).

The NOAEL from the epidemiological study (0.48 mg/m^3) is used as starting point for the risk characterisation for systemic effects after repeated dermal and inhalation exposure. Given the MOSs (0.05-1) between this NOAEL and the inhalation exposure levels (0.5-10mg/m^3) and the minimal MOS, it is concluded that there is concern for systemic effects after inhalation exposure in scenario 2 and 3 (**conclusion iii**). Because skin exposure in scenario 1 is limited to accidental events, risk characterisation for repeated exposure is not relevant. Given the MOS (24) between the NOAEL (0.48mg/m^3, i.e., 4.8mg/d) and the dermal exposure level in scenario 2 (0.2mg/d) systemic effects due to occupational dermal exposure are not expected. Because dermal exposure in scenario 3 cannot be estimated, systemic effects cannot be excluded. Therefore, (**conclusion iii)** may be applicable for scenario 3.

There are no indications for concern for mutagenicity and carcinogenicity (**conclusion ii**).

The oral NOAEL (10mg F^-/kg bw/d) from the 2-generation study with NaF is used as starting point for the risk characterisation (see also 4.2). The MOS between the NOAEL and the inhalation exposure levels are 50, 10, and 2.5->25 for scenario 1, 2 and 3, respectively, indicating concern for scenario 3. Because skin contact in scenario 1 is limited to accidental events there is no concern for reproductive toxicity. Therefore (**conclusion iii)** is indicated for scenario 3. The MOS between the NOAEL and the dermal exposure levels is 15 in scenario 2 or unknown in scenario 3. Comparison with a minimal MOS (36) indicates a risk for reproductive effects in scenario 3.

The current occupational limit values are predominantly based on irritation and corresponded well with the data in the present report to characterise the risk for local effects. However, in the present report reference is made to additional studies, which should be taken into account for the establishment of OELs. Therefore, it is recommended to reconsider the current OELs.

4.3.2 Consumers

Information obtained from the Anti-poison centre in Belgium shows that a significant number of accidents have occurred through the use of rust cleaning and stone and wood cleaning agents, available to consumers. In the majority of cases symptoms concerned burned lesions of the hands. In all cases medical care was needed. Because of the strong corrosive properties of the substance and because of the fact that incidental dermal exposure of consumers through the use of the above mentioned products cannot be excluded it is concluded that risk reduction measures are needed (**conclusion iii**).

4.3.3 Man indirectly exposed via the environment

Inhalation exposure

Repeated dose toxicity

For the risk characterisation the ambient background F concentration in air has been added to the calculated concentrations in air as presented in section 4.1.3. For the ambient background F concentration a value of 0.07µg/m^3 is chosen.

The resulting estimates of HF concentrations in air are compared to the NOAEL (DCV) of 128µg/m^3 from the 90 day rats study. At this dose no irritation or systemic effects were observed. It is known that in healthy workers exposed to fluoride in air at a concentration of 114.2µg/m^3 no fluorosis occurs after 10 years of exposure. Because this NOAEL is approx. equal to the NOAEL (DCV) in the 90-day rat study a MOS of 100 is considered sufficient.

For one end use plant the margin of safety indicates a concern for human safety following inhalatory exposure to HF, indirectly via the environment (**conclusion iii**). For all other plants and end-users the MOSs indicate no concern (**conclusion ii**).

Reproductive toxicity

The local estimates for HF air concentrations measured as well as calculated to be used as starting point for the risk characterisation are already mentioned under section 4.1.3.

There are no studies available on reproductive toxicity with HF. Therefore, the oral studies with NaF are used. It is concluded that HF is of no concern with respect to developmental effects, since fluoride causes effects on the progeny only at maternally toxic doses (**conclusion ii**).

As already explained in section 4.2 the 2-generation study of US-FDA with rats will be used as starting-point for risk characterisation. At the highest dose level tested (about 10 mg F^-/kg bw/d) no effects on fertility were observed. By route to route extrapolation assuming complete oral and inhalatory absorption an inhalatory equivalent NOAEL of 35mg/m^3 can be calculated for a continuously exposed person of 70kg and a daily respiratory volume of 20 m^3. When comparing this inhalatory equivalent NOAEL with the measured and calculated local HF concentrations (see section 4.13) all margins of safety are >>2800. Hence it is concluded that this risk estimation indicates no additional risk for fertility effects. (**conclusion ii**)

Intake via all media

In section 4.1.3 it is concluded that HF contribution to the total daily fluoride intake is considered negligible. Therefore no risk characterisation has been performed for humans after exposure to total fluoride.

4.3.4 Combined exposure

Since nearly all scenarios described in the previous sections caused concern for the environment/workers/public at large as discussed, it seems not useful to characterise the risk more specifically after combined exposure.

5 OVERALL RESULTS OF THE RISK ASSESSMENT

5.1 ENVIRONMENT

( ) There is need for further information and/or testing;
( ) There is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied;
(X) There is a need for limiting the risks: risk reduction measures which are already being applied shall be taken into account.

Conclusion (iii) is reached because:

- for a number of HF producing and HF using sites the local environmental risk characterisation points to risks for either 1) the aquatic compartment, or 2) the atmospheric compartment or 3) livestock and wildlife exposed via air.

5.1.1 Man indirectly exposed via the environment

( ) There is need for further information and/or testing;
( ) There is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied;
(X) There is a need for limiting the risks: risk reduction measures which are already being applied shall be taken into account.

Conclusion (iii) is reached because:

- for one HF using site the local environmental risk characterisation indicates a significant risk for humans indirectly inhalatory exposed via the environment.

5.2 CONSUMERS

( ) There is need for further information and/or testing
( ) There is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied
(X) There is a need for limiting the risks: risk reduction measures which are already being applied shall be taken into account

Conclusion (iii) is reached because:

- concerns for skin irritation and/or corrosivity, depending on concentration, as a consequence of single exposure to the hydrogen fluoride liquid arising from the use of HF containing rust cleaning and stone and wood cleaning agents.

5.2.1 Workers

( ) **i)** There is need for further information and/or testing
( ) **ii)** There is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied

(X) **iii)** There is a need for limiting the risks: risk reduction measures which are already being applied shall be taken into account

Conclusion (iii) is reached because:

- the general warnings on (1) the formation of H_2 by reaction of HF solutions of less than 65% with metals, and (2) on the violent behaviour upon dilution of concentrated HF with water, should be included in all MSDSs.

- concerns for skin and respiratory tract irritation and/or corrosivity, depending on concentration, as a consequence of repeated exposure to gaseous hydrogen fluoride at production and use as an intermediate in the chemical industry and use of aqueous HF-solutions.

- concerns for general systemic toxicity as a consequence of repeated inhalatory exposure arising from the use of aqueous HF-solutions.

- concerns for skin irritation and/or corrosivity, depending on concentration, as a consequence of single exposure to the hydrogen fluoride liquid arising from the use of aqueous HF-solutions.

- concerns for respiratory tract irritation and/or corrosivity, depending on concentration, as a consequence of single exposure to gaseous hydrogen fluoride at production and use as an intermediate in the chemical industry and at the use of aqueous HF-solutions.

GLOSSARY

Standard term / Abbreviatio	**Explanation/Remarks and Alternative Abbreviation(s)**
Ann.	Annex
AF	assessment factor
BCF	bioconcentration factor
bw	body weight / *Bw, b.w.*
°C	degrees Celsius (centigrade)
CAS	Chemical Abstract System
CEC	Commission of the European Communities
CEN	European Committee for Normalisation
CEPE	European Council of the Paint, Printing Ink and Artists' Colours Industry
d	day(s)
d.wt	dry weight / dw
DG	Directorate General
DT_{50}	period required for 50 percent dissipation (define method of estimation)
DT_{50lab}	period required for 50 percent dissipation under laboratory conditions (define method of estimation)
DT_{90}	period required for 90 percent dissipation (define method of estimation)
$DT_{90field}$	period required for 90 percent dissipation under field conditions (define method of estimation)
EC	European Communities
EC	European Commission
EC_{50}	median effective concentration
EEC	European Economic Community
EINECS	European Inventory of Existing Commercial Chemical Substances
EU	European Union
EUSES	European Union System for the Evaluation of Substances
f_{oc}	Fraction of organic carbon
G	gram(s)

PNEC(s)	predicted no effect concentration(s)
$PNEC_{water}$	predicted no effect concentration in water
(Q)SAR	quantitative structure activity relationship
STP	sewage treatment plant
TGD	Technical Guidance Document[4]
UV	ultraviolet region of spectrum
UVCB	Unknown or Variable composition, Complex reaction products or Biological material
v/v	volume per volume ratio
w/w	weight per weight ratio
w	gram weight
GLP	good laboratory practice
h	hour(s)
ha	Hectares / *h*
HPLC	high pressure liquid chromatography
IARC	International Agency for Research on Cancer
C_{50}	median immobilisation concentration or median inhibitory concentration 1 / *explained by a footnote if necessary*
ISO	International Standards Organisation
IUPAC	International Union for Pure Applied Chemistry
kg	kilogram(s)
kPa	kilo Pascals
K_{oc}	organic carbon adsorption coefficient
K_{ow}	octanol-water partition coefficient
Kp	Solids water partition coefficient
l	litre(s)
log	logarithm to the basis 10
$L(E)C_{50}$	lethal concentration, median
m	Meter
µg	microgram(s)

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[4] Commission of the European Communities, 1996. Technical Guidance Documents in Support of the Commission Directive 93/67/EEC on risk assessment for new substances and the Commission Regulation (EC) No 1488/94 on risk assessment for existing substances. Commission of the European Communities, Brussels, Belgium.
ISBN 92-827-801[1234]

mg	milligram(s)
MOS	margins of safety
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
NOEL	no observed effect level
OECD	Organisation for Economic Co-operation and Development
OJ	Official Journal
pH	potential hydrogen -*logarithm* (to the base 10) of the hydrogen ion concentration $\{H^+\}$
pKa	-*logarithm* (to the base 10) of the acid dissociation constant
pKb	-*logarithm* (to the base 10) of the base dissociation constant
Pa	Pascal unit(s)
PEC	predicted environmental concentration