European Chemicals Bureau

Institute for Health and Consumer Protection

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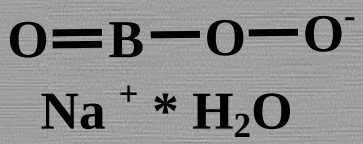
Existing Substances

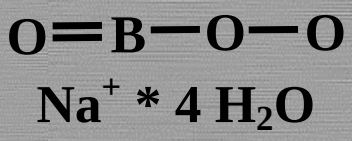
European Union Risk Assessment Report

CAS No: 11138-47-9

EINECS No: 234-390-0

perboric acid, sodium salt





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PL-3

71

3rd Priority List

Volume: 71

JRC EUROPEAN COMMISSION

EUR 22873 EN

with addendum 2007

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The Toxicology and Chemical Substances Unit (TCS), commonly known as the European Chemicals Bureau (ECB), provides scientific and technical input and know-how to the conception, development, implementation and monitoring of EU policies on dangerous chemicals including the co-ordination of EU Risk Assessments. The aim of the legislative activity of the ECB is to ensure a high level of protection for workers, consumers and the environment against dangerous chemicals and to ensure the efficient functioning of the internal market on chemicals under the current Community legislation. It plays a major role in the implementation of REACH through development of technical guidance for industry and new chemicals agency and tools for chemical dossier registration (IUCLID5). The TCS Unit ensures the development of methodologies and software tools to support a systematic and harmonised assessment of chemicals addressed in a number of European directives and regulation on chemicals. The research and support activities of the TCS are executed in close co-operation with the relevant authorities of the EU Member States, Commission services (such as DG Environment and DG Enterprise), the chemical industry, the OECD and other international organisations.

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EUR 22873 EN
ISSN 1018-5593
Luxembourg: Office for Official Publications of the European Communities, 2007

Printed in Italy

European Union Risk Assessment Report

PERBORIC ACID, SODIUM SALT

Addendum – 2007

(followed by the comprehensive risk assessment report)

CAS No: 11138-47-9

EINECS No: 234-390-0

RISK ASSESSMENT

EXPLANATORY NOTE

This report is an addendum to the European Risk Assessment Report (RAR) on perboric acid, sodium salt, that has been prepared by Austria 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 comprehensive Final Risk Assessment Report (Final RAR), which follows after this addendum.

CONTENTS

TABLES

1 INTRODUCTION

The risk assessment on the Austrian priority substance perboric acid, sodium salt was concluded for the environment part with **conclusion (iii)** - "there is a need for limiting the risks" - drawn for the following scenarios:

- for the aquatic compartment: for two production sites (C, F) producing perboric acid, sodium salt as well as hydrogen peroxide;
- for the aquatic compartment: for two formulation sites;
- for microorganisms in STP: for two production sites (B, F)

During the preparatory work for the development of a risk-reduction-strategy Industry submitted new information on the production and formulation sites at risk that leads to a change of the conclusions:

- risk for the aquatic compartment:

1. production sites C: Industry informed that the production at this site was ceased in June 2003 (letter dated 23.02.04). Therefore, a RRS is not considered necessary any more.
2. production sites F: The production of sodium perborate at this site has already stopped (mail dated 10.03.04). Therefore, there are no risks related with production site F.
3. risk for the aquatic compartment for two formulation sites: AISE informed (letter from 17.05.04) that one site at risk does not produce detergents anymore. The other site will also stop its detergents production by mid-2004 and in the meantime no untreated water will be released in the river.

- risk for microorganisms in STP:

4. production sites B: For production site B a risk was identified for microorganisms in the STP. However, according to information from Industry the production process at this site is an inorganic process and for this reason there is no biological waste water treatment plant (mail from 10.03.04). Therefore, there are no risks for microorganisms at production site B.
3. production sites F: The production of sodium perborate at this site has already stopped (mail dated 10.03.04). Therefore, there are no risks related with production site F.
   Additionally, the rapporteur has been informed on two additional minor uses. Detailed information on these minor uses is being collected and will be considered in the HH part of the RAR.

2 AMENDMENT OF THE ENVIRONMENTAL RISK ASSESSMENT REPORT TEXT RESULTS

0 OVERALL RESULTS OF THE RISK ASSESSMENT

The risk assessment on hand assesses the risk arising from sodium perborate and its degradation product hydrogen peroxide. The risk of the degradation product boric acid has not been assessed so far, but will be done when the EU risk assessment of boric acid will be available.

Overall results of the risk assessment:

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

This conclusion applies for the aquatic compartment (water) for all production and formulation sites, for processing and for the consumer and institutional use of detergents and bleaching agents.

This conclusion applies for microorganisms in WWTP to all production and formulation sites.

This conclusion is reached for the exposure of sediments, the atmosphere, the terrestrial compartment and non-compartment specific effects relevant to the food chain (secondary poisoning).

2 GENERAL INFORMATION ON EXPOSURE

2.1 PRODUCTION

In the EU member states 12 production sites of 7 producers were identified. At four of these sites the production was ceased recently. The remaining sites are located in Austria, Belgium, Germany, Italy, Portugal and Spain, see **Table 2.1**.

Table 2.1 Production sites of sodium perborate monohydrate/ tetrahydrate

Company	Location
Ausimont	Bussi, Italy[c]
Caffaro	Brescia, Italy[a]
Degussa	Antwerpen, Belgium
	Rheinfelden, Germany
Aktivsauerstoff GmbH	Treibach, Austria
Elf Atochem	Pierre Bénite, France[b]
FMC Foret	La Zaida, Spain

Table 2.1 continued overleaf

Table 2.1 continued Production sites of sodium perborate monohydrate/ tetrahydrate

Company	Location
Solvay	Warrington, UK[c]
	Bad Hönningen, Germany
	Rosignano, Italy
	Povoa, Portugal
	Torrelavega, Spain

a) Production ceased in 1999 (CEFIC, 2000);
b) Production ceased in summer 1999 (Elf Atochem, 1999);
c) Production ceased in 2003

2.2 USE PATTERN

Two additional minor uses have been identified for sodium perborate: It is used in detergents used for hospital cleaning (IC 5 and 6, UC 8 and 9) and it is used as preservative in artificial tears (IC 5, UC 39). Detailed information on these minor uses are being collected and will be used for calculation of the exposure to humans (further details see in the revised HH RAR of sodium perborate).

3 EVIRONMENT

3.1 ENVIRONMENTAL EXPOSURE

3.1.1.1 Releases into the environment

Table 3.1 Release of sodium perborate into the environment during production (reference year: 1997; according to CEFIC, 1999a)

Production site	Production capacity (t/y)	Waste water treatment plant	Type of receiving water	Total release into water (t/y)[a]	Total release into air (t/y)	Total release into soil (t/y)	Total release with waste (t/y)
A	120,000	partly (industrial, precipitation)	river	1.9 (boron)	0.3 (total dust) (PBS4[b] < 20 mg/m³ in exhaust stream)	no emissions	no emissions
B	55,700	yes (industrial, inorganic)	river	165 (boron)	6.6 (total dust)	no data	24 (boron; B content of waste: 0.4 %)
C[f]	72,000	No	river	58 (boron)	1.07 (boron)	no data	no data
D	10,000	No	estuary	32.9 (boron)	3 (total dust)	no data	33 (boron; B content of waste: 0.79 %)
F[c]	84,000	No	river/estuary	1992: 6.7-40.5 (boron)	3.1 (total dust)	no data	52 (boron; B content of waste: 0.66 %)
H	100,000	yes (industrial)	river	17.3 (boron)	9 (total dust)	no data	23.9 (not specified)
I	100,000	waste water is collected in an effluent pond and recycled into production process[e]	none	no emissions	10.4 (total dust)	no data	no boron containing waste
J[d]	450,00	no (physico-chemical treatment)	river	no emissions	< 0.2 (borate)	no data	no data
K	32,000	no	estuary	35 (boron)	0.41 (PBS4[b])	no data	4.1 (boron; B content of waste: 0.18 %)

a) These releases may also contain borates from the starting material of the production process (see Section 2.1), a differentiation is not possible by analytical means (see Section 1.3);
b) PBS4 = sodium perborate, tetrahydrate;
c) Production ceasedbefore January 2003;
d) Due to a change of the production process (different starting material) in July 2001, sodium perborate is no longer emitted;
e) (CEFIC, 2001);
f) Production ceased in June 2003

3.1.1.7 Estimation of PEClocal $_{water}$ for aquatic systems

Production

It can be assumed that sodium perborate is completely degraded at plants with waste water treatment (see also Section 3.1.1.2.2). Also the emerging hydrogen peroxide will be degraded rapidly in the WWTP (see EU Risk Assessment Report on Hydrogen Peroxide) so that only boric acid is to be expected in the effluent. **Table 3.5** shows the boron content of the effluents and the local boron concentration in the receiving surface water. Production site B is equipped with a waste water treatment plant which is run on an inorganic process. As far as production sites have no waste water treatment plant (sites C, D, F, G, J and K; see **Table 3.1**) the degradation behaviour of sodium perborate has to be considered in more detail: As sodium perborate in aqueous solution is in equilibrium with hydrogen peroxide (see Section 1.3) the hydrogen peroxide concentrations in the effluent can be used as a marker indicating the presence of active oxygen in the effluent which may be due to sodium perborate. For these production sites therefore an evaluation of the hydrogen peroxide content of the effluent is necessary. As they are also production sites for hydrogen peroxide they were already evaluated in the EU Risk Assessment on Hydrogen Peroxide. The Clocal$_{water}$ data on hydrogen peroxide are given in **Table 3.5** additionally for completeness. It has to be borne in mind that they relate to production of hydrogen peroxide and processing of the substance to sodium perborate and therefore represent a worst case situation. Some more recent data on the hydrogen peroxide content of the effluents which were provided by Industry do not change the evaluation and were therefore not considered further.

Table 3.5 Concentrations of boron/hydrogen peroxide in the effluents from the production of sodium perborate (with and without STP) and the respective Clocal$_{water}$ data (according to CEFIC, 1999a)

Production site	Effluent (m^3/d)	Flow rate receiving water (m^3/s)	Dilution	Number of production days /year	Clocal$_{,eff}$ (PBS) [b] [boron] (mg/l)	Clocal$_{water}$ (boron)(µg/l)
A*	47,024	low 518 (mean 1,030)	953 (1,890)	345	1.5 [0.11]	0.11
B**	7,920	low 1,000 (mean 2,000)	10,900 (21,800)	365	767 [57]	5.2
C*[e]	150,000	low 20 mean 25	13 (15)	359	13.5 [1]	76 H_2O_2: < 500
D*	45,600	no data, estuary	default: 10	330	27 [2]	183 H_2O_2: 30
F* [c]	9,504	low 20 (mean 30)	183	310	25.7-1526 [1.9-113]	9-524 H_2O_2: < 100
H*	4,770	low 40.3 (mean 121)	732	340	134 [9.9]	13

Table 3. 5 continued overleaf

Table 3.5 continued Concentrations of boron/hydrogen peroxide in the effluents from the production of sodium perborate (with and without STP) and the respective $Clocal_{water}$ data (according to CEFIC, 1999a)

Production site	Effluent (m^3/d)	Flow rate receiving water (m^3/s)	Dilution	Number of production days /year	$Clocal_{,eff}$ (PBS) [b] [boron] (mg/l)	$Clocal_{water}$ (boron)(µg/l)
I*	no emissions					
J [d]	no emissions					
K*	84,000	no data, estuary	default: 10	330	17.6 [1.3]	117 H_2O_2: 1

a) Considering 250 production days/year;
b) Mean molecular weight (PBS) = 145.8 g/mol corresponding to a ratio of tetrahydrate : monohydrate of 85:15 (see also Section 2.1);
c) Production ceased before January 2003;
d) Due to a change of the production process (different starting material) in July 2001, sodium perborate is no longer emitted;
e) Production ceased in June 2003
* These production sites were already evaluated in the EU Risk Assessment Report on Hydrogen Peroxide;
** Production site already evaluated in the EU Risk Assessment Report on Hydrogen Peroxide, production of Hydrogen Peroxide stopped in 1995; this site is equipped with a waste water treatment plant running on an inorganic process.

Formulation

Table 3.6 Boron concentrations in the effluents of European formulation sites and calculated $Clocal_{water}$ data (AISE, 2000)

Formulation site[a]	$Clocal_{effluent}$ (PBS) [boron] (mg/l)*	$Clocal_{water}$ (boron) (µg/l)
AA	0 [0]	0
BB	0.675 [0.05]	5
CC	0.945 [0.07]	7
DD	0.945 [0.07]	7
EE	1.89 [0.14]	14
FF	2.7 [0.2]	20
GG	2.7 [0.2]	20
HH	3.4 [0.25]	25
II	5.1 [0.38]	38
JJ	7.3 [0.54]	54
KK	10.1 [0.75]	75

Table 3.6 continued overleaf

Table 3.6 continued Boron concentrations in the effluents of European formulation sites and calculated $Clocal_{water}$ data (AISE, 2000)

Formulation site[a]	$Clocal_{effluent}$ (PBS) [boron] (mg/l)*	$Clocal_{water}$ (boron) (µg/l)
LL	10.5 [0.78]	78
MM	11.3 [0.84]	84
NN	14.9 [1.1]	110
OO	20.3 [1.5]	150
PP	43.2 [3.2]	320

* Mean molecular weight (PBS) = 145.8 g/mol corresponding to a ratio of tetrahydrate: monohydrate of 85:15 (see also Section 2.1)

a) According to AISE, two formulation sites which gave rise to concern, stopped formulation of detergents.

3.1.2.6 Summary of $PEClocal_{water}$ derived for the aquatic environment

Table 3.7 Overview of $PEClocal_{water}$ (production, formulation) for the aquatic environment

Production site	PEC $local_{water}$(boron) (mg/l)[a]	Formulation site[f]	$PEClocal_{, water}$ (boron) (mg/l)[a, b]
A	0.18	AA	0.18
B	0.19	BB	0.19
C [e]	0.26 H_2O_2: < 503 µg/l	CC	0.19
D	0.36 H_2O_2: 33 µg/l	DD	0.19
E	0.19	EE	0.19
F [c]	0.19-0.7 H_2O_2: < 103 µg/l	FF	0.2
		GG	0.2
H	0.19	HH	0.21
I	0.18	II	0.22
J [d]	0.18	JJ	0.23
K	0.3 H_2O_2: 4 µg/l	KK	0.26

Table 3.7 continued overleaf

Table 3.7 continued Overview of $PEClocal_{water}$ (production, formulation) for the aquatic environment

Production site	PEC local $_{water}$(boron) (mg/l)[a]	Formulation site[f]	PEClocal$_{, water}$ (boron) (mg/l)[a, b]
L		LL	0.26
		MM	0.26
		NN	0.29
		OO	0.33
		PP	0.5

a) PEClocal, water = C local, water + PEC regional, water;
b) 2 formulation sites without WWTP: $PEClocal_{water}$ for H_2O_2: : < 31.5 µg/l;
c) Production ceased before January 2003;
d) Due to a change of the production process (different starting material) in July 2001, sodium perborate is no longer emitted;
e) Production ceased in June 2003;
f) According to AISE two formulation sites which gave rise to concern stopped the formulation of detergents

3.1.3.2 Estimation of PEClocal for the atmosphere

Production

Emissions from WWTPs into the atmosphere have not to be considered as the substance is not volatile from aqueous solutions due to its chemical structure, i.e. $Estp_{air} = 0$. It has to be borne in mind however, that basis data referring to boron or borate (sites F and J) may also be influenced by some amount of the starting material borax. However, production of sodium perborate stopped at site F. Furthermore, site J changed its production process and thus no longer emits sodium perborate. In a worst case approximation it is assumed that these exhaust stream concentrations are solely caused by sodium perborate tetrahydrate.

Table 3.8 $Clocal_{air}$ from the production of sodium perborate tetrahydrate

Production site	$Clocal_{air,ann}$ (mg/m^3)	Number of production days per year	$PEClocal_{air}$ PBS4 (mg/m^3)
C[a]	0.8 (boron)	359	11.4
J[b]	<0.2 (borate $H_2BO_3^-$)	200-250	< 0.5
K	0.3 (PBS4)	330	0.3

a) Production ceased in June 2003;
b) Due to a change of the production process (different starting material) in July 2001, sodium perborate is no longer emitted

3.3 RISK CHARACTERISATION

3.3.1 Aquatic compartment

PEC/PNEC$_{water}$

Production

Hydrogen peroxide:
For production sites with WWTP it is assumed that hydrogen peroxide is completely degraded in the WWTP or that there are no emissions. 6 out of 9 production sites were already assessed in the EU Risk Assessment Report on Hydrogen Peroxide as these are also production sites for hydrogen peroxide. There is one production site with sole production of sodium perborate. This site has no WWTP, but it has changed the production process in July 2001 so that sodium perborate is no longer emitted. Therefore it is assumed that no hydrogen peroxide is emitted either and **conclusion (ii)** can be derived for this site. Production sites C and F (which did not have WWTP and which had been assessed in the EU RAR on hydrogen peroxide) ceased production of sodium perborate in 2003. Therefore, **conclusion (iii)** is no longer relevant and is changed to **conclusion (ii)**.
For PEClocal data see Section 3.1.1.11.

Formulation

Hydrogen peroxide:
For formulation sites with WWTP (individual abbreviation not known) it is assumed that hydrogen peroxide is completely degraded in the WWP.
These have therefore not to be considered further in the risk characterisation: **Conclusion (ii)**. For the remaining two sites a PEClocalwater of 31.5 µg/l was estimated (see Section 3.1.1.7). From this a PEC/PNEC ratio of 3.15 is calculated which leads to **conclusion (iii)**.
However, according to AISE these two sites which gave rise to concern stopped formulating detergents. **Conclusion (iii)** is no longer relevant and is changed to **conclusion (ii)**.
Boron.
For PEClocal data see Section 3.1.1.11.

PEC/PNEC$_{stp}$

Table 3.10 PEC/PNEC$_{stp}$ for production and formulation

Production site	PEC/PNEC$_{stp}$
A	0.003
B [b]	1.5
C [c]	0.027
D	0.054
F [a]	0.051-3.1
H	0.27
I	0
K	0.04

Formulation site	PEC/PNEC$_{stp}$
AA	0
BB	0.001
CC	0.002
DD	0.002
EE	0.004
FF	0.005
GG	0.005
II	0.01
JJ	0.01
KK	0.02
LL	0.02
MM	0.02
NN	0.03
OO	0.04
PP	0.09

a) Production ceased before January 2003;
b) Due to the application of an inorganic process in the waste water treatment plant, there is no concern for microorganisms;
c) Production ceased in June 2003

For two production sites (B, F) the PEC/PNECstp ratio exceeds 1 which would lead to **conclusion (iii)**. However, the waste water treatment plant of site B runs on an inorganic process, so there is no concern for microorganisms. Production at site F ceased before January 2003. Therefore, for all production sites and all formulation sites **conclusion (ii)** can be derived.

Information on the PEC/PNECstp for the degradation product hydrogen peroxide can be found in the EU Risk Assessment Report on Hydrogen Peroxide.

5 RESULTS

5.1 ENVIRONMENT

5.1.1.1 Aquatic compartment (incl. sediment)

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

This conclusion applies to all production and formulation sites, for processing as well as the consumer and institutional use of detergents and bleaching agents for the aquatic compartment (water). Furthermore, this conclusion applies to all production and formulation sites for microorganisms in STP

European Union Risk Assessment Report

PERBORIC ACID, SODIUM SALT

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EINECS No: 234-390-0

RISK ASSESSMENT

Cataloguing data can be found at the end of this publication

Luxembourg: Office for Official Publications of the European Communities, 2007

Printed in Italy

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CAS No: 11138-47-9

EINECS No: 234-390-0

RISK ASSESSMENT

2007

Austria

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Date of Last Literature Search :	**2006**
Review of report by MS Technical Experts finalised:	**2005**
Final report:	**2007**

Foreword

We are pleased to present this Risk Assessment Report which is the result of in-depth work carried out by experts in one Member State, working in co-operation with their counterparts in the other Member States, the Commission Services, Industry and public interest groups.
The Risk Assessment was carried out in accordance with Council Regulation (EEC) 793/93[1] on the evaluation and control of the risks of "existing" substances. "Existing" substances are chemical substances in use within the European Community before September 1981 and listed in the European Inventory of Existing Commercial Chemical Substances. Regulation 793/93 provides a systematic framework for the evaluation of the risks to human health and the environment of these substances if they are produced or imported into the Community in volumes above 10 tonnes per year.
There are four overall stages in the Regulation for reducing the risks: data collection, priority setting, risk assessment and risk reduction. Data provided by Industry are used by Member States and the Commission services to determine the priority of the substances which need to be assessed. For each substance on a priority list, a Member State volunteers to act as "Rapporteur", undertaking the in-depth Risk Assessment and recommending a strategy to limit the risks of exposure to the substance, if necessary.
The methods for carrying out an in-depth Risk Assessment at Community level are laid down in Commission Regulation (EC) 1488/94[2], which is supported by a technical guidance document[3]. Normally, the "Rapporteur" and individual companies producing, importing and/or using the chemicals work closely together to develop a draft Risk Assessment Report, which is then presented at a meeting of Member State technical experts for endorsement. The Risk Assessment Report is then peer-reviewed by the Scientific Committee on Health and Environmental Risks (SCHER) which gives its opinion to the European Commission on the quality of the risk assessment.
If a Risk Assessment Report concludes that measures to reduce the risks of exposure to the substances are needed, beyond any measures which may already be in place, the next step in the process is for the "Rapporteur" to develop a proposal for a strategy to limit those risks.
The Risk Assessment Report is also presented to the Organisation for Economic Co-operation and Development as a contribution to the Chapter 19, Agenda 21 goals for evaluating chemicals, agreed at the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992 and confirmed in the Johannesburg Declaration on Sustainable Development at the World Summit on Sustainable Development, held in Johannesburg, South Africa in 2002.
This Risk Assessment improves our knowledge about the risks to human health and the environment from exposure to chemicals. We hope you will agree that the results of this in-depth study and intensive co-operation will make a worthwhile contribution to the Community objective of reducing the overall risks from exposure to chemicals.

Roland Schenkel
Director General
DG Joint Research Centre

Mogens Peter Carl
Director General
DG Environment

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[1] O.J. No L 084, 05/04/199 p.0001 – 0075

[2] O.J. No L 161, 29/06/1994 p. 0003 – 0011

[3] Technical Guidance Document, Part I – V, ISBN 92-827-801 [1234]

0 OVERALL RESULTS OF THE RISK ASSESSMENT[4]

CAS Number: 11138-47-9 (number for the anhydrous form which covers mono- and tetrahydrate)
EINECS Number: 234-390-0 (number for the anhydrous form which covers mono- and tetrahydrate)
EINECS name: Perboric acid, sodium salt
CAS name: Perboric acid, sodium salt
IUPAC name: Sodium perborate
Common names: Sodium perborate monohydrate and sodium perborate tetrahydrate

The risk assessment on hand assesses the risk arising from sodium perborate and its degradation product hydrogen peroxide. The risk of the degradation product boric acid has not been assessed so far, but will be done when the EU risk assessment of boric acid and sodium tetraborates will be available.

Environment

Aquatic compartment (incl. sediment)

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

This conclusion applies to two production sites and two formulation sites (water) as well as two production sites (microorganisms in STP)[5].

Terrestrial compartment

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

A risk characterisation for this compartment is not deemed necessary.

Atmosphere

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

This conclusion applies to all life cycle steps.

Secondary poisoning

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

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

[5] Please, note that new information was received after the finalisation of the environmental report, and that this information affects the conclusions presented above. The new information is presented, together with the revised environmental conclusions, in an Addendum attached to this report. Thus, the correct, revised environmental conclusions can be found in the Addendum as well as in the Summary Report, but chapters 0-5 have not been updated.

A risk characterisation for non-compartment specific effects relevant for the food chain is not deemed necessary.

Human Health

Workers

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

This conclusion applies to highly exposed workers in the production of sodium perborate via inhalation of the dust. There is concern for effects on the upper airways and for developmental effects. Therefore risk reduction measures for exposure by inhalation have to be applied.

Consumers

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

This conclusion applies to all scenarios and endpoints.

Humans exposed indirectly via the environment

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

Indirect exposure to sodium perborate is not to be expected due to the degradation of the compound.

Indirect exposure to the degradation products: No exposure to H_2O_2 is expected due to the hydrolysis. The risk for humans exposed to boric acid indirectly via the environment will be evaluated in the foreseen EU risk assessment on boric acid and sodium tetraborates (4^{th} Priority List).

Combined exposure

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

For sodium perborate, the combined exposure is not relevant. The combined exposure to boric acid from different sources will be addressed in the foreseen EU risk assessment on boric acid and sodium tetraborates (4^{th} Priority List).

Human Health (physico-chemical properties)

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

CONTENTS

EUSES Calculations can be viewed as part of the report at the website of the European Chemicals Bureau: http://ecb.jrc.it

TABLES

1 GENERAL SUBSTANCE INFORMATION

1.1 IDENTIFICATION OF THE SUBSTANCE

Table 1.1 Substance identification

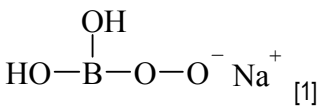
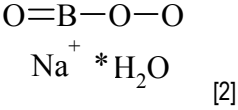
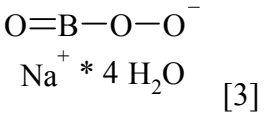
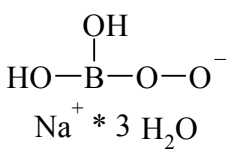
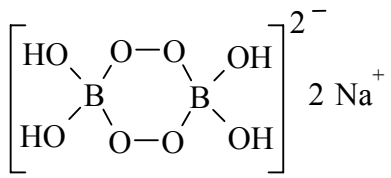
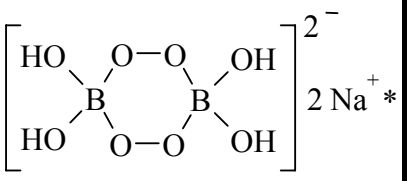
CAS No.	11138-47-9[a)]	
EINECS No.	234-390-0 [a)]	
EC name	Perboric acid, sodium salt	
CAS name	Perboric acid, sodium salt	
IUPAC name	Sodium perborate	
Sub-groups sodium perborates		
Synonyms:	sodium perborate monohydrate [b)] sodium peroxoborate monohydrate, perboric acid, sodium salt PBS1; PBSM "anhydrous sodium perborate" [c)]	sodium perborate tetrahydrate [b)] sodium peroxoborate tetrahydrate PBS4; PBST "sodium perborate hexahydrate" [c)]
EINECS no:	239-172-9 [1]	not available
EC name:	Sodium perborate [1]	
CAS no:	15120-21-5 [1] 10332-33-9 [2]	10486-00-7 [3] 13517-20-9 [4]
CAS name:	Perboric acid (H3BO2(O2)), monosodium salt [1] Perboric acid (HBO(O2)), sodium salt, monohydrate [2]	Perboric acid (HBO(O2)), sodium salt, tetrahydrate [3] Perboric acid (H3BO2(O2)), monosodium salt, trihydrate [4]
Molecular formula according to CAS [d]:	$BH_3O_4.Na$ [1] $BHO_3.H_2O.Na$ [2]	$BHO_3.4H_2O.Na$ [3] $BH_3O_4.3H_2O.Na$ [4]
Structural formula of the salts:	 [1]  [2]	 [3]  [4]

Table 1.1 continued overleaf

Table 1.1 continued Substance identification

Sub-groups sodium perborates		
Molecular weights g/mol:	99.8 [1/2] e)	153.9 [3,4] e)
Revised structural formulas:	 anhydrous sodium perborate c)	 sodium perborate hexahydrate c)
Molecular weights (revised structural formulas) g/mol:	199,6 e)	307,7 e)

a) Collective CAS/EINECS Number for the mono- and the tetrahydrate of sodium perborate;
b) Common, but "old" nomenclature of the sodium perborates;
c) Correct term and formula according to Xray diffraction studies (Koberstein et al., 1970);
d) According to the "multicomponent molecular formula" as used in the CAS registry system
e) Since for exposure calculations and read-across between the monohydrate and the tetrahydrate boron equivalents were used, the differences in the molecular weight can be neglected because the relative boron content of the different formulas the same.

Anhydrous sodium perborate (CAS No. 90568-23-3) and sodium perborate hexahydrate (CAS No. 125022-34-6) (see revised structural formulas above), are in accordance with today's knowledge on the dimeric nature of the peroxoboron anions, i.e. dimers of CAS No.s 10332-33-9 and 10486-00-7, respectively, which are the commonly used "old" formulas. Since it is still customary to use these "old" formulas and nomenclature of the perborates, which disregards the dimeric structure of the molecules, the terms "sodium perborate monohydrate" and "sodium perborate tetrahydrate" are used throughout this assessment report.

Two additional sodium perborates are described in the literature: dehydrated sodium perborate (dexol, oxoborate; CAS No. 7632-04-4) and sodium perborate trihydrate ("old" nomenclature: sodium peroxoborate trihydrate, correct term: "sodium perborate tetrahydrate"; CAS No.s 28962-65-4 and 28108-09-0). The trihydrate is not of commercial importance (Kleinschmidt et al., 1991). Dehydrated sodium perborate is a not well defined compound deliberating the releasable oxygen spontaneously as elemental oxygen when coming into contact with water. It is supposed to consist of sodium borate and a boron oxygen radical (Kleinschmidt et al., 1991). The spontaneous decomposition of the substance is the reason for its use in denture cleanser tablets (see also Section 2; Degussa-Hüls, 1999a).

1.2 PURITY/IMPURITIES, ADDITIVES

In the scientific literature the addition of silicates (sodium and magnesium) or other magnesium salts in a concentration range of 0.1 to 10% is described to avoid the decomposition of the technical product (Jakobi et al., 1987; Büchel et al., 1999).

According to data of the European producers the purity of sodium perborates can be summarised as given in **Table 1.2** (Degussa, 1994a; Degussa, 1997a; Solvay, 1997; Elf Atochem, 1997; FMC foret, 1997).

Table 1.2 Overview of purity, impurities and additives of sodium perborate monohydrate/tetrahydrate

Parameter	CAS-No.	Name	Value	Comment
Purity	10332-33-9	Sodium perborate monohydrate	≥ 94%	-
	10486-00-7	Sodium perborate tetrahydrate	≥ 96%	-
Impurities	1303-96-4 (x 10 H_2O) 1330-43-4 (without water)	Borax	< 2%	-
	7732-18-5	Water	≤ 1%	-
	-	several metals	< 200 ppm total metal content	-
Additives	7487-88-9	$MgSO_4$	≤ 1.2%	Stabiliser The concentrations in the monohydrate are somewhat higher than in the tetrahydrate; one product contains additionally an unknown stabiliser

The generation of active oxygen in aqueous solutions is the basis for the use of sodium perborate as bleaching component in detergent products and bleaching agents (see Sections 1.3 and 2.2). Therefore the purity of the technical products is furthermore characterised by their active oxygen content. Pure sodium perborate monohydrate contains a maximum of 16.0% active oxygen, pure tetrahydrate maximum 10.38% (calculated from the empirical formula assuming that the peroxo bridges in the molecules are completely degraded with oxygen emerging (see Sections 1.1 and 1.3; Kleinschmidt et al., 1991). From the safety data sheets of the European producers the following data are available for the commercial products:

Monohydrate: Approximately 15% w/w (Aktivsauerstoff, 1995; Degussa, 1997a; Caffaro, 1997; FMC foret, 1995; Ausimont, 1994)

Tetrahydrate: Approximately 10% w/w (Aktivsauerstoff, 1995; Degussa, 1994a; Caffaro, 1997; FMC foret, 1995; Ausimont, 1994).

1.3 PHYSICO-CHEMICAL PROPERTIES

The physico-chemical properties were compiled from the available safety data sheets (Aktivsauerstoff, 1995; Degussa, 1994a; 1997a; Caffaro, 1997; FMC foret, 1995; Ausimont, 1994) and from relevant reviews and handbooks (Kleinschmidt et al., 1991; ECETOC, 1997; WHO, 1998; Auer, 1989). The surface tension was experimentally determined by Degussa AG (Degussa, 1997b). **Table 1.3** gives an overview.

Table 1.3 Summary of the physico-chemical properties

Parameter	Sodium perborate monohydrate		Sodium perborate tetrahydrate	
	Value	Comment	Value	Comment
Physical state	Solid			
Melting point (°C):	-	decomposition (only few data available: > 50 - > 180°C)	approximately 60-65.5	melting in its own crystallisation water; beginning decomposition
Boiling point (°C):	-	decomposition	-	decomposition
Density (20°C):	0.4-0.65	relative density	0.65-0.9	relative density
Vapour pressure (hPa, 20°C):	-	not applicable due to ionic hydrated structure; deliberation of crystallisation water at reduced pressure	-	not applicable due to ionic hydrated structure; deliberation of crystallisation water at reduced pressure
Surface tension (mN/m, 20°C):	-	it can be assumed that the surface tension of both hydrates is equal	64.6	aqueous solution of 1 g perborate/l
Water solubility (g/l, 20°C):	approximately 15-16	-	approximately 23	-
Dissociation constant pKa:	-	not applicable due to decomposition	-	not applicable due to decomposition
Partition coefficient log K_{OW}:	-	not applicable (analytical difficulties); see also derogation statement and Section 1.3	-	not applicable (analytical difficulties); see also derogation statement and Section 1.3
Particle size of the technical product (mm):	> 0.1-0.16 (98%)	details on particle size distribution especially for the fraction below 0.1 mm not available	> 0.1 (95%)	details on particle size distribution especially for the fraction below 0.1 mm not available
Conversion factor:	dose (monohydrate) x 0.108 = equivalent dose (boron) dose (monohydrate) x 0.341 = equivalent dose (hydrogen peroxide)	-	dose (tetrahydrate) x 0.07 = equivalent dose (boron) dose (tetrahydrate) x 0.221 = equivalent dose (hydrogen peroxide)	-

The sodium perborates are white, odorless crystalline powders (20°C, 1013 hPa). The molecular crystalline structure consists of dimeric $[(HO)_2(BOO)]^-$ units which form symmetric cyclic hexagonal anions with two peroxo bridges each. In its crystalline form the substances are stable under dry conditions (Kleinschmidt et al., 1991; ECETOC, 1997; WHO, 1998). Sodium perborate tetrahydrate dehydrates at elevated temperatures (starting at temperatures of about 50°C) via the trihydrate towards the monohydrate which then decomposes to the metaborate (Koberstein et al., 1970; Rietz and Grande, 1970).

1.3.1 Properties of aqueous solutions

As the behaviour of sodium perborate especially in aqueous solutions is a key issue for the evaluation of the environmental releases from the different processes (see Section 3) the available data are discussed in the following in detail.

Aqueous solutions of sodium perborate react like alkaline solutions of hydrogen peroxide. As far as the technical relevant concentrations are concerned the pH of 10.1 to 10.4 is practically not dependent on the concentration of the substance in water (Kleinschmidt et al., 1991). However, at low concentrations in the mg/l range pH values of 8 to 9 are to be expected (see e.g. Solvay Duphar, 1993b). Considering the use of the perborate in detergent products and bleaching agents furthermore the rate of dissolution in water is of technical relevance. The dissolution of the monohydrate in water proceeds much more rapidly than that of the tetrahydrate (Kleinschmidt et al., 1991).

In aqueous solutions at room temperature an equilibrium between sodium perborate and hydrogen peroxide/sodium metaborate is instantly established (see reaction equation I).:

$$\underset{\text{Sodium perborate tetrahydrate}}{[NaBO_2(OH)_2 \cdot 3\ H_2O]_2} \xrightleftharpoons{H_2O} \underset{\substack{\text{Sodium metaborate} \quad \text{Hydrogen peroxide} \quad \text{Water}}}{2NaBO_2 + 2H_2O_2 + 6\ H_2O} \qquad \text{I}$$

From cryoscopic measurements Koberstein et al. (1970) concluded that at low concentrations (about ≤ 2 g/l, i.e. also in the environmentally relevant concentration range) the equilibrium is largely on the side of the hydrolysis products whereas at higher concentrations (about ≥ 12 g/l) the undissociated molecule is present in aqueous solutions. Further measurements in the "environmental" concentration range of some mg/l are not available.

Via degradation to (active) oxygen and water (II) the hydrogen peroxide can be removed from the equilibrium leading to an irreversible shift of the equilibrium given in equation I to the degradation products sodium metaborate and water:

$$2\ H_2O_2 \longrightarrow 2\ H_2O + O_2 \qquad \text{II}$$

Reaction II is the basis of the bleaching effect of the sodium perborate in the washing process (see Section 2). The active oxygen will react with the stains on the laundry. Up to temperatures of about 60°C reaction II is proceeding slowly (Fine et al, 1974; Mecheels, 1982; Jakobi et al., 1987). With further increasing temperature and under the influence of heavy metal ions acting as catalysts (e.g. Fe, Cu, Mn) it is significantly accelerated (Jakobi et al., 1987; Kleinschmidt et al., 1991; EU Risk Assessment Report on Hydrogen Peroxide).

The active oxygen concentration in the aqueous solutions of sodium perborate serves as a measure of the degree of their decomposition. It can be determined via titration of the hydrogen peroxide or potentiometrically (Degussa, 1993; Degussa, 1994a). Unfortunately, these methods are shifting the equilibrium reaction towards the end products and therefore may be afflicted with considerable uncertainities. From the measurement of the boron content of the solutions the degradation rate of the perborates cannot be determined either as it cannot be decided whether sodium perborate or sodium metaborate/boric acid, respectively, are the underlying sources. The analytical determination of the perborate anion itself is not possible.

The degradation product sodium metaborate is the salt of a strong base (sodium hydroxide) and a weak acid (boric acid). Therefore the substance is expected to be present in aqueous solutions at environmental temperature and pH mainly as the weakly dissociated boric acid (pK_a value at room temperature 9.25; Hollemann, 1995):

$NaBO_2 + 2H_2O \longrightarrow Na^+ + OH^- + H_3BO_3$ (Boric acid) III

$H_3BO_3 + H_2O \rightleftarrows H^+ + B(OH_4)^-$ IV

Further considerations on degradation products of sodium perborate e.g. in the hazard part of this risk assessment will therefore focus on boric acid as the predominant species.

1.4 CLASSIFICATION

1.4.1 Current Classificatiom

The provisional classification by manufacturer (see IUCLID data sheet of 27th of May, 1999) is:

Classification	Sodium perborate monohydrate	Sodium perborate tetrahydrate
Class of danger	O, Xn, Xi	Xi
R phrases	R8, R22, R36/38	R36

1.4.2 Proposed classification

Environment: The EU Classification and Labelling group agreed not to classify sodium perborate as dangerous for the environment (C&L meeting in June 2003).

Sodium perborate is instable in water. The hydrolysis resp. degradation products hydrogen peroxide and boric acid (i.e. boron) have been taken into account for classification.

The EU Classification and Labelling group has decided against classifying hydrogen peroxide and boric acid as dangerous for the environment.

Human health: The EU Working Group on Classification and Labelling of Dangerous Substances has agreed on split-entries dependent on particle size as follows (C&L meeting in March 2006):

Sodium perborate monohydrate:

- containing < 0.1% (w/w) of particles with an aerodynamic diameter of below 50 µm: O; R8 - Repr. Cat.2; R61 - Repr. Cat.3; R62 - Xn; R22 - Xi; R37-41 (with Specific Concentration Limits for eye irritation and reproductive toxicity)
- containing ≥ 0.1% (w/w) of particles with an aerodynamic diameter of below 50 µm**:** O; R8 - Repr.Cat.2; R61 - Repr.Cat.3; R62 - T; R23 - Xn; R22 - Xi; R37-41 (with Specific Concentration Limits for eye irritation and reproductive toxicity)

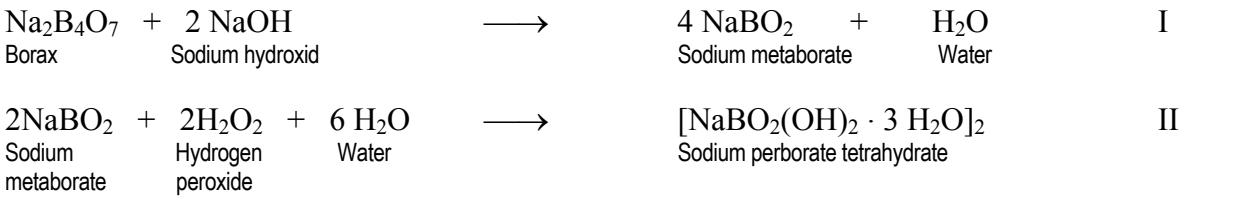
Sodium perborate tetrahydrate:

- containing < 0.1% (w/w) of particles with an aerodynamic diameter of below 50 µm**:** Repr.Cat.2; R61 - Repr.Cat.3; R62 - Xi; R37-41 (with Specific Concentration Limits for eye irritation and reproductive toxicity)
- containing ≥ 0.1% (w/w) of particles with an aerodynamic diameter of below 50 µm: Repr.Cat.2; R61 - Repr.Cat.3; R62 - Xn; R20 - Xi; R37-41 (with Specific Concentration Limits for eye irritation and reproductive toxicity)

2 GENERAL INFORMATION ON EXPOSURE

2.1 PRODUCTION

Sodium perborate tetrahydrate is produced in a two-stage process with borax, sodium hydroxide and hydrogen peroxide as starting materials. The process is based on the following reaction scheme:



Reaction I is carried out at temperatures between 60 and 95°C. Instead of borax also impure minerals such as kernite and tincal can be used. However, it is then necessary to filter the salt solution. Reaction II is carried out at a temperature of about 25°C. At the end of the process the solution is cooled down to 15°C and the precipitated sodium perborate tetrahydrate is separated by filtration. The remaining solution can be fed back to the process to achieve a continous production. However, also a batch technique is possible. Both methods are aimed to give an as attrition-resistant product as possible. Sodium perborate monohydrate is gained from the tetrahydrate by dehydration in a fluidised-bed dryer with warm air or in a vacuum (Kleinschmidt et al., 1991; Büchel et al., 1999).

In the EU member states 12 production sites of 7 producers were identified. At three of these sites the production was ceased recently. The remaining sites are located in Austria, Belgium, Germany, Italy, Portugal, Spain and the United Kingdom, see **Table 2.1**.

The recent data on production and consumption quantities for mono- and tetrahydrate are summarised in **Table 2.2**. Sodium perborate tetrahydrate is commercially the by far more important compound compared to the monohydrate. Sodium perborate monohydrate is produced at most of the sites but the produced quantities of the monohydrate amount only to about 10 to 20% of the tetrahydrate. In a total the consumption ratio of sodium perborate monohydrate versus tetrahydrate is estimated to 15:85 (AISE, 1999c). From one site also the production of the dehydrated sodium perborate is reported.

The perborate quantities for the European market are almost exclusively produced in the EU member states. Imports of 5,101 tonnes from Slovenia[6] are reported for 1997 (CEFIC, 1999b).

[6] Slovenia is a Member State of the EU since 2004.

Table 2.1 Production sites of sodium perborate monohydrate/tetrahydrate

Company	LOCATION
Ausimont	Bussi, Italy
Caffaro	Brescia, Italy[a]
Degussa	Antwerpen, Belgium
	Rheinfelden, Germany
Aktivsauerstoff GmbH	Treibach, Austria
Elf Atochem	Pierre Bénite, France[b]
FMC Foret	La Zaida, Spain
Solvay	Warrington, UK
	Bad Hönningen, Germany
	Rosignano, Italy
	Povoa, Portugal
	Torrelavega, Spain

a) Production ceased in 1999 (CEFIC, 2000);
b) Production ceased in summer 1999 (Elf Atochem, 1999);

Table 2.2 Consumption and production quantities of sodium perborate in the EU

Year	Consumption (tonnes/year)	Production (tonnes/year)	Import (tonnes/year)	Export (tonnes/year)	Reference
1990	540,000	no data	no data	no data	Kleinschmidt et al. (1991)
1991	400,000	no data	no data	no data	Büchel et al. (1991)
1993	620,000	no data	no data	no data	ECETOC (1997)
1992-1994		316,000 – 1,115,000	30,000 – 135,000	no data	IUCLID data sheets*
1995	no data	Approximately 513,400	no data	no data	CEFIC (1999a)
1997	approximately 421,600	approximately 569,600	approximately 5,000 (approximately 1% of the production quantity)	approximately 153,000 approximately 27% of the production quantity)	CEFIC (1999a); CEFIC (1999b); Elf Atochem (1999)

* These quantities were calculated from the ranges given in the IUCLID data sheets of the producers.

2.2 USE PATTERN

Due to the deliberation of active oxygen during degradation (see Section 1.3) sodium perborate mono- and tetrahydrate are used as oxidising and bleaching agents mainly in detergents (household detergents as well as detergents for institutional uses) and also in cleaning (e.g. automatic dishwashers, stain removers in form of bleach booster tablets) and cosmetic preparations (denture cleansers) (Jakobi et al., 1987; Kleinschmidt et al., 1991; CEFIC, 1997; AISE, 1999a; c). In the laundry washing perborates are applied in regular and compact heavy-duty powders (heavy-duty detergents = detergents which are suited to all types of washing and all wash temperatures; light-duty = special purpose detergents; see Jakobi et al., 1987) whereas heavy-duty colour and light-duty powders and heavy- and light-duty liquids do not contain any

bleaching agent (Reynolds and Lindfors, 1998). About 50% of the bleach containing detergents are formulated on the basis of sodium perborate (AISE, 1999a).

Data on industrial and use categories of sodium perborate in the different life cycle steps including the uses (according to AISE, 1999a) are given in **Table 2.3** and **Figure 2.1**.

Up to the early 90's the sodium perborate appeared to be the most important bleaching agents especially in European heavy duty detergents whereas in the US and Japan due to the lower washing temperatures still the bleaching with hypochlorite preparations is more common (Jakobi et al., 1987). In 1988 more than 70% of the heavy-duty powder detergents available in Europe contained a persalt – mainly sodium perborate, to a minor extent other bleaching agents such as sodium percarbonate (Reinhardt et al., 1989). Sodium percarbonate reached in 1991 about 25% of the production capacity of the perborate (Büchel et al., 1999). Obviously, sodium perborate is mainly favoured due to their longer shelf life in the formulation of the detergent (Jakobi et al., 1987). More recent data on the percentage use of sodium percarbonate in the EU is not available.

The main disadvantage of the sodium perborate is its rather slow rate of degradation at low temperatures which leads to a slow deliberation active oxygen in the washing process (see also Section 1.3). Therefore, in the past the substances were used in heavy-duty detergents only for washings that can be boiled. Since about 20 years bleaching activators are added to the washing powders which accelerate the degradation rate already at temperatures between 30 and 40°C (Fine et al., 1974; Mecheels, 1982). In 1988, 50-60% of the washing powders in Europe contained an activator system. The economically most relevant activating compound is tetraacetylethylenediamine (TAED). In this case the formation of active oxygen proceeds via the peracetic acid which is more active as bleaching compound than hydrogen peroxide at low temperatures (Reinhardt et al., 1989).

From the older literature there is also some evidence that sodium perborate monohydrate was used as a component of mouthwash solutions (Dill et al., 1977; Edwall et al., 1979). Obviously, in Europe this use was discontinued in the 80's when Directives on cosmetics containing inter alia limit values for the boron content of cosmetics were established in several member states. Sodium perborate is not included in some recently published exemplary formulations for mouthwash concentrates (Umbach et al., 1991).

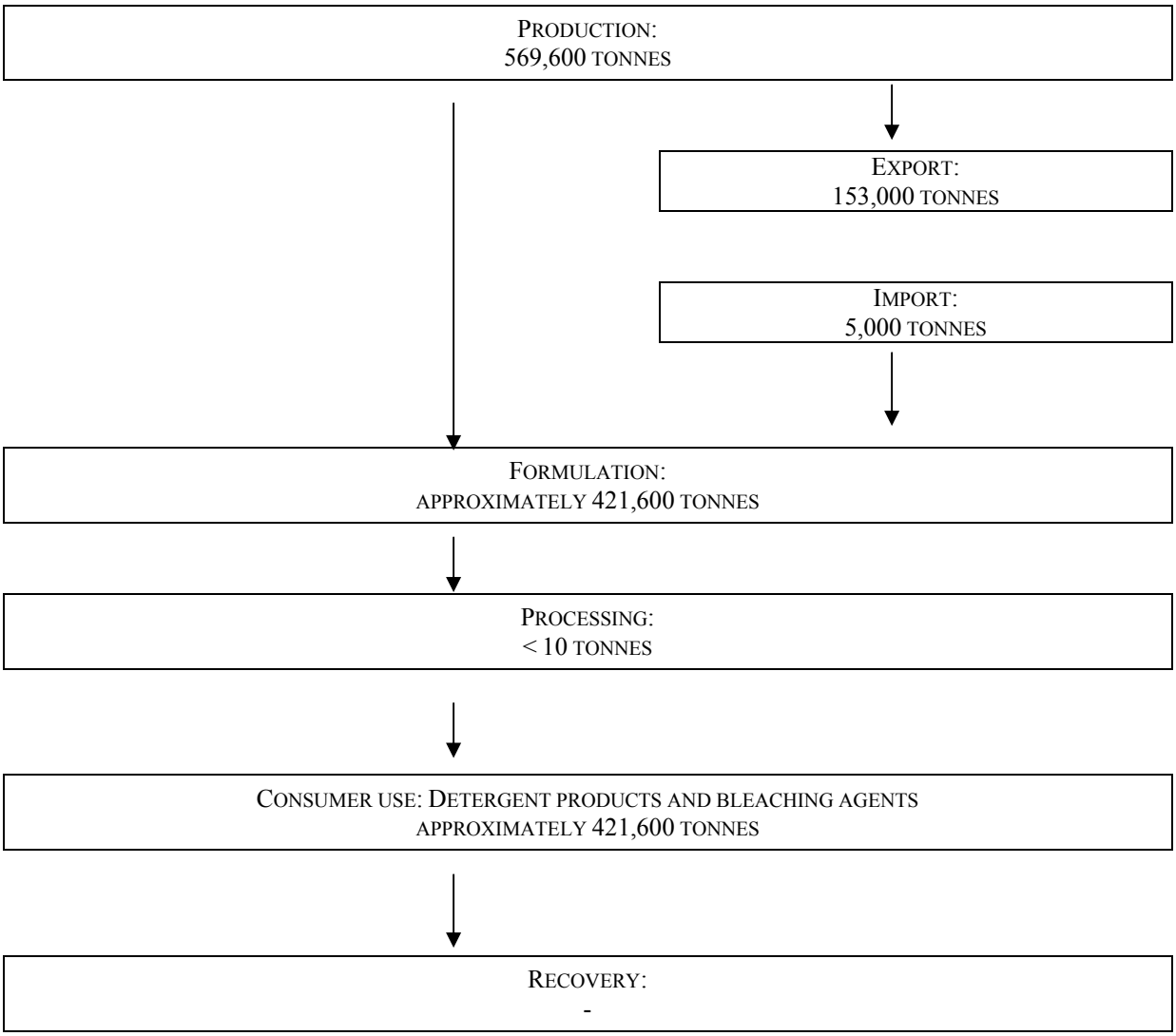
The substance is not included in the list on oral care agents of the current International Nomenclature of Cosmetics Ingredients which gives an inventory of ingredients used in cosmetics products in the EU. However, it is listed as an oxidising agent. Restrictions as to use field or contents in cosmetic preparations are not reported (INCI, 1999). In a number of US denture cleansers boron contents between 3.85 and 184 mg/kg wet weight were determined whereas the boron content of toothpastes was in general significantly < 1 mg/kg (Hunt et al., 1991). The boron contents of denture cleansers would correspond to e.g. sodium perborate monohydrate concentrations in the products of about 0.4 to 17% (see also **Table 4.9**). Unfortunately the authors give no information if these denture cleansers contained sodium perborate or other boron compounds.

Table 2.3 Industrial and use categories of sodium perborate

Scenario	Industry category[a]	Use category[b]	Main category[c]	Percentage use[d]	Quantity (tonnes/year; (reference year: 1997)[e]
Production	5	8	1b		569,600
Formulation	5	8	3		approximately 421,600
Processing (polymerisation aid in polysulfide sealants)[f]	3	37	1b	< 1	< 10[f]
Use:	5/6	8/9			approximately 421,600
Laundry detergents (heavy duty powders)				approximately 96	404,740 (tetra- and monohydrate)
Dishwashing agents (automatic dishwashers)				approximately 3	12,650 (tetra-hydrate)
Bleaching agents (denture cleansures, stain removers, buffer salts for textile bleaching[g])				< 1	< 4200 (tetra-hydrate, monohydrate and dehydrated compound[h])

a) IC5 = Personal/domestic; IC3 = Chemical industry: chemicals used in synthesis;
b) UC8 = Bleaching agents; UC37 = Oxidising agents;
c) MC1b = Isolated intermediates stored on-site, or substances (other than intermediates) produced in a continous production process; MC3 = Multi-purpose equipment;
d) Use data according to AISE (1999a);
e) For figures on consumption, production, im- and export see Table 2.2;
f) Degussa-Hüls (2001);
g) About 10 tonnes/year for industrial uses according to Degussa-Hüls (2001);
h) The dehydrated compound is of minor commercial importance (Degussa-Hüls, 1999a)

Figure 2.1 Sodium perborate life cycle in the EU (reference year: 1997)



2.3 TRENDS

A clear tendency concerning the production quantities of sodium perborate in the past ten years cannot be derived from the available data. Whereas in mid- and Northern Europe the consumption of washing powders is decreasing since 1989 with an increasing use of compact powders (market share > 50%) the countries of Southern Europe show an increasing tendency in the consumption of washing powders with a decrase in the application of compact powders (market share 10-20%). At a maximum dosage of 120 g for regular powders and of 110 g for compact powders 15-20 g and 18-25 g sodium perborate is applied per washing cycle (Reynolds and Lindfors, 1998). From this it can be concluded that the increased use of compact powders will not necessarily lead to a decrease in the consumption of bleaching agents per washing cycle, in the contrary there may be a slight increase.

There is some evidence, however, that perborate was partly substituted by percarbonate in the last two years and that the importance of percarbonate as a bleaching agent will increase further. Quantitative data on this trend for Europe on the whole was not available. In Germany the number of perborate containing laundry detergents for domestic and institutional uses has decreased significantly within the last four years (UBA, 2000). From investigations in the frame of the German Washing and Cleaning Agents Act, the quantities of sodium perborate and sodium percarbonate in laundry detergents can be estimated to be about the same in 2000 although sodium percarbonate quantitites were slightly higher. However, in dish washing detergents sodium perborate is the bleaching agent with the highest used amount, sodium percarbonate having only a share of 20% (UBA, 2001).

3 ENVIRONMENT

3.1 ENVIRONMENTAL EXPOSURE

3.1.1 General discussion

As far as the emissions are concerned it is not necessary to differentiate between sodium perborate mono- and tetrahydrate as it is not to be assumed that the differing water content will have any effects on the fate and behaviour of the substances in the environment. Therefore, both substances will be dealt together in the following characterisation of the environmental releases. In general, the concentrations in the receiving environmental compartments are not given in relation to a specific substance but only in form of the summary term "boron" being the parameter which is determined in chemical analyses. However, it has to be kept in mind that, besides the perborates, there are numerous other sources for the occurrence of boron compounds in the environment including natural sources. The unambigous identification of the affiliate source (sodium perborate mono- or tetrahydrate, its degradation product boric acid or other boron compounds) appears to be difficult in many cases (see also Section 1.3).

During the use of consumer products containing sodium perborate for cleaning and bleaching purposes the perborate is intended to be decomposed to hydrogen peroxide which is the acting agent in the bleaching and cleaning process and to sodium metaborate which is mainly available as boric acid under environmental conditions (see Section 1.3). From this it can be assumed that apart from the releases of sodium perborate during the industrial production and the formulation of detergent products and bleaching agents the aquatic environment will be mainly exposed to its degradation products.

3.1.1.1 Releases into the environment

Production

The production process of sodium perborate mono- and tetrahydrate in the EU member states takes place in continuously working, closed and automated systems which are located in closed buildings (CEFIC, 1999a). In general the process is carried out on more than 300 days/year.

The reported release data concerning the hydrosphere and the atmosphere (see CEFIC, 1999a) are compiled in **Table 3.1**. Unless otherwise stated, 1997 was taken as the reference year.

Table 3.1 Release of sodium perborate into the environment during production (reference year: 1997; according to CEFIC, 1999a)

Production site	Production capacity (t/y)	Waste water treatment plant	Type of receiving water	Total release into water (tonnes/year)[a]	Total release into air (tonnes/year)	Total release into soil (tonnes/year)	Total release with waste (tonnes/year)
A	120,000	partly (industrial, precipitation)	river	1.9 (boron)	0.3 (total dust) (PBS4 [b)] < 20 mg/m^3 in exhaust stream)	no emissions	no emissions
B	55,700	yes (industrial)	river	165 (boron)	6.6 (total dust)	no data	24 (boron; B content of waste: 0.4%)
C	72,000	no	river	58 (boron)	1.07 (boron)	no data	no data
D	10,000	no	estuary	32.9 (boron)	3 (total dust)	no data	33 (boron; B content of waste: 0.79%)
F [c)]	84,000	no	river/estuary	1992: 6.7-40.5 (boron)	3.1 (total dust)	no data	52 (boron; B content of waste: 0.66%)
H	100,000	yes (industrial)	river	17.3 (boron)	9 (total dust)	no data	23.9 (not specified)
I	100,000	waste water is collected in an effluent pond and recycled into production process [e)]	none	no emissions	10.4 (total dust)	no data	no boron containing waste
J [d)]	45,000	no (physico-chemical treatment)	river	no emissions	< 0.2 (borate)	no data	no data
K	32,000	no	estuary	35 (boron)	0.41 (PBS4)[b)]	no data	4.1 (boron; B content of waste: 0.18%)

a) These releases may also contain borates from the starting material of the production process (see Section 2.1), a differentiation is not possible by analytical means (see Section 1.3);
b) PBS4 = sodium perborate, tetrahydrate;
c) Production will be ceased before January 2003;
d) Due to a change of the production process (different starting material) in July 2001, sodium perborate is no longer emitted;
e) CEFIC (2001).

The waste water of 3 of the sites are released into estuaries.

If releases from waste occur these are in the range between 1 and 50 tonnes boron/year for each site (CEFIC, 1999a). They consist mainly of insoluble parts of the raw material used for synthesis and are typically viscous liquids. As far as sodium perborate is concerned minor amounts which e.g. do not fulfil the specifications are recycled in the production process (Degussa-Hüls, 2001).

Direct releases into soil and into the biosphere are not to be expected from the production process of sodium perborate mono- and tetrahydrate as it is carried out in closed systems in closed buildings.

Formulation

During formulation sodium perborate is mostly handled in continously working, closed and automated systems (AISE, 1999c). Information on the quantities of sodium perborate which is formulated to detergent products and bleaching agents at individual sites and on the technological processes being applied are not available. The release estimations are therefore based on estimations on the percentage released of the substances related to the total formulated quantity (detergent products and bleaching agents) and refer to the entire EU. For surface waters releases between 0.002 and 0.03% of the total formulated quantity with a 90th percentile of 0.015% are reported from 16 European formulation sites (AISE, 1999c). Data on releases into the atmosphere and from the disposal of waste are not available. Defaults were taken from the TGD-Emission Scenario Document "IC5 personal/domestic and IC6 Public Domain" which was originally developed for release estimations concerning the formulation of surfactants in detergent products. These data are compiled in **Table 3.2** (reference year 1997).

Table 3.2 Estimations of the total released quantity of sodium perborate mono-/ tetrahydrate during the formulation of detergent products and bleaching agents (reference year: 1997; estimations according to TGD - Emission Scenario Document "IC5 Personal/domestic and IC6 Public Domain" and data from AISE, 1999c)

Washing agent	Surface water		Air		Solid waste	
	% [a]	t/y [b]	% [c]	t/y [b]	% [c]	t/y [b]
Regular powder / Compact powder	0.015	Approximately 63 (= 4.7 t boron/y)*	0.02	Approximately 84 (= 6.2 t boron/y)*	0.73 / 0.81	ca. 3,000 / ca. 3,400 (= 222/ 252 t boron/y)*

a) According to data compilation from the European formulation sites; 90percentile (AISE, 1999c);
b) Related to the total perborate quantity formulated to laundry detergents and dishwashing agents in the EU (see Table 2.2);
c) According to TGD – Emission Scenario Document IC5/IC6;
* Calculated on the basis of an average molecular weight of 145.8 g/mol for sodium perborate monohydrate and tetrahydrate based on the production pattern of 15% monohydrate and 85% tetrahydrate (see Section 2.1)

The highest amounts are obviously emitted via the solid waste. Data on the treating and/or disposal of the solid waste are not available.

Processing

Only sodium perborate monohydrate is used in small quantitites in organic synthesis (< 10 tonnes/year in Europe, < 50 tonnes/year worldwide) as a polymerisation aid in polysulfide sealants (Degussa-Hüls, 2001; see also **Table 2.3**). Due to these small quantities negligible

releases into the environment are to be expected from this scenario. It is therefore not further considered in this report.

Consumer/institutional use of detergents and bleaching agents

From the wide dispersive use of detergent products a release fraction of sodium perborate from detergent products and bleaching agents of 1 (=100%) is derived for the hydrosphere according to the TGD, i.e. the entire amount of sodium perborate in detergent products and bleaching agents (421,600 tonnes in 1997) is released into the domestic waste water. For 1997, this would be a quantity of approximately 31,300 tonnes boron equivalents which are emitted into waste water in the EU assuming that the consumption ratio of sodium perborate mono- and tetrahydrate is 15:85 (see Section 2.1).

The release of sodium perborate into surface water from the consumer and institutional use is mainly dependent on the degradation rate of the substance in the washing/bleaching process and the degradation rate in domestic waste water and municipal STPs, respectively. Measured data from three washing cycles at 40, 60 and 90°C with a heavy-duty detergent containing 12.5% sodium perborate monohydrate gave degradation/disappearance rates of active oxygen between 65 and 78% after 1 hour washing time. The remaining active oxygen at the end of the washing process was estimated to about 22-35% of the initial value of 79.8 ppm (calculated from the sodium perborate content of the detergent) (AISE, 1999b). Furthermore also the degradation of the substances in domestic waste water and in subsequent sewage treatment plants (see Section 3.1.1.2.2) is rapid. In the following exposure assessment it is therefore assumed that sodium perborate from consumer and institutional use will be completely degraded in the domestic waste water even if no STP is available and will reach surface water only in form of its degradation products boric acid and water.

3.1.1.2 Degradation

3.1.1.2.1 Abiotic degradation

Water

In several degradation tests with sodium perborate as initial test substance, the decomposition was determined by measuring the decrease of active oxygen.

In sterile batches of the closed bottle test for sodium perborate monohydrate no elimination of the substance was found (Solvay Duphar, 1993a) and in the reconstituted water of a daphnia test only low amounts of the applied test substance were decomposed (Solvay Duphar, 1993c) (see also **Table 3.3**). Even at increased temperatures the degradation rate of the perborate in pure water appears to be rather slow: Gerike et al. (1976) reported a degradation rate of 50% of a solution of 30 g/l sodium perborate tetrahydrate which was heated to 95°C in a 25-minute time period, the high temperature being held for about 5 minutes and then cooled down to room temperature.

No data were identified concerning the decomposition of sodium perborate by direct and indirect photochemical reactions in water.

Air

No data were identified concerning the decomposition of sodium perborate by direct and indirect photochemical reactions in air.

3.1.1.2.2 Biodegradation

Water

The few studies available, in which the elimination of sodium perborate in laboratory aqueous test systems was examined, are summarised in **Table 3.3**. Enclosed are results of experiments on ready biodegradability and removal in river water, as well as relevant data from ecotoxicity tests on *Selenastrum capricornutum* and *Daphnia magna*.

Table 3.3 Degradation of sodium perborate in different aquatic test systems

Compound/ Concentration	Inoculum/ cell densitiy	Incub. time	Degrad. [%]	Remarks	Reference
Monohydrate/ 20 mg/l	20 mg/l activated sludge sterile water	48 hours 48 hours	85 0	Closed bottle test, OECD 301 D, modified, 1) high concentration of secondary activated sludge from a STP receiving predominantly domestic waste water 2) colorimetric determination of decrease of active oxygen as measure of degradation	Solvay Duphar (1993a)
Monohydrate/ Tetrahydrate/ 1 – 25 mg/l	domestic raw waste water / 4 x 10^6/g activated sludge / 2.5 g/l (d.w.)	2 hours 2 hours		Half-lives ($t_{1/2}$) at different initial perborate hydrate concentrations (colorimetric determination of decrease of active oxygen): 1 mg/l : 0.5 – 1 minutes 5 mg/l : 2.5 – 2.7 minutes 25 mg/l : 8.2 – 8.5 minutes 1 mg/l : 0.5 minutes 5 mg/l : 0.8 – 0.9 minutes 25 mg/l : 1.2 – 1.3 minutes	Guhl and Berends (2000)
Monohydrate/ 1 mg/l	natural river water/ not given	7 days 28 days	60 85	water from river Main, D $t_{1/2}$ = 59 hours	Degussa (1994b)
Monohydrate/ 0.62 - 10 mg/l	*Selenastrum capricornutum*/ 2 x 10^4- 2 x 10^6	24 hours 48 hours	20 – 54 33 - >90	ecotoxicity test according to OECD 201	Solvay Duphar (1993d)
Monohydrate/ 2 - 32 mg/l	Reconstituted water	24 hours	4 – 15	ecotoxicity test with *Daphnia magna* according to OECD 202	Solvay Duphar (1993c)

For the test on ready biodegradability (OECD 301 D) (Solvay Duphar (1993a), the method was modified taking into account the physico-chemical properties of the ionic test substance and the assumed degradation mechanism in aquatic media containing viable microorganisms (see below). The inoculum consisted of 20 mg/l of activated sludge (based on dry weight; 10^7-10^8 cells/ml) instead of unadapted secondary effluent (like prescribed in the guideline). The removal of the test substance was determined by a colorimetric method measuring the decrease

of active oxygen and not by determination of the oxygen demand. The test is considered valid. The degradation in this test, however, was less fast and complete (85% after 48 hours) than in the study of Guhl and Berends (2000). An explanation for the slower degradation is – besides the lower inoculum density - possibly the pretreatment of the sludge. Before the start of incubation the activated sludge was preconditioned to reduce endogenous respiration. This was done by aerating the sludge for one week. By this procedure microbial activity of the inoculum is expected to be significantly reduced due to shortage of substrate. As no additional substrate was added after diluting the sludge in aqeous mineral solution and starting of incubation, no recovery of the microbial activity (degradation potential) was possible which may have led to the reduced degradation of sodium perborate compared to the tests of Guhl and Berends (2000).

In laboratory tests Guhl and Berends (2000) found rapid removal (measured as decrease of active oxygen) of 1-25 mg/l sodium perborate monohydrate and tetrahydrate by domestic activated sludge ($t_{1/2}$: 0.5 – 1.3 minutes) and also by domestic raw waste water ($t_{1/2}$: 1-8.5 minutes), which was taken from the grit chamber of a STP. No significant difference between the two perborate hydrates could be detected. Besides the removal of sodium perborate also the degradation behaviour of hydrogen peroxide as initial test substance was determined in the study. Half-lives for this compound in activated sludge ($t_{1/2}$: 0.5-1 minutes) as well as in domestic raw waste water ($t_{1/2}$: 0.5 – 8.2 minutes) were exactly in the range of the perborate. This fact supports the conclusion that the degradation of the perborate to peroxide may have happened within a few seconds.

The significant decrease of sodium perborate in the ecotoxicity test with the green alga *Selenastrum capricornutum* (90% elimination after 2 days of incubation; Solvay Duphar, 1993d) shows that not only bacteria are capable to degrade this compound in the aquatic compartment.

The degradation of sodium perborate monohydrate in natural river water (River Main, D) was determined by measuring the decrease of active oxygen (screening tests). After an incubation period of 28 days 85% of the initial sodium perborate concentration (15 mg/l $NaBO_3 \cdot H_2O$/l) had been removed (Degussa, 1994b). Quantitative data on the kinetics of the degradation reaction such as rate constants for the elimination of the starting material or the formation of the products active oxygen and boric acid are not available. From the data measured by Degussa it is obvious that it is not satisfying to describe the process with simple kinetic equations such as first or second order. A data fit via a polynom gave a half life time of about 59 hours for the degradation of sodium perborate monohydrate in river water.

So there is evidence that microorganisms are able to degrade peroxy-compounds rather quickly with borates, water and oxygen being the end products of decomposition. This type of decomposition is expected to depend on the origin, adaptation and amount of the microbial population in the tested aquatic medium with removal rates increasing at higher cell numbers.

It has to be noted, however, that the test parameter ‘decrease of active oxygen’ used in degradation studies is only indicative for the biotic or abiotic degradation/decomposition of the applied sodium perborate but not for the underlying mechanism. It can be assumed that this degradation is due to the reaction with detoxifying enzymes like catalase, which is present in nearly all aerobic bacteria as well as many other organisms. In addition the oxygen consumption of the bacteria may shift the equilibrium of sodium perborate in solution towards the degradation products. Here also catalytic reactions with metal compounds (see Section 1.3) may be involved.

No information is available on the degradation of sodium perborate under anaerobic conditions.

Conclusion: From the results of the modified closed bottle test, the degradation by domestic activated sludge and by domestic raw waste water and the elimination experiments in natural

river water primary degradation of sodium perborate in industrial and municipal STP as well as in domestic waste water is expected to be rapid. Hence, for the exposure assessment concerning the elimination of sodium perborate in STPs complete biodegradation of the compound is assumed.

Data from a stability test in natural river water as well as from some ecotoxicity tests indicate also primary degradation of sodium perborate emitted directly to surface water, but decomposition here should be significantly slower. From the test on stability in water of the River Main (D) a half life of 59 hours for the elimination of sodium perborate in surface water can be derived. The degradation rate of sodium perborate and its degradation product hydrogen peroxide is assumed to depend mainly on the density of the natural microbial population present in water and/or the presence of catalytic material (e.g. detoxifying enzymes, transition metals).

Terrestrial compartment

No experimental results are available on the degradation of sodium perborate in soil. It is to be assumed, however, that due to the nature of the compound a significant decomposition can be expected in all environmental compartments, where a viable microflora and/or catalytic materials (e.g. metals, enzymes) are present.

3.1.1.3 Distribution

Studies on the environmental distribution behaviour of sodium perborate are not available. From the physico-chemical properties and the use pattern of sodium perborate (see Sections 1.3 and 2.2) it is obvious that the by far most important target compartment for the anthropogenic releases is the hydrosphere. From the ionic structure of the substances a significant volatilisation from water is not to be expected. Due to the intended decomposition during use and the degradation in the aquatic environment an assessment of the adsorption behaviour should be derived from the data on the degradation products.

Further information from tests with degradation products

Studies quantifying the adsorption of the degradation products boric acid onto soil, sediments or sewage sludge are not available. Elevated concentrations of boron due to natural sources (e.g. weathering of rocks) or man-made emissions were not detected in these compartments. There is some evidence, that water-soluble borates have a slight tendency for adsorption to soil, sediment particles and sewage sludge, depending e.g. on pH, organic matter content and the number of active adsorption sites (Butterwick et al., 1989). Significant adsorption, however, was only detected at alkaline pH levels of up to 9.5 when boron is mainly present as the borate ion (WHO, 1998; Blume et al., 1980). Greatest adsorption was found in soils with high amounts of fine particles particularly with iron and aluminum compounds on the surface (Sprague, 1972). Depending on soil properties the adsorption of boron was mostly found to be reversible and the compound was easily leached. Boric acid, the predominant borate species present at acidic pH levels, was found to be mobile in soil and sediment. At relevant environmental pH values of ≤ 7 no significant adsorption of boron compounds in soil and the aquatic compartments are to be expected (EPA, 1975; Koehnlein, 1972).

3.1.1.4 Accumulation and metabolism

Experimental data on the bioaccumulation of sodium perborate are not available.

Further information from tests with degradation products

Due to the ionic nature of sodium perborate and its degradation products a potential for bioaccumulation is not to be expected. Furthermore, the emerging hydrogen peroxide will be reduced rapidly (see EU Risk Assessment Report on Hydrogen Peroxide).

Concerning bioaccumulation of inorganic borates in fish ECETOC (1997) reviewed bioconcentration factors (BCF) calculated from borate concentrations in field collections of several fish. BCF values were in the range of 0.1 - 1.25 indicating no significant potential for bioaccumulation. Log P_{OW} (0.175) as well as experimental results from tests with aquatic organisms indicate also only low bioaccumulation potential for boric acid (Howe, 1998).

3.1.1.5 Secondary poisoning

From the ionic structure of sodium perborate and boric acid it can be concluded that a significant accumulation of these substances in the biota is not to be expected.

Further information from tests with degradation products

Hydrogen peroxide generated from sodium perborate will be rapidly degraded by abiotic and biotic processes. The estimated log P_{OW} value of about -1.5 does not indicate a potential for bioconcentration (see EU Risk Assessment Report on Hydrogen Peroxide).

3.1.2 Aquatic compartment

From their inorganic structure it can be concluded that boron compounds will not adsorb to organic matter. Only a sorption to the inorganic constituents of sediment such as clays seems to be possible. Therefore, $PEC_{local,\ sediment}$ cannot be calculated with the estimation method given in the TGD as this method is based on the adsorption of substances to the organic matter of the sediment. From the scientific literature, however, there is no evidence for a significant adsorption of the substances to soil or sediment under environmentally relevant conditions (see Section 3.1.1.3). An accumulation of any of the borate salts in the sediment is not to be expected and the quantification of $PEClocal_{sediment}$ seems to be of minor importance.

3.1.2.1 Monitoring data

Monitoring data on the sodium perborate themselves were not identified as only indirect methods are available for the analytical determination (see Section 1.3). Whereas the hydrogen peroxide emerging during degradation of the sodium perborate can be assumed to be rapidly degraded to water and oxygen the remaining boric acid is stable in the aqueous phase. Due to the extensive use of sodium perborate in detergent products and bleaching agents and the lack of removal of the borate anion by STPs the boron content of surface waters is regarded as an indicator for the anthropogenic pollution of surface waters (Jakobi et al., 1987).

There are numerous studies on the boron content of surface waters in Europe. Since many years the determination of borate measured as boron is an integral part of a number of surface water survey programmes of water works and regional environmental authorities in the EU member states (see e.g. for Austria the publications of Schoeller et al., 1981; Schoeller and Bolzer, 1989; Schoeller, 1990; Schoeller et al., 1997, for Belgium Verbanck et al., 1989; for Italy Tartari and Camusso, 1988; Benfenati et al., 1992; Mezzanotte et al., 1995, for Germany the compilation of

Lind et al., 1998, for the Netherlands Feijtel et al., 1995 and for Switzerland Kistler and Meier, 1990). The determination of the boron levels in selected European rivers (Germany and UK) is also a part of the European GREAT-ER project. This is a GIS (Geographical Information System)-based model for the prediction of environmental concentrations of pollutants in freshwaters. For the Aire/Calder catchment (UK) 90th percentile data of 0.186 mg boron/l were calculated including unpolluted upstream sites compared to a mean of 90th percentiles of 0.242 mg/l from the monitoring data (Fox et al., 2000).

The boron content of water is furthermore relevant in the context of irrigation processes as elevated boron levels appear to have phytotoxic properties (e.g. Navarro et al., 1992; Schoeller et al., 1997; see also Section 3.2.2).

In addition, boron in form of borate is released by the weathering of rocks so that also surface waters in remote areas may contain small amounts of boron from natural sources. From measurements in several German rivers, the detergents based fraction of the boron concentrations in surface waters was estimated to be between 50 and 70% for the 70's and early 80's (Müller et al., 1978; Butterwick et al., 1989; Gerike et al., 1989). More recent data are not available.

From the most recent compilation of data on the boron concentrations in freshwaters and sewage effluent the concentration ranges summarised in **Table 3.4** can be derived for Europe (ECETOC, 1997).

Table 3.4 Boron concentrations in European surface waters and sewage effluent (summarised from ECETOC, 1997)

Type of water	Concentration ranges (mg B/l)
Sea water	4-5
Rivers and lake, not influenced by anthropogenic activities and without special geological conditions ("background concentration")	< 0.05
Rivers and lakes in volcanoic areas	up to 20,000
Rivers and lakes, influenced by anthropogenic activities (e.g. domestic discharges, boronated fertiliser used in region)	0.05-1 mg/l
Rain or snow	up to 0.1
Ground water	< 0.1 - > 1 (depending very strongly on local geological circumstances)
Sewage effluent	0.2-5

Representative data on the boron levels in estuaries are not available. From the few measurements cited in the literature it is obvious that these concentrations may vary considerable (ECETOC, 1997). For the risk assessment it is assumed that the boron concentrations in estuaries are similar to that in the open sea.

It is discussed in the literature (see e.g. Lind et al., 1998) that the boron concentration in anthropogenically influenced rivers is decreasing since about 1991 due to a decreasing quantity of sodium perborates used in washing detergents. To our opinion, this tendency may be valid for some, especially Northern EU member states where the per capita consumption of detergent products is decreasing since about 10 years (Reynolds and Lindfors, 1998; see also Section 2.3). But it cannot be confirmed for the entire EU neither from the consumption data in Section 2 nor from the freshwater concentrations given in the literature. The further trend will be mainly

dependent on the degree of substitution of sodium perborate by sodium percarbonate (see also Section 2.3).

3.1.2.2 Estimation of PEClocal $_{water}$ for aquatic systems

Production

The concentrations in the effluent of the European production sites were measured in terms of boron (CEFIC, 1999a). Data on the fraction of sodium perborate in these effluents are not available. This is inter alia due to the difficulties during the analytical determination of sodium perborate in aqueous solutions (see Section 1.3). It cannot be excluded that also the starting material borax or the intermediate sodium metaborate (see Section 2.1) are released with the waste water from the production process. The measured concentrations in the effluent and the calculation of the respective $Clocal_{water}$ data are given in **Table 3.5**.

The calculations were carried out as described in the TGD based on low flow rate conditions of the receiving surface water. The default values for the estimation of the sorption onto suspended solids (Kp_{susp}) cannot be used for these calculations dealing with inorganic compounds. From literature data it can be assumed that the sorption of sodium perborate and boric acid is of minor importance at relevant environmental conditions in aquatic compartments (see Section 3.1.1.3). Therefore, sorption onto suspended solids in the water phase was excluded.

It can be assumed that sodium perborate is completely degraded in plants with waste water treatment (see also Section 3.1.1.2.2). Also the emerging hydrogen peroxide will be degraded rapidly in the STP (see EU Risk Assessment Report on Hydrogen Peroxide) so that only boric acid is to be expected in the effluent.

Table 3.5 shows the boron content of the effluents and the local boron concentration in the receiving surface water. As far as production sites have no waste water treatment plant (sites C, D, F, G, J and K; see **Table 3.1**) the degradation behaviour of sodium perborate has to be considered in more detail: As sodium perborate in aqueous solution is in equilibrium with hydrogen peroxide (see Section 1.3) the hydrogen peroxide concentrations in the effluent can be used as a marker indicating the presence of active oxygen in the effluent which may be due to sodium perborate. For these production sites therefore an evaluation of the hydrogen peroxide content of the effluent is necessary. As they are also production sites for hydrogen peroxide they were already evaluated in the EU Risk Assessment on Hydrogen Peroxide. The $Clocal_{water}$ data on hydrogen peroxide are given in **Table 3.5** additionally for completeness. It has to be borne in mind that they relate to production of hydrogen peroxide and processing of the substance to sodium perborate and therefore represent a worst case situation. Some more recent data on the hydrogen peroxide content of the effluents which were provided by industry do not change the evaluation and were therefore not considered further.

Table 3.5 Concentrations of boron/hydrogen peroxide in the effluents from the production of sodium perborate (with and without STP) and the respective $Clocal_{water}$ data (according to CEFIC, 1999a)

Production site	Effluent (m^3/day)	Flow rate receiving water (m^3/s)	Dilution	Number of production days /year	$Clocal_{,eff}$ (PBS) [b] [boron] (mg/l)	$Clocal_{water}$ (boron)(µg/l)
A*	47,024	low 518 (mean 1,030)	953 (1,890)	345	1.5 [0.11]	0.11
B**	7,920	low 1,000 (mean 2,000)	10,900 (21,800)	365	767 [57]	5.2
C*	150,000	low 20 mean 25	13 (15)	359	13.5 [1]	76 H_2O_2: < 500
D*	45,600	no data, estuary	default: 10	330	27 [2]	183 H_2O_2: 30
F* [c]	9,504	low 20 (mean 30)	183	310	25.7-1526 [1.9-113]	9-524 H_2O_2: < 100
H*	4,770	low 40.3 (mean 121)	732	340	134 [9.9]	13
I*	no emissions					
J	no emissions [d]					
K*	84,000	no data, estuary	default: 10	330	17.6 [1.3]	117 H_2O_2: 1

a) Considering 250 production days/year;
b) Mean molecular weight (PBS) = 145.8 g/mol corresponding to a ratio of tetrahydrate: monohydrate of 85:15 (see also Section 2.1);
c) Production will be ceased before January 2003;
d) Due to a change of the production process (different starting material) in July 2001, sodium perborate is no longer emitted;
* These production sites were already evaluated in the EU Risk Assessment Report on Hydrogen Peroxide;
** Production site already evaluated in the EU Risk Assessment Report on Hydrogen Peroxide, production of Hydrogen Peroxide stopped in 1995

Formulation

In 1999 measurements on the boron content of the waste water effluent of the European detergent formulation sites using > 1,000 tonnes/year sodium perborate each were carried out. The results for the individual sites are given in **Table 3.6**. Detailed data on the receiving surface waters are not available. Ten of the reported sites discharge to municipal waste water treatment plants, 4 have an on-site treatment of the waste water with or without discharge to a municipal STP, 1 discharges to a major canal system and 1 has no sewage treatment (no further specification of the individual plants). The latter two effluents contain boron concentrations < 100 µg/l (AISE, 2000). Assuming that the equilibrium between sodium perborate and hydrogen peroxide is completely shifted towards hydrogen peroxide and that there is no degradation of this substance in the waste water stream this corresponds to $Clocal_{effluent}$ < 315 µg H_2O_2/l and $Clocal_{water}$ < 31.5 µg/l.This figure was used for the risk characterisation (see Section 3.3). For those sites which are connected to STPs it is assumed that sodium perborate and hydrogen peroxide are completely degraded, boric acid being the only relevant degradation product (see Section 3.1.1.2.2).

The calculations are carried out as described in the TGD based on a default dilution factor of 10 and 365 emission days/year. The default values for the estimation of the sorption onto suspended

solids (Kp_{susp}) cannot be used for these calculations dealing with inorganic compounds. From measurements in the scientific literature it can be assumed that the sorption of boron compounds is of minor importance under environmentally relevant conditions (see Section 3.1.1.3). Therefore, sorption onto suspended solids in the water phase was excluded.

Table 3.6 Boron concentrations in the effluents of European formulation sites and calculated $Clocal_{water}$ data (AISE, 2000)

Formulation site	$Clocal_{effluent}$ (PBS) [boron] (mg/l)*	$Clocal_{water}$ (boron) (µg/l)
AA	0 [0]	0
BB	0.675 [0.05]	5
CC	0.945 [0.07]	7
DD	0.945 [0.07]	7
EE	1.89 [0.14]	14
FF	2.7 [0.2]	20
GG	2.7 [0.2]	20
HH	3.4 [0.25]	25
II	5.1 [0.38]	38
JJ	7.3 [0.54]	54
KK	10.1 [0.75]	75
LL	10.5 [0.78]	78
MM	11.3 [0.84]	84
NN	14.9 [1.1]	110
OO	20.3 [1.5]	150
PP	43.2 [3.2]	320

* Mean molecular weight (PBS) = 145.8 g/mol corresponding to a ratio of tetrahydrate : monohydrate of 85:15 (see also Section 2.1)

Consumer use of detergents and bleaching agents

From investigations in the frame of the German Washing and Cleaning Agents Act (UBA, 2001) it can be concluded that about 60% of the sodium perborate containing detergent products are used in consumer products. Assuming that these data are representative for the EU a generic scenario being based on boron was calculated via EUSES (IC5 Personal Domestic). According

to this Emission Scenario Document the release fraction of the sodium perborate used, as an ingredient of detergent products and bleaching agents, is supposed to be 1 i.e. the total amount is released into the environment. Due to the degradation of the sodium perborate during the washing process (see Section 3.1.1.1) and the biodegradation in the waste water and subsequent sewage treatment plants (see Section 3.1.1.2.2) the substance will be completely degraded to boric acid. The emerging hydrogen peroxide is degraded via reductive processes with the stains on the textiles or bleaching substrate, in the domestic waste water or in STPs. The boron compounds are not significantly adsorbed onto sewage sludge (see Section 3.1.1.3). Having this in mind the $PEClocal_{water}$ calculation was carried out with EUSES on the basis of boron. The following input parameters were used (all related to boron):

Molecular weight	=	10.8 g/mol
Vapour pressure	=	0
Log Pow	=	0
Water solubility	=	39.9 g/l
Biodegradation		None
Adsorption		None
Volatilisation		None

The production, import and export quantities were also converted to boron equivalents.

From measurements by ECETOC (2001) on the boron concentrations in a number of domestic STPs in the Netherlands, Germany, UK and Italy it can be concluded that a factor of 2 is sufficient to consider the intra-regional consumption differences of detergents deviating from the factor of 4 which is commonly used according to TGD.

Bleaching agents are not discussed separately as it is assumed that sodium perborate shows the same degradation as in detergent products.

From this, $PEClocal_{water}$ is calculated to:

$$PEC\ local_{water} = 0.6\ mg\ boron/l$$

Institutional use of detergents

Measured data on the boron or hydrogen peroxide content of waste water from institutional uses are not available. From investigations in the frame of the German Washing and Cleaning Agents Act (UBA, 2001) it can be concluded that about 40% of the sodium perborate containing detergent products are used by institutions. Assuming that these data are representative for the EU a generic scenario being based on boron was calculated via EUSES (IC6 Public domain) (input parameters see above). It is not to be expected that hydrogen peroxide is released into surface water from the institutional use of sodium perborate containing detergents as it is degraded via reductive processes with the stains on the textiles or bleaching substrate, in the domestic waste water or in STPs.

From this $PEClocal_{water}$ is calculated to:

$$PEC\ local_{water} = 0.4\ mg\ boron/l$$

3.1.2.3 Estimation of PEC_{STP}

It is not to be expected that significant amounts of boron are released from the STP via volatilisation into the atmosphere or via adsorption processes with the activated sludge (see also Section 3.1.1.3). Therefore the fraction of emission directed to water by STP $Fstp_{water}$ is 1. In this case the concentration in the untreated waste water $Clocal_{infl}$ = $Clocal_{eff}$ (substance concentration in the STP effluent; see TGD, Environmental Risk Assessment, Section 2.3.7).

Production

The data on $Clocal_{eff}$ are compiled in **Table 3.5**. Assuming homogenous mixing in the STP tanks PEC_{STP} can be set equal to $Clocal_{eff}$.

Formulation

Measured data on the boron content of the effluent of the reported European formulation sites are available (see **Table 3.6**). Similar assumptions as with production apply to formulation sites. Therefore the data on $Clocal_{eff}$ in **Table 3.6** can be set equal to PEC_{STP}.

Consumer use of detergent and bleaching agents

The PEC_{STP} from the EUSES calculations (see above) is 4.29 mg boron/l. Due to the rapid degradation of sodium perborate in domestic waste water (see Section 3.1.1.2.2) it is not to be expected that significant amounts of sodium perborate or hydrogen peroxide will reach the STP.

Institutional use of detergent and bleaching agents

The PEC_{STP} from the EUSES calculations (see above) is 1.71 mg boron/l. It can be assumed that the laundries to be considered will be mainly connected to domestic STPs. Due to the rapid degradation of sodium perborate in domestic waste water (see Section 3.1.1.2.2) it is not to be expected that significant amounts of sodium perborate or hydrogen peroxide will reach the STPs.

3.1.2.4 Estimation of PECregional for aquatic systems

The $PECregional_{water}$ (boron) was taken from the EUSES calculations described in Section 3.1.2.2 including also production and formulation. The $PECregional_{water}$ (H_2O_2) was already derived in the EU Risk Assessment on Hydrogen peroxide and is given to 3 µg/l.

$PECregional_{water}$ is calculated to:

$$PECregional_{water} = 0.18 \text{ mg boron/l}$$

This concentration is in the range of the boron levels which can be derived from the monitoring data for European surface waters (see **Table 3.4**).

3.1.2.5 Estimation of PECcontinental for aquatic systems

The $PECcontinental_{water}$ (boron) was taken from the EUSES calculations described in Section 3.1.2.2. The $PECcontinental_{water}$ (H_2O_2) was already derived in the EU Risk Assessment on Hydrogen peroxide and is given to 0.4 µg/l.

$PECcontinental_{water}$ is calculated to:

$$PECcontinental_{water} = 0.06 \text{ mg boron/l}$$

3.1.2.6 Summary of $PEClocal_{waters}$ derived for the aquatic environment

The hydrosphere is the by far main target compartment of sodium perborate due to the physico-chemical properties (see Section 1.3) and the use characteristics (see Section 2.2). From the degradation behaviour of sodium perborate it is concluded that in most cases boric acid is the relevant compound in the aquatic environment. Only at production and formulation sites without STP hydrogen peroxide releases into surface water can occur. These were mainly already evaluated in the EU Risk Assessment on Hydrogen Peroxide. The PECs on the basis of boron for the aquatic compartment are summarised in **Table 3.7** including the $PECregional_{water}$ (boron) calculated by EUSES. Where appropriate also $PEClocal_{water}$ (H_2O_2) is given for completeness.

Table 3.7 Overview of $PEClocal_{water}$ (production, formulation) for the aquatic environment

Production site	PEC local water(boron) (mg/l) [a]	Formulation site	PEClocal, water (boron) (mg/l) [a), b)]
A	0.18	AA	0.18
B	0.19	BB	0.19
C	0.26 H_2O_2: < 503 µg/l	CC	0.19
D	0.36 H_2O_2: 33 µg/l	DD	0.19
E	0.19	EE	0.19
F [c]	0.19-0.7 H_2O_2: < 103 µg/l	FF	0.2
		GG	0.2
H	0.19	HH	0.21
I	0.18	II	0.22
J [d]	0.18	JJ	0.23
K	0.3 H_2O_2: 4 µg/l	KK	0.26
L		LL	0.26
		MM	0.26
		NN	0.29
		OO	0.33
		PP	0.5

a) PEClocal, water = C local, water + PEC regional, water;
b) 2 formulation sites without STP: $PEClocal_{water}$ for H_2O_2: < 31.5 µg/l;
c) Production will be ceased before January 2003;
d) Due to a change of the production process (different starting material) in July 2001, sodium perborate is no longer emitted

$PEClocal_{water}$ (boron) for the consumer and institutional use of sodium perborate containing detergent products and bleaching agents was calculated with EUSES to 0.6 mg boron/l and 0.4 mg boron/l. Significant releases of hydrogen peroxide into surface water from these uses can be excluded as the substance is completely degraded during the washing process and in domestic water water.

3.1.3 Atmosphere

3.1.3.1 Monitoring data

Measured data concerning the concentrations of sodium perborate in ambient air, e.g. in form of dust are not available.

3.1.3.2 Estimation of PEC_{local} for the atmosphere

Production

Measurements in the exhaust stream of 10 European production sites are available. However, the data base is inhomogenous: for 6 sites only the concentration of total dust in the exhaust stream is given. These data were not included into the exposure assessment for ambient air as no data is available on the sodium perborate concentration in the dust. At the remaining 4 sites the concentrations are given in terms of boron, borate or perborate. At these sites exclusively sodium perborate tetrahydrate is produced. Measured data from production sites where also sodium perborate monohydrate is produced is not available. As the monohydrate is gained from the tetrahydrate by dehydration in an additional step (see Section 2.1) the atmospheric releases during the production of the monohydrate may be somewhat higher.

A generic emission scenario on the basis of the emission tables in the TGD for the remaining sites leads to a $PEClocal_{air}$ of 0 for the following reasons:

- the vapour pressure of sodium perborate cannot be determined due to thermal instability. It can be assumed, however, that it is significantly < 1 Pa (=lowest vapour pressure category in A-Tables of the TGD) due to their ionic structure
- the combination of this vapour pressure with MC 1b (see **Table 2.3**) leads to estimated releases into air from production of 0 (see TGD, A-Tables: IC5 Personal/domestic).

The calculation of $PEClocal_{air}$ with the available data on airborne boron, borate or perborate emissions (see **Table 3.1**) was carried out according to the TGD and are compiled in **Table 3.8**. Emissions from STPs into the atmosphere have not to be considered as the substance is not volatile from aqueous solutions due to its chemical structure, i.e. $Estp_{air} = 0$. It must be borne in mind however, that data referring to boron or borate (sites F and J) may also be influenced by some amount of the starting material borax. In a worst case approximation it is assumed that these exhaust stream concentrations are solely caused by sodium perborate tetrahydrate.

Table 3.8 $Clocal_{air}$ from the production of sodium perborate tetrahydrate

Production site	$Clocal_{air,ann}$ (mg/m³)	Number of production days per year	$PEClocal_{air}$ PBS4 (mg/m³)
C	0.8 (boron)	359	11.4
J	< 0.2 (borate $H_2BO_3^-$)	200-250	< 0.5
K	0.3 (PBS4)	330	0.3

With the available data, estimations on possible hydrogen peroxide releases from the photolytic degradation of sodium perborate in the atmosphere cannot be carried out (see also Section 3.1.1.2.1). However, these are assumed to be of minor importance due to the numerous other sources of atmospheric hydrogen peroxide from photo-oxidative processes (see EU Risk Assessment Report on Hydrogen Peroxide).

Formulation

Data on the emissions of sodium perborate into the atmosphere from individual formulation sites are not available. The calculation of $PEClocal_{air}$ on the basis of a generic emission scenario as given in the TGD leads to the following result:

$Clocal_{air, ann} = PEClocal_{air} = 0.03$ mg sodium perborate/m³

Assumptions:

Formulation quantity (total)	421,600 tonnes
Formulation quantity per site	26,350 tonnes (total quantity equally distributed among 16 sites)
Emission factor (air) MC3	0.0025
Fraction of the main local source	0.6
Number of formulation days	300
$PECregional_{air}$ (see Section 3.1.3.3)	0.33 µg/m³

Consumer use of detergents and bleaching agents

Significant releases of sodium perborate into the atmosphere from the use of the respective detergents and bleaching agents by consumers are not to be expected. Small amounts of perborate containing dusts may be released into ambient air during filling or transferring operations. A quantification is not possible with the available data but is not supposed to be relevant.

3.1.3.3 Estimation of PECregional and PECcontinental for the atmosphere

According to the TGD 10% of the estimated emissions from production, formulation and use are used as input for the calculation of the $PECregional_{air}$. Data on atmospheric emissions for the formulation of sodium perborate containing products are not available. From the use of the respective consumer products no relevant emissions into the atmosphere are to be expected.

From the emission data for the individual European production sites a total release of > 10 tonnes boron/year can be derived (see Section 3.1.1.1; data on atmospheric releases summed up). This figure corresponds to > 1 tonnes boron/year for the region. With the basic data of the regional system (see Table 10, TGD: area 4 · 10 km^2; mixing height 1 km) an atmospheric concentration of > 25 ng boron/m^3 (= 338 ng sodium perborate/m^3; mean molecular weight of sodium perborate 145.8 g/mol assuming tetrayhdrate to monohydrate ratio of 85:15; see Section 2.1) can be calculated. This is a maximum concentration for the boron content of the gaseous phase as wet and dry deposition processes leading to a removal of the substances from air were not considered. Due to the high water solubility of the sodium perborate and borate salts these deposition processes are considered to reduce the atmospheric concentrations considerably.

The total tropospheric burden for gas-phase and particulate boron was estimated from measurements in the U.S. to 60,000–110,000 tonnes with average boron concentrations in the atmosphere between 4 and 8 ng/m^3 at continental and coastal sites. Atmospheric releases from oceans, burning of coal and refuse and volcanoic activities are the most relevant sources for boron or borate containing dusts (Anderson et al., 1994a). A contribution of 0.002–0.009% to the natural atmospheric boron burden from the use of detergents was estimated by the authors.

Hydrogen peroxide which may emerge from the degradation of airborne sodium perborate is also considered to be of minor importance due to the numerous other sources of atmospheric hydrogen peroxide from photo-oxidative processes (see EU Risk Assessment Report on Hydrogen Peroxide).

The same holds on an even lower level for the continental pollution of the atmosphere with boron compounds and hydrogen peroxide from the production and use of sodium perborate.

3.1.4 Terrestrial compartment

The possible emissions into the terrestrial compartment e.g. via wastes from production cannot be quantified as data on the treatment of waste is lacking.

Releases from the application of sodium perborate or borate containing activated sludge appear to be of minor importance as literature data show that the adsorption of sodium perborate and boric acid onto activated sludge from STPs seems to be low under environmentally relevant conditions (see Section 3.1.1.3). Also hydrogen peroxide generated from sodium perborate will degrade rapidly in the sludge and therefore no hydrogen peroxide emissions to soil from the application of sludge will be assumed (EU Risk Assessment Report on Hydrogen Peroxide). In addition deposition of sodium perborate from emissions of sodium perborate into the atmosphere e.g. from production sites appears to be possible. Due to its ionic structure, a significant volatilisation potential is not to be expected (see Section 3.1.1.3). Hence, it can be assumed that sodium perborate is solely emitted with dust and further completely adsorbed onto the airborne aerosol. The total aerial deposition flux/kg soil and day calculated according to TGD for the production sites given in **Table 3.8** is then in the range of some nanograms to ≤ 3 µg/kg soil and day. The estimated releases from formulation are even lower. Aerial deposition of sodium perborate is therefore assumed to be of minor importance.

3.1.5 Secondary poisoning

From the ionic structure of sodium perborate and boric acid it can be concluded that a significant accumulation of these substances in the biota is not to be expected. Furthermore, a significant

bioaccumulation of hydrogen peroxide as well as a reactive polar substance with short half-lives in the aquatic compartment is not to be expected (EU Risk Assessment Report on Hydrogen Peroxide).

3.2 ENVIRONMENTAL EFFECTS ASSESSMENT

3.2.1 Aquatic compartment (including sediment)

As a consequence of the decomposition behaviour of sodium perborate in aqueous solution and having in mind the analytical problems concerning the determination of perborates in water the results of laboratory tests on aquatic toxicity of sodium perborate do not allow conclusions on the nature of the substance or degradation products, to which the test species were exposed. The primary degradation product of sodium perborate in aqueous solution is boric acid. Furthermore exposure to hydrogen peroxide may occur as sodium perborate is in aqueous solutions in equilibrium with this substance (see Section 1.3). Concerning this exposure most aquatic organisms have developed detoxifying mechanisms to prevent cell damage. Antioxidant enzyme systems containing catalase decompose reactive oxygen species stepwise to water. More information on the ecotoxic effects of hydrogen peroxide can be found in the EU-Risk Assessment Report for this compound. After degradation of hydrogen peroxide the remaining borate species should be the sole toxicologically relevant substances with sodium metaborate being the first degradation product. The most important borate species which will be present in aqueous media under environmental conditions should be boric acid (H_3BO_3).

The ecotoxicity of inorganic borates including boric acid has been reviewed by Butterwick (1989), ECETOC (1997), WHO (1998) and RIVM (1999). Effect data for boric acid as the most relevant degradation product under environmental conditions from studies on different aquatic species cited in these reviews were analysed whether they aid to the evaluation of sodium perborate. Inorganic borates and boric acid are on the 4th priority list and will be dealt with in detail in a future EU Risk Assessment Report.

If relevant, this information is given in separate subheading “Further information on the degradation products”. Information on degradation products will be used in this section for identifying possible hazards or for validating data of sodium perborate, but not for quantitative risk assessment purposes.

An extensive evaluation of the effect data available for boric acid will be performed within the future risk assessment of the priority substances boric acid and disodium tetraborate.

Available effect data on sodium perborate

For the aquatic compartment short term toxicity tests on fish, invertebrates, plants, protozoa and bacteria are available. At least one short-term toxicity test with sodium perborate for each trophic level required in the TGD was performed according to standard guidelines. Long term tests were performed with plants, protozoa, bacteria and a microcosm system. In **Table 3.9** the results of the ecotoxicity studies on the effect of sodium perborate on the different aquatic species are summarised. Effect data are expressed as concentrations of sodium perborate (PBS), boron and hydrogen peroxide equivalents.

Table 3.9 Toxicity of sodium perborate (PBS) to aquatic organisms

Species	Method/ Testsystem	Test conditions	Applied compound	Duration	Effect Concentrations*				Remarks	Reference
						mg PBS/l	mg H_2O_2/l	mg B/l		
Fish										
Leuciscus idus	corresponding to OECD guideline 203; semistatic		Tetrahydrate	48 hours	LC_0 LC_{50}	100 125	21 27	7 8.8	insufficient documentation	Henkel (1991a)
Brachydanio rerio	OECD guideline 203; semistatic	reconstituted water (ISO)	Monohydrate	96 hours	NOEC LC_{50}	25 51	7.8 16	2.7 5.5	Monitoring of active oxygen; results based on nominal conc.	Solvay Duphar (1993b)
Brachydanio rerio	OECD guideline 203; semistatic	reconstituted water	Tetrahydrate	72 hours	LC_{50}	150	32	10.5	Nominal concentration	Thybaud and Lamy (1996)
Oncorhynchus mykiss	static	tap water; fish adapted	Hydrate, unspecified	24 hours	NOEC	250			Nominal concentration	Mann (1973)
Lebistes reticulatus	static	tap water; fish adapted	Hydrate, unspecified	24 hours	NOEC	250			Nominal concentration	Mann (1973)
Anguilla anguilla	static	fish adapted; tap water salt water (12.38/20.05 ‰)	Hydrate, unspecified	24 hours 24 hours	NOEC NOEC	500 250			Nominal concentrations; NOEC equal at different salt concentrations	Mann (1973)

Table 3.9 continued overleaf

Table 3.9 continued Toxicity of sodium perborate (PBS) to aquatic organisms

Species	Method/ Testsystem	Test conditions	Applied compound	Duration	Effect Concentrations*				Remarks	Reference
						mg PBS/l	mg H_2O_2/l	mg B/l		
Invertebrates										
Daphnia magna	OECD guideline 202		Tetrahydrate	48 hours	NOEC EC_{50}	15 30	3.2 6.4	1.05 2.1	insufficient documentation	Henkel (1991b)
Daphnia magna	NF T 90301	reconstituted water	Tetrahydrate	48 hours	EC_{50}	25	5.3	1.75	Nominal concentration	Thybaud and Lamy (1996)
Daphnia magna	OECD guideline 202; semistatic	reconstituted water (ISO)	Monohydrate	48 hours	NOEC EC_{50}	8 11	2.5 3.4	0.86 1.2	Monitoring of active oxygen; EC: based on nominal conc., NOEC: based on measured conc.	Solvay Duphar (1993c)
Daphnia magna	static test; acute toxicity	artificial medium; pH: 7.6; hardness: 272 mg $CaCO_3$/l	Tetrahydrate	24 hours	EC_0 EC_{50}	870 4,850	190 1,030	61 340	nominal concentrations	Bringmann and Kühn (1977)
Gammarus tigrinus	static test; acute toxicity	tap water	Hydrate, unspecified	24 hours	NOEC	7,500			nominal concentration	Mann (1973)

Table 3.9 continued overleaf

Table 3.9 continued Toxicity of sodium perborate (PBS) to aquatic organisms

Species	Method/ Testsystem	Test conditions	Applied compound	Duration	Effect Concentrations*				Remarks	Reference
						mg PBS/l	mg H_2O_2/l	mg B/l		
Algae										
Selenastrum capricornutum	OECD guideline 201; chronic toxicity		Monohydrate	72 hours	EC_{50}	3.3	1.1	0.36	Monitoring of active oxygen; results based on nominal conc.	Solvay Duphar (1993d)
Selenastrum capricornutum	OECD guideline 201; chronic toxicity	reconstituted water	Tetrahydrate	72 hours	EC_{50}	5..5	1.2	0.38	nominal concentration	Thybaud and Lamy (1996)
Scenedesmus quadricauda	cell multiplication inhibition test; static	artificial medium; pH: 7.0	Tetrahydrate	7 days	LOEC	8.3	1.8	0.58	nominal concentration	Bringmann and Kühn (1980a)
Scenedesmus subspicatus	corresponding to OECD guideline 201; chronic toxicity		Tetrahydrate	96 hours	EC_{50}	19.4	4.1	1.4	insufficient documentation	Henkel (1991c)
Scenedesmus subspicatus	corresponding to OECD guideline 201; chronic toxicity		Tetrahydrate	96 hours	EC_{50}	24.3	5.2	1.7	insufficient documentation	Henkel (1991d)
Scenedesmus subspicatus	corresponding to OECD guideline 201; chronic toxicity		Tetrahydrate	96 hours	EC_{50}	26.8	5.7	1.9	insufficient documentation	Henkel (1991e)

Table 3.9 continued overleaf

Table 3.9 continued Toxicity of sodium perborate (PBS) to aquatic organisms

Species	Method/ Testsystem	Test conditions	Applied compound	Duration	Effect Concentrations*				Remarks	Reference
						mg PBS/l	mg H_2O_2/l	mg B/l		
Algae										
Elodea canadensis	photosynthesis inhibition test; flow through system	pH 6.5	Trihydrate	21 days	EC_{22}	25	6.2	2	1 concentration tested on 4 plants; insufficient documentation	Nobel (1981)
Blue-green algae										
Microcystis aeruginosa	cell multiplication inhibition test; static	artificial medium; pH: 7.0	Tetrahydrate	8 days	LOEC	1,040	220	73	nominal concentration	Bringmann and Kühn (1978)
Protozoa										
Chilomonas paramaecium	cell multiplication inhibition test; static	artificial medium; pH: 6.9	Tetrahydrate	48 hours	LOEC	540	116	38	nominal concentration	Bringmann and Kühn (1980b)
Entosiphon sulcatum	cell multiplication inhibition test; static	artificial medium; pH: 6.9	Tetrahydrate	72 hours	LOEC	14.3	3.0	1	nominal concentration	Bringmann and Kühn (1980a)
Uronema parduczi	cell multiplication inhibition test; static	artificial medium; pH: 6.9	Tetrahydrate	20 hours	LOEC	1,560	330	109	nominal concentration	Bringmann and Kühn (1980c)
Bacteria										
Pseudomonas putida	cell multiplication inhibition test; static	artificial medium; pH: 7.0	Tetrahydrate	16 hours	LOEC	14,870	3,160	1,040	nominal concentration	Bringmann and Kühn (1980a)

* Concentrations given as Perborate (PBS) as specified under "applied compound", as H_2O_2 and as boron equivalents

3.2.1.1 Aquatic effects data

As can be seen in **Table 3.9** most aquatic tests were conducted on sodium perborate tetrahydrate. Based on test substance concentrations the few effect data on the monohydrate determined with the same species (fish, daphnia, algae) in comparable test systems were in general by a factor of 2 – 4 lower than results for the tetrahydrate. This is consistent with the lower water content of the monohydrate. Based on boron equivalents, however, data were more or less in the same order of magnitude. So the assessment of the aquatic toxicity was performed for sodium perborate as a whole (based on boron equivalents) and not separately for the mono- and the tetrahydrate.

3.2.1.1.1 Toxicity to fish

Results available on the acute toxicity of sodium perborate on fish are summarised in **Table 3.9** Long-term studies on fish were not available.

The tests performed by Henkel (1991a), Thybaud and Lamy (1996) and Mann (1973) were not considered valid due to insufficient documentation or because the test substance concentrations were not measured during test. The test with zebra fish (*Brachydanio rerio*), which revealed the lowest NOEC (25 mg PBS/l; 7.8 mg H_2O_2/l; 2.7 mg B/l) and LC_{50} (51 mg PBS/l; 16 mg H_2O_2/l; 5.5 mg B/l) values (Solvay Duphar, 1993b), was considered valid without restrictions. Active oxygen concentration was determined before and after the daily renewal of the test solution. At nominal perborate concentrations of 25 - 100 mg/l (corresponding to 7.8 – 31.2 mg H_2O_2/l) active oxygen concentrations were found to be stable during exposure, which could be attributed to the use of reconstituted water (lacking microbial activity). Only at a nominal concentration of 6.3 mg/l (2 mg H_2O_2/l) a decline of active oxygen was observed.

No information on the effects of sodium perborate on marine fish species could be identified.

Further information from tests with degradation products

The acute toxicity of hydrogen peroxide has been comprehensively reviewed in the draft EU-Risk Assessment Report (EU Risk Assessment Report on Hydrogen Peroxide). LC_{50} values were in general lower than 50 mg/l. For *Pimephales promelas* as the most sensitive species tested in a standardised semistatic test system a 96-hour LC_{50} value of 16.4 mg/l was observed (measured concentration) which corresponds closely to the 96-hour LC_{50} value (in hydrogen peroxide equivalents) determined for sodium perborate monohydrate on *Brachydanio rerio* (see above).

The lowest short-term effect values on the acute toxicity of boric acid on fish reviewed by ECETOC (1997), WHO (1998) and RIVM (1999) were found for juvenile Colorado squawfish (*Ptychocheilus lucius*), Razorback sucker (*Xyrauchen texanus*) and Bonytail (*Gila elegans*) exhibiting a 96-hour LC_{50} value of 100 mg B/l each. Most of the reported LC_{50} values, however, were in the range of 220 – 3,400 mg B/l.

Chronic exposure to boric acid revealed lower effect values, particularly when embryo-larval stages of fish were exposed. LC_{50} values were in the range of 22 – 155 mg B/l. NOECs determined in natural surface waters ranged between 0.75 – 18 mg B/l (ECETOC, 1997; RIVM, 1999) with rainbow trout (*Oncorhynchus mykiss*) proving to be most sensitive. Extensive surveys on trout streams and hatcheries in the UK, Germany and the USA gave no indication, that natural boron concentrations of up to 1 mg/l (hatcheries) resp. > 3 mg/l (trout streams) had a limiting effect on rainbow trout populations (EA, 1994; ECETOC, 1997).

In the few tests available boron toxicity on salt water species was found to be in a similar range as for the majority of freshwater fish. The assumption that saltwater species may be more tolerant to elevated boron levels due to higher background levels of boron in seawater compared to freshwater was not verified in two tests. Coho salmon (under yearlings) and common eel (see also **Table 3.9**) proved to be more sensitive in saltwater than in freshwater resp. in water with lower salinity (ECETOC, 1997; WHO, 1998).

3.2.1.1.2 Toxicity to aquatic invertebrates

Results on the acute toxicity of sodium perborate on aquatic invertebrates are summarised in **Table 3.9**. Long-term studies on aquatic invertebrates were not available.

Only the test resulting in the lowest EC_{50} and NOEC values of 11 and 8 mg PBS/l (3.4 and 2.5 mg H_2O_2/l; 1.2 and 0.86 mg B/l) for the toxicity of sodium perborate monohydrate on water fleas (*Daphnia magna*), respectively, could be considered valid without restrictions (Solvay Duphar, 1993c). For initial nominal sodium perborate concentrations of 2 - 32 mg/l loss of active oxygen concentrations measured daily during exposure was < 11 %. Two other guideline studies with *Daphnia magna* and sodium perborate tetrahydrate are considered less reliable because of insufficient documentation (Henkel, 1991b) or because effect data were based on nominal concentrations (Thybaud and Lamy, 1996). Nevertheless results from both studies (EC_{50}: 6.4 and 5.3 mg H_2O_2/l; 2.1 and 1.05 mg B/l, respectively) support the effect data reported in Solvay Duphar (1993c).

No information on the effects of sodium perborate on marine invertebrates could be identified.

Further information from tests with degradation products

Results from two short-term tests on the toxicity of hydrogen peroxide on *Daphnia magna* and *Daphnia pulex* have been reviewed in the EU Risk Assessment Report on Hydrogen Peroxide, revealing EC_{50} values of 2.3 and 2.4 mg/l, respectively. Effect data from long-term tests were not available.

From short-term-tests on the toxicity of boric acid on *Daphnia magna* EC_{50} values in the range of 73 - 320 mg B/l were reported in RIVM (1999). Lowest NOEC values from long-term tests (21 d) were between 6 and 29 mg B/l.

3.2.1.1.3 Toxicity to aquatic plants, including algae

Results on the long-term toxicity of sodium perborate on aquatic plants are summarised in **Table** 3.9. Three studies on the effect of sodium perborate on cell multiplication of the green algae *Selenastrum capricornutum* and *Scenedesmus quadricauda* revealed similar results. The EC_{50} value of 3.3 mg PBS/l (1.1 mg H_2O_2/l; 0.36 mg B/l) from the test on *Selenastrum capricornutum* performed by Solvay Duphar (1993d) was the lowest valid EC_{50} value reported for aquatic species. Only in this test the active oxygen content has been monitored during exposure. Thus, it is the only test among the algal test performed which can be considered valid. A rapid decrease of active oxygen, probably due to biotic elimination (see Section 3.1.1.2), was observed in this test: 35% after one day and nearly 90% after 2 days of incubation. As stated in OECD-guideline 201, however, disappearence of the test compound in the test solution does not necessarily invalidate the test. So, considering the removal of the test substance in the test medium, the results are taken into account for the evaluation of the aquatic toxicity of sodium perborate.

Furthermore, an inhibition of the biomass growth was observed in this study at the lowest nominal concentration tested (0.62 mg PBS/l), but not at the higher concentrations. This leads to an unclear monotonic dose response curve and consequently no NOEC could be derived (NOEC should be 2.5 mg PBS/l, but has to be confirmed by repeating the test).

No information on the effects of sodium perborate on marine plants could be identified.

Further information from tests with degradation products

The lowest LOEC/NOEC values from long-term tests on the effect of hydrogen peroxide on different algal species were in general ≤ 1 mg/l (EU Risk Assessment Report on Hydrogen Peroxide) and therefore comparable to the results observed in tests with sodium perborate (see **Table 3.9**).

For the chronic toxicity of boric acid on *Scenedesmus subspicatus* LC_{10}/LC_{50} values of 24/52 mg B/l were reported in ECETOC (1997).

Two studies are available on the toxicity of boric acid on marine phytoplankton revealing effect values in the same order of magnitude as for freshwater algae (ECETOC, 1997). At concentrations of ≥ 50 mg B/l a redistribution of marine algal species was observed, favouring the growth of the more tolerant species and supressing the sensitive among the 19 species tested (Anitia and Cheng, 1975).

3.2.1.1.4 Toxicity to sediment dwelling organisms

Experimental studies on the effects of sodium perborate on sediment dwelling organisms were not available.

3.2.1.1.5 Toxicity to micro-organisms, including protozoa

From the two tests on bacteria summarised in **Table 3.9**, *Pseudomonas putida* showed only low sensitivity in a cell multiplication inhibition test with sodium perborate tetrahydrate, whereas the blue-green alga *Microcystis aeruginosa* proved to be more sensitive exhibiting a long-term LOEC of 1,040 mg PBS/l (220 mg H_2O_2/l; 73 mg B/l). A cell multiplication inhibition test with hydrogen peroxide (*Pseudomonas putida)* revealed a much lower effect value (see below). No explanation for this considerable difference in bacteria toxicity between sodium perborate and hydrogen peroxide was found in the underlying literature. Rapid degradation of perborate/H_2O_2 in the applied artificial medium of Bringmann and Kuehn (1980a) may have resulted in only minimal exposure of the test species result but more reasonable are specific differences in species sensitivity under the given test regime.

Significant differences in sensitivity were found in tests on the influence of sodium perborate tetrahydrate on 3 species of protozoa, which occur in activated sludge (see **Table 3.9**). The LOEC value for *Entosiphon sulcatum* (14.3 mg PBS/l; 3.0 mg H_2O_2/l; 1.0 mg B/l) was by a factor of approximately 100 lower than the value for *Uronema parduczi* and 40 times higher than that for *Chironomas paramaecium*. These differences are unexpected considering the fact that *Entosiphon sulcatum* has been found in aeration tanks of biological waste water treatment plants with an annual average concentration of 2.12 mg B/l (Guhl, 1992) and may tolerate borate concentrations of up to 10 mg B/l with appropriate feeding (Guhl, 1996). A possible explanation

for these conflicting results may be found in a specific sensitivity of *Entosiphon* for the primary degradation product hydrogen peroxide.

Gerike et al. (1976) tested the influence of sodium perborate trihydrate on the activity of activated sludge, indicated by the decrease of methylenblue (MBAS) and the chemical oxygen demand (COD) in laboratory models of waste water treatment plants (OECD confirmatory test). The test substance was applied in wastewater, adapted for 2 weeks, at concentrations of 125, 250 and 500 mg PBS/l (31, 62 and 124 mg H_2O_2/l; 10, 20 and 40 mg B/l). The retention time in the activated sludge vessels was 3 hours. For both parameters concentrations of up to 250 mg PBS/l (62 mg H_2O_2/l; 20 mg B/l) showed a slight increase, indicating a slight improvement in the clean-up performance of activated sludge. At 500 mg PBS/l (124 mg H_2O_2/l; 40 mg B/l) a slight inhibitory effect was observed but not quantified.

Dimkov et al. (1985) examined the effect of sodium perborate on the biodegradation of alkylbenzene sulphonates by *Pseudomonas fluorescens* and *Aspergillus* sp., isolated from non-adapted sewage effluent. No exact information was given on test conditions and the nature of the perborate compound used. The presence of 20% sodium perborate in detergents reduced the biodegradation of alkylbenzene sulphonates for *Pseudomonas fluorescens* by 65% and for *Aspergillus sp*. by 40%. Sodium perborate reduced biomass growth of both strains to a lesser degree than biodegradation.

Further information from tests with degradation products

From a cell multiplication inhibition test on the toxicity of hydrogen peroxide on *Pseudomonas putida* an EC_{10} value of 11 mg/l (nominal concentration) was reported, which is in contrast to the low value determined for sodium perborate with the same bacterium (see **Table 3.9**). In an activated sludge respiration inhibition test (according OECD guideline 209) with non-adapted sludge an EC_{50} value of 466 mg/l was determined. Bacteriostatic effects of hydrogen peroxide on *Pseudomonas aeruginosa* and *Staphylococcus aureus* were observed at a concentration of 5.1 mg/l (EU Risk Assessment Report on Hydrogen Peroxide).

No data were available on the aquatic toxicity of boric acid on microorganisms.

3.2.1.1.6 Toxicity in microcosm studies

The aquatic toxicity of sodium perborate tetrahydrate was examined in a laboratory multi-species system consisting of unicellular (bacteria algae, protozoa) and small multicellular organisms (Henkel, 1991f). During the exposure period the test solution was renewed daily. After 3 weeks of incubation a NOEC value of 1.4 mg PBS/l (0.32 mg H_2O_2/l; 0.10 mg B/l) and a LOEC of 2.5 mg PBS/l (0.58 mg H_2O_2/l; 0.18 mg B/l) based on nominal sodium perborate concentrations were determined. Due to the insufficient documentation this study can not be considered valid.

3.2.1.2 Calculation of PNEC for the aquatic compartment

In aqueous solutions sodium perborate is in equilibrium with hydrogen peroxide. This equilibrium is largely on the side of hydrogen peroxide in the environmentally relevant concentration range (see Section 1.3). The short-term effects found in tests with fish, invertebrates, green algae and microorganisms (see **Table 3.9**) are assumed to be dominated by the effects of the reactive peroxo group, which is present both in sodium perborate and in the degradation product hydrogen peroxide, for the following reasons:

- given as hydrogen peroxide concentrations the effect concentrations summarised in **Table 3.9** closely correspond to effect concentrations from investigations with hydrogen peroxide reported in the risk assessment report of hydrogen peroxide (EU Risk Assessment Report on Hydrogen Peroxide)
- the pattern of effect concentrations in different species is very similar for sodium perborate and hydrogen peroxide (Table 3.1; EU Risk Assessment Report on Hydrogen Peroxide)
- given as boron concentrations, short-term toxicity tests with sodium perborate revealed much lower effect levels for most aquatic species than comparable tests with boric acid.

From this it can be concluded that short-term effects are dominated by the presence of hydrogen peroxide (active oxygen) in the aqueous solutions. For the evaluation of short-term effects therefore the PNECaqua (H_2O_2) was used which was already derived in the EU Risk Assessment Report on Hydrogen Peroxide and is given to 10 µg/l.

Boric acid is assumed to be the relevant long-term degradation product. Undissociated boric acid is expected to be the predominant boron species in natural fresh water with a pH of 6-9 (ECETOC, 1997) and should be responsible for possible aquatic toxicity in this compartment. Hence, the environmental risk assessment for long-term aquatic effects of sodium perborate should consider boric acid which is part of the boron compounds from the 4th priority list and will be evaluated in that context.

No experimental data are available on the effects of sodium perborate on marine organisms. Estuarine and marine organisms are assumed to be tolerant to boron compounds, considering their chronic exposure to – compared to freshwater – elevated boron concentrations of approximately 5 mg/l. Although in some fish studies salt water species proved to be more sensitive than freshwater species (WHO, 1998), most reviewers conclude that toxicity of boron is similar in seawater and freshwater (RIVM, 1999).

3.2.1.3 Calculation of PNEC for the sediment dwelling organisms

Experimental results are not available and the application of the estimation method given in the TGD is not assumed to be adequate for ionic substances (see Section 3.1.2.2). So a PNEC for sediment dwelling organisms cannot be calculated.

Sodium perborate is rapidly degraded in natural water containing viable micro-organisms (see Section 3.1.1.2) and a significant adsorption in surface water is not to be expected (see Section 3.1.1.3). Hence, benthic organisms are expected to be sufficiently covered by the PNEC derived for aquatic organisms of the water-phase (see Section 3.2.1.2).

3.2.1.4 Calculation of PNEC for the microorganisms, including protozoa

None of the available results determined in tests with microorganisms including bacteria, protozoa, blue-green algae and activated sludge were performed according to internationally accepted guidelines.

Effects of sodium perborate tetrahydrate on blue-green algae, protozoa and on the activity of activated sludge were in the relatively narrow range of 540 – 1,560 mg PBS/l with the exception of *Pseudomonas putida* showing very low sensitivity and the protozoa *Entosiphon sulcatum* exhibiting high sensitivity in a cell multipication inhibition tests.

According to the TGD (1996) and the Technical Recommendation ECB4/TR1/98 from 09/1998 the $PNEC_{microorganisms}$ should take into account adverse effects on the microbial activity in a STP. Results from tests using a mixed microbial inoculum are considered to be more relevant than effects determined in single species tests. According to the TGD short-term results should be preferred for assessment considering retention times in STPs (e.g. few hours). Taking furthermore into account the rapid degradation of sodium perborate in most non-sterile aqueous media, it seems adequate only to consider the slight inhibitory effect (treated here as LOEC) of sodium perborate trihydrate on activated sludge activity observed by Gerike et al. (1976) at 500 mg PBS/l as a basis for deriving the $PNEC_{microorganisms}$. In this test the effect on two different parameters was determined both indicative for microbial activity/degradation potential of the activated sludge (retention time in the activated sludge vessels: 3 hours).

According to the TGD a NOEC or EC_{10} from 'other test systems' (relevant to microbial degradation activity in STP) has to be divided by an assessment factor of 10, but as the measured endpoints are directly related to the protection of the microbial degradation activity in STP, an assessment factor of 1 was used for calculating the $PNEC_{microorganisms}$:

$$PNEC_{microorganisms} = 500 \text{ mg PBS/l}$$

Information on the $PNEC_{microorganisms}$ for the degradation product hydrogen peroxide can be found in the EU Risk Assessment Report on Hydrogen Peroxide.

3.2.2 Terrestrial compartment

Experimental studies on the effects of sodium perborate on terrestrial organisms were not available. As for the assessment of effects on sediment dwelling organisms the application of the estimation method given in the TGD is not assumed to be adequate for ionic substances (see Section 3.1.2.2).

Further information from tests with degradation products

Studies on the toxicity of boric acid on different terrestrial species have been reviewed in Butterwick (1989), ECETOC (1997) and WHO (1998). Whereas bacteria and fungi proved to be not very sensitive to boron, high concentrations of boric acid are used as effective insecticides in protecting wood and other substrates against insect attack (doses: 0.25 - 0.55 kg B/m^3 of substrate). LD_{50} for honey bees was approximately 100 mg boric acid/l (in syrup). Boron has long been recognised as an essential micronutrient for plants involved in many metabolic processes, although the precise nature of its functioning is still unclear. Boron content in crops is plant dependant generally in the range of 1 - 100 mg B/kg dry weight with the margin between the amounts necessary for optimal growth and phytotoxic concentrations for many species obviously being very small. In sensitive species like barley or citrus phytotoxic effects (e.g. chloroses) are seen at contents of 100-115 mg B/kg with the lowest values reported for lemon trees (1 mg B/kg) (Sposito and Calderone, 1988). Severe toxicity symptoms may be produced when crops are irrigated with water from wells located in areas with boron excess in soil: e.g. arid soils, soils derived from marine sediments or any parent material rich in boron.

3.2.3 Atmosphere

Experimental studies on the effects of sodium perborate in the atmosphere were not available.

3.2.4 Secondary poisoning

Due to the ionic nature of sodium perborate and their degradation products a potential for bioaccumulation is not to be expected. Furthermore, the emerging hydrogen peroxide will be reduced rapidly (see EU Risk Assessment Report on Hydrogen Peroxide).

Further information from tests with degradation products

No experimental results on the bioaccumulation of boric acid could be identified in the available reviews.

Concerning bioaccumulation of inorganic borates in fish ECETOC (1997) reviewed Bioconcentration Factors (BCF) calculated from borate concentrations in field collections of several fish; BCF values were in the range of 0.1 - 1.25 indicating no significant potential for bioaccumulation. Further studies on bioaccumulation of boron were discussed by WHO (1998).

3.3 RISK CHARACTERISATION

The risk assessment on hand assesses the risk arising from sodium perborate and its degradation product hydrogen peroxide. The conclusions drawn solely refer to the risk arising from these substances.

The risk characterisation of the degradation product boric acid will be done when the results of the effect assessment of boric acid will be available.

3.3.1 Aquatic compartment

Water is the main target compartment of sodium perborate due to its physico-chemical properties and its use pattern. As the substance is instable in water the hydrolysis resp. degradation products hydrogen peroxide and boric acid (i.e. boron) have to be considered for risk assessment.

The $PNEC_{water}$ for hydrogen peroxide was derived in the EU RAR on Hydrogen Peroxide to 10 µg/l.

The $PNEC_{water}$ for boron will be derived in the future EU Risk Assessment on boric acid and sodium tetraborates. The PEC data derived in this report will be then used to complete the risk characterisation for boric acid.

PEC/$PNEC_{water}$

Production Hydrogen peroxide:

For production sites with STP it is assumed that hydrogen peroxide is completely degraded in the STP or that there are no emissions. 6 out of 9 production sites were already assessed in the EU Risk Assessment Report on Hydrogen Peroxide as these are also production sites for hydrogen peroxide. There is one production site with sole production of sodium perborate. This site has no STP, but it has changed the production process in July 2001 so that sodium perborate is no longer emitted. Therefore it is assumed that no hydrogen peroxide is emitted either and **conclusion (ii)**

	can be derived for this site. **Conclusion (iii)** applies to two production sites (C, F) producing sodium perborate as well as hydrogen peroxide, which do not have STP and which were already assessed in the EU Risk Assessment Report on hydrogen peroxide. Boron: For PEClocal data see Section 3.1.2.6.
Formulation	Hydrogen peroxide: For formulation sites with STP (individual abbreviation not known) it is assumed that hydrogen peroxide is completely degraded in the STP. These have therefore not to be considered further in the risk characterisation: **Conclusion (ii)**. For the remaining two sites a $PEClocal_{water}$ of 31.5 µg/l was estimated (see Section 3.1.2.2). From this a PEC/PNEC ratio of 3.15 is calculated which leads to **conclusion (iii)**. Boron: For PEClocal data see Section 3.1.2.6.
Processing	Only very small amounts of the production quantity are used in organic synthesis. A significant additional risk from possible releases into the aquatic compartment is not to be expected: **Conclusion (ii)**.
Consumer use of detergents and bleaching agents	Hydrogen peroxide: It is assumed that hydrogen peroxide is completely degraded during the washing process and in domestic waste water. This has therefore not to be considered further in the risk characterisation: **Conclusion (ii)**. Boron: For PEClocal data see Section 3.1.2.6.
Institutional use of detergents and bleaching agents	Hydrogen peroxide: It is assumed that hydrogen peroxide is completely degraded during the washing process and in domestic waste water. This has therefore not to be considered further in the risk characterisation: **Conclusion (ii)**. Boron: For PEClocal data see Section 3.1.2.6.

PEC/$PNEC_{stp}$

A $PNEC_{stp}$ for sodium perborate of 500 mg/l was derived in Section 3.2.1.2. As it is not to be expected that significant amounts of the substance are removed from the STP via volatilisation or adsorption the concentration in the STP effluent $Clocal_{effl} = Clocal_{infl} = PEC_{stp}$. Data on PEC_{stp} are available for production and formulation (see **Table 3.5** and **Table 3.6**). The risk characterisation ratios are given in **Table 3.10**. Only very small quantities of sodium perborate are processed in chemical synthesis. A quantification of PEC_{stp} deems therefore not to be necessary. Due to its rapid degradation in the washing process and in domestic waste water it is

not to be expected that significant amounts of sodium perborate are released to STPs from the consumer and institutional use of detergents and bleaching agents.

A PEC_{stp} (boron) was derived for these uses which have to be considered in the future EU Risk Assessment on boric acid and sodium tetraborates.

Table 3.10 $PEC/PNEC_{stp}$ for production and formulation

Production site	$PEC/PNEC_{stp}$
A	0.003
B	1.5
C	0.027
D	0.054
F [a]	0.051-3.1
H	0.27
I	0
K	0.04

Formulation site	$PEC/PNEC_{stp}$
AA	0
BB	0.001
CC	0.002
DD	0.002
EE	0.004
FF	0.005
GG	0.005
II	0.01
JJ	0.01
KK	0.02
LL	0.02
MM	0.02
NN	0.03
OO	0.04
PP	0.09

a) Production will be ceased before January 2003

For two production sites (B, F) the PEC/PNECstp ratio exceeds 1 which leads to **conclusion (iii)**. For the remaining production sites and the formulation sites **conclusion (ii)** can be derived.

Information on the PEC/PNECstp for the degradation product hydrogen peroxide can be found in the EU Risk Assessment Report on Hydrogen Peroxide.

$\underline{PEC/PNEC_{sediment}}$

Data on $PEC_{sediment}$ and $PNEC_{sediment}$ of sodium perborate are not available. The calculation methods given in the TGD are not assumed to be adequate for ionic substances. It is not to be expected that sodium perborate or its degradation product boric acid adsorb significantly onto the sediment. Therefore a risk characterisation for this compartment is not deemed necessary.

3.3.2 Atmosphere

Under dry conditions no degradation of sodium perborate will occur. $PECregional_{air}$ (sodium perborate) was estimated to > 338 ng/m^3 (> 25 ng boron/m^3). There are no data available on the effects of airborne sodium perborate on terrestrial species. An effects assessment for airborne sodium perborate seems not of high priority as the atmosphere is not the main target

compartment of the substance. It is furthermore to be expected that airborne sodium perborate will be rapidly washed out of the atmosphere by wet deposition due to its high water solubility. **Conclusion (ii)** applies to all life cycle steps mentioned below as there are no significant releases to be expected.

Production	Release data are available for sites producing sodium perborate tetrahydrate. $PEClocal_{air}$ is between 0.3 and 11.4 mg/m^3.
Formulation	A generic estimation gave a mean $PEClocal_{air}$ of 0.03 mg sodium perborate/m^3.
Processing	Only very small amounts of the production quantity are used in organic synthesis.
Consumer use of detergents and bleaching agents	No significant releases to be expected.
Institutional use of detergents and bleaching agents	No significant releases to be expected.

3.3.3 Terrestrial compartment

Data on the treatment of waste from production and formulation are lacking. According to one producer, material which e.g. does not fulfil the specifications is recycled in the process. It is not clear if this information is representative for industry. Emissions into the terrestrial compartment from sewage sludge or via atmospheric deposition are assumed to play a minor role. Studies on the effects of sodium perborate on terrestrial organisms are not available.

As it is to be assumed that sodium perborate will degrade rapidly in soil, terrestrial organisms may further be exposed to the degradation product boric acid. An effects evaluation for these compounds will be carried out in a future EU Risk Assessment Report on Boric acid and sodium tetraborates.

3.3.4 Secondary poisoning

From the ionic structure of sodium perborate and its degradation product boric acid it can be concluded that a significant accumulation of these substances in the biota is not to be expected. Also the bioaccumulation potential of hydrogen peroxide emerging during degradation is low (see EU RAR on Hydrogen Peroxide). A risk characterisation of non-compartment specific effects relevant to the food chain is therefore not necessary.

4 HUMAN HEALTH

4.1 HUMAN HEALTH (TOXICITY)

4.1.1 Exposure assessment

4.1.1.1 General discussion

Exposure to sodium perborate from dusts and in several cases also from contact with solutions can take place at the workplace during the production, formulation and use of detergent products and bleaching agents.

The general public may be exposed to sodium perborate from the use of detergent products during laundry washing and automatic dishwashing and from the use of denture cleansers. During the consumer use of detergent products and bleaching agents, in addition to the exposure to sodium perborate tetra- and monohydrate an exposure to the degradation products, i.e. hydrogen peroxide and boric acid, may also occur.

An indirect exposure of man via the environment to sodium perborate is unlikely as it is degraded in sewage treatment plants (see Section 3.1.1.2.2). However, boron from sodium perborate may be ingested with drinking water which was produced from fresh water containing boric acid from the use of detergent products and bleaching agents.

4.1.1.2 Occupational exposure

Substance specific occupational exposure limit values (OELs) for sodium perborate are not available. As the substances are used at the workplaces in the form of powder the general threshold limit value for dust could be applied. It has to be mentioned, however, that sodium perborate dust is soluble whereas the OELs for dust relate to insoluble particulate matter. In Germany this is established as a concentration of the respirable fraction of the powder of 1.5 mg/m^3 and a concentration of the inhalable fraction of 4 mg/m^3. The occasional exceeding of the MAC value by single shift average levels can be tolerated up to a factor of two (MAK, 2001). In other European countries (Italy, France) obviously the US ACGIH standard of 10 mg/m^3 for inhalable particulates and 5 mg/m^3 for respirable particulates is applied (ACGIH, 1992/1993). In its most recent edition the treshold limit value for respirable dust was lowered to 3 mg/m^3 (ACGIH, 2000). In Spain the limit for the inhalable fraction is 10 mg/m^3, and the respirable fraction 3 mg/m^3 (Ministry of Labour, Spain, 2001-2002)

Occupational exposure occurs mainly during production of sodium perborate and during formulation of detergents containing sodium perborate. These exposure scenarios are analysed in detail in Section 4.1.1.2.1 and Section 4.1.1.2.2.

Minor amounts (< 10 tonnes each) are used as polymerisation aid in polysulfide-sealants and in the textile bleaching industry. Little information on exposure is available for these scenarios, but they may involve similar operations as in production and formulation, especially filling operations. Therefore it is assumed that these uses are covered by the scenarios production and formulation.

Exposure may also occur from professional use of the detergents either in laundries or in canteens or restaurants and from the use of detergents for hospital cleaning. Only little information from industry is available. The exposure assessment is presented in Section 4.1.1.2.3.

No information is available on professional users exposed to products containing residual perborate. This exposure is considered of minor importance, because professional use, especially of detergents, always involves conditions where sodium perborate is degraded, as bleaching by the degradation products is the intended purpose. As shown in Section 2.1.1.1 between 65 and 78% of the sodium perborate is degraded during machine washing.

A number of dust measurements are available especially for production and formulation (see **Table 4.1** and **Table 4.5**). These were used for the estimation of the inhalation exposure to sodium perborate. Measurements on the dermal exposure are not available. This was therefore calculated with the workplace model EASE. Oral exposure is assumed to be prevented by personal hygiene measures.

4.1.1.2.1 Production

Production of sodium perborate is essentially a continuous process conducted in closed systems until the product is transported on a conveyor belt to the dryer, the process itself is automated and all operations are fully located within a closed building. Dust exposure may occur during filling operations and maintenance. During maintenance and cleaning, contact with a sodium perborate solution of about 5% might occur (CEFIC, 1998).

Operations associated with rework of powder range from 10 minutes once per day to 30 minutes once per week (CEFIC, 2001b).

According to the information for 2 plants, maintenance work is typically conducted in production units that are not running (CEFIC, 2001c).

For most of the workplace operations the use of gloves and goggles is common practice at the manufacturing companies. For some operations such as process and maintenance operations also the use of dust masks is reported. At several manufacturers the filling and weighing processes are segregated or provided with local exhaust ventilation (CEFIC, 1998; 1999a). The closed dryers either work under reduced pressure which drags the exhaust to the exhaust treatment devices or under positive pressure where excess dust is removed by a cyclone/jet filter (CEFIC, 1998).

Altogether, about 250 persons are employed continuously (> 50% of the working hours, 3 shifts, no females) in the production of sodium perborate and about 150 intermittently (≤ 50% of the working hours, 6 females) (CEFIC, 1999).

Inhalation

Measured data for the inhalation exposure to dusts containing sodium perborate during the workplace operations “Filling / emptying / transferring”, “Weighing / mixing”, “Transport of bags”, “Storage”, “Process”, “Cleaning / maintenance” and “Laboratory operations” and Disposal/waste management are available for 8 of the 12 European production sites. The data provided by CEFIC (1999a; 2001b) are compiled in **Table 4.1**. As only measurements from one company are available for disposal/waste management also calculated levels are given. For the EASE model dry manipulation with local exhaust ventilation was assumed. The substance was

defined in terms of EASE as mobile solid without vapour pressure generating a non-fibrous, non-aggregating dust. **Table 4.1** gives the results of the exposure measurements provided by CEFIC.

For some of the production sites quite a number of measurements are available. The measurements were performed between 1990 and 2001. The number of measurements per production site ranged from 1 to 16. Single values were not provided. Ranges for the exposure measurements are available in most cases, 90^{th} percentiles and medians only for some cases. Area as well as personal measurements are available.

The parameter measured was in most cases inhalable dust. The data in **Table 4.1** and **Table 4.2** show, that the amount of the respirable dust in workplace air is about 30 to 50% of the inhalable fraction in the personal samples at workplaces with filling, emptying and transferring operations (CEFIC, 1999; CEFIC 2001a; Site A, site L). A lower proportion (about 10%) was found in process operations in area measurements.

In the risk assessment the data on the exposure concentrations for inhalable dust are used for the following reasons:

- very extensive database for different exposure situations
- highest concentrations measured
- the inhalable dust is the maximum dose which may reach any part of the airways.

Exposure measurements were made by weighing the dust; in some cases specific measurements were made on the boron content of the dust. From several measurements related to the boron concentration of the dust it can be concluded that both, inhalable and respirable dust consist mainly of sodium perborate (**Table 4.1**, site A and site J: filling, emptying, transferring, CEFIC, 1999). Also in a recent study, where boron concentrations of inhalable and respirable dust were measured during filling operations, it was shown, that sodium perborate monohydrate and sodium perborate tetrahydrate accounted for the total dust concentration measured (CEFIC, 2001a).

For the risk assessment, it was assumed that the inhalable dust consists solely of the sodium perborate.

It was not specified for a number of measurements whether these were carried out during the production of the tetrahydrate or the monohydrate. It was not possible to gain information on this as sodium perborate tetrahydrate and monohydrate are produced both at these sites. Nevertheless, the results from measurements with a specified compound do not differ significantly as the same technological processes are used for the production of tetra- and monohydrate. Therefore for the risk assessment, no difference was made for sodium perborate or sodium perborate monohydrate.

Table 4.1 Worker exposure to sodium perborate mono- and tetrahydrate containing dusts from the production

Production site	Origin of dust	Workplace operation	Measurements			Concentration (mg/m³)				Year	Reference
			No	Type		Inhalable			Respirable		
						range	median	90th perc	range		
A	not specified	Filling, emptying, transferring	3	personal	TWA				0.2-0.4	1991-1993	CEFIC (1999)
A	PBS1* production	Filling, emptying, transferring	2	personal	TWA				0.3-0.4 PBS1 e)	1991	CEFIC (1999)
A	not specified	Filling, emptying, transferring	5	personal	TWA	0.06-0.4				1994-1995	CEFIC (1999)
A	not specified	Filling, emptying, transferring	6	area	TWA				0.4-0.7	1991	CEFIC (1999)
A	not specified	Filling, emptying, transferring	5	area	TWA	0.2-0.8				1994-1995	CEFIC (1999)
A	PBS1	Filling, emptying, transferring	1	personal	4hours	1.09			0.36	2001	CEFIC (2001a)
A	PBS1	Filling, emptying, transferring	1	personal	4hours	1.40 PBS1			0.40 PBS1	2001	CEFIC (2001a)
A	PBS4	Filling, emptying, transferring	1	area	1.5 hours	1.22			0.15	2001	CEFIC (2001a)
A	PBS4	Filling, emptying, transferring	1	personal	1.5hours	0.56			0.15	2001	CEFIC (2001a)
C c)	not specified	Filling, emptying, transferring	2	area	no data	2.1-2.4				1998	CEFIC (1999)
E a)	not specified	Filling, emptying, transferring	4 per year	area	no data	1.5 / 4.5				1997/98	CEFIC (1999)
F d)	not specified	Filling, emptying, transferring	8	area	TWA	0.1-13.7	0.95	12.1		1996	CEFIC (1999)
F d)	not specified	Filling, emptying, transferring, Weighing, mixing, Transport of bags	9	personal	TWA	0.2-6.5	1.0	5.0		1996	CEFIC (1999)
F d)	not specified	Filling, emptying, transferring, Weighing, mixing, Transport of bags	8	personal	TWA	0.1-2.8	1.8	2.7		1997	CEFIC (1999)
G b)	PBS4* production	Filling, emptying, transferring, Weighing, mixing, Transport of bags	15	personal	no data	0.50-11.7				1990	CEFIC (1999)

Table 4.1 continued overleaf

Table 4.1 continued Worker exposure to sodium perborate mono- and tetrahydrate containing dusts from the production

Production site	Origin of dust	Workplace operation	Measurements			Concentration (mg/m³)				Year	Reference
			No	Type		Inhalable			Respirable		
						range	median	90th perc	range		
G [b]	PBS4 production	Filling, emptying, transferring	16	personal	no data	0.50-0.99		0.95		1992	CEFIC (1999)
G [b]	PBS4 production	Filling, emptying, transferring, Weighing, mixing, Transport of bags	5	personal	no data	0.15-4.85	2.14	4.78		1997	CEFIC (1999)
G [b]	PBS4* production	Filling, emptying, transferring, Weighing, mixing, Transport of bags	6	personal	no data	0.32-2.26	0.43	1.82		1997	CEFIC (1999)
G [b]	PBS4 production	Filling, emptying, transferring, Weighing, mixing, Transport of bags	6	personal	no data	0.32-1.55	0.58	1.46		1997	CEFIC (1999)
G [b]	PBS1*	Filling, emptying, transferring, Weighing, mixing, Transport of bags	15	personal	no data	0.50-8.62	2.45	7.53		1990	CEFIC (1999)
G [b]	PBS1	Filling, emptying, transferring, Weighing, mixing, Transport of bags	no data	personal	no data	0.50-4.21	0.51	3.18		1997	CEFIC (1999)
L [a]	not specified	Filling, emptying, transferring, Weighing, mixing, Transport of bags	7	personal	TWA	0.61-5.9			0.44-2.09	1993-1997	CEFIC (1999)
F [d]	not specified	Filling, emptying, transferring, Weighing, mixing, Transport of bags	12	area	TWA	0.1-4.4	0.55	4.3		1997	CEFIC (1999)
J	PBS4* production	Filling, emptying, transferring, Weighing, mixing, Transport of bags	2	area	2 hours	1.3-2.0				1991	CEFIC (1999)
J	PBS4 production	Filling, emptying, transferring, Weighing, mixing, Transport of bags	2	area	2 hours	0.73-1.4 4 PBS4 [e]				1991	CEFIC (1999)
I	not specified	Weighing, mixing	no data	area	24 hours contin.	3-9				1998	CEFIC (1999)
C [c]	not specified	Weighing, mixing	2	area	no data	3.3-3.7				1998	CEFIC (1999)

Table 4.1 continued overleaf

Table 4.1 continued Worker exposure to sodium perborate mono- and tetrahydrate containing dusts from the production

Production site	Origin of dust	Workplace operation	Measurements			Concentration (mg/m³)				Year	Reference
			No	Type		Inhalable			Respirable		
						range	median	90th perc	range		
E a)	not specified	Weighing, mixing	4 per year	area	no data	1.3 / 1.5				1997/98	CEFIC (1999)
C c)	not specified	Transport of bags	2	area	no data	0.9-1.1				1998	CEFIC (1999)
L a)	not specified	Process	>2	personal	TWA	1.95			0.13-0.23	1993	CEFIC (1999)
E a)	not specified	Process	8 per year	area	no data	0.8 / 1.0				1997/98	CEFIC (1999)
-	-	Disposal, Waste management		calculated	2-30 min	5-25				-	CEFIC (2001b)
-	-	Disposal, Waste management		calculated	8 hours TWA	2.8				-	CEFIC (2001b)
-	-	Disposal, Waste management		calculated	TWA	2-5				-	EASE (own calculations)
F d)	PBS4	Rework of powder	12	personal	8 hours TWA	0.1-1.1	0.5	0.88		1998, 1999	CEFIC (2001b)
C c)	not specified	Storage, Maintenance, Laboratory operations	2	area	no data	0.8-0.9				1998	CEFIC (1999)
C c)	not specified	Storage, Maintenance, Laboratory operations	2	area	no data	0.3-0.4				1998	CEFIC (1999)
C c)	not specified	Storage, Maintenance, Laboratory operations	2	area	no data	0.3				1998	CEFIC (1999)

a) Production ceased in 1999 (CEFIC, 2000a);
b) Production ceased in 2000 (CEFIC, 2000b),
* PBS4 = Sodium perborate, tetrahydrate;
PBS1 = sodium perborate, monohydrate;
c) Production discontinued permanently in June 2003,
d) Production ceased before January 2003,
e) Measured as boron,
- not applicable

Short-term measurements were in the range of the 8-hour TWA measurements, even if they were carried out at workplaces with presumed high exposure. Four short-term measurements (site J in **Table 4.1**, combined workplace operations "Filling, emptying, transferring", "Weighing, mixing", "Transport of bags") being carried out by area air sampling do not significantly differ from the personal TWA values. Also 4 hours personal average concentrations of sodium perborate monohydrate and 1.5 hours personal average concentrations of sodium perborate tetrahydrate (inhalable dust) at site A (CEFIC, 2001a) at workplaces with maximum exposure (i.e. filling in bags, inspecting and cleaning of the production unit) were 1.09 and 0.56 mg/m^3 of inhalable dust (**Table 4.2**) and thus even in the lower range of the exposure levels given in **Table 4.1**. In this investigation airborne dust was sampled and monitored continuously. In **Figure 4.1**, the personal measurements for a filling operation are shown. Although, there is indeed one short term peak of up to 20 mg/m^3 of inhalable dust, the overall dust concentration during this operation is about 1 mg/m^3.

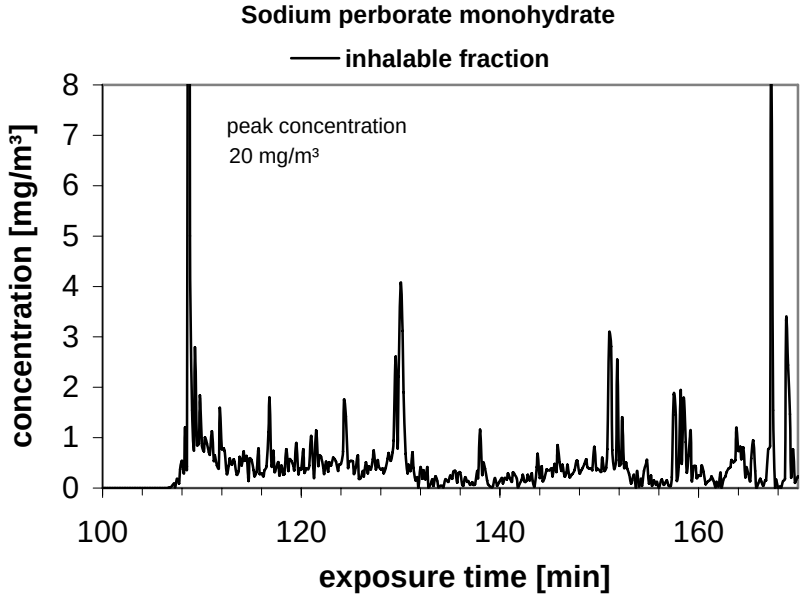
Therefore for the risk assessment a scenario on short term exposure was not included.

Table 4.2 Average mass concentration of perborate during filling and cleaning (Site A)

Comp.	Duration of measurement (h)	Dust concentration					
		Inhalable dust personal measurement (mg/m³)		resp. (%)	Inhalable dust, stationary measurement (mg/m³)		resp. (%)
		Grav.	Chem.		Grav.	Chem.	
PBS	4	1.09	1.40	33	1.9	1.83	44
PBS4	1.5	0.56	n.d.	27	1.22	n.d.	12

Grav. Gravimetric determination of dust concentration
Chem. Determination of boron in sample, concentrations given as PBS and PBS4 respectively
resp. Respirable fraction of dust

Figure 4.1 Personal measurement of inhalable sodium perborate monohydrate dust during a filling operation (CEFIC 2001a)



The results of the measurements of inhalable dust are summarised in **Table 4.3**.

Most measured data are available for the combined workplace operations "Filling, emptying, transferring", "Weighing, mixing" and "Transport of bags". The few available data on the individual workplace operations show that there is no significant difference between these operations. Therefore these operations will not be considered separately in the risk assessment. For the other operations ("Process", "Storage", "Maintenance", "Laboratory operations") the data base is too small, but they are in the same order of magnitude as the other values. Therefore also these operations will not be considered separately in the risk assessment.

Exposure concentrations for inhalable dust ranged from 0.06 to 13.7 mg/m³ (90th percentile: 0.95-12.1 mg/m³). The one high concentration of 13.7 mg/m^3 was measured in an area air sample at the top of a dissolution tank, where the residence time of workers is very short. In general, area air and personal samples gave rather similar results.

Therefore, in the risk assessment the highest 90th percentile value of 12.1 mg/m^3 (inhalable dust, area measurement) will be used for the reasonable worst case.

The medians (only few values are available from the compilation from industry) range from 0.43 to 2.14 mg/m^3. The more recent measurements at workplaces with presumed high exposure show that exposure concentrations may be in the order of 1 mg/m^3.

Therefore for the risk assessment as typical value 1 mg/m^3 is chosen.

Table 4.3 Summary of exposure measurements (Table 4.1) in production plants

Workplace operation	Area measurements (mg PBS4*/ m³) Inhalable dust, TWA	Personal measurements (mg PBS4*/ m³) Inhalable dust, TWA	Remark
Filling, emptying, transferring Weighing, mixing Transport of bags	0.1-13.7 (range) 4.3-12.1 (90th perc.) 0.55-0.95 (median)	0.06-8.62 (range) 0.95-7.53 (90th perc.) 0.43-2.14 (median)	great number of measurements from several sites, not for all measurements 90th percentiles and means available, no major difference between personal and area measurements, 12.1 mg/m³ typical worst case for risk characterisation
Process	0.8-1 (range)	1.95 n.sp.	personal and area measurements from 2 different sites, only ranges available
Disposal / waste management		0.1-1.1 (range) 0.88 (90th percentile) 0.5 (median)	measurements from one site
Other (storage, maintenance, laboratory operations)	0.3-0.9 (range)		measurements from one site
Overall typical value		1	based on median values

* PSB4 = sodium perborate, tetrahydrate

Dermal exposure

For 4 of the 12 sites the possibility of dermal exposure to perborate containing solutions during cleaning and maintenance operations is reported (sodium perborate concentration in the solutions 3-10% according to CEFIC, 1999). Measured data on dermal exposure are not available. Skin contact to sodium perborate containing dust or respective solutions may occur during weighing/mixing, transport of bags and laboratory operations as far as these processes are carried

out semi-automated or manual. Cleaning and maintenance as well as rework of powder can be considered as incidental (CEFIC 2001b,c). The results of the EASE calculations and the basis data for these calculations are compiled in **Table 4.4**.

The value of 12 mg/kg bw/day was taken forward for risk assessment. In the processes described here, dermal contact may be only for some minutes.

Table 4.4 EASE calculations for the dermal exposure to sodium perborate during production

Workplace operation	Pattern of use / Pattern of control	Frequency of exposure	EASE results		Weight fraction of PBS[a]		Dermal exposure		Exposed area	External dose		External	
			mg/cm² /day		%		mg/cm² /day		cm²	mg/person		mg/kg bw/day	
			min	max	min	max	min	max		min	max	min	max
Filling, emptying, transferring Weighing, mixing	Non-dispersive use / direct handling	Intermittent	0.1	1	100[b]		0.1	1	840	84	840	1.2	12*
Transport of bags	Non-dispersive use / direct handling	intermittent	0.1	1	100[b]		0.1	1	840	84	840	1.2	12*
Cleaning and maintenance	Non-dispersive use / direct handling	Incidental	0	0.1	3[c]	10[c]	0	0.01	840	0	8.4	0	0.12
Laboratory operations	Non-dispersive use / direct handling	Intermittent	0.1	1	100[b]		0.1	1	420	42	420	0.6	6
			0.1	1	3[c]	10[c]	0.003	0.1	420	1.26	42	0.018	1
Disposal / waste management	Non-dispersive use / direct handling	Incidental	0	0.1	3[c]	10[c]	0	0.01	840	0	8.4	0	0.1

* Used in the risk assessment;
a) PBS4 = sodium perborate tetrahydrate was chosen as a calculation basis due to its higher commercial importance and its broader toxicological data basis;
b) Exposure to sodium perborate dust;
c) Exposure to sodium perborate solution.

4.1.1.2.2 Formulation

Sodium perborate is post-dosed to the base detergent powder at a post-dosing belt. The product then goes through a mixer for homogenisation and then a sieve to remove lumps. At the next stage the material goes directly to the packing machines or into intermediate storage in bins, silos, or big bags (AISE, 2001).

According to AISE (1999c), most of the operations are continuous automated processes. Exposure only occurs in semi-automated filling, emptying, transferring, weighing and mixing operations and in maintenance and disposal/waste management operations. Depending on the

size of the individual site, up to 150 persons (average < 10) are exposed continuously with the formulation of sodium perborate (> 50% of the working hours, no females). In addition, up to 150 persons (average < 25) are exposed intermittently (≤ 50% of the working hours) up to 35 of those being females (average < 5) (AISE, 1999c, 2001).

For most operations, no information is available on the frequency and duration of dermal contact. Due to the semi automated processes, it is assumed to occur only less than ten times per day. Therefore intermittent exposure was assumed. Processes associated with rework of powder take a maximum of 30 minutes and a maximum of 10 times per day (AISE, 2001). Therefore these are considered also as intermittent.

The use of gloves and goggles is common practice in most of the formulating companies. For some operations such as filling, weighing, process and maintenance operations also the use of dust masks is reported. At several manufacturers the filling and weighing processes are carried out under full containment or provided with general or local exhaust ventilation.

Inhalation

Dust measurements (presumably inhalable dust) from detergent factories (AISE, 2001) are summarised in **Table 4.5**. The number of measurements, total range, information on personal or area monitoring and duration of measurements are not available. Data on the concentrations of respirable dust and on the size distribution of the dust particles, and here especially of the fine dust (particle diameter < 10 μm), are lacking. In general exposure is lower than in the perborate production. 90th percentiles of the overall exposure concentrations ranged from 0.18 for packing to 0.93 mg/m^3 for dosing /tipping.

Other measurements of inhalable dust at a not specified workplace in the formulating industry were in the same magnitude with an average of 0.55 mg/m^3 (0.32-0.92 mg/m^3) (AISE, 1999c).

The perborate concentrations in commercial detergent products are generally between 5 and 25% and 50% at a maximum (see **Table 4.9**) and perborate is presumably only one of 15 to 20 components in the dust. As data on the perborate content of the dust is lacking, as a worst-case it is assumed that these concentrations are solely caused by sodium perborates.

Table 4.5 Dust monitoring results for representative European detergent factories

		Concentration (mg /m^3)				
Factory	Years	Dosing/ Tipping	Packing	Waste Recovery	Others	Overall Mean
A						
Mean	1995-2000	0.34	0.22	0.25	0.22	0.28
90th Percentile		0.41	0.24	0.30	0.24	0.33
B						
Mean	1995-2000	0.23	0.15	0.27		0.18
90th Percentile		0.27	0.18	0.34		0.21

Table 4.5 continued overleaf

Table 4.5 continued Dust monitoring results for representative European detergent factories

		Concentration (mg /m³)				
Factory	Years	Dosing/ Tipping	Packing	Waste Recovery	Others	Overall Mean
C						
Mean	1995-2000	0.22	0.26	0.33	0.34	0.26
90th Percentile		0.26	0.32	0.45	0.37	0.30
D						
Mean	1995-2000	0.36	0.18	0.21		0.23
90th Percentile		0.49	0.225	0.27		0.28
E						
Mean	1995-2000	0.41	0.18	0.14		0.29
90th Percentile		0.66	0.27	0.18		0.45
F						
Mean	1995-2000	0.20	0.24	0.25		0.22
90th Percentile		0.29	0.31	0.33		0.30
G						
Mean	1995-2000	0.59	0.23	0.43	0.44	0.37
90th Percentile		0.93	0.31	0.49	0.62	0.50
Overall mean	1995-2000	0.34	0.21	0.26	0.36	0.26
Overall 90th Percentile		0.63	0.30	0.40	0.60	0.43

Table 4.6 Summary of exposure measurements (Table 4.5) in formulation plants

Workplace operation	Inhalation exposure (mg PBS4*/ m³)	Remark
Dosing/ tipping/Packing/Others	0.26 -0.93	Inhalable dust, 90percentile TWA
Packing	0.18-0.32	Inhalable dust, 90percentile TWA
Waste recovery	0.18-0.49	Inhalable dust, 90percentile TWA

* PBS2=sodium perborate, tetrahydrate

Dermal exposure

Measured data are not available. The workplace operations which are assumed to be of concern in terms of skin cont act and the results of corresponding EASE calculations are presented in **Table 4.7**. The value of 12 mg/kg bw/day was taken forward for risk assessment.

Table 4.7 EASE calculations for the dermal exposure to sodium perborate in semi-automated and manual operations during the formulation of detergent products and bleaching agents

Workplace operation	Pattern of use / Pattern of control	Frequency of exposure	EASE results	Weight fraction of PBS[a)]	Dermal exposure concentration	Exposed area	External dose		External dose[c)]	
			mg/cm²/day	%	mg PBS4[b)]/cm²/day		mg/day		mg/kg bw/day	
							Min	Max	Min	Max
Dosing, tipping	Non-dispersive use / direct handling	Intermittent	0.1-1	100	0.1-1	840	84	840	1.2	12*
Transport of bags	Non-dispersive use / direct handling	Intermittent	0.1-1	100	0.1-1	840	84	840	1.2	12*
Cleaning and maintenance	Non-dispersive use / direct handling	Intermittent	0.1-1	10-50	0.01-0.5	840	8.4	420	0.12	6
Laboratory operations	Non-dispersive use / direct handling	Intermittent	0.1-1	10-50	0.01-0.5	420	4.2	210	0.06	3
Disposal/ waste management	Non-dispersive use / direct handling	Intermittent	0.1-1	10-50	0.01-0.5	840	8.4	420	0.12	6
Rework powder	Non-dispersive use / direct handling	Intermittent	0.1-1	10-50	0.01-0.5	840	8.4	420	0.12	6

* Used in the risk assessment;
a) See Table 4.9;
b) PBS4 = sodium perborate tetrahydrate was chosen as a calculation basis due to its higher commercial importance and its broader toxicological data basis
c) Body weight: 70 kg

4.1.1.2.3 Occupational exposure from end uses

Occupational exposure from end uses may occur in laundries, canteens and restaurants. According to AISE (2002) sodium perborate is used in professional laundries or in small institutions on the laundries' premises.

In professional laundries, the powder (up to 8% w/w sodium perborate) is dispensed and prediluted in a closed dosing system. Exposure occurs only very occasionally during maintenance or troubleshooting.

The exposure on the laundries' premises can vary from 4 to 12 times per day for the person who doses powder (up to 20% w/w sodium perborate) in the washing machine dispenser.

Exposure therefore is maximum 12 times higher than consumer exposure (calculation see Section 4.1.1.3.1, handling of detergents), where 1 exposure per day had been assumed, but it still is considered as negligible.

Furthermore occupational exposure may result from detergents containing sodium perborate used for hospital cleaning (Hansen, 1983). No further information could be obtained (AISE, 2004).

4.1.1.2.4 Conclusions for workplace exposure

In general, dust concentrations (presumably due to a high degree of automation in the processes involved and due to efficient local exhaust ventilation) were low (in the formulation plants with a factor of 10 lower than in the production plants). The concentration in the formulation plants might be even lower, if one considers that not all of the dust consists of sodium perborate. Similarly calculated dermal exposure concentrations were very low.

Exposure of professional end users during dosing of detergents is negligible.

The risk assessment will be performed for sodium perborate tetrahydrate because this is the compound which is commercially by far more important (see Section 2.1) and for which the toxicological database is more extensive than for the monohydrate.

4.1.1.3 Consumer exposure

An overview of the substances (sodium perborate and degradation products) to which exposure may occur is given in **Table 4.8**. During the use of detergent products and bleaching agents containing sodium perborate the substance is hydrolysed to a significant extent (e.g. approximately 70% during laundry washing; AISE, 1999b). Therefore, for some exposure scenarios also the exposure to the degradation products hydrogen peroxide and boric acid has to be taken into account.

Table 4.8 Overview of the substances (sodium perborate and degradation products) to which exposure may occur from the consumer use of detergent products and bleaching agents

Exposure scenario	Exposure to		
	sodium perborate	hydrogen per-oxide	boric acid
Handling of detergent products (heavy duty laundry detergents, machine dishwashing detergents, bleach booster tablets)	•	-	-
Handwashing with machine wash detergents	•	•	•
Handling of bleaching agents:			
denture cleansers	•	•	•
stain removers	•	•	•
Application of medical care products			
Artificial tears	•	•	•
Mouthwash solutions	•	•	•
Tooth bleaching agents	•	•	•

Data on the content of the substances in the different consumer products are given in **Table 4.9**.

Table 4.9 Content of sodium perborate in consumer products

Type of product	Perborate content (%)		Substance
Detergent products			
Heavy duty laundry detergents	15–25 15-31	AISE (1999a) AISE (2002)	Mono- and tetrahydrate
Laundry additive	16-20	AISE (2002)	not given
Automatic dishwasher detergents	10–15 4-18	AISE (1999a) AISE (2002)	Tetrahydrate
Bleaching agents			
Denture cleansers	5-25 Approx. 5	AISE (1999a)	Mono- and tetrahydrate dehydrated compound
Stain removers	5 - 50		Monohydrate
Medical care products			
Artificial tears[7]	0.028	Epharmacy (2004), Noecker, 2001	not given
Mouthwash solution[8]	1.19 g/package	Pharmakontor (2004)	not given
Tooth bleaching agents	No information		

4.1.1.3.1 Use of detergent products (laundry detergents, dishwashing detergents)

Measured data concerning the exposure to sodium perborate from the use of detergent products are not available. For technical reasons (separation of fine dust particles leading to an inhomogeneous mixture of the product in the package) fine dust particles are kept to a minimum by the formulators of the detergents products (AISE, 1999c). Nevertheless inhalation and dermal exposure may occur during pouring or other handling operations.

Inhalation

Detergents containing sodium perborate are either granulated or in tablet form. Therefore dust release is low. According to van de Plassche et al. (1998) studies indicate an average release of 0.27 µg detergent /cup of product used for machine laundering, of which up to 31% could consist of sodium perborate hydrates, i.e. approximately 0.08 µg. If one assumes that 10% are respirable this corresponds to 0.008 µg. Even if one assumes, that this is distributed in a rather small volume of less than 1 m^3 near the nose of the person handling the washing powder this results in a maximum exposure concentration of less than 0.008 µg/m^3. Furthermore exposure duration is very low (typically < 1 min/event). Exposure from this scenario therefore is negligible. Even lower concentrations can be assumed for the use of machine dishwashing agents, due to the smaller volumes handled and their lower content of perborate (20%).

[7] This use has been identified only recently. It is mentioned in the Addendum to the environmental risk assessment report already published (section 2.2).

[8] In section 2.2 of the environmental risk assessment it was mentioned, that this use has been discontinued. However, a product containing sodium perborate has been recently detected.

Dermal exposure

Dermal exposure to sodium perborate may occur during handling of these products, i.e. during machine filling operations.

Furthermore, although sodium perborate is only present in heavy duty laundry detergents for machine washing, it might be possible, that these detergents are used also for handwashing. The exposure can be calculated with the assumptions in **Table 4.10**. Results of the calculations on dermal exposure are given in **Table 4.11**.

For the risk assessment, it was assumed that the exposure from detergent products occurs only to sodium perborate tetrahydrate because this is the compound which is commercially more important (see Section 2.1) and for which the toxicological database is more extensive than for the monohydrate.

As is indicated in **Table 4.11**, dermal exposure to sodium perborate is negligible.

Table 4.10 Exposure estimation concerning the use of heavy duty detergent containing sodium perborate hydrates for handwashing

Parameter	Value/Assumption
Content of detergent in the washing solution	1%
Content of sodium perborate in detergent	31%
Degradation	0%
Thickness of layer on skin	0.01 cm

Table 4.11 Dermal exposure to sodium perborate during the use of detergent products

Exposure scenario	Dose calculated for PBS	Weight fraction of PBS in detergent product	max exposure to detergent product	Exposed area	External dose	External dose	Frequency of exposure
	mg/cm^2	%	$mg/cm^2/day$	cm^2	mg/person	mg/kg bw/day	
Handling of heavy duty detergents	0.1[a]	31	0.031	420	13.2	< 0.2	30 s max. 5 times/week
Hand-washing with heavy duty detergents	0.1	31	0.031	1980	61.4	< 1 assuming complete hydrolysis: boric acid: 0.6 H_2O_2: 0.3	10 min per day, max 6 times/week
Handling of machine dish-washing detergents	0.11	18	0.018	420	7.6	< 0.1	30 s, 7 times/week

a) Frequency data from ECB discussion paper DE/04/99

4.1.1.3.2 Use of bleaching agents (denture cleansers, stain removers)

Measured data concerning the exposure to sodium perborate from the use of bleaching agents are not available.

The estimations for the exposure to bleaching agents are related to sodium perborate monohydrate as this substance appears to be commercially more relevant in these consumer products than the tetrahydrate. Stain removers (= bleach booster tablets) are containing usually percarbonate today (AISE, 1999c). Nevertheless they were included in the exposure assessment as there may be some products on perborate basis left. The estimations on the consumer exposure from the use of denture cleansers are shown in **Table 4.12**. Exposure may occur either by absorption from the mucous membranes or by swallowing of the solution.

Exposure by handling of either denture cleanser or bleach booster tablets is considered to be negligible. Due to the tablet form of the preparation, development of dust or release of powder from tablets is not to be expected.

Table 4.12 Exposure estimation concerning the use of denture cleansers containing sodium perborate

Parameter	Assumption/Result
Preparation	Tablets
Weight per tablet	5 g
Concentration of sodium perborate in the tablet	maximum 25% sodium perborate monohydrate (see Table 4.9)
Cleaning solution	5 g denture cleansure (i.e. 1 tablet) /200 ml water
Substance	Sodium perborate monohydrate
Adsorption of cleaning solution to denture	1%[a]
Removal of cleaning solution during rinsing with water after the cleaning process	99%
Weight fraction PBS in denture cleanser	25%
Total external exposure to PBS1	12.5 mg
Exposure to boric acid assuming complete degradation of PBS1	8 mg
Exposure to hydrogen peroxide assuming complete degradation of PBS1	4 mg
Absorption	100% absorption in the mucosa of the mouth (overestimation), or 100% absorption in the intestinal tract if swallowed
Internal dose PBS1	0.17 mg/kg bw/day
Internal dose boric acid (assuming complete hydrolysis)	0.11 mg/kg bw/day
Internal dose hydrogen peroxide (assuming complete hydrolysis)	0.06 mg/kg bw/day

a) Corresponding to 2 ml solution, higher adsorption does not seem plausible having in mind the size of dentures

A number of consumer products such as hair bleaching agents contain hydrogen peroxide directly without being released from a peroxy compound (see EU Risk Assessment Report on Hydrogen Peroxide). The exposure concentrations from all these products appear to be much higher than from the use of sodium perborate containing products as the substance is released

immediately whereas the hydrolysis is an equilibrium reaction which is shifted towards the hydrolysis products boric acid and hydrogen peroxide from the consumption (i.e. reduction of hydrogen peroxide).

4.1.1.3.3 Use as preservative in artificial tears

According to Noecker (2001) sodium perborate is used as a preservative in artificial tears. The content of sodium perborate in Genteal eye drops or Eye Gel is 0.28 mg/g (EPharamacy 2004a, 2004b). If one assumes, that 20 µl (=20 mg) of the artificial tears are applied 10· per day the total dose would be 20 mg · 0.28/1,000 ·10 = 0.056 mg/day. The total dose may reach the nasopharyngeal tract and may be swallowed. Therefore 100% absorption is assumed, the resulting dose being 0.056 mg/person/day, or 0.0008 mg/kg bw (for a body weight of 70 kg), which is negligible.

4.1.1.3.4 Use in mouthwash solutions

According to recent information some smaller companies may sell mouth wash solutions containing sodium perborate (COLIPA, 2004). Obviously, the product which was analysed in the publication of Edwall et al. (1979, see Section 4.1.2.1) is still available (Pharmacontor, 2004).

According to Edwall, the content of a package (1.2 g sodium perborate) is dissolved in a small amount of water; the solution is circulated in the mouth, and afterwards spat out. About 3% of the dose remain in the mouth and are nearly completely absorbed in the gastrointestinal tract after swallowing. Accordingly, per mouthwash 36 mg sodium perborate will be taken up. If one assumes two mouthwashes per day, the daily dose would be 72 mg sodium perborate per person or 1 mg sodium perborate per kg bw/ day (for a body weight of 70 kg).

4.1.1.3.5 Conclusions for consumer exposure

The consumer exposure concentrations of sodium perborate are summarised in **Table 4.13**. With the exception of exposure via mouthwash solutions, for all exposure situations the exposure concentrations are very low.

Table 4.13 Overview of consumer exposure estimations for sodium perborate and its degradation products from the use of detergent products and bleaching agents

Exposure scenario	Inhalation exposure (µg/m³)	Remark	External dermal dose (mg/kg bw/day)	Remark	Oral exposure (mg/kg bw/day)	Remark
Laundry detergents handling of powder	PBS4: 0.008	PBS4 due to its higher commercial importance	PBS4: 0.2	PBS4 as the basis due to its higher commercial importance	-	prevented by personal hygiene measures
Laundry detergents: Handwashing	negligible		PBS4: 1		-	prevented by personal hygiene measures

Table 4.13 continued overleaf

Table 4.13 continued Overview on consumer exposure estimations for sodium perborate and its degradation products from the use of detergent products and bleaching agents

Exposure scenario	Inhalation exposure (µg/m³)	Remark	External dermal dose (mg/kg bw/day)	Remark	Oral exposure (mg/kg bw/day)	Remark
Automatic dishwashing detergents handling of powder	PBS4: < 0.008	PBS4 as the basis due to its higher commercial importance	PBS4: 0.1	PBS4 as the basis due to its higher commercial importance	-	prevented by personal hygiene measures
Denture cleansers	PBS1: not relevant	tablet form of preparation, PBS1 due to its higher commercial importance	PBS1: 0.17	total amount absorbed by mucous membranes	PBS1: 0.17	total amount swallowed
	H_2O_2: not relevant	low amounts dissolved in the water phase	H_2O_2: 0.06		H_2O_2: 0.06	
	$B(OH)_3$: not relevant	ionic substance dissolved in the water phase	$B(OH)_3$: 0.11		$B(OH)_3$: 0.11	
Stain removers	not relevant	tablet form of preparation	not relevant	tablet form of preparation	not relevant	prevented by personal hygienic measures
Artificial tears	Not relevant	Liquid solution	PBS, H_2O_2 $B(OH)_3$ negligible	total amount absorbed by mucous membranes	negligible	Total amount swallowed
Mouthwash solutions	Not relevant	Liquid solution	PBS: 1	total amount absorbed by mucous membranes	PBS: 1	Total amount swallowed
			H_2O_2: 0.4		H_2O_2: 0.4	
			$B(OH)_3$:0.6		$B(OH)_3$: 0.6	

4.1.1.4 Indirect exposure via the environment

Possible sources for an indirect exposure of the general public to sodium perborate and its degradation products appear to be inhalation of ambient air, consumption of drinking water and skin contact with natural waters from swimming and bathing. The hydrosphere is the main target compartment for the substances from the use pattern and the physico-chemical properties.

Ambient air

An inhalative exposure is not to be expected for sodium perborate and boric acid as significant quantities of airborne dust will not emerge from the use pattern and the physico-chemical properties of these substances either. The total tropospheric burden for gas-phase and particulate boron was estimated from measurements in the U.S. to 60,000-110,000 tonnes with average boron concentrations in the atmosphere between 4 and 80 ng/m^3, at continental and coastal sites. Atmospheric releases from oceans, burning of coal and refuse and volcanoic activities are the most relevant sources for boron or borate containing dusts (Anderson et al., 1994a). A

contribution of 0.002-0.009% to the natural atmospheric boron burden from the use of detergents was estimated by the authors. Therefore, it is to be expected that the contribution to the regional atmospheric boron concentrations by production, formulation and use of sodium perborate is of minor importance and will not be considered further in this risk assessment.

Furthermore, it can be also presumed that the inhalation uptake of hydrogen peroxide from sodium perborate based commercial products is of minor importance compared to other hydrogen peroxide sources (EU Risk Assessment Report on Hydrogen Peroxide, ECB, 2003).

Drinking water

An oral uptake of sodium perborate itself is not to be expected due to its hydrolysis behaviour. Also the emerging hydrogen peroxide should not reach the drinking water due to degradation. The uptake of boron (in form of boric acid) via drinking water is reported in the literature without specifying the underlying sources. For Germany, drinking water concentrations of < 0.2 mg boron/l (with a median of 0.02 mg/l) were measured (reference year: 1985/86; Krause et al., 1991) but it has to be mentioned that the boron content of the drinking water increased with an increase in the size of population. This is probably due to the fact that in large urban centres also freshwaters are used for the preparation of drinking water. These results were confirmed in more recent measurements of Wiecken and Wübbold-Weber (1995) and Abke et al. (1997). In a worldwide data compilation of WHO (1998b), it was found that the most values were clearly below 0.4 mg/l. In contrast, bottled mineral water of different origin showed in a number of cases significantly higher concentrations (up to 4 mg/l) (Allen et al., 1989). Perhaps this is due to the geological surroundings of the various springs. Assuming a maximum value of 0.4 mg boron/l drinking water made up to 50% from fresh water sources and to 50% from ground water (boron content 0.1 mg/l at a maximum; see Section 3.1.2.1) and a contribution of 50 to 70% to the boron content of the fresh water from the use of sodium perborate containing detergent products and bleaching agents (data from the 70's and mid 80's; see Section 3.1.2.1) a maximum of about 0.2 mg boron/l drinking water may be caused by the use of sodium perborate.

In the European Council Directive 98/83/EC on the quality of water intended for human consumption a parametric value for boron of 1 mg/l is given (OJ, 1998). A guidance value of 0.5 mg/l is recommended by the WHO (1998b).

Swimming and bathing in natural waters

A dermal exposure to borate or hydrogen peroxide is possible during the swimming and bathing in natural waters which are polluted with the above mentioned substances. A quantification is not possible with the available data. As also natural boron sources will contribute to this exposure path (e.g. weathering of rocks) and compared to other boron sources such as the ingestion of drinking water this exposure path is regarded as of minor importantance and will not be considered further in this risk assessment.

4.1.1.5 Combined exposure

Exposure at the workplace has been identified to be by far the most important source of human exposure to sodium perborate. Therefore combined exposure is not considered relevant.

With respect to borates as degradation product, this has to be considered in context with the evaluation of the borates.

4.1.2 Effects assessment: Hazard identification and Dose (concentration) - response (effect) assessment

Studies are available on both, sodium perborate tetrahydrate and sodium perborate monohydrate. The database is not satisfactory for several endpoints. Therefore, if necessary, it is checked whether for the degradation products borate and H_2O_2 (see Section 4.1.2.1) additional information is available, which is given in a separate subheading "Further information on the degradation products". One has to keep in mind, however, that the toxicokinetics of borate and H_2O_2 will be different, if they are applied as original substance or will be generated from sodium perborate. Therefore, information on both degradation products will be used in this section for identifying possible hazards or for validating data of sodium perborate, but not for quantitative risk assessment purposes.

4.1.2.1 Toxicokinetics, metabolism and distribution

No information is available on absorption via inhalation of sodium perborate. No quantitative data are available on dermal absorption. Oral absorption can be concluded from the experiments described below.

In a study with human volunteers, absorption of sodium perborate monohydrate from Bocosept mouthwash solutions by the oral mucosa or the gastrointestinal tract was tested (Edwall et al., 1979). For one mouthwash a Bocosept package containing 1.2 g sodium perborate monohydrate and 0.5 g sodium bitartrate is dissolved in a small volume of water, circulated in the mouth and then spat out.

A single mouthwash was performed by 2 gingivitis patients and 2 healthy volunteers. Prior to the experiment the mean blood concentration of boron was 0.04 µg/ml. Two minutes after completion of the mouthwash the boron concentration was 0.06 µg/ml and it rose gradually, reaching a maximum of 0.14 µg/ml 2 hours later. The highest individual concentration was 0.2 µg/ml. The mean concentration 24 hours after the mouthwash was 0.07 µg/ml. No differences in blood boron concentration were found between patients and healthy volunteers. 97% (94-101%) of the dose were spat out. The remaining 3% correspond to 36 mg sodium perborate.

In another experiment absorption and excretion after repeated exposures was investigated in five patients who rinsed their mouth with Bocosept every morning and evening for 7 days. The mean blood boron concentration prior to the experiment was 0.07 µg/ml. During the treatment the mean concentration lay between 0.15 and 0.20 µg/ml. Two days after completion of the treatment the mean blood boron concentration had returned to the background level. Four days after discontinuation of the treatment also urine boron levels reached constant values, presumably background values. However in contrast to blood no values are given on the initial or background boron concentration in urine. The mean total amount of boron excreted in the urine until the fourth day after discontinuation of the treatment was 47.5 mg, corresponding to 2.8% of the total amount of sodium perborate administered. As the total dose which is not spat out (3% of the dose, see paragraph above) appears in the urine, 100% absorption either in the mucosa of the mouth or in the gastrointestinal tract can be concluded.

When 51 mg (approximately 3% of a dose of Bocosept) were swallowed under the same experimental conditions as above in the experiment with the repeated applications, the blood and urine concentrations were similar to those obtained after the mouthwashes. Therefore the major route of absorption is the gastrointestinal tract

In all experiments, the blood boron concentrations returned to the initial level within 1-2 days after a single mouthwash as well as after completion of prolonged treatment. A blood half-life of 5 – 10 hours was estimated from these curves and from the observation that the plateau level of boron in blood following long-term administration was reached after only 24 hours.

No information is available on the distribution of sodium perborate within the body.

No data on metabolism of sodium perborate are available.

As described in section 1.3 at room temperature, there is an equilibrium between perborate and its degradation products boric acid and hydrogenperoxide. If hydrogen peroxide is further degraded by enzymes, the equilibrium is shifted towards the degradation products, leading to further degradation of sodium perborate.

In the lung rather effective degradation can be assumed, due to the presence of catalase.

For the oral route, from the generation of foam and bloating of the stomach and the intestine presumably due to the development of gas (Degussa, 1987; Dufour et al., 1971; Interox, 1987a), it can be concluded, that in the stomach in the presence of HCl boric acid (see Section 1.3) and H_2O_2 are generated very effectively, the latter being further degraded by catalase to H_2O and O_2. Also from the toxicologic profile it may be assumed, that several, if not all of the systemic toxic effects are caused by the degradation products. For example the acute effects on the stomach (see "Studies in animals" under Section 4.1.2.2) are in common with H_2O_2 (EU Risk Assessment Report on Hydrogen Peroxide, ECB, 2003). Reduced food intake, effects on the haematological system as well as developmental effects are shared with the borates (ECETOC, 1995; WHO, 1998a). Nevertheless, it cannot be ruled out that at least some perborate as original substance is available in the tissues.

After dermal exposure, degradation at the site of contact may be less effective. However due to the high catalase activity in blood (EU Risk Assessment Report on Hydrogen Peroxide, ECB, 2003), degradation should then occur in the blood.

No data is available on the further distribution of sodium perborate in the body.

Further information from tests with degradation products

Dermal absorption of H_2O_2 is considered to be negligible. Distribution of H_2O_2 and the degradation products H_2O and O_2 is expected to be evenl throughout the body and no accumulation in organs or fatty tissues is anticipated (EU Risk Assessment Report on Hydrogen Peroxide, ECB, 2003).

Boron compounds are readily (> 90%) absorbed from the human gastrointestinal tract (Dourson et al., 1998; Sutherland et al., 1998).

In contrast, dermal absorption (measured as excess boron excreted in the urine) of different boron compounds (boric acid, borax or disodium octaborate tetrahydrate) in humans was very low and amounted to only 0.122 to 0.226% of the applied dose within 6 days after 24 hours application of the respective boron compound as 5% or 10% solution (2µl/cm^2) to the back of human volunteers. It did not increase significantly, if the skin was damaged with sodium lauryl sulfate before the treatment with the boron compounds (Wester et al., 1998).

Distribution of boric acid is evenl throughout the body fluids, with lower concentrations in adipose tissue and higher concentrations in bone than in other tissues (WHO, 1998a).

Boron is proposed to be an essential trace element. The dietary requirements can, however, not be established with the available data (Sutherland et al., 1998). Studies in humans gave indications that there is a homeostatic mechanism in the kidney for maintaining relatively constant tissue boron concentrations. Preliminary data suggest that reproductive hormone secretion and bone metabolism may be influenced by tissue boron status (Sutherland et al., 1998).

Boron compounds are completely eliminated after oral application mainly as un-dissociated boric acid in urine (Dourson et al., 1998; ECETOC, 1995, Usuda et al., 1988; WHO, 1998a). Clearance is about 4-fold higher in rats than in humans (Dourson et al., 1998).

Conclusion

From a study with human volunteers it can be concluded that oral absorption is 100%. For the risk assessment, oral absorption and the absorption via inhalation of sodium perborate hydrates are assumed to be 100%.

There are no valid quantitative data on the absorption of sodium perborate following dermal exposure. Absorption from the mucous membranes of the mouth seems to be low. Dermal absorption of H_2O_2 is negligible. A thorough investigation showed that dermal absorption of other boron compounds is very low. Therefore for the risk assessment dermal absorption of 1% was assumed.

Peak levels in human plasma presumably after swallowing of sodium perborate are reached after 2 hours, half life in plasma is about 6 to 10 hours.

Sodium perborate is assumed to be degraded to boric acid and H_2O_2 after oral application and to be excreted as boric acid via the urine.

No data is available on the distribution of sodium perborate (and subsequent degradation products) within the body. From investigations with other boron compounds, it may be suspected that elevated boron concentrations are found in the bones.

4.1.2.2 Acute toxicity

Studies in animals

Results from studies on acute toxicity of sodium perborate are given in **Table 4.14**. There are only very few studies, which are performed according to current guidelines (Degussa, 1987; Interox, 1987 a, b). Further the publication of Momma et al., (1986) and the report of DuPont (1987) is of good quality. For most of the other studies, the entries in the table are rather incomplete due to lack of information. But they give some supporting evidence or additional information.

Oral

The oral LD_{50} for sodium perborate is low, ranging from 1,700 to 2,700 mg/kg bw in rats (Degussa, 1966, 1987; Dufour et al., 1971; Interox, 1987a). Female animals were more sensitive than male animals (Degussa, 1987; Dufour et al., 1971; Interox, 1987a; Momma, 1986). For example, the LD_{50} for female rats of sodium perborate monohydrate was 1,700 mg/kg bw and for male rats 2,100 mg/kg bw (Interox, 1987a). Furthermore, the toxicity of more concentrated aqueous solutions is higher than that of less concentrated solutions (Procter and Gamble, 1965).

With a LD_{50} of 1,800 mg/kg bw (male and female rats combined) the acute toxicity of the monohydrate (Interox, 1987a) was higher than the LD_{50} of the tetrahydrate with a LD_{50} of 2,567 mg/kg bw (Degussa, 1987). The higher toxicity of the monohydrate is consistent with the lower water content of the salt. Given as boron, there is only little difference between both compounds. The LD_{50} from these studies are 194 mg boron/kg bw, for the monohydrate and 180 mg boron/kg bw for the tetrahydrate, respectively.

Clinical symptoms were salivation, lethargy, ptosis, chromorhinorrhea, ataxia, prostration, bloated abdomen and diarrhoea. Necropsy at death revealed some abnormalities of the lungs, liver, kidneys, spleen and gastrointestinal tract and brain (Degussa, 1987; Dufour et al., 1971; Interox, 1987a; Momma, 1986). Typical findings in all animals were hyperaemia or necrosis of the stomach. The effects on the stomach were reversible within 10 or 14 days after treatment (Dufour et al., 1971).

Table 4.14 Results from studies on acute toxicity of sodium perborate

Compound	Species Strain Nr per Group, Sex	Protocol Application	LD_{50} [mg/kg bw]	Dose [mg/kg bw]	Toxicological Effects	Reference
oral						
PBS1	rat Wistar 5 m, 5 f	EPA F 81-1 mixed with distilled water to make a thin paste	1,800 2,100 (m) 1,700 (f)		lethary, ptosis, chromorhinorrhea, ataxia, prostration, bloated abdomen, diarrhoea, abnormalities of the lungs, liver, kidneys, spleen and gastrointestinal tract	Interox, 1987a
PBS1	rat n.g. 10-33 per dose	1.3 % aqueous solution		130 260 325	1/36 animals hyperemia of stomach mucosa	Mulinos et al., 1952
		2.6 % aqueous solution		260 520 650	27/61 animals with hyperaemia of stomach mucosa (no differentiation between the three doses)	
PBS4	rat, Wistar 9 m 9 f	OECD 401 in 1 % aqueous Tragent-suspension	2567 2,670 (m) 2,360 (f)		stomach enlarged, hyperaemia, reversible within 14 days, diarrhoea, salivation	Degussa, 1987
PBS4	rat n.g. n.g.	20 % aqueous solution	1,600		n.g.	Procter and Gamble, 1965
		50 % aqueous solution	1,200			
PBS n.sp	rat Wistar 25 m, 25 f	in 2 % gummi arabicum,	2,243		diarrhoea, salivation, apathia, hyperaemia of stomach, with white foam, females more susceptible	Dufour et al., 1971
PBS n.sp	rat Wistar 10 m	in 2 % gummi arabicum		2,000	reduced weight gain; reversible hyperaemia of stomach serosa with reversible(within 10 days) superficial necrosis; no lesions in histopathological examinations, no pathological change in liver, kidneys and intestines no controls	Dufour et al., 1971

Table 4.14 continued overleaf

Table 4.14 continued Results from studies on acute toxicity of sodium perborate

Compound	Species Strain Nr per Group, Sex	Protocol Application	LD_{50} [mg/kg bw]	Dose [mg/kg bw]	Toxicological Effects	Reference
oral						
PBS n.sp	rat n.g.	n.g.	2,440		n.g.	Degussa, 1966
PBS n.sp	rat ChR-CD 5 m	n.g.	3,600 (m)		n.g.	DuPont, 1972
PBS n.sp	mouse ddY 10m, 10f		3,600 (m) 3,250 (f)		diarrhoea, stomach bloated, hyperaemia in stomach, brain, lung	Momma, 1986
PBS n.sp	mouse	n.g.	2730			Degussa, 1966
PBS n.sp	dogs beagle 1 m	in 10 % gummi arabicum		25, 50, 100, 250, 500	50, 250, 500: vomiting 100, 500: congestions of mucosa of stomach	Dufour et al., 1971
Inhalation			[mg/m³]	[mg/m³]		
PBS4	Rat Crl:CD®BR 6 m	4h MMAD: 3.3 – 4.2 µm Diameter: 86-94 % < 10µm	1,164 mg/m³	160, 480, 1,100, 2,900 mg/m³	Lethality: 0/6, 1/6, 3/6, 5/6 during exposure: ≥ 160 mg/m³: gasping, red nasal discharge ≥ 480 mg/m³: laboured breathing ≥ 1100 mg/m³: no startle response during postexposure period: in some surviving rats: red ocular, nasal or oral discharges, diarrhea, gasping, lung noise slight to severe body weight losses within 24 hours of exposure	Du Pont, 1987; Asta Medica, 2001)

Table 4.14 continued overleaf

Table 4.14 continued Results from studies on acute toxicity of sodium perborate

Compound	Species Strain Nr per Group, Sex	Protocol Application	LD_{50} [mg/kg bw]	Dose [mg/kg bw]	Toxicological Effects	Reference
Inhalation			[mg/m³]	[mg/m³]		
PBS4	n.g.	n.g.		3.7, 11.3 mg/m³	no effect	Silajev, 1984
				39 mg/m³	reduced respiration rate, increase in total cell number in lavage from nasopharynx	
				58 mg/m³	reduction in nervo-muscular excitability, increase in number of cells in lung lavage	
				74 mg/m³	toxic effects, not further specified	
Dermal						
PBS1	rabbit New Zealand 5 m, 5 f	OECD 402 24 h occlusive application of original substance slightly moistened with water,		2,000	9/10 animals survived, 1 male died on day 13 after a 3-days-period of diarrhoea, from day 5-9 no signs of illness animal that died: diarrhoea, yellow nasal discharge, soiling of anogenital area, abnormalities of lungs, liver, spleen, gatrostrointestinal tract 1 animal: distended intestines. 1 animal: skin reactions	Interox, 1987b
Intravenous						
PBS1	cat 5, sex n.g.	3 % in water		700-900	Injection from a burette at 1 cc per minute increased respiratory effort, dark colour of blood, death	Mulinos et al., 1952
PBS1	rabbit 1-11 per group, sex n.g.	2 % in water	78	22 50-56 60-68 70-80	deep cyanosis, asphyxial death	Mulinos et al., 1952

Table 4.14 continued overleaf

Table 4.14 continued Results from studies on acute toxicity of sodium perborate

Compound	Species Strain Nr per Group, Sex	Protocol Application	LD_{50} [mg/kg bw]	Dose [mg/kg bw]	Toxicological Effects	Reference
Intravenous						
PBS n.sp.	dog beagle 1 m	dogs anaesthetised to avoid vomiting, after intravenous infusion oral application of the same dose (exception: animal which received 500 mg/kg bw) in physiologic serum		25 50	no effects	Dufour et al., 1971
				100 250	irritation of stomach mucosa, vomiting	
				500	death	
Intraperitoneal						
PBS, n.sp.	rat ng.	n.g.	795		n.g.	Degussa, 1966
PBS n.sp	mouse ng.	n.g.	1,070		n.g.	Degussa, 1966

PBS n.sp. Sodium perborate, compound not specified
PBS1: Sodium perborate monohydrate
PBS4: Sodium perborate tetrahydrate
n.g. not given
MMAD: mass median aerodynamic diameter, d: diameter

Beagle dogs receiving 25, 50, 100, 250 and 500 mg/kg bw of sodium perborate (not specified) showed a strong vomiting reflex at concentrations of ≥ 50 mg/kg bw. This was attributed to the pressure resulting from hydrogen peroxide production and subsequent release of oxygen in the stomach. At concentrations ≥ 100 mg/kg bw congestions of the stomach mucosa were observed. No mortality or histopathological lesions were observed in anaesthetised dogs receiving up to 250 mg/kg bw of sodium perborate intravenously and at the end of the intravenous application additionally the same dose per os (Dufour et al., 1971). The authors conclude that the risk for intoxication in humans is low due to the vomiting reflex induced by sodium perborate.

Inhalation

In an acute inhalation study (DuPont, 1987) male Crl:CD®BR rats were exposed to 160, 480, 1,100 and 2,900 mg/m^3 PBS4 (particle size 3.3.-4.2 µm). All exposed animals exhibited gasping and red nasal discharge. At concentrations higher than 480 mg/m^3 also laboured breathing was observed. Surviving animals showed slight to severe body weight losses. 3 of 6 animals died at 1,100 mg/m^3. Probit analysis of the experimental data revealed an LC_{50} of 1,164 mg/m^3 (Asta Medica, 2001).

Another inhalation study is insufficiently described (Silajev, 1984). Concentrations between 3.7 and 74 mg/m^3 were investigated (species not given). At 39 to 74 mg/m^3 the authors observed respiratory irritation (reduced respiration rate and an increase in total cell number in lung lavage fluid). No information, however, is given on analytical control of exposure concentration, particle size, exposure time, number of animals tested.

Dermal

The acute dermal toxicity of sodium perborate monohydrate is low. After dermal application of 2,000 mg sodium perborate monohydrate/kg bw 9 of 10 animals survived. One male animal died on day 13 immediately after diarrhoea on 3 consecutive days. Diarrhoea was also reported in the other animals, as well as mild to moderate skin irritation, yellow nasal discharge, soiling of the anogenital area and distended intestines (Interox, 1987b).

Intravenous

In studies with intravenous application sodium perborate itself becomes systemically available. But it can be assumed that decomposition of perborate occurs to some degree in the blood. The toxicity is higher than for other routes of application (Dufour 1971; Mulinos et al., 1952), cats died after dosing of 700 –900 mg/kg bw.

Poisoning symptoms in cats were increased respiration rate and dark blood (Mulinos et al., 1952).

Studies in humans

A poison centre report under the UK home accidents surveillance scheme (DTI, 1998) summarises an analysis of accidents with household products for the year 1998, which were the most recent data available. However, the report included a survey from 1991 to 1998, which showed that the numbers were relatively constant. Of a total number of accident records of 145,361, 717 were related to cleaning products. 59 records of those were related to laundry and dishwashing agents: 30 to detergents/wash powder (4%), 21 to dishwasher products (3%), 8 to clothes wash liquid. Most of the injuries were categorised as “chemical injury” (40), in 17 cases no injury was diagnosed, 9 cases of non-injurious foreign body reactions and 6 cases of injurious

foreign body reactions were reported. Other injuries (unspecified or soft tissue) were reported in 8 cases, one case of specific injury and 5 cases were categorised as unspecific injuries. Poisoning was reported in 9 cases for detergents/wash powder, 11 cases each for dishwasher products and 2 for wash liquid. Corrosion was stated in 2 cases for detergents/wash powder and dishwashing agents. No allergic reactions were observed with those products. The age distribution of the accidents with laundry detergents and dishwashing agents is largely biased towards small children between 0-4 years: 5 accidents occurred with wash liquid, 17 with wash powder, and 15 with dishwasher products. "Poisoning", ingestion and skin contact (referred to as chemical injury) were the main causes of these accidents (69% of the accidents in children of 0-4 years related to washing or dishwashing, while only 23% were reported to have chemical injury in the age group of 15 to 64 and no cases were reported in people above 65 years). Foreign body/eye injuries were reported in very few people: 4 cases for washing or dishwasher detergents, thereof 3 in children aged 0-4 years and one in the age group of 15-64.

The severity of the accidents seems rather low. No fatalities were reported and 59% of the accidents involving laundry and dishwashing agents could be treated at home. Further 46% could be treated ambulant by a doctor. None of the patients involved in laundry detergent/dishwashing agent accidents was treated in a hospital. The majority of the accidents in the household with products that could contain sodium perborates consist of accidental ingestion or skin contact in particular of small children with seemingly slight effects only. No firm conclusions on the involvement of perborate can be drawn, but it is noteworthy that only very few cases of eye irritation were observed (DTI, 1998).

Conclusion

In animal experiments, after oral intake typical findings were hyperaemia and necrosis of the stomach, dogs showed a strong vomiting reflex. Using studies performed according to current guidelines, sodium perborate monohydrate should be classified as "Harmful if swallowed" (Xn; R22) due to the oral LD_{50} in rats of 1,800 mg/kg bw (Interox, 1987a). No classification is required for the perborate tetrahydrate due to its lower toxicity (LD_{50} in rats: 2,567 mg/kg bw, Degussa, 1987).

According to the study of DuPont (1987) sodium perborate tetrahydrate (thoracic fraction of dust particles) should be classified as "Harmful by inhalation" (Xn; R20). Based on read across and the knowledge from acute oral studies, the thoracic particle fraction of sodium perborate monohydrate should also be classified as T; R23.

For the dermal route, due to the LD_{50} of more than 2,000 mg/kg bw for the monohydrate no classification is required and it is assumed that the same holds for the tetrahydrate, which was less toxic via the oral route due to the higher water content.

4.1.2.3 Irritation

4.1.2.3.1 Skin irritation

Studies in animals

The results of tests on skin irritation are summarised in **Table 4.15**.

Two studies show no irritation potential at all of both sodium perborate monohydrate and tetrahydrate (ICI, 1986a, b). Another study indicates a weak irritating potential of sodium perborate monohydrate (Interox, 1987c). It has to be noted, that these results are somewhat contradictory as in the study of Interox (Interox, 1987 c) some irritation was observed under semi-occlusive conditions, while no irritation at all was observed in the ICI study (ICI, 1986b) with exposure under occlusive i.e. more stringent conditions. However irritation was also shown in a study on acute toxicity, after exposure for 24 hours instead of 4 hours in the "normal" irritation studies (Interox, 1987b). Furthermore, in the acute toxicity study the effects were not completely reversible (Interox, 1987b).

Solutions with 10% sodium perborate tetrahydrate had also mild irritating effects (Procter & Gamble, 1966b).

Table 4.15 Results from studies on skin irritation of sodium perborate in rabbits

Compound	Application	Mean Draize Scores after, 24, 48, 72 hours			Remarks, Protocol		Reference
		Occlusion	Erythema	Edema			
PBS1	Moistened, vehicle n.g.	semi – occlusive	1.1	0.44	exposure 4 hours OECD 404		Interox 1987c
PBS1	Paste with de-ionised water (0.3 ml)	occlusive	0	0	exposure 4 hours		ICI, 1986b
PBS1	Granules slightly moistened with water	occlusive			study on acute toxicity, exposure 24 hours, scores on day 1 2(erythema), 2.7 (edema), not completely reversible within 14 days, OECD 402		Interox, 1987b
PBS4	10% solution in water	n.g.			studies on repeated dose toxicity; test conditions n.g.	applied during 20 days to abraded skin, skin near normal with individual animals showing mild irritation	Procter and Gamble, 1965; 1966a
PBS4	2.5% solution in water	n.g.				applied during 90 days, no skin irritation at any time	Procter and Gamble, 1966b
PBS4	Paste with deionised water	occlusive	0	0	exposure 4 hours		ICI, 1986a

n.g. Not given

Sudies in humans

A patch test was conducted in 26 volunteers (healthy humans aged 18 to 65). A sequential single patch test procedure was used applying 0.2 g of sodium perborate monohydrate on to a 25 mm plain hill top chamber containing a moistured Webril pad to the upper outer arm progressively from 15 minutes to 4 hours starting with 15 minutes for security reasons. When irritation occurred the test was to be stopped on that person. Treatment sites were assessed for the presence of irritation using a 4-point scale. A positive skin reaction included irritation of all grades at any time point. Sodium dodecyl sulfate (SDS) was included as a weak positive control substance. 1 of 26 test persons showed a positive skin reaction while 21 of the 26 reacted to the positive control. On the basis of this result the material was evaluated as non-irritant to human skin (York et al., 1996).

Conclusion

Both, sodium perborate monohydrate and tetrahydrate tested as a solid substance according to the criteria for classification should not be classified as skin irritants. However, in some studies with the monohydrate after prolonged exposure very mild irritating effects were observed which were not completely reversible in some cases.

Solutions of 10% sodium perborate tetrahydrate are mildly irritating. There is no information on the irritating potential of more concentrated solutions.

4.1.2.3.2 Eye irritation

Studies in animals

The studies on eye irritation by sodium perborate are described in **Table 4.16**. In all studies according to standard protocols sodium perborate showed severe eye irritating effects, when applied as solid substance to the eyes (Bagley et al., 1994; ICI, 1986a, b; Interox, 1987d; Momma et al., 1986). Moderate corneal opacity, severe iritis and conjunctival effects which consisted of severe redness, moderate chemosis and severe discharge were recorded. The effects were not completely reversible. Rinsing within 30 seconds after application reduced the severity of the effect considerably (Momma et al., 1986). Also with lower amounts than in standard protocols the effect was weaker (Procter & Gamble, 1965, 1973 Maurer et al., 2001). The irritating potential of sodium perborate tetrahydrate seems to be lower than for the monohydrate, being consistent with its higher water content (ICI, 1986 a, b).

Studies in humans

Accoring to a questionnaire (Solvay, 2002a) 1 case of eye irritation which was reversible within one day has been reported for a filter change worker. Slight reversible irritative effects on the mucosa of the nose have been reported in another plant. The duration of exposure, number of workers examined and timeframe covered by the questionnaire was not given.

Conclusion

Sodium perborate caused strong eye irritation in animal studies, the effects being not reversible in most of the animals tested. Although the scores for irritation are not sufficient for classification with R41, due to the irreversible effect, both sodium perborate monohydrate and sodium perborate tetrahydrate are proposed to be classified with Xi; R41, “Risk of serious damage to eyes”.

4.1.2.3.3 Respiratory irritation

Studies in animals

Signs of irritation of the respiratory tract have been described in acute inhalation studies (see Section 4.1.2.2).

Studies in humans

The limit for respiratory irritation in human volunteers of both sexes of sodium perborate tetrahydrate was 21 mg/m^3. No further information was given (Silajev, 1984).

Slight reversible irritative effects on the mucosa of the nose have been reported in a questionnaire covering 4 production plants (Solvay, 2002a). The duration of exposure, number of workers examined and timeframe covered by the questionnaire was not given.

Conclusion

Due to the irritant effects on the respiratory tract a classification with Xi; R37 is proposed.

Table 4.16 Results from studies on eye irritation of sodium perborate in rabbits

Compound	amount instilled (mg) special treatments of the sample	Protocol	Cornea	Iris	Conjuctivae		MAS	Result	Reference
					Redness	Chemosis			
PBS1	"equivalent of 0,1 ml"	OECD 405 average scores after, 24, 48, 72 hours	2	2	3	2.3	36	severely irritating 3 animals tested, not completely reversible in 1 animal within 21 days	Interox, 1987d
PBS1	≈ 100	average scores after, 24, 48, 72 hours	2.7	1.3	3	2.7	86	severely irritating 1/3 animals tested because of severity of reaction, not completely reversible within 21 days	ICI 1986b
PBS1	Amount equivalent to 10 µl volume material was ground and sieved through 40 –mesh sieve =6.3 mg	"Low-volume eye test" Scores after 3 hours N = 12, macroscopic findings in lightmicroscopy study	1.7	4.2	7.5		13.3	Mildly irritating but corneal injury in 1 animal and no complete recovery within 35 days, mechanical irritation discussed as possibly contributing	Maurer et al., 2001
		N=22, macroscopic findings in confocal microscopy and Life/dead Assay	2.7	8.5	3.2		14.5		
PBS4	≈ 100	average scores after, 24, 48, 72 hours	2,3	1	3	2	66	severely irritating 2 animals tested. 1 animal killed after 3 days, because of severity of reaction, not completely reversible within 21 days	ICI, 1986a

Table 4.16 continued overleaf

Table 4.16 continued Results from studies on eye irritation of sodium perborate in rabbits

Compound	amount instilled (mg) special treatments of the sample	Protocol	Cornea	Iris	Conjuctivae		MAS	Result	Reference
					Redness	Chemosis			
PBS4	3	undiluted, no rinse	n.g.	n.g.	n.g.	n.g.	9.3	Slight transient conjunctival irritation. At 10%, the conjunctival irriation was greater but was still considered to be only mild to moderate. Reversible within 4 days, cornea was not involved	Procter and Gamble, 1965, 1973
		undiluted, rinse after 10 sec.	n.g.	n.g.	n.g.	n.g.	2		
		10 % w/v, no rinse	n.g.	n.g.	n.g.	n.g.	4		
PBS, n.sp	100	OECD 405, mean total score after 24 hours including area involved (maximum score 110), eyes without rinsing after application:	n.g.	n.g.	n.g.	n.g	63.3	severely irritating not completely reversible within 21 days	Momma et al., 1986
		eyes rinsed after 4 seconds	n.g.	n.g.	n.g.	n.g.	6.7	mildly irritating	
		eyes rinsed after 30 seconds	n.g.	n.g.	n.g.	n.g.	6.0	mildly irritating	
PBS, n.sp.	n.g.	modified Draize test					34.3	severely irritating not completely reversible within 35 days	Bagley et al., 1994
	n.g.	"low volume eye test"					24.3	severely irritating reversible within 7 days	

* If not indicated otherwise the original substance was applied to the eye without dilution
MAS maximum average score as given in the study reports, includes area affected, maximum 110
PBS n.sp. Sodium perborate, compound not specified
PBS1 Sodium perborate monohydrate
PBS4 Sodium perborate tetrahydrate
n.g. Not given

4.1.2.4 Corrosivity

Studies in animals

Sodium perborate is not corrosive to rabbit skin but may cause irreversible damage to the eyes (see above).

Studies in humans

Sodium perborate is not corrosive to human skin (see above).

Conclusion

Sodium perborate is not to be classified as corrosive to skin, but as causing irreversible damage to the eyes (R41).

4.1.2.5 Sensitisation

4.1.2.5.1 Skin sensitisation

Studies in animals

Sodium perborate monohydrate was tested in a Bühler test according to OECD guideline 405 test in 10 guinea pigs (5 males, 5 females) applying 0.5 ml/animal (not further specified, probably powder as it is, 6 hours/day, occlusive) once every seven days for a total of three applications. 14 days after the last induction the animals were challenged with 0.5 ml of a 5% solution in distilled water (maximum non-irritant concentration). 10 untreated animals served as controls. One of 10 test group animals as well as one of 10 control group animals showed a very slight erythema after 24 hours. The test substance was regarded to be not skin sensitising in this test (Interox, 1987e).

Studies in humans

There are no reliable studies in humans available on skin sensitisation. A strong sensitising potential would have been detected considering the exposure of the general population (see Section 4.1.1.3.1).

4.1.2.5.2 Respiratory sensitisation

Studies in animals

10 guinea pigs were exposed to sodium perborate tetrahydrate at 1 hour intervals for a total of 4 hours to 9 mg/m^3 or for 1 hour per week for 6 consecutive weeks to 11 mg/m^3. 6 weeks after the first exposure both exposure groups were challenged with the same concentration as above for 1 hour. One guinea pig responded with retracted breathing. Skin tests, passive cutaneous anaphylaxis and agar gel diffusion test and histological evaluation of lung tissue did not reveal an effect in any of the animals. Therefore the authors argue that the observed effect is

non-immunologic (no further information available, Procter and Gamble, 1973). The authors concluded that sodium perborate was neither significantly irritating nor allergenic to the guinea pig at these levels of exposure. However, due to the fact that only 2 dose levels were tested which were rather low, the insufficient documentation of the design and results of the study and the lack of a positive control, no general conclusion on the potential of sodium perborate for respiratory sensitisation can be drawn from this study.

Studies in humans

No studies in humans are available.

Further information from tests with degradation products

H_2O_2 is considered to be not skin sensitising (EU Risk Assessment Report on Hydrogen Peroxide, ECB, 2003). Boric acid and sodium borate were negative in the Buehler test and disodium tetraborate decahydrate was negative in a Bühler and a Maximisation test (IUCLID, 2000).

Conclusion

Considering skin sensitisation, according to the available Bühler test, sodium perborate is not to be regarded as a skin sensitising substance. The applied test is not regarded to be highly sensitive. But studies on H_2O_2 and boron compounds also give no concern for this endpoint.

Furthermore, there is no concern for respiratory sensitisation.

4.1.2.6 Repeated dose toxicity

Studies in animals

Results of studies with repeated application of sodium perborate are summarised in **Table 4.17**.

Table 4.17 Results from studies on repeated dose toxicity of sodium perborate

Species; strain; Animals / Group; Sex	daily Dose [mg/kg bw]	Compound Protocol Vehicle	Duration of treatment, post exposure period	Parameters investigated	Effects	Reference
Oral application (gavage)						
rat; 20 m	0 200	PBS n.sp. 20 mg/ml in 2% gummi arabicum	6 d; 3 d	body weight gain; food consumption; organ weights (liver; kidneys); gross pathology; histopathology (liver, kidney, stomach, intestine); haematology: Hb, Hct, RBC, WBC, reticulocytes	no change compared with controls	Dufour et al., 1971
rat; 20 test/ 12 control, m	0 1,000	100 mg/ml in 2% gummi arabicum	6 d; 8 d		haematological changes: RBC + 20% (control +6%, compared to controls from experiment above) Hct in test group during treatment normal, 3d after treatment elevated, Hb during treatment lower, after end of treatment elevated	
rat Wistar 5 m, 5 f	0 and 1,000	PBS4 OECD 215 mg/ml in 1% Tylose suspension	28 d / 7d/w 0 d	mortality, behaviour, clinical symptoms, body weight and body weight gain, reflexes, eye, ear and teeth; histopathology, urinalysis, haematology: RBC, WBC, Hct, Hb, MCH and MCHC, MCV and platelets	m + f: salivation after application, some animals up to 70 min, slight acanthosis and hyperkeratosis in forestomach, hyperplasia of fundic mucosa, red blood cell count ↓, Hb ↓, Hct ↓, platelets↑ (further details on haematology see Table 4.18), total protein ↓ , cholinesterase ↓ m: food intake ↓, bw gain ↓ (15 %), abs. weight of testes ↓ (18 %), brain ↓, heart↓, kidneys↓, number of lymphocytes ↓, spleen size in 2/5 animals ↓, spleenic parenchyma in 5/5 ↓, rel. weight of adrenals ↑, albumin ↓ f: rel. liver weight ↑, cholesterol ↓, calcium ↓ Reduction in absolute organ weights is assumed to be due to reduced food consumption and body weight gain.	Degussa, 1989
rat Crl:CD (SD) BR 25 f	0 / 100 / 300 / 1,000	PBS4 OECD 1% methyl-cellulose	d 6 – 15 of pregnancy; 5 d	general toxicity: body weight and body weight gain, food consumption	Teratogenicity study: 100 mg/kg bw: no effects on body weight gain 300 and 1,000 mg/kg bw: body weight gain and food consumption ↓	Bussi, 1995, 1996

Table 4.17 continued overleaf

Table 4.17 continued Results from studies on repeated dose toxicity of sodium perborate

Species; strain; Animals / Group; Sex	daily Dose [mg/kg bw]	Compound Protocol Vehicle	Duration of treatment, post exposure period	Parameters investigated	Effects	Reference
Dermal application						
rabbits; New Zealand white 3m, 3f	200	PBS4 10 % aqueous solution abraded skin	20 d (daily) 0 d	body weight and bw gain; organ weights (liver, kidney), blood parameters: RBC, WBC, Hb, Hct, white differential, histological examination of 15 organs	No adverse effects No statement on application (occlusive or non-occlusive Skin: mild irritation; no other changes detected indications of liver parasites in two animals and gastritis in one animal); one animal died each in control and in test group, for this animal no autopsy performed due to excessive autolysis	Procter & Gamble, 1965, 1966a
rabbits; New Zealand white 3m, 3f	50	PBS4 2.5 % aqueous solution intact skin	13 w; 5x / w 0 d		no adverse effects no statement on application (occlusive or non-occlusive) Skin: no irritation; no other changes detected: one animal died each in control and in test group, no autopsy performed due to excessive autolysis	Procter and Gamble, 1966b

PBS n.sp. Sodium perborate, compound not specified
PBS1 Sodium perborate monohydrate
PBS4 Sodium perborate tetrahydrate
n.g. Not given
↑ Increased
↓ Decreased
Hb Haemoglobin content
MCH Mean corpuscular haemoglobin
Hct Haematocrit
RBC Red blood cell count
MCHC Mean corpuscular haemoglobin concentration
MCV Mean corpuscular volume
platelets Thrombocytes
WBC White blood cell count and differentiation of leucocytes
m /f Male / female

Oral

Experiments with oral application (via gavage) of sodium perborate have been performed with the tetrahydrate (Degussa, 1989, 1,000 mg/kg bw, 215 mg/ml, 28 days) or not further specified perborate (Dufour, 1971, 200 mg/kg bw or 1,000 mg/kg bw for 6 days). Targets for toxic effects at a dose level of 1,000 mg/kg bw were the stomach, the haematologic system and possibly the testes (see Section 4.1.2.9.1).

In the 28-day study from Degussa (1989) acanthosis and hyperkeratosis in the forestomach and hyperplasia of the fundic mucosa were observed after application of 1,000 mg/kg bw via gavage. No effects on the stomach were found in the study of Dufour et al. (1971) in rats receiving the same dose. But in this study the exposure was only for 6 days to a more diluted solution and the animals were examined only after a recovery period of 8 days.

Haematological effects have been observed in both studies. In the study of Degussa (1989) after application of 1,000 mg/kg bw at the end of the study red blood cell count, haemoglobin, haematocrit and number of lymphocytes was statistically significantly decreased, the number of platelets was statistically significantly increased. The spleen size and spleenic parenchyma were reduced. In contrast in the Dufour-study, (with 6 days duration instead of 28 days in the Degussa study) no changes in blood cell parameters were observed during the study but haemoglobin and haematocrit were increased up to 15 days after the end of the application. This was explained by depression of haematopoiesis during the study and overregulation at the termination of the application. In order to assess the relevance of their findings Degussa has supplied control data from other experiments (Degussa-Hüls, 2000), performed from 1991 to 1993 (from earlier times no records were available) which are presented together with the findings of the Degussa Study in **Table 4.18**. As can be seen from the table, statistically significant decreases in measures of red blood cell parameters occurred consistently in male and female animals and therefore have to be considered as substance related. Platelet counts were higher than the physiological range. If these changes are secondary to the local effects in the stomach as proposed by Degussa-Hüls (2000) cannot be judged from the available information. In conclusion the NOEL for these endpoints is below the dose of 1,000 mg/kg bw tested.

Table 4.18 Haematological parameters in the Degussa study

Parameter	Unit	Male rats			Female rats		
		Controls 1991-1993 n=44-45	Controls study	1,000 mg/kg bw PBS4	Controls 1991-1993 n=41-42	Controls study	1,000 mg/kg bw PBS4
Red blood cells	per plate	6.53	6.94	6.05*	7.09	6.6	5.71*
Haemoglobin	g/dl	13.3	15.9	14.3*	13.9	15.7	13.6*
Haematocrit	l/l	0.316	0.449	0.384*	0.318	0.415	0.362*
Mean corpuscular haemoglobin conc.	g/dl	32.1	35.4	37.3*	33.0	37.9	37.6
Platelets	per nl	926	1,015	1,175*	930	1,020	1,200*
White blood cells	per nl	10.4	12.9	9.4*	9.2	11.1	9.3
Lymphocytes	per nl	9.01	11.36	8.19	8.12	9.83	8.2

* Statistically significant (5% level)

Inhalation

No tests for repeated dose toxicity by inhalation are available. However there is concern for this endpoint, as effects on the respiratory tract have been reported in studies on acute inhalation toxicity (DuPont, 1987; Silajev, 1984).

Dermal

Two dermal studies, both on sodium perborate tetrahydrate, with limited reporting of the results are available. New Zealand white rabbits received either a dermal dose of 200 mg/kg bw in 10% aqueous solution on the abraded skin for 3 weeks (Proctor and Gamble, 1965; 1966a) or 50 mg/kg bw as 2.5% solution on the intact skin for 13 weeks (Procter and Gamble, 1966b). In both studies there were no statistically significant differences compared to controls in growth, organ/body weight ratios (liver, kidney), blood parameters (all relevant parameters investigated, figures included in the report), gross pathology, or histopathology (organs required in current guidelines investigated). Skin effects are given in **Table 4.15**. Only during the application of the 10% solution to the abraded skin, some animals showed mild irritative effects.

Studies in humans

Inhalation

Health surveillance data are available for workers in perborate production (see **Table 4.19**).

Routine examinations have been performed with 67 workers of two production sites exposed to 0.2-0.8 mg/m^3 sodium perborate mono and/or tetrahydrate during 3-36 years (Degussa-Hüls, 1999b). These included lung function measurements by spirometry determining forced vital capacity (FVC) and peak expiratory flow (PEF). According to a questionnaire filled in by the physicians, no alterations related to exposure to sodium perborate were observed. It should be noted however, that the questions relating to health effects were rather general. Data on individual workers were provided for 26 workers in one plant (Degussa, 2003), which included yearly measurements of forced vital capacity (FVC), forced expiratory volume 1 (FEV1), vital capacity (VC) and peak expiratory flow (PEF). Smoking habits and confounding diseases or medication were also reported. 15 workers have been exposed for more than 20 years, 4 workers have been exposed 11 to 20 years and 8 workers 6 to 8 years. No trend for decreasing lung function compared to standard values was found, which could be attributed to exposure to sodium perborate.

Similarly according to questionnaires in 4 other production plants (Solvay, 2002a), no effects on FVC and FEV1 have been found in general medical examinations performed every 3 years. Also no effects were found in one plant, where spirometry was performed before and after filter change work. 1 case of eye irritation which was reversible within one day has been reported for a filter change worker. Slight reversible irritative effects on the mucosa of the nose have been reported in another plant. The duration of exposure, number of workers examined and timeframe covered by the questionnaire was not given. From one production plant more detailed data are available (Solvay, 2002b). For 16 operators the FVC and FEV1 have been analysed from 1992 to 2001 and no differences compared to the standard predicted values were found. The exposure concentrations in this time ranged from 0.1 to 2.8 mg/m^3 of total inhalable dust, the medians from 0.4 to 1.8 mg/m^3. In addition information on individual workers was provided (Solvay, 2003a, b). None of the workers showed values, which were clearly below the standard predicted values. Furthermore, for none of the workers a trend towards lower values with increasing exposure duration could be detected.

In another production plant FVC and FEV 1 were measured in 15 workers from 2000-2002 (FMC foret, 2003) and FEV1/FVC (ITF) was calculated. No significant deviations from a non smoking reference population of 443 non smokers (in an age between 20-70 years) were found. The average value for FVC was 89 ± 13% of the control, the average FEV1 92% ± 13% and ITF was 105% ± 8%. No information on exposure concentrations was given in this study.

Besides the exposure data given in **Table 4.19**, workplace surveillance data are available for the companies where the spirometric measurements have been conducted. They are included in **Table 4.1**. A reasonable worst case concentration of 12.1 mg/m^3 and a typical value of 1 mg/m^3 was derived from the data covering also several other companies. The NOAEC for effects on the lung might therefore be in this range, rather higher than 1 mg/m^3 as exposure concentrations are assumed to have been higher in former years.

Although no clear NOAEC can be derived for repeated dose lung effects in workers the health surveillance data that have been obtained over up to 20 years from a high proportion of the workplaces with the highest potential exposure levels suggest that there is no concern with regard to possible effects on the lung (see also Section 4.1.3.2).

Table 4.19 Repeated dose toxicity via inhalation – human surveillance data

Examinations	Parameters measured	Production plants	Workers observed	Exposure mg/m^3 range median	Years	Exposure duration	Reference
routine examinations	FVC, PEF	2	67	0.06- 0.8	1991-1995	3 – 36 year 46 workers: > 9 years	Degussa-Hüls, 1999b
data on individual workers from one of the 2 companies above	yearly measurements of FVC, FEV1, VC, PEF	1	27			15 workers: > 20 yrs 4 workers: 11 – 20 yrs 8 workers: 6 – 10 yrs	Degussa, 2003
routine examinations	every 3 years	4	n.g.	n.g.	n.g.	n.g.	Solvay 2002a
data on individual workers	yearly measurements of FVC, FEV1	1	16	0.1 – 2.8 (median: 0.4 – 1.8)	1992 - 2001	10	Solvay, 2002b, 2003a, b
measurements of	FVC, FEV1;	1	15	n.g.	2000 - 2002	3	FMC foret, 2003

n.g. Information not given

Further information from tests with degradation products

Oral

Decreased body weight gain (associated with reduced food intake) and duodenal mucosal hyperplasia was a typical finding in animals exposed to H_2O_2. The NOAEL in a 90-day drinking water study with catalase-deficient mice, which are particularly sensitive, is given as 26 mg/kg for males, the LOEL was 78 mg/kg bw (EU Risk Assessment Report on Hydrogen Peroxide,

ECB, 2003). This would correspond to a sodium perborate concentration of 229 mg/kg bw for the monohydrate and 353 mg/kg for the tetrahydrate.

With borate in a two year study with mice, besides atrophy of the testes a dose dependent lymphoid depletion in the spleen occurred, the LOAEL being 48 mg/kg bw (NTP, 1987 in ECETOC, 1995; WHO, 1998a). In a 2-year study in rats also effects on the haematological system were found with a LOAEL of 58.4 mg boron/kg bw and a NOAEL of 17.5 mg/kg. Other changes were decreased testes weight and increased weight of the brain and the thyroid gland (Weir and Fisher, 1972, in ECETOC, 1995; WHO, 1998a). This NOAEL would correspond to a sodium perborate concentration of 162 mg/kg bw for the monohydrate and of 250 mg/kg for the tetrahydrate.

Inhalation

A 28-day range finding inhalation toxicity study with H_2O_2 was performed in the rat (EU RAR Hydrogen peroxide, ECB, 2003). Respiratory tract irritation was seen at the exposure levels of 14.6 and 33 mg/m^3, but not at 2.9 mg/m^3. Regarding histopathology, at the two higher levels concentration-related necrosis and inflammation of the epithelium in the anterior regions of the nasal cavity was found. In the larynx, mononuclear cell infiltration was seen in two females at the highest exposure concentration. Moreover, in the lungs, one male rat in each exposure group and two female rats in the top dose group exhibited perivascular neutrophil infiltration, and there was haemorrhage in some animals at the two lower dose levels. Control animals did not exhibit changes. As regards pathology in the lungs, the authors of the study considered it unlikely that the effects were treatment related due to the absence of a relationship with exposure concentration and the low incidence, and hence the NOAEC of the study would be 2.9 mg/m^3.

A provisional LOAEC of 2 mg/m^3 H_2O_2 was derived from a human investigation, where eye and airway irritation, and asthma symptoms were found. These effects may however have been due to peak exposures (up to 4.2 and 11.3 mg/m^3 at two machines).

No irritating effects have been found in a company after the exposure levels had been reduced to below 0.8 mg/m^3 H_2O_2. It was provisionally concluded that exposures to hydrogen peroxide in access of 1.4 mg/m^3 (8-hour TWA) may cause risk of irritation for the upper airways. Therefore this value can be considered as NOAEC for irritating effects for the upper airways. (see Section 4.1.3.2.1 of Hydrogen peroxide Risk assessment report).

The NOAEC for the rat would correspond to a NAEC of 13.1 mg/m^3 for sodium perborate tetrahydate. The human exposure level of 1.4 mg/m^3 corresponds to 6.3 mg/m^3 of sodium perborate tetrahydrate.

For the borates the information is inadequate.

Conclusion

Oral

Effects after oral application of sodium perborate can be attributed to the degradation products.

From the 28-day study from Degussa (1989) a NOAEL cannot be derived, because the only dose investigated was 1,000 mg/kg bw which showed effects on the stomach, spleen and the haematopoietic system. No effects were recorded in the study of Dufour (1971) at 200 mg/kg bw. This study was only for 6 days with 3 days of recovery and only a limited

number of parameters have been investigated. Therefore also from this study a NOAEL cannot be derived.

Systemic effects, which have to be considered, are the effects on the haematopoietic system. Thus the LOAEL is 1,000 mg sodium perborate tetrahydrate/kg bw (70 mg boron/kg bw) and no NOAEL can be derived.

Inhalation

The toxicity by inhalation cannot be evaluated with the available animal studies. No extrapolation from the oral LOAEL can be made, due to expected local effects. From the available acute toxicity studies and due to the strong irritating effects at mucous membranes rather low effect levels are expected.

A NAEC of about 13.1 mg/m^3 can be derived for sodium perborate based on the results of the rat inhalation study with H_2O_2. However, the target of intoxication and consequently the NOAEC for sodium perborate particles may be different from H_2O_2 gas.

No effects in the lungs have been reported in spirometric examinations of about 100 workers in production plants, even at workplaces with presumed high exposure (filter change). Furthermore, follow-up of the workers for several years to more than 20 years did not show deterioration of the lung function measured as FVC, FEV1, VC and PEF. Although, these parameters are not very sensitive, especially for small airways disease, the absence of effects in a great number of workers and even in workers exposed for more than 20 years leads to the conclusion that there is no concern for obstructive lung effects such as asthma or chronic bronchitis in production workers.

Considering the information on exposure from the workplace surveillance data and the data on exposure in perborate production plants in general (see **Table 4.1**), which gave a rather narrow range for all measurements, a NOAEC for effects on the lung may be in the range from 1 mg/m^3 to 12 mg/m^3.

Although no clear NOAEC can be derived for repeated dose lung effects in workers the health surveillance data that have been obtained over up to 20 years from a high proportion of the workplaces with the highest potential exposure levels suggest that there is no concern with regard to possible effects on the lung (see also Section 4.1.3.2).

Table 4.20 Repeated dose toxicity via inhalation – human surveillance data

Examinations	Parameters measured	Production plants	Workers observed	Exposure mg/m^3 range median	Years	Exposure duration	Reference
routine examinations	FVC, PEF	2	67	0.06- 0.8	1991-1995	3 – 36 year 46 workers: > 9 years	Degussa-Hüls, 1999b
data on individual workers from one of the 2 companies above	yearly measurements of FVC, FEV1, VC, PEF	1	27			15 workers: > 20 yrs 4 workers: 11 – 20 yrs 8 workers: 6 – 10 yrs	Degussa, 2003

Table 4.19 continued overleaf

Table 4.19 continued Repeated dose toxicity via inhalation – human surveillance data

Examinations	Parameters measured	Production plants	Workers observed	Exposure mg/m^3 range median	Years	Exposure duration	Reference
routine examinations	every 3 years	4	n.g.	n.g.	n.g.	n.g.	Solvay 2002a
data on individual workers	yearly measurements of FVC, FEV1	1	16	0.1 – 2.8 (median: 0.4 – 1.8)	1992 - 2001	10	Solvay, 2002b, 2003a, b
measurements of	FVC, FEV1;	1	15	n.g.	2000 - 2002	3	FMC foret, 2003

n.g. Information not given

Further information from tests with degradation products

Oral

Decreased body weight gain (associated with reduced food intake) and duodenal mucosal hyperplasia was a typical finding in animals exposed to H_2O_2. The NOAEL in a 90-day drinking water study with catalase-deficient mice, which are particularly sensitive, is given as 26 mg/kg for males, the LOEL was 78 mg/kg bw (EU Risk Assessment Report on Hydrogen Peroxide, ECB, 2003). This would correspond to a sodium perborate concentration of 229 mg/kg bw for the monohydrate and 353 mg/kg for the tetrahydrate.

With borate in a two year study with mice, besides atrophy of the testes a dose dependent lymphoid depletion in the spleen occurred, the LOAEL being 48 mg/kg bw (NTP, 1987 in ECETOC, 1995; WHO, 1998a). In a 2-year study in rats also effects on the haematological system were found with a LOAEL of 58.4 mg boron/kg bw and a NOAEL of 17.5 mg/kg. Other changes were decreased testes weight and increased weight of the brain and the thyroid gland (Weir and Fisher, 1972, in ECETOC, 1995; WHO, 1998a). This NOAEL would correspond to a sodium perborate concentration of 162 mg/kg bw for the monohydrate and of 250 mg/kg for the tetrahydrate.

Inhalation

A 28-day range finding inhalation toxicity study with H_2O_2 was performed in the rat (EU RAR Hydrogen peroxide, ECB, 2003). Respiratory tract irritation was seen at the exposure levels of 14.6 and 33 mg/m^3, but not at 2.9 mg/m^3. Regarding histopathology, at the two higher levels concentration-related necrosis and inflammation of the epithelium in the anterior regions of the nasal cavity was found. In the larynx, mononuclear cell infiltration was seen in two females at the highest exposure concentration. Moreover, in the lungs, one male rat in each exposure group and two female rats in the top dose group exhibited perivascular neutrophil infiltration, and there was haemorrhage in some animals at the two lower dose levels. Control animals did not exhibit changes. As regards pathology in the lungs, the authors of the study considered it unlikely that the effects were treatment related due to the absence of a relationship with exposure concentration and the low incidence, and hence the NOAEC of the study would be 2.9 mg/m^3.

A provisional LOAEC of 2 mg/m^3 H_2O_2 was derived from a human investigation, where eye and airway irritation, and asthma symptoms were found. These effects may however have been due to peak exposures (up to 4.2 and 11.3 mg/m^3 at two machines).

No irritating effects have been found in a company after the exposure levels had been reduced to below 0.8 mg/m^3 H_2O_2. It was provisionally concluded that exposures to hydrogen peroxide in access of 1.4 mg/m^3 (8-hour TWA) may cause risk of irritation for the upper airways. Therefore this value can be considered as NOAEC for irritating effects for the upper airways. (see Section 4.1.3.2.1 of Hydrogen peroxide Risk assessment report).

The NOAEC for the rat would correspond to a NAEC of 13.1 mg/m^3 for sodium perborate tetrahydate. The human exposure level of 1.4 mg/m^3 corresponds to 6.3 mg/m^3 of sodium perborate tetrahydrate.

For the borates the information is inadequate.

Conclusion

Oral

Effects after oral application of sodium perborate can be attributed to the degradation products.

From the 28-day study from Degussa (1989) a NOAEL cannot be derived, because the only dose investigated was 1,000 mg/kg bw which showed effects on the stomach, spleen and the haematopoietic system. No effects were recorded in the study of Dufour (1971) at 200 mg/kg bw. This study was only for 6 days with 3 days of recovery and only a limited number of parameters have been investigated. Therefore also from this study a NOAEL cannot be derived.

Systemic effects, which have to be considered, are the effects on the haematopoietic system. Thus the LOAEL is 1,000 mg sodium perborate tetrahydrate/kg bw (70 mg boron/kg bw) and no NOAEL can be derived.

Inhalation

The toxicity by inhalation cannot be evaluated with the available animal studies. No extrapolation from the oral LOAEL can be made, due to expected local effects. From the available acute toxicity studies and due to the strong irritating effects at mucous membranes rather low effect levels are expected.

A NAEC of about 13.1 mg/m^3 can be derived for sodium perborate based on the results of the rat inhalation study with H_2O_2. However, the target of intoxication and consequently the NOAEC for sodium perborate particles may be different from H_2O_2 gas.

No effects in the lungs have been reported in spirometric examinations of about 100 workers in production plants, even at workplaces with presumed high exposure (filter change). Furthermore, follow-up of the workers for several years to more than 20 years did not show deterioration of the lung function measured as FVC, FEV1, VC and PEF. Although, these parameters are not very sensitive, especially for small airways disease, the absence of effects in a great number of workers and even in workers exposed for more than 20 years leads to the conclusion that there is no concern for obstructive lung effects such as asthma or chronic bronchitis in production workers.

Considering the information on exposure from the workplace surveillance data and the data on exposure in perborate production plants in general (see **Table 4.1**), which gave a rather narrow range for all measurements, a NOAEC for effects on the lung may be in the range from 1 mg/m^3 to 12 mg/m^3.

Although no clear NOAEC can be derived for repeated dose lung effects in workers the health surveillance data that have been obtained over up to 20 years from a high proportion of the workplaces with the highest potential exposure levels suggest that there is no concern with regard to possible effects on the lung (see also Section 4.1.3.2.1).

Slight and temporary reversible irritating effects have been found in the eyes and in the nose. These effects may be attributed to peak exposures, as they were reported only incidentally. As a worst case estimate, assuming that all sodium perborate is deposited in the upper airways and is degraded to H_2O_2, the NOAECs from H_2O_2 can be applied: The NOAEC for H_2O_2 in the rat study was 2.9 mg/m^3, a provisional human LOAEC was 2 mg/m^3. No effects occurred in humans exposed at workplaces to H_2O_2-concentrations below 0.8 mg/m^3. It was provisionally concluded that exposures to hydrogen peroxide in excess of 1.4 mg/m^3 (8-hour TWA) may cause risk of irritation for the upper respiratory tract. Therefore this value can be considered as NOAEC for irritating effects for the upper airways. (see Section 4.1.3.2.1 of Hydrogen peroxide Risk assessment report).

The NOAEC for the rat would correspond to a NAEC of 13.1 mg/m^3 for sodium perborate tetrahydate, the provisional human LOAEC to 9 mg/m^3. The human exposure level of 1.4 mg/m^3 corresponds to 6.3 mg/m^3 of sodium perborate tetrahydrate.

Dermal

The reporting of the results of the available studies (Procter and Gamble, 1965, 1966a;b) is limited. However all relevant organs have been examined by histopathology and also haematological parameters have been investigated, which have shown changes in the oral studies. Therefore the studies are considered as sufficient for the risk assessment. In comparison with the results from the oral studies and as it can be assumed that sodium perborate is not taken up by the skin very efficiently the NOAEL of this study of 200 mg/kg bw, which was the highest dose tested, may be too low.

4.1.2.7 Mutagenicity

Studies *in vitro*

The results of the *in vitro* mutagenicity studies are described in detail in **Table 4.21**.

Sodium perborate was genotoxic without metabolic activation in reverse mutation assays in s. typhimurium TA 100 (Seiler, 1989) and 102 (Seiler, 1989; Watanabe et al., 1998), TA 2638 (Watanabe et al., 1998) and in e.coli WP2/pKM101 and WP2 uvrA/pKM101 (Watanabe et al., 1998), in a DNA repair test in e. coli (Rosenkranz, 1973) and in a test on chromosomal aberrations in CHO-K1-cells (Seiler, 1989). The addition of S9 reduced both, cytotoxicity and mutagenicity in S. typhimurium TA 100 and 102. The genotoxic activity may be due to the generation of H_2O_2 because genotoxicity is reduced in the presence of catalase (Seiler, 1989; Rosenkranz, 1973). Rosenkranz speculates that the activity of sodium perborate was not abolished completely by catalase, because sodium perborate was taken up partly by the bacteria.

Studies *in vivo*

No data are available on mutagenicity *in vivo*.

Further information from tests with degradation products

H_2O_2 is a genotoxicant in a variety of *in vitro* test systems (EU Risk Assessment Report on Hydrogen Peroxide, ECB, 2003). Effects were reduced by the presence of catalase. No significant genotoxicity *in vivo* was observed, probably due to effective inactivation mechanisms. The EU RAR concludes, that "the available studies are not in support of a significant genotoxicity/mutagenicity for hydrogen peroxide under *in vivo* conditions."

Borates are negative in genotoxicity assays (WHO, 1998a)

Conclusion

The studies *in vitro* on sodium perborate show a genotoxic potential, which may be due to the generation of H_2O_2, as similar to investigations with H_2O_2 the responses observed were reduced by the presence of catalase. Therefore analogous to H_2O_2 the genotoxic potential may not be relevant *in vivo*. Furthermore in contrast to H_2O_2, due to its ionisation, sodium perborate itself should be taken up by cells less easily than H_2O_2.

Table 4.21 Results from studies *in vitro* on mutagenicity of sodium perborate

Test Organism	Type of test	Compound Concentration range	Result			Remarks	Reference
			- S9	+ S9	+ cat		
cell free	oxidation of thymidine to thymidine glycol	PBS, n.sp. 20-50 mg/ml	+	n.i.	n.i.	positive at 40 and 80° C	Seiler, 1989
S. typhimurium TA 98 TA 100 TA 102	reverse mutation	PBS, n.sp. 10 – 2,000 µg/plate	- + (+)	- - -	n.i. - n.i.	toxic without S9 at > 50 µg/plate	Seiler, 1989
S typhimurium TA 102 TA 2638	Reverse mutation	PBS4 93.5-5,000 µg/plate	 + +	 n.i. n.i.	 n.i. n.i	Test performed in parallel in 2 laboratories with equal results Toxic at ≥ 3,000 µg/plate for both strains Differences in toxicity between laboratories Strains especially sensitive to oxidative damage	Watanabe et al., 1998

Table 4.20 continued overleaf

Table 4.20 continued Results from studies *in vitro* on mutagenicity of sodium perborate

Test Organism	Type of test	Compound Concentration range	Result			Remarks	Reference
			- S9	+ S9	+ cat		
E. coli WP2/pKM101 WP2 uvrA/pKM101	Reverse mutation	PBS4 93.5-5,000 µg/plate	 + +	 n.i. n.i.	 n.i. n.i.	Test performed in parallel in 2 laboratories Toxic at ≥1,500 µg/plate for both strains Differences in toxicity between laboratories Strains especially sensitive to oxidative damage	Watanabe et al., 1998
E. coli W3110, pol A^+	DNA-repair	PBS, n.sp. 0.003-0.004 µmoles	n.i.	+	(+)	pol⁻ strains DNA repair deficient (no polymerase I) more sensitive, activity of sodium perborate not completely abolished by catalase, activity of H_2O_2 completely abolished by catalase	Rosen-kranz, 1973
E. coli P 3478 pol A^-	DNA-repair		n.i.	+	(+)		
CHO-K1	chromosome aberrations	PBS, n.sp. 10 – 100 µg/ml	+	-	n.i.	especially chromosomal rearrangements	Seiler, 1989

cat Catalase,
CHO Chinese hamster ovary cells,
n.sp. Not specified,
n.i. Not investigated,
PBS n.sp. Sodium perborate, compound not specified

4.1.2.8 Carcinogenicity

Studies in animals

No data on carcinogenicity is available. In the 28-day test 1,000 mg/kg bw sodium perborate tetrahydrate led to hyperplasia of the fundic mucosa of the stomach in rats (see **Table 4.17**).

Studies in humans

No data on carcinogenicity is available.

Further information from tests with degradation products

In a carcinogenicity study with H_2O_2 applied via drinking water to different strains of mice, erosion and ulcer in the glandular stomach and duodenal nodules were observed in a dose dependent manner. The latter showed a marked tendency of regression after cessation of the treatment (Ito et al., 1981a, 198b in EU Risk Assessment Report on Hydrogen Peroxide, ECB,

2003). In a study with rats with similar concentrations no effects were observed (Takayama, 1980¸ in EU Risk Assessment Report on Hydrogen Peroxide).

The EU Risk Assessment Report on Hydrogen Peroxide (ECB, 2003) concludes as follows: "The mechanism of carcinogenic effect is unclear. Given that hydrogen peroxide causes DNA damage on contact with cells, a genotoxic mechanism cannot be excluded. Unfortunately, no cytogenetic studies *in vivo* have been available on the target tissue in various stages of histopathological injury. As regards tumour promotion, several mechanisms might be operative: direct genotoxicity, impairment of DNA repair, and chronic inflammation. The special nature of the demonstrated carcinogenicity of hydrogen peroxide, and the overall evidence available at this time cast some doubt on whether hydrogen peroxide should be regarded as a carcinogen of practical significance. The weak effect found in complete carcinogenesis studies in mice as well as in some promotion studies suggest promotion type of activity and possible underlying genotoxic mechanisms. Given the fact that mammalian cells have of necessity built defences against reactive oxygen species arising in endogenous metabolism, the injuries caused by hydrogen peroxide may well be non-stochastic, i.e. have a dose/dose rate threshold. It was further concluded that "although a local carcinogenic effect (observed at higher doses) by a genotoxic mechanism cannot be excluded, the weight of evidence at this time does not suggest that carcinogenicity should be regarded as the critical effect." (see Section 4.1.3 of hydrogen peroxide RAR).

Boric acid and borax were negative in carcinogenicity studies with rats, dogs and mice (Hubbard, 1998; WHO, 1998a).

Conclusion

As hyperplasia has been found in the forestomach after application of high concentrations of sodium perborate via gavage, it may be speculated that in analogy to H_2O_2 prolonged exposure to high irritating concentrations of sodium perborate may cause tumours as a consequence of increased cell proliferation. From the reversibility of the effects on the stomach with sodium perborate as well as with H_2O_2, it can be argued, that doses, which would not lead to irritation, also would not lead to tumour formation.

4.1.2.9 Toxicity for reproduction

4.1.2.9.1 Fertility

Studies in animals

A 28-day limit dose study (Degussa, 1989), where 1,000 mg/kg bw sodium perborate tetrahydrate was applied by gavage to rats is described in detail in Section 4.1.2.6. Food intake was significantly reduced in treated males from day 8, while treated females did not differ in this respect from controls. An 18% significant decrease in absolute testicular weights was recorded with relative testes weights not reduced. By the authors of the study this was attributed to a generalised weight reduction of 15% in week 4 as a result of reduced food intake since other absolute organ weights (brain, heart and kidney) appeared to be similarly affected.

A histopathological examination of the testes revealed no adverse effects. Also a re-examination of the slides of this study did not reveal effects such as pachytene cell death, germ cell exfoliation and advanced epithelial cell disorganisation (Harleman, 1999, Nolte; 2001).

Sudies in humans

There are no studies in humans available.

Further information from tests with degradation products

From studies with borates there is concern for effects of sodium perborate on male reproduction (ECETOC, 1995); WHO 1998a). In several studies effects on male fertility have been observed such as reduced testes weights, reduced sperm concentrations and motility, changes in sperm morphology, at high concentrations also atrophy of the testes, degeneration of the seminiferous tubules. The LOELs in several studies are at about 25 mg boron/kg bw in rats and mice. As these concentrations often were the lowest dose levels tested, it is difficult to derive a NOAEL. From the mild effects observed at this concentration it seems, however, to be not far below. From one valid study with rats receiving borax or boric acid in the diet for two years a NOAEL of 17.5 mg Boron/kg bw could be derived (Weir and Fisher, 1972, cited from WHO, 1998a). This would correspond to a NOAEL of 161 mg/kg bw for sodium perborate monohydrate and of 249 mg/kg bw for sodium perborate tetrahydrate.

In the study from Ku et al. (1993) histopathological examinations (staging analysis) revealed testicular toxicity after application of boric acid in concentrations corresponding to 26 to 68 mg/kg bw boron, which was apparent after 4 weeks of treatment.

Discussion at the Specialised Experts Meeting (Ispra, Oct. 2004)

At the Specialised Experts Meeting results from the study with sodium perborate tetrahydrate (Degussa, 1989) were compared with effects seen in studies on boric acid/borax after similar durations of treatment (see **Table 4.21**). Based on these data it was discussed if sodium perborate has the same properties as borates and whether it is possible to read across.

The LOAELs for changes in the testes weights in the different studies are in a comparable order of magnitude.

The reduction of absolute testes weights from 2.09g (standard deviation of 0.11) to 1.71g (standard deviation of 0.14) is significant at a probability level of 1% (Degussa, 1989). The Specialised Experts discussed if testes effects might be a consequence of reduction in body weight gain or a compound related effect. The general influence of food restriction or decreased food uptake on the weight development of rats was taken into account (see **Table 4.22**). In a comparable study with boric acid (Ku et al., 1993) a reduction in body weight gain and in absolute testes weights was seen, while no information on relative testes weights is given. In the study from Oishi et al. (1979) the relative testes weights increase with almost no effect on the absolute testes weights. Based on these data the testes effects seen in Degussa (1989) are likely to be substance related. On the other hand, Feron et al. (1973) showed in their study reduced absolute and relative testes weights by the use of cellulose diet to prevent the rats from starving.

The reduction in testes weights seems to be a relevant finding as there is a common view that due to their importance brain and testes weights will generally not be affected by a reduction in body weight. But it has to be stated that in the available study on sodium perborate also absolute brain, heart, and kidney weight of male rats were affected.

No effects are seen in the histopathology of the testes in the original study and after re-evaluation of the histopathology (Harleman, 1999; Nolte, 2001) but due to the method used some effects could have been overlooked.

Usually 95% or more of the testis weight is due to the seminiferous tubules with full sperm production. If sperm production is hampered a reduction in cellular number and a shrinking of the tubules will be seen. Cellcounts or the measurement of the diameter of the seminiferous tubules would have been an option to detect the very first signs of impairment of spermatogenesis resulting in a decrease in testis weight. The first sign of testicular atrophy is always a reduction in testis size, a total degeneration of germ cells will follow as a later step.

The data of the 28-day study (Degussa, 1989) are very limited and difficult to interpret. The study cannot exclude effects on fertility as the duration of exposure was probably too short and the examination of histological data and effect on testes weights left some doubts. The limit dose of 1,000 mg/kg bw of perborate correspond to 70 mg boron/kg bw, which is considered as a low dose in boron equivalents. At this concentration clear effects were seen in studies with boric acid while in the perborate study only effects on testes weights were observed. The reduction of testicular weight is a sign of an effect and it cannot be excluded that at higher doses or after a longer period of exposure clear detectable effects would have been manifested.

The Specialised Experts pointed out that boric acid as a metabolite of sodium perborate will be systemically available and, therefore, the same effects are expected and the data of borates have to be taken into consideration for read across. Based only on read across the classification for boric acid/borates (category 2 for effects on fertility) should also apply for sodium perborate.

Based on this discussion the conclusion by the Specialised Experts was that the studies in animals on fertility (Degussa, 1989) alone are very limited and insufficient for classification but causing some concern. However, evidence that sodium perborate is converted to boric acid, which has a recommended classification as Repr. Cat. 2; R60, suggests that sodium perborate may affect fertility and on this basis the Specialised Experts recommended classification as Repr. Cat. 3; R62.

Table 4.22 Comparison of effects on fertility (Sodium perborate – Boric acid/borax) after similar durations of treatment

Reference	Degussa, 1989 Harleman, 1999	Lee et al., 1978*	Ku et al., 1993*	Treinen and Chapin, 1991	Yoshizaki et al., 1999	Caujolle et al., 1962	Weir and Fisher, 1972
Compound	Sodium perborate tetrahydrate	Borax	Boric acid	Boric acid	Boric acid	Boric acid	Boric acid and Borax
Species, strain	Rat, Wistar	Rat, Sprague Dawley	Rat F344	Rat F344	Rat Wistar	Rat Wistar	Rat Spraque Dawley
Dose levels	1,000 mg/kg bw	500, 1,000, 2,000 ppm of B in food	3,000, 4,500, 6,000, 9,000 ppm Boric acid in food	9,000 ppm in food (348 mg/kg bw)	50, 150, 500 mg/kg bw	200, 400, 800 mg/kg bw	52.5, 175, 525, 1750, 5250 ppm B
Dose levels (mgB/kg bw/day)	70	25, 50, 100	26, 38, 52, 68	60.9	9, 26, 88	35, 70, 140	2.6, 8.8, 26, 88, 263
Study duration	28 days	30 days	up to 90 days	28 days	21 days	30 days	90 days
		60 days	6 animals sacrificed every week	Interim sacrifices			
Histopathology							
Fixation	Formalin	Bouin´s	Formalin	Glutaraldehyde/Formalin	Bouin´s/Formaldehyde	??	Formalin
Embedding	Paraffin	Paraffin	Plastic	Plastic	Paraffin	??	?
LOAEL absolute testis weight (mg B/kg bw)	70	no changes (30 d)	52 in presence of atrophy	n.d.	88	n.d.	88 in presence of complete atrophy
LOAEL histopath (mg B/kg bw)	No changes detected	50 (30 days)	26 (inhibited spermiation) 38: severe and widspread inhibition of spermiation (4 weeks)	60.9 (advanced epithelial disorganisation, cell exfoliation, luminal occlusion, cell death)	88 (atrophy, giant cells, cell debris) minimal effects at 26	70 atrophy minimal effects at 35	26 (partial atrophy)

* To allow comparison with sodium perborate tetrahydrate, the effects after similar durations of treatment are given.

Table 4.23 Influence of reduced body weight gain on absolute and relative testes weights

	Degussa, 1989	Ku et al., 1993	Oishi et al., 1979	Feron et al.,
Species Strain	Rat Wistar	Rat F344	Rat Wistar	Rat Wistar
	Sodium perborate 1,000 mg/kg bw	Boric acid 9,000 ppm in food	Food restriction	Increased cellulose in diet
Food intake	↓ 15%	↓ 11%	↓ 25-30%	
Reduction in body weight gain	15%	16%	≈ 30%	22%
Relative testes weights compared to control	unchanged	n.g.	↑ 31%	↓ 13%
Absolute testes weights compared to control	↓ 18%	↓ ≈20%	↓ 3%	↓ 25%

n.g. Not given

Conclusion

The testes are target organs of toxicity of boron compounds. In the 28-day study after oral application of 1,000 mg sodium perborate tetrahydrate/kg bw a decrease in absolute testes weights was recorded, which could be an early sign of testicular toxicity. Body weight gain (due to reduced food intake) and absolute weights of other organs were reduced as well, but testes weights seem to be less affected by body weight decreases from reduced food intake than other organs (Oishi et al., 1979).

Histological examinations of the testes in this perborate study did not reveal any signs of toxicity at 1,000 mg sodium perborate tetrahydrate/kg bw (corresponding to 70 mg/kg boron). However, testes were fixed with formalin, a method which allows only detection of major effects as this leads to cellular shrinkage. Using more sensitive methods of histopathology i.e. perfusion with glutaraldehyde/paraformaldehyde and embedding with methacrylate revealed much more subtle effects with other compounds including borates (Ku et al., 1993; Treinen and Chapin, 1991).

At the meeting in October 2004, the Specialised Experts declared that the 28-day study of Degussa (1989) alone was very limited and insufficient for classification. Since boric acid as a metabolite of sodium perborate is systemically available, a NAEL of 249 mg/kg bw was deduced for sodium perborate tetrahydrate based on read across from the boron content. Following the opinion of the Specialised Experts, reduced testes weights as early signs of testicular toxicity cannot be dismissed in view of the known testicular toxicity of the borates. Thus, the dose level of 1,000 mg/kg bw is considered a LOAEL and is taken forward to Risk Characterisation.

4.1.2.9.2 Developmental Toxicity

Studies in animals

In a developmental toxicity study according to OECD Guideline 414 groups of 25 mated Crl:Cd (SD) BR rats were dosed by gavage from day 6 to day 15 of pregnancy with 0, 100, 300 and 1,000 mg/kg bw of sodium perborate tetrahydrate in 1% aqueous methylcellulose (Bussi, 1995; Bussi, 1996). The results are summarised in **Table 4.23**.

Since no clinical signs of toxicity were reported, the only criteria for assessment of maternal toxicity are effects on body weight gain and food intake. Significant reductions in body weight

gain were observed at the two top doses. A significant reduction in food intake was observed in the top dose group (1,000 mg/kg). The reduced body weight gain of the dams is partly (in later stages of pregnancy) due to reduced weights of the litters, due to reduced foetal weights and increased number of resorptions. No significant differences for the different doses and no clear dose response are found for the weight gain of the dams from day 20 except for gravid uterine weight. As maternal toxicity was also apparent during the earlier parts of the pregnancy the NOAEL for maternal toxicity is 100 mg/kg.

At 100 mg/kg/day six externally malformed foetuses with ablepharia, acrania, exencephaly, macroglossia, cleft palate, cleft lip and facial cleft were found. The increase compared to controls was statistically significant. The authors of the study considered this finding incidental, since these kinds of malformations were only present in 2 litters and not at the higher dosages. Historical control data for the years 1993-1999 (Instituto di Ricerche Biomediche, 2000) showed, that such malformations occurred, however extremely seldom, with an incidence of 0-0.12%. According to Giavini (2000) the observed malformations showed a syndromic appearance. All the foetuses were affected by the same association of malformations: exencephaly with acrania, macroglossia and cleft palate which are due to a failure of closure of the cephalic neural folds. In contrast the malformations reported at 1,000 mg/kg bw were unspecific (see below). This assumption of a syndrome of genetic origin could be supported, if both litters were from the same male. However, data on the individual mating regime are not available in the investigating laboratory (Bussi, 2000).

A dose related effect was found on the ossification and the bone system. At 100 mg/kg/day statistically significant effects were found for unossified 5th sternebra and supraoccipital incomplete ossification, both being close to the historical control data. At 300 mg/kg/day and above, various incomplete ossifications and wavy ribs occurred. At 1,000 mg malformations (fused ribs) were observed.

In addition visceral changes were found. At lower dosages (100 mg/kg) and above, the number of kidney variants was statistically significantly increased although without a clear dose-response relationship. At 1,000 mg/kg bw also the number of anomalies and malformations was increased. The malformation included hydronephrosis and hypoplasia. Other visceral malformations were microphtalmia or anophthalmia, vascular ring, displaced or double aortic arch, displaced botallus duct. The malformations were different from those observed at 100 mg/kg. Furthermore, at 300 and 1,000 mg/kg/day dose-related increases of post implantation losses and early resorptions and dose-related lower mean foetal and placental weights were observed. The authors of the study considered 100 mg/kg bw as NOAEL for foetal effects.

Table 4.24 Results of developmental toxicity study with sodium perborate tetrahydrate in rats (Bussi, 1995; Bussi, 1996)

	historical observations (1992/1993) on 2146 foetuses	0	100	300	1,000
		mg/kg bw/day			
No of females pregnant		21	20	20	19
No of females with complete resorptions		0	0	2	1
No of females with resorptions		8	7	9	14*

Table 4.23 continued overleaf

Table 4.23 continued Results of developmental toxicity study with sodium perborate tetrahydrate in rats (Bussi, 1995; Bussi, 1996)

		historical observations (1992/1993) on 2146 foetuses	0	100	300	1,000
			mg/kg bw/day			
body weight gain gd 1-20			153.81	144.5	119.2*	110.89*
body weight gain excluding gravid uterus			67.17	60.58	50.91*	55.12
No of implantations/number of corpora lutea			320/369	301/345	272/332	272/352*
Total number of resorptions			9	7	16*	29*
Number of early resorptions			8	7	12	24*
No of resorptions per litter		0.7± 1.1	0.43	0.35	0.80	1.53*
live foetus weight [g]		3.7 ± 0.4	3.69	3.57	3.28*	2.4*
placenta weight [g]		0.5 ± 0.08	0.5	0.51	0.48	0.37*
litter weight [g]		53.9	54.97	52.62	46.49	32.52*
No of live foetuses			311	295	256*	242*
No of live foetuses / litter		14.4 ± 3.3	14.8	14.75	14.2	13.4
number of animals examined for skeletal / visceral abnormities:			156/155	144/145	129/127	123/119
malformations [%]	external	0.007	0	6*[a]	0	0
	skeletal	0.000	1	0	0	2[b]
	visceral	0.020	0	0	0	11*[c]
anomalies [%]	external	0.115	0	0	0	0
	skeletal	20.500	59	62	65	95*[d]
	visceral	0.415	1	1	2	9*[e]
variants[%]	skeletal	86.440	98	99	100	100
	visceral	12.410	18	37*	33*	54*[f]

* Statistically significant effect P < 0.05; statistical analysis by Chi-squared and Fischer's exact test or ANOVA parametric or nonparametric, where applicable, compared to control

a) 6 plurimalformed foetuses: ablepharia (5), acrania (6), exencephaly (6), exophthalmia (3), macroglossia (6), cleft palate (5), cleft lip (2), facial cleft (1)

b) 2 foetuses: fused ribs (2)

c) 11 foetuses: microphthalmia or anophthalmia (4), vascular ring (2), bilateral hydronephrosis (1), displaced or double aortic arch (3), displace botallus duct (2), hypoplasia of kidney (1)

d) Dose related: incomplete ossification (all doses) or unossified (1,000 ppm) of cranium, head, pelvic girdle, ribs and vertebrae

e) 9 foetuses: dilated lateral cerebral ventricles (2), absence of renal papillae (8), kidney hemorrhagic (1)

f) Dilated or convoluted ureter, dilated renal pelvis

Further information from tests with degradation products

For borates in studies on developmental toxicity skeletal effects (especially short ribs) have been observed as well. From metabolism studies it is also known, that boron accumulates in the bones. Furthermore borates share the vascular system as target with sodium perborate (**Table 4.23**, 1,000 mg/kg bw). However, external malformations as observed at 100 mg/kg bw have not been observed with borates. The NOAEL for borates for developmental effects is 9.6 mg boron/kg bw (ECETOC, 1995; WHO, 1998a). This would correspond to a NOAEL of sodium perborate monohydrate of 88.7 and of 136.8 mg/kg body weight for the tetrahydrate, respectively. They are therefore in a similar dose range as described above.

Discussion at the Specialised Experts Meeting (Ispra, Oct. 2004)

In a comparison of studies on sodium perborate and boric acid (see **Table 4.24**) it can be seen that the NOAEL for sodium perborate is lower than for boric acid. The LOAEL based on reduced weight gain in female rats was lower than for boric acid but within the same order of magnitude. The NOAELs and LOAELs based on embryo or foetal effects are in a similar order of magnitude for borate and sodium perborate but depend on the evaluation of the effects at the lowest dose level of the sodium perborate study.

In contrast to boric acid, where no resorptions have been observed up to the highest dose level tested, resorptions are seen after administration of sodium perborate (Bussi, 1995). The possibility of hidden malformation has to be considered in that case.

The increased incidence of malformations in the low dose group 100 mg/kg bw (Bussi, 1995) was - in the opinion of the Specialised Experts and Giavini et al, (2000) - of syndromic nature as the malformations seen are completely different from the effects in the mid and high dose groups. The resorptions in the mid and high dose groups cannot explain the isolated findings in the low dose groups. Unfortunately, only limited historical control data of the laboratory (two other cases in five years in the colony) and no information on the mating male are available to support this assumption.

Effects on the 13th rib are typical after boric acid administration but cannot be seen with sodium perborate (Bussi, 1995). In the latter case skeletal malformations, like incomplete ossification, wavy ribs, fused ribs can be observed. Similar effects with both substances could be seen in the area of visceral (craniofacial) malformations and malformation in the kidney. The vascular system is affected by both substances in a similar way.

It can be assumed that the embryotoxic effects of sodium perborate are due to release of boron as the malformations observed at the highest dose (1,000 mg/kg bw) are similar to those induced by boric acid in other experiments. Variations may be explained by differences in administration (gavage, food) and absorption.

The authors of the study on sodium perborate (Bussi, 1995) considered the reduction of maternal weight gain and food consumption as clear signs for maternal toxicity because reduction of body weight was seen in both groups including or excluding females with total resorptions. The Specialised Experts however, could not agree on this assumption as the reduced weight gain may be related to the resorptions detected. No effects can be seen on the bodyweight of the high dosed group by excluding the gravid uterus.

The Specialised Experts agreed that sodium perborate as well as boric acid are developmental toxicants but - based on the pattern of malformations - maybe on a slightly different mechanism (different kinetics due to different kind of administration).

The Specialised Experts agreed that the developmental effects of sodium perborate in one rat study (Bussi, 1995), which are not a consequence of general systemic toxicity, warrant classification as Repr. Cat.2; R61. The majority of the Specialised Experts assessed the boric acid data as supportive to this classification.

Table 4.25 Comparison of developmental toxicity studies (sodium perborate – boric acid)

Compound	Sodium perborate	Boric acid	Boric acid	
Reference	Bussi , 1995	Price et al., 1996	Heindel et al., 1992, Price et al., 1990	
Species, strain	Rat, Crl:CD	Rat, CD	Rat, CD	
Route of application	Oral, gavage	Oral, food	Oral, food	
Durations	GD 6-15	GD 0-20	GD 0-20	GD 6-15
Dose levels study	0, 100, 300, 1,000 mg/kg bw	0, 0.025, 0.05, 0.075, 0.1, 0.2% in food, 0, 19, 36, 55, 76, 143 mg boric acid/kg bw/d	0, 0.1, 0.2, 0.4% in food 0, 78, 163, 330 mg boric acid/kg bw/d	0, 0.8% in food 539 mg boric acid/kg bw/d
Dose levels mg B/kg bw	0, 7, 21, 70	0, 3.3, 6.3, 9.6, 13.3, 25	0, 13.7, 28.5, 57.8	94.3
Maternal effects				
NOAEL mg B/kg bw	7	≥ 25	13.7	
LOAEL mg B/kg bw	21 Bw ↓, corrected bw ↓ bw weight gain↓ (d 6-15, d6-8: 35% 14%, d 15-20: 31%) Food intake ↓ 70 Bw ↓, corrected bw ↓ Body weight gain: ↓ (d6-15 : 28%, d 6-8: 82% d 15-20: 33%) Food intake ↓	(slight kidney weight ↑ 25)	28.5 food intake ↑, relative liver and kidney weight ↑	Food, water intake ↓ Relative liver and kidney weight ↑ Bw gain ↓, corrected bw ↑
Embryo/foetal effects				
Overall NOAEL mg B/kg bw	7	9.6	-	
Overall LOAEL mg B/kg bw	21	13.3	13.7	

Table 4.24 continued

Table 4.24 continued Comparison of developmental toxicity studies (sodium perborate – boric acid)

Compound	Sodium perborate	Boric acid	Boric acid	
Embryo/foetal effects				
LOAEL resorptions mg B/kg bw	21 mgB/kg/d 2 females with total resorptions only if these included total number of resorptions ↑ (5.9%, control: 2.8%), if excluded no significant ↑ % resorptions/litter no significant: ↑ 4%, control: 2% 70 mg/B/kg/d 1 female with total resorption this included total number of resorptions: ↑ (10.7%), early resorptions: ↑ (8.8%, control: 2.5%) female with total resorption not included: total number of resorptions: ↑ (9.7%), early resorptions: ↑ (8.9%) Resorptions/litter: ↑ (8%) postimplantation loss/litter: ↑ 10.5%, control: 2.9%	No effect	No effect	94.3 % resorptions/litter ↑ (36, control: 4.4) % late fetal deaths/litter ↑ (2.4, control: 0) Non-live implants/litter: ↑ (38.6; control 4.4) % life fetuses/litter ↓ (9.7, control 15.4)
LOAEL mean foetal weight/litter ↓ mg B/kg bw	21 11% ↓* average fetal bw/litter 70: 35% ↓*	13.3 6% ↓, 25 12% ↓ (did nor persist postnatally)	13.7 dose related ↓ (5.2, 13.2, 36.8 %)	(53.8%)

Table 4.24 continued

Table 4.24 continued Comparison of developmental toxicity studies (sodium perborate – boric acid)

Compound	Sodium perborate	Boric acid	Boric acid	
Embryo/foetal effects				
Malformations %foetuses/litter	70 mgB/kg bw: ↑ with visceral malformations: ↑ 50% control: 0% with skeletal malformations: 11% control: 4.8% (not sign)		Total: 28.5 mgB/kg bw: ↑ (8%), 57.8 mgB/kg bw ↑ (50%) (control 2%) Visceral: 57.8 mgB/kg bw: ↑ (7.8%, controls: 0.46%) Skeletal: 28.5: ↑ (8.1%) 57.8: ↑ (43.5%)	Total ↑ 73% (control 3%) visceral: ↑ 26%, control: 1.9% skeletal: ↑ 52.9%, control: 1.9%
External malformations	7 mg B/kg bw (only, 4 in one litter, 2 in second litter) Ablepharia, Acrania, Exencephaly, macroglossia, Cleft palate, Cleft lip, Facial cleft	-		Short tail (11%, 0 control), Anasarca (1.4% control 0) Polydactyly, hindpaw (0.7%, control: 0)
Skeletal malformations	70 mg B/kg bw Fused ribs 1.63% (not sign)	≥ 13.3 mg B/kg bw Short rib XIII dose related	≥ 28.5 mg B/kg bw Short rib XIII 57.8 mg B/kg bw additionally: Agenesis of rib XIIII Cleft sternum: 2%, control: 0	Short rib XIII: 36.7%, control: 0 Agenesis of rib XIIII: 12.5%, control: 0.47% fused ribs: 5.9%, control: 0 Vertebral malformations : 6.6%, control: 0.47% Sternal: cleft sternum: 9.5%, control: 0
Skeletal variations	≥ 21 mg B/kg bw incomplete ossification, wavy ribs (not clearly dose related) 70 mgB/kg bw: several skeletal anomalies (ribs, vertebrae)	≥ 13.3: Wavy ribs (dose related) Decreased extra rib lumbar 1 (25 mgB/kg bw)	≥ 13.3: Wavy ribs dose related 57.8: incomplete ossification	Wavy ribs low percentage, incomplete ossification

Table 4.24 continued

Table 4.24 continued Comparison of developmental toxicity studies (sodium perborate – boric acid)

Compound	Sodium perborate	Boric acid	Boric acid	
Embryo/foetal effects				
Visceral malformations	70 mg B/kg bw Craniofacial malformation: Anophthalmia: 0.84%, control 0 Microphtalmia: 2.5% control: 0 Vascular: (4.2%, control: 0). aortic arch displaced: 1.68%; control:0 botallus duct displaced: 1.68%, control: 0 double aortic arch: 0.84%, control: 0 Kidney: (1.7% control: 0) Hydronephrosis: (0.84%, control: 0) Hypoplasia: (0.84% control: 0)	-	57.8 Enlarged lateral ventricles of brain (5.4%, control: 0) Enlarged and spotted adrenals: (2.3%, control: 0)	Enlarged lateral ventricles of the brain (17.6%, control: 0) Craniofacial malformation: anophthalmia, (4.4%, control: 0.5%), Microphthalmia: 3.6%, control: 0), displaced eye (4.4%, 0 control) Heart: (4.4%, control:0) enlarged left ventricle Intraventricular septal defect Vascular defects: (8.8%, control: 0) Pulmonary artery and aorta rise from right Transposition of aorta and pulmonary artery Other pulmonary artery malformations Kidney (3.6%, control: 0.9%): renal agenesis Hydronephrosis Hydroureter: bilateral, right or left
Shape of overall dose-response curve	Unclear	Very steep		

Conclusion

In a study on developmental effects of sodium perborate tetrahydrate according to OECD Guideline 414, 100 mg/kg bw of sodium perborate tetrahydrate was regarded by the authors of the study as the NOAEL for both maternal and developmental toxicity.

Although reduced maternal weight gain as measure of maternal toxicity may be due to an increased number of resorptions and reduced foetal weights, other toxicological studies support the view that doses above 100 mg/kg bw via gavage are toxic to the dams.

Critical is the evaluation of the external malformations at 100 mg/kg bw. They were statistically significant but considered incidental due to lack of dose response by the authors of the study and in an expert report (Giavini, 2000). This is supported by the fact that with other boron compounds which have very similar developmental effects as sodium perborate at higher dose levels, this type of effect was not found. The hypothesis of the syndromic origin of these malformations as proposed by Giavini seems therefore plausible. On the other hand the effects occurred in two litters and the syndromic nature of the effects cannot be supported further as no

information was provided on the mating males. Although there are some uncertainties, due to the absence of these effects in investigations with the other boron compounds, these effects are not taken into consideration for deriving the NOAEL for sodium perborate. The NOAEL therefore is 100 mg/kg bw.

4.1.3 Risk characterisation

4.1.3.1 General aspects

In general, the database on health effects is very weak for sodium perborate hydrates.

The risk assessment is carried out on sodium perborate tetrahydrate, as more data are available on this compound than on sodium perborate monohydrate. Sodium perborate tetrahydrate is less toxic than sodium perborate monohydrate, as can be seen from acute toxicity data. This is in agreement with its higher water content. However the differences are considered as minor, compared to other uncertainties in the evaluation of the database.

For some consumer exposure scenarios, exposure will be to the degradation products boric acid and hydrogen peroxide and not to sodium perborate. For these exposure scenarios the risk for hydrogen peroxide is evaluated based on the EU Risk Assessment for Hydrogen Peroxide (ECB, 2003). For boric acid the risk will be evaluated in the future EU Risk Assessment Report on boric acid and sodium tetraborates (4th Priority List).

An overview of the toxic effects and the values used for risk characterisation is given in **Table** 4.26.

Summary of Human Health Effects

From a study with human volunteers it can be concluded that oral absorption is higher than 30%. For the risk assessment, oral absorption and the absorption via inhalation of sodium perborate hydrates are assumed to be 100%. There are no valid quantitative data on the absorption of sodium perborate following dermal exposure. Absorption from the mucous membranes of the mouth seems to be low. Dermal absorption of H_2O_2 is negligible. A thorough investigation showed that dermal absorption of other boron compounds is very low. For the risk assessment a dermal absorption of 1% was assumed.

Peak levels in human plasma presumably after swallowing of sodium perborate are reached after 2 hours, half life in plasma is about 6 to 10 hours. Sodium perborate is assumed to be degraded to boric acid and H_2O_2 after oral application and to be excreted as boric acid via the urine.

No data is available on the distribution of sodium perborate (and subsequent degradation products) within the body. From investigations with other boron compounds, it may be suspected that elevated boron concentrations are found in the bones.

In animal experiments, after oral intake typical findings were hyperaemia and necrosis of the stomach, dogs showed a strong vomiting reflex. Using studies performed according to current guidelines, sodium perborate monohydrate should be classified as “Harmful if swallowed” (Xn; R22) due to the oral LD_{50} in rats of 1,800 mg/kg bw. No classification is required for the perborate tetrahydrate due to its lower toxicity (LD_{50} in rats: 2,567 mg/kg bw).

In an acute inhalation study with rats gasping, red nasal discharge and laboured breathing were the main poisoning symptoms, the LC_{50} was 1,164 mg/m^3. Sodium perborate tetrahydrate should

be classified as "Harmful by inhalation" (Xn; R20) related to the thoracic fraction of dust particles.

For the dermal route, due to the LD_{50} of more than 2,000 mg/kg bw for the monohydrate, no classification is required and it is assumed that the same holds for the tetrahydrate, which was less toxic via the oral route due to the higher water content.

Both, sodium perborate monohydrate and tetrahydrate tested as a solid substance according to the criteria for classification should not be classified as skin irritants. However, in some studies with the monohydrate after prolonged exposure very mild irritating effects were observed which were not completely reversible in some cases. Solutions of 10% sodium perborate tetrahydrate are mildly irritating. There is no information on the irritating potential of more concentrated solutions.

Sodium perborate caused strong eye irritation in animal studies, the effects being not reversible in most of the animals tested. Although the scores for irritation are not sufficient for classification with R41, due to the irreversible effect, both sodium perborate monohydrate and sodium perborate tetrahydrate are proposed to be classified with R41, "Risk of serious damage to eyes".

Considering skin sensitisation, according to the available Bühler test, sodium perborate is not to be regarded as a skin sensitising substance. The applied test is not regarded to be highly sensitive. But studies on H_2O_2 and boron compounds also give no concern for this endpoint.

Furthermore, there is no concern for respiratory sensitisation.

Effects after repeated oral application of sodium perborate can be attributed to the degradation products. From the one available 28-day study a NOAEL cannot be derived, because the only dose investigated was 1,000 mg/kg bw which showed effects on the stomach, spleen and the haematopoietic system. Thus the LOAEL is 1,000 mg sodium perborate tetrahydrate/kg bw.

The repeated dose toxicity by inhalation cannot be evaluated with the available animal studies. No extrapolation from the oral LOAEL can be made for the local effects in the airways. From the available acute toxicity studies and due to the strong irritating effects at mucous membranes rather low effect levels are expected.

A NAEC of about 13.1 mg/m^3 can be derived for sodium perborate based on the results of the rat inhalation study with H_2O_2. However, the target of intoxication and consequently the NOAEC for sodium perborate particles may be different from H_2O_2 gas.

No effects in the lungs have been reported in spirometric examinations of about 100 workers in production plants, even at workplaces with presumed high exposure (filter change). Furthermore, follow-up of the workers for several years up to more than 20 years did not show deterioration of the lung function measured as FVC, FEV1, VC and PEF. Although, these parameters are not very sensitive, especially for small airways disease, the absence of effects in a great number of workers and even in workers exposed for more than 20 years leads to the conclusion that there is no concern for obstructive lung effects such as asthma or chronic bronchitis in production workers. Considering the information on exposure from the workplace surveillance data and the data on exposure in perborate production plants in general, which gave a rather narrow range for all measurements, a NOAEC for effects on the lung may be in the range from 1 mg/m^3 to 12 mg/m^3. However, a definitive figure for the value of the NOAEL could not be derived for the lung effects, as exposure measurements are not available for the health surveillance data, which cover all possible exposure scenarios and the whole exposure

period. Nevertheless due to the complete absence of effects in several workforces, which have been exposed in several production plants for a long period leads to the conclusion, that there is no concern for effects on the lung in workers in production plants, and consequently also not for workers in formulation or the use of the end product, who are exposed to lower concentrations than the production workers.

Slight and temporary reversible irritating effects have been found in the eyes and in the nose. These effects may be attributed to peak exposures, as they were reported only incidentally. As a worst case estimate, assuming that all sodium perborate is deposited in the upper airways and is degraded to H_2O_2, the NOAECs from H_2O_2 can be applied. A provisional human LOAEC was 2 mg/m^3. No effects occurred in humans exposed at workplaces to H_2O_2-concentrations below 0.8 mg/m^3. It was provisionally concluded that exposures to hydrogen peroxide in access of 1.4 mg/m^3 (8-hour TWA) may cause risk of irritation to the upper airways. Therefore this value can be considered as NOAEC for irritating effects for the upper airways (see Section 4.1.3.2.1 of Hydrogen peroxide Risk assessment report). For sodium perborate tetrahydrate, the provisional human LAEC would correspond to 9 mg/m^3. The human exposure level of 1.4 mg/m^3 corresponds to 6.3 mg/m^3 of sodium perborate tetrahydrate.

The studies *in vitro* on sodium perborate show a genotoxic potential, which may be due to the generation of H_2O_2, as similar to investigations with H_2O_2 the responses observed were reduced by the presence of catalase. Therefore analogous to H_2O_2 the genotoxic potential may not be relevant *in vivo*. Furthermore in contrast to H_2O_2, due to its ionisation, sodium perborate itself should be taken up by cells less easily than H_2O_2.

As hyperplasia has been found in the forestomach after application of high concentrations of sodium perborate via gavage, it may be speculated that in analogy to H_2O_2 prolonged exposure to high irritating concentrations of sodium perborate may cause tumours as a consequence of increased cell proliferation. From the reversibility of the effects on the stomach with sodium perborate as well as with H_2O_2, it can be argued, that doses, which would not lead to irritation, also would not lead to tumour formation. For hydrogen peroxide it was concluded that "although a local carcinogenic effect (observed at higher doses) by a genotoxic mechanism cannot be excluded, the weight of evidence at this time does not suggest that carcinogenicity should be regarded as the critical effect." (see Section 4.1.3 of hydrogen peroxide RAR).

The testes are target organs of toxicity of boron compounds. In the 28-day study after oral application of 1,000 mg sodium perborate tetrahydrate/kg bw a decrease in absolute testes weights was recorded, which could be an early sign of testicular toxicity. Body weight gain (due to reduced food intake) and absolute weights of other organs were reduced as well, but testes weights seem to be less affected by body weight decreases from reduced food intake than other organs. Histological examinations of the testes from a 28-day study with sodium perborate did not reveal any signs of toxicity at 1,000 mg sodium perborate tetrahydrate/kg bw (corresponding to 70 mg/kg boron). However, testes were fixed with formalin, a method which allows only detection of major effects as this leads to cellular shrinkage. Using more sensitive methods of histopathology i.e. perfusion with glutaraldehyde/paraformaldehyde and embedding with methacrylate revealed much more subtle effects with other compounds including borates. The effect levels related to boron were in a similar order of magnitude as the 1,000 mg/kg sodium perborate per kg bw possibly affecting the testes weight. Therefore, reduced testes weights as early signs of testicular toxicity cannot be dismissed in view of the known testicular toxicity of the borates and 1,000 mg sodium perborate/kg bw is considered as LOAEL concerning effects on fertility. The classification and labelling for effects on fertility has been discussed in a specialised experts meeting in October 2004. The conclusion was that the studies in animals on fertility are very limited and alone are insufficient for classification. However, evidence that

sodium perborate is converted to boric acid, suggests that sodium perborate may affect fertility and on this basis the Specialised Experts recommended classification as Repr. Cat. 3: R62

In a study on developmental effects of sodium perborate tetrahydrate according to OECD Guideline 414, 100 mg/kg bw of sodium perborate tetrahydrate was regarded by the authors of the study as the NOAEL for both maternal and developmental toxicity. Although reduced maternal weight gain as measure of maternal toxicity may partly be due to an increased number of resorptions and reduced foetal weights, other toxicological studies support the view that doses above 100 mg/kg bw via gavage are toxic to the dams. Critical is the evaluation of the external malformations at 100 mg/kg bw. They were statistically significant but considered incidental due to lack of dose response by the authors of the study and in an expert report (Giavini, 2000). This is supported by the fact that with other boron compounds which have very similar developmental effects as sodium perborate at higher dose levels, this type of effect was not found. The hypothesis of the syndromic origin of these malformations as proposed by Giavini seems therefore plausible. On the other hand the effects occurred in two litters and the syndromic nature of the effects cannot be supported further as no information was provided on the mating males. Although there are some uncertainties, due to the absence of these effects in investigations with the other boron compounds, these effects are not taken into consideration for deriving the NOAEL for sodium perborate. The NOAEL therefore is 100 mg/kg bw. The classification and labelling for effects on development has been discussed in a specialised experts meeting in October 2004. The Specialised Experts agreed that the developmental effects of sodium perborate in one rat study, which is not a consequence of general systemic toxicity, warrants classification as Repr. Cat.2; R61.

Route to Route Extrapolation:

Inhalation: Route to route extrapolation is performed for systemic toxic effects from the 28-day study with rats.

For estimating effects on development, route to route extrapolation for inhalation is possible due to the systemic nature of the effects.

For workers the following values are used:

respiratory rate $_{rat}$	0.8 l/min/kg bw
volume respired during 8h	0.384 m^3/kg bw
correction light activity	6.7/10
absorption oral	1 = 100%
absorption inhalation	1 = 100%

Repeated Dose Toxicity

$LOAEL_{oral\ rat}$	1,000 mg sodium perborate tetrahydrate/kg bw
LAEC $_{systemic\ inhalation\ worker}$	1,736 mg sodium perborate tetrahydrate/m^3

Fertility

$LOAEL_{oral\ rat}$	1,000 mg sodium perborate tetrahydrate/kg bw
LAEC $_{inhalation\ worker}$	1,736 mg sodium perborate tetrahydrate/m^3

Developmental Toxicity

$NOAEL_{oral\ rat}$	100 mg sodium perborate tetrahydrate /kg bw
$NAEC_{inhalation\ worker}$	174 mg sodium perborate tetrahydrate/m^3

Table 4.26 Summary of effects of sodium perborate hydrates and values applied for the risk assessment

Effect	Route		
	Oral	Inhalation	Dermal
Acute toxicity LD_{50}			
monohydrate	1,800 mg/kg bw	no data	> 2,000 mg/kg bw
tetrahydrate	2,567 mg/kg bw	1,164 mg/m^3	no data
Irritation/Corrosivity	local effects in stomach	eye and nose irritation in production workers	skin: non irritating to slightly irritating eyes: corrosive
Sensitisation	--	no cases reported in workers, no indications from lung function measurements	not sensitising
Repeated dose toxicity			
systemic effects *tetrahydrate*	rat, 28-day study targets: stomach, haematopoiesis LOAEL 1,000 mg/kg bw	LAEC: 1,736 mg/m^{3*}	NOAEL > 200 mg/kg bw
local effects: lung *monohydrate and tetrahydrate*		spirometric examination of workers in sodium perborate production, no effects at workplaces in production	
local effects: upper airways		Extrapolation from 28 day study with H_2O_2 with rats NAEC 13.1 mg/m^3, extrapolation from studies in humans with H_2O_2: NAEC 6.3 mg/m^3	
Mutagenicity	Genotoxicity *in vitro* attributed to generation of H_2O_2, efficient repair assumed in analogy to H_2O_2		
Carcinogenicity	No carcinogenicity assumed in analogy to H_2O_2 and at concentrations which are not irritating.		
Reproductive toxicity Fertility impairment *tetrahydrate*	absolute testis weight decreased at 1,000 mg/kg bw in study on repeated dose toxicity LOAEL 1,000 mg/kg bw	LAEC 1,736 mg/m^3	LAEL 100,000 mg/kg bw (assuming 1% absorption)

Table 4.25 continued overleaf

Table 4.25 continued Summary of effects of sodium perborate hydrates and values applied for the risk assessment

Effect	Route		
	Oral	Inhalation	Dermal
Reproductive toxicity Developmental toxicity			
tetrahydrate	malformations, delayed ossification, resorptions, decreased fetal and placental weights, NOAEL maternal toxicity 100 mg/kg bw NOAEL foetal effects 100 mg/kg bw	NAEC 174 mg/m³	NAEL 10,000 mg/kg bw (assuming 1% absorption)

* LAEC is higher than value on acute toxicity: acute toxicity due to local effects

4.1.3.2 Workers

Inhalation

Table 4.26 shows the risk characterisation for exposure by inhalation.

There is no concern for acute toxicity, irritation, sensitisation, mutagenicity and carcinogenicity for workers exposed in production and formulation of sodium perborate and from exposure to the end product. **Conclusion (ii)**.

The risk from repeated exposure has been assessed for:

- Systemic effects (LAEC extrapolated from an oral study)
- Lung effects by using spirometric investigations from workplace surveillance data
- Effects on the upper airways (NAEC extrapolated from data with H_2O_2)

Systemic effects were assessed by applying route to route extrapolation from the oral route. There is no concern for systemic effects for any exposure scenario. **Conclusion (ii)**.

A definitive figure for the value of the NOAEL could not be derived for the lung effects, as exposure measurements are not available for the health surveillance data, which cover all possible exposure scenarios and the whole exposure period. Nevertheless due to the complete absence of effects in several workforces, which have been exposed in several production plants for a long period leads to the conclusion, that there is no concern for effects on the lung in workers in production plants, and consequently also not for workers in formulation or the use of the end product, who are exposed to lower exposure concentrations than the production workers.

The situation is different for effects on the upper airways. As a worst case estimate the assumption can be applied, that all sodium perborate is deposited in the upper airways, and decomposed to H_2O_2. Then the NOAEC for H_2O_2 can be applied. The resulting NAECs, both from a rat study (13.1 mg/m^3) as well as human experience (6.3 mg/m^3) show that for the reasonable worst case for the sodium perborate concentration of 12 mg/m^3 there is concern for irritative effects. This fits very well to the actual experience with sodium perborate, that accidentally effects have been reported, which probably can be related to high exposure concentrations. Therefore **Conclusion (iii**) is drawn for this scenario. However sufficient measures to mitigate the risks may already be in place.

No concern is derived for the typical exposure in production plants of 1 mg/m^3 and for all other worker exposure scenarios.

Regarding developmental effects, there is concern for highly exposed workers in production. Taking into consideration the interindividual differences and the type of effect, a MOS of 14 leads to **conclusion (iii)** for this scenario. In contrast, the MOS is sufficient for the reasonable worst case concentrations in formulation and use of the end product, for the typical exposure in all worker scenarios as well as for effects on fertility.

Table 4.27 Risk characterisation for workers: Exposure via inhalation of dust

Type of effect	Result	Exposure scenario	Exposure conc. (mg/m^3)	MOS	Comment	Conclusion
Acute toxicity	LD_{50} 1,164 mg/m^3	All exposure scenarios	< 12.1	-		ii
Irritation Corrosivity	cases of reversible eye and nose irritation in production workers	Production reasonable worst case	12.1	-	it has to be assured, that for operations with presumed high exposure concentrations, suitable protection is worn; classification with Xi; R37-41	ii
Repeated dose toxicity systemic effects	LAEC 1,736 mg/m^3	All exposure scenarios	< 12.1	> 143	MOS sufficient	ii
Repeated dose toxicity local effects in the lung		All exposure scenarios			No effects in reliable lung function measurements from a great number of long term exposed production workers (the workforce exposed to the highest exposure levels).	ii
Repeated dose toxicity local effects upper airways	NAEC 13.1 mg/m^3	Production, reasonable worst case	12.1	1	NAEC from animal experiments with H_2O_2, human LOAEL same order of magnitude, MOS not sufficient for workplace operations with high exposure, worker protection necessary	iii
		Production, typical value, formulation, handling of detergents containing sodium perborate	$\leq$ 1	>10	Exposure concentration lower than NAEC from animal experiments with H_2O_2 and provisional human LAEC, effects reversible	ii
Mutagenicity	mutagen *in vitro*	All exposure scenarios		-	Efficient repair is assumed in analogy to H_2O_2, boron compounds not mutagenic	ii

Table 4.26 continued overleaf

Table 4.26 continued Risk characterisation for workers: Exposure via inhalation of dust

Type of effect	Result	Exposure scenario	Exposure conc. (mg/m³)	MOS	Comment	Conclusion
Carcinogenicity	no data	All exposure scenarios			No concern in analogy to H_2O_2 and boron compounds for non irritating concentrations	ii
Fertility	LAEC 1,736 mg/m³	All exposure scenarios	< 12.1	> 143		ii
Developmental toxicity	NAEC 174 mg/m³	Production, reasonable worst case	12.1	14	Concern if taking into consideration interindividual differences and type of effect.	iii
		Production, typical value, formulation, handling of detergents containing sodium perborate	≤ 1	> 174	MOS sufficient	ii

Dermal Exposure

Table 4.27 shows the risk characterisation for dermal exposure. There is no concern for all endpoints and exposure scenarios.

Table 4.28 Risk characterisation for workers – Dermal exposure

Type of effect	Result	Exposure scenario	Dose	MOS	Comment	Conclusion
Acute toxicity	LD_{50} > 2,000 mg/kg bw	All exposure scenarios	≤ 12mg/kg bw	-	The LD_{50} is orders of magnitude higher than the exposure concentrations	ii
Repeated dose toxicity	$NOAEL_{dermal}$ > 200 mg/kg bw			>>17	No concern due to low dermal absorption	ii
Irritation/ Corrositivity	not irritating to slightly irritating			-		ii
Eye irritation	Corrosive to the eyes			-	risk can be prevented by suitable protection measures	ii
Sensitisation	not sensitising			-		ii
Mutagenicity	mutagen *in vitro*			-	Efficient repair is assumed in analogy to H_2O_2,, boron compounds not mutagenic	ii

Table 4.27 continued overleaf

Table 4.27 continued Risk characterisation for workers – Dermal exposure

Type of effect	Result	Exposure scenario	Dose	MOS	Comment	Conclusion
Carcinogenicity	no data			-	No concern in analogy to H_2O_2 and boron compounds.	ii
Fertility	LAEL 100,000 mg/kg bw			>8,000		ii
Developmental toxicity	NAEL 10,000 mg/kg bw			>800		ii

Combined exposure

From the highest exposure value of 12.1 mg/m^3 a body dose of about 2 mg/kg bw/day can be derived assuming 10 m^3 respired per workday, 100% absorption in the lung and 70 kg bw. The maximum dermal dose would be 0.12 mg/kg bw assuming 1% absorption, which is negligible compared to the uptake via inhalation. Therefore the conclusions derived for uptake via inhalation also hold for combined exposure.

4.1.3.3 Consumers

Inhalation

There is no risk for exposure by handling of detergents for all endpoints as the exposure is negligible.

Dermal

There is no concern for the systemic toxicity of the sodium perborate hydrates from any endpoint for the handling of detergent products either as solution or as powder as the exposure is negligible and the absorption is very low. This includes also irritation/corrosivity: there is no concern because the concentration of sodium perborate is approximately 0.3%. 10% solutions of sodium perborate are only mildly irritating.

Since the sodium perborate degrades during use, for this exposure scenario also the toxicity of the degradation products should be considered.

Exposure to hydrogen peroxide assuming complete hydrolysis is 4 mg/kg bw (see **Table 4.12**). No concern was derived for hair dying in the Risk Assessment on hydrogen peroxide (ECB, 2003) at doses which are by orders of magnitude higher. Therefore there is also no concern from the generation of hydrogen peroxide.

The risk for exposure to boric acid should be assessed in the future EU Risk Assessment on boric acid and sodium tetraborates (4th Priority List).

Oral

The use of sodium perborate in mouthwash solutions is a very minor use. However it leads to the highest exposure concentrations of all consumer exposure scenarios of 1 mg/kg bw/day.

Therefore a risk characterisation for all endpoints is performed in **Table 4.28**. No concern was derived for all endpoints.

Table 4.29 Risk characterisation for consumers: exposure via mouthwash solutions

Type of effect	Result	Exposure scenario	Dose	MOS	Comment	Conclusion
Acute toxicity	LD_{50} > 2,000 mg/kg bw	Use of mouthwash solutions containing PBS	1 mg/kg bw/day		The LD 50 is orders of magnitude higher than the exposure concentrations	ii
Repeated dose toxicity	$LOAEl_{oral}$ > 1,000 mg/kg bw			1,000	Sufficient MOS	ii
Irritation/ Corrositivity	not irritating to slightly irritating			-	Obviously, the use is tolerated without irritation. 10% solutions of PBS are only mildly irritating	ii
Eye irritation	Corrosive to the eyes			-		ii
Sensitisation	not sensitising			-		ii
Mutagenicity	mutagen *in vitro*			-	Efficient repair is assumed in analogy to H_2O_2,, boron compounds not mutagenic	ii
Carcinogenicity	no data			-	No concern in analogy to H_2O_2 and boron compounds.	ii
Fertility	LOAEL 1,000 mg/kg bw			1,000	Sufficient MOS	ii
Developmental toxicity	NOAEL 100 mg/kg bw			100	Sufficient MOS	ii

For this exposure scenario also the toxicity of the degradation products should be considered.

Exposure to hydrogen peroxide assuming complete hydrolysis is 0.4 mg/kg bw (see **Table 4.12**). No concern was derived for tooth bleaching in the Risk Assessment on hydrogen peroxide at doses which are orders of magnitude higher. Therefore there is also no concern from the generation of hydrogen peroxide in mouthwash solutions.

The risk for exposure to boric acid (0.6 mg/kg bw) should be assessed in the future EU Risk Assessment on boric acid and sodium tetraborates (4th Priority List).

Lower exposure concentrations were derived for the use of sodium perborate in denture cleansers and in artificial tears. Therefore also for these exposure scenarios there is no concern for all endpoints. This includes also eye irritation for the use in artificial tears. The concentration of sodium perborate is very low (0.028%), presumably below any irritation threshold.

4.1.3.4 Humans exposed indirectly via the environment

Indirect exposure to sodium perborate is not to be expected due to the degradation of the compound. Also no exposure to H_2O_2 is expected due to the hydrolysis.

For boric acid the consumption of drinking water was identified as the only relevant boron source resulting from the commercial use of sodium perborate hydrates. A drinking water concentration of about 0.2 mg boron/l at a maximum can be related to the use of sodium perborate hydrates in detergent products and bleaching agents. Assuming a consumption of 2 l drinking water/day and a body weight of 70 kg this would correspond to a body dose of maximum 6 µg boron/kg bw/day.

This corresponds to 25% of the background exposure of 24 µg boron/kg bw/day via food in Germany.

The risk assessment of the degradation product boric acid for this exposure scenario will be performed in the foreseen EU risk assessment on boric acid and sodium tetraborates (4th Priority List).

4.1.3.5 Combined exposure

For sodium perborate, exposure at the workplace by inhalation is by far higher than consumer exposure. Therefore combined exposure is not relevant.

For H_2O_2, the exposure to the compound itself is by far more important than exposure from the degradation of sodium perborate.

The combined exposure to boric acid from different sources will be addressed in the planned EU risk assessment on boric acid and sodium tetraborates (4th Priority List).

4.2 HUMAN HEALTH (PHYSICO-CHEMICAL PROPERTIES)

4.2.1 Worker

From the physico-chemical properties of sodium perborate hydrates no adverse effects on human health are to be expected. The substances are not flammable or explosive. Also explosion of dusts is therefore not to be expected. Sodium perborate monohydrate is classified as oxidising. Involved in fire both perborate hydrates may decompose yielding oxygen which supports combustion.

4.2.2 Consumer

No adverse effects on human health from the physico-chemical properties on human health are to be expected as sodium perborate hydrates in consumer products are present in form of preparations and not in pure form. The substances are not flammable or explosive.

5 RESULTS

5.1 ENVIRONMENT

5.1.1.1 Aquatic compartment (incl. sediment)

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

The conclusion for the aquatic compartment (water) is based on the EU-RAR for hydrogen peroxide as far as the production of sodium perborate is concerned. It applies to 2 production sites (C, F) producing sodium perborate as well as hydrogen peroxide, which were already assessed in the hydrogen peroxide RAR. Furthermore it applies to 2 formulation sites.

It also applies for the biological process of STP in 2 production sites (B, F)[9].

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

This conclusion applies for the remaining production and formulation sites with STP: It applies to 1 production site with sole production of sodium perborate and 6 production sites producing sodium perborate as well as hydrogen peroxide. The latter were already assessed in the EU-RAR on hydrogen peroxide. It also applies for the aquatic compartment for two formulation sites, for processing and for the consumer and institutional use of detergents and bleaching agents. This conclusion applies for biological process of STP in 6 production sites and 14 formulation sites.

5.1.1.2 Terrestrial compartment

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

A risk characterisation for this compartment is not deemed necessary.

5.1.1.3 Atmosphere

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

This conclusion applies to all life cycle steps.

[9] Please, note that new information was received after the finalisation of the environmental report, and that this information affects the conclusions presented above. The new information is presented, together with the revised environmental conclusions, in an Addendum attached to this report. Thus, the correct, revised environmental conclusions can be found in the Addendum as well as in the Summary Report, but chapters 0-5 have not been updated

5.1.1.4 Secondary poisoning

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

A risk characterisation for non-compartment specific effects relevant for the food chain is not deemed necessary.

5.2 HUMAN HEALTH

5.2.1 Human Health (toxicity)

5.2.1.1 Workers

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

This conclusion applies to highly exposed workers in the production of sodium perborate via inhalation of the dust. There is concern for effects on the upper airways and for developmental effects.

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

This conclusion applies to all endpoints for workers employed in formulation and from occupational exposure to the end product.

It also applies to the endpoints acute toxicity, irritation, sensitisation, mutagenicity, carcinogenicity and fertility for workers exposed in production.

5.2.1.2 Consumers

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

This conclusion applies to all scenarios and endpoints.

5.2.1.3 Humans exposed indirectly via the environment

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

Indirect exposure to sodium perborate is not to be expected due to the degradation of the compound.

Indirect exposure to the degradation products: No exposure to H_2O_2 is expected due to the hydrolysis. The risk for humans exposed to boric acid indirectly via the environment will be evaluated in the foreseen EU risk assessment on boric acid and sodium tetraborates (4th Priority List).

5.2.1.4 Combined exposure

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

For sodium perborate, the combined exposure is not relevant. The combined exposure to boric acid from different sources will be addressed in the foreseen EU risk assessment on boric acid and sodium tetraborates (4th Priority List).

5.2.2 Human Health (physico-chemical properties)

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

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ABBREVIATIONS

ADI	Acceptable Daily Intake
AF	Assessment Factor
ASTM	American Society for Testing and Materials
ATP	Adaptation to Technical Progress
AUC	Area Under The Curve
B	Bioaccumulation
BBA	Biologische Bundesanstalt für Land- und Forstwirtschaft
BCF	Bioconcentration Factor
BMC	Benchmark Concentration
BMD	Benchmark Dose
BMF	Biomagnification Factor
bw	body weight / *Bw*, *b.w.*
C	Corrosive (Symbols and indications of danger for dangerous substances and preparations according to Annex III of Directive 67/548/EEC)
CA	Chromosome Aberration
CA	Competent Authority
CAS	Chemical Abstract Services
CEC	Commission of the European Communities
CEN	European Standards Organisation / European Committee for Normalisation
CMR	Carcinogenic, Mutagenic and toxic to Reproduction
CNS	Central Nervous System
COD	Chemical Oxygen Demand
CSTEE	Scientific Committee for Toxicity, Ecotoxicity and the Environment (DG SANCO)
CT_{50}	Clearance Time, elimination or depuration expressed as half-life
d.wt	dry weight / dw
dfi	daily food intake
DG	Directorate General
DIN	Deutsche Industrie Norm (German norm)
DNA	DeoxyriboNucleic Acid
DOC	Dissolved Organic Carbon
DT50	Degradation half-life or period required for 50 percent dissipation / degradation
DT90	Period required for 90 percent dissipation / degradation
E	Explosive (Symbols and indications of danger for dangerous substances and preparations according to Annex III of Directive 67/548/EEC)
EASE	Estimation and Assessment of Substance Exposure Physico-chemical properties [Model]
EbC50	Effect Concentration measured as 50% reduction in biomass growth in algae tests
EC	European Communities

EC10	Effect Concentration measured as 10% effect
EC50	median Effect Concentration
ECB	European Chemicals Bureau
ECETOC	European Centre for Ecotoxicology and Toxicology of Chemicals
ECVAM	European Centre for the Validation of Alternative Methods
EDC	Endocrine Disrupting Chemical
EEC	European Economic Communities
EINECS	European Inventory of Existing Commercial Chemical Substances
ELINCS	European List of New Chemical Substances
EN	European Norm
EPA	Environmental Protection Agency (USA)
ErC50	Effect Concentration measured as 50% reduction in growth rate in algae tests
ESD	Emission Scenario Document
EU	European Union
EUSES	European Union System for the Evaluation of Substances [software tool in support of the Technical Guidance Document on risk assessment]
F(+)	(Highly) flammable (Symbols and indications of danger for dangerous substances and preparations according to Annex III of Directive 67/548/EEC)
FAO	Food and Agriculture Organisation of the United Nations
FELS	Fish Early Life Stage
FEV1	Forced expiratory volume 1
FVC	Forced vital capacity
GLP	Good Laboratory Practice
HEDSET	EC/OECD Harmonised Electronic Data Set (for data collection of existing substances)
HELCOM	Helsinki Commission -Baltic Marine Environment Protection Commission
HPLC	High Pressure Liquid Chromatography
HPVC	High Production Volume Chemical (> 1000 t/a)
IARC	International Agency for Research on Cancer
IC	Industrial Category
IC50	median Immobilisation Concentration or median Inhibitory Concentration
ILO	International Labour Organisation
IPCS	International Programme on Chemical Safety
ISO	International Organisation for Standardisation
ITF	FEV1/FVC
IUCLID	International Uniform Chemical Information Database (existing substances)
IUPAC	International Union for Pure and Applied Chemistry
JEFCA	Joint FAO/WHO Expert Committee on Food Additives
JMPR	Joint FAO/WHO Meeting on Pesticide Residues

Koc	organic carbon normalised distribution coefficient
Kow	octanol/water partition coefficient
Kp	solids-water partition coefficient
L(E)C50	median Lethal (Effect) Concentration
LAEC	Lowest Adverse Effect Concentration
LAEL	Lowest Adverse Effect Level
LC50	median Lethal Concentration
LD50	median Lethal Dose
LEV	Local Exhaust Ventilation
LLNA	Local Lymph Node Assay
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
LOED	Lowest Observed Effect Dose
LOEL	Lowest Observed Effect Level
MAC	Maximum Allowable Concentration
MATC	Maximum Acceptable Toxic Concentration
MC	Main Category
MITI	Ministry of International Trade and Industry, Japan
MOE	Margin of Exposure
MOS	Margin of Safety
MW	Molecular Weight
N	Dangerous for the environment (Symbols and indications of danger for dangerous substances and preparations according to Annex III of Directive 67/548/EEC
NAEL	No Adverse Effect Level
NOAEL	No Observed Adverse Effect Level
NOEL	No Observed Effect Level
NOEC	No Observed Effect Concentration
NTP	National Toxicology Program (USA)
O	Oxidizing (Symbols and indications of danger for dangerous substances and preparations according to Annex III of Directive 67/548/EEC)
OECD	Organisation for Economic Cooperation and Development
OEL	Occupational Exposure Limit
OJ	Official Journal
OSPAR	Oslo and Paris Convention for the protection of the marine environment of the Northeast Atlantic
P	Persistent
PBS	sodium perborate
PBS4	sodium perborate, tetrahydrate

PBS1	sodium perborate, monohydrate
PBT	Persistent, Bioaccumulative and Toxic
PBPK	Physiologically Based PharmacoKinetic modelling
PBTK	Physiologically Based ToxicoKinetic modelling
PEF	Peak expiratory flow
PEC	Predicted Environmental Concentration
pH	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
PNEC	Predicted No Effect Concentration
POP	Persistent Organic Pollutant
PPE	Personal Protective Equipment
QSAR	(Quantitative) Structure-Activity Relationship
R phrases	Risk phrases according to Annex III of Directive 67/548/EEC
RAR	Risk Assessment Report
RC	Risk Characterisation
RfC	Reference Concentration
RfD	Reference Dose
RNA	RiboNucleic Acid
RPE	Respiratory Protective Equipment
RWC	Reasonable Worst Case
S phrases	Safety phrases according to Annex III of Directive 67/548/EEC
SAR	Structure-Activity Relationships
SBR	Standardised birth ratio
SCE	Sister Chromatic Exchange
SDS	Safety Data Sheet
SETAC	Society of Environmental Toxicology And Chemistry
SNIF	Summary Notification Interchange Format (new substances)
SSD	Species Sensitivity Distribution
STP	Sewage Treatment Plant
T(+)	(Very) Toxic (Symbols and indications of danger for dangerous substances and preparations according to Annex III of Directive 67/548/EEC)
TDI	Tolerable Daily Intake
TG	Test Guideline
TGD	Technical Guidance Document
TNsG	Technical Notes for Guidance (for Biocides)
TNO	The Netherlands Organisation for Applied Scientific Research
UC	Use Category

UDS	Unscheduled DNA Synthesis
UN	United Nations
UNEP	United Nations Environment Programme
US EPA	Environmental Protection Agency, USA
UV	Ultraviolet Region of Spectrum
UVCB	Unknown or Variable composition, Complex reaction products of Biological material
VC	Vital capacity
vB	very Bioaccumulative
vP	very Persistent
vPvB	very Persistent and very Bioaccumulative
v/v	volume per volume ratio
w/v	Weight per volume ratio
w/w	weight per weight ratio
WHO	World Health Organization
WWTP	Waste Water Treatment Plant
Xn	Harmful (Symbols and indications of danger for dangerous substances and preparations according to Annex III of Directive 67/548/EEC)
Xi	Irritant (Symbols and indications of danger for dangerous substances and preparations according to Annex III of Directive 67/548/EEC)

European Commission
DG Joint Research Centre, Institute of Health and Consumer Protection
Toxicology and Chemical Substances (TCS)
European Chemicals Bureau

EUR 22873 EN **European Union Risk Assessment Report**
perboric acid, sodium salt, **Volume 71**

Editors: S.J. Munn, K. Aschberger, O. Cosgrove, W. De Coen, B-O. Lund, S. Pakalin, A. Paya-Perez, S. Vegro.

Luxembourg: Office for Official Publications of the European Communities

2007 – VIII pp., 138 pp. – 17.0 x 24.0 cm

EUR – Scientific and Technical Research series; ISSN 1018-5593

The report provides the comprehensive risk assessment of the substance sodium perborate (sodium perborate monohydrate and sodium perborate tetrahydrate). It has been prepared by Austria in the frame of Council Regulation (EEC) No. 793/93 on the evaluation and control of the risks of existing substances, following the principles for assessment of the risks to humans and the environment, laid down in Commission Regulation (EC) No. 1488/94.

Part I - Environment

This part of the evaluation considers the emissions and the resulting exposure to the environment in all life cycle steps. Following the exposure assessment, the environmental risk characterisation for each protection goal in the aquatic, terrestrial and atmospheric compartment has been determined.

The environmental risk assessment concludes that there is no concern for any compartment arising from the use of the substance.

Part II – Human Health

This part of the evaluation considers the emissions and the resulting exposure to human populations in all life cycle steps. The scenarios for occupational exposure, consumer exposure and humans exposed via the environment have been examined and the possible risks have been identified.

The human health risk assessment concludes that there is no concern for the endpoints acute toxicity, irritation, sensitisation, mutagenicity, carcinogenicity, and fertility for workers in production. No concern for any endpoints also applies to workers during formulation and contact to end products, as well as to consumers and humans exposed via the environment.

For workers in the production of sodium perborate, there is concern for effects on the upper airways and for developmental effects after high inhalation exposure to sodium perborate dust.

The conclusions of this report will lead to risk reduction measures to be proposed by the Commission’s committee on risk reduction strategies set up in support of Council Regulation (EEC) N. 793/93.

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European Union Risk Assessment Report

perboric acid, sodium salt

CAS No: 11138-47-9 EINECS No: 234-390-0

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