NICNAS

National Industrial Chemicals Notification and
Assessment Scheme

Ammonium, Potassium and Sodium Persulfate

Priority Existing Chemical Assessment Report No. 18

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Preface

This assessment was carried out under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). This Scheme was established by the *Industrial Chemicals (Notification and Assessment) Act 1989* (the Act), which came into operation on 17 July 1990.

The principal aim of NICNAS is to aid in the protection of people at work, the public and the environment from the harmful effects of industrial chemicals.

NICNAS assessments are carried out in conjunction with Environment Australia and the Therapeutic Goods Administration, which carry out the environmental and public health assessments, respectively.

NICNAS has two major programs: the assessment of the health and environmental effects of new industrial chemicals prior to importation or manufacture; and the other focussing on the assessment of chemicals already in use in Australia in response to specific concerns about their health/or environmental effects.

There is an established mechanism within NICNAS for prioritising and assessing the many thousands of existing chemicals in use in Australia. Chemicals selected for assessment are referred to as Priority Existing Chemicals.

This Priority Existing Chemical report has been prepared by the Director (Chemicals Notification and Assessment) in accordance with the Act. Under the Act manufacturers and importers of Priority Existing Chemicals are required to apply for assessment. Applicants for assessment are given a draft copy of the report and 28 days to advise the Director of any errors. Following the correction of any errors, the Director provides applicants and other interested parties with a copy of the draft assessment report for consideration. This is a period of public comment lasting for 28 days during which requests for variation of the report may be made. Where variations are requested the Director's decision concerning each request is made available to each respondent and to other interested parties (for a further period of 28 days). Notices in relation to public comment and decisions made appear in the *Commonwealth Chemical Gazette.*

In accordance with the Act, publication of this report revokes the declaration of this chemical as a Priority Existing Chemical, therefore manufacturers and importers wishing to introduce this chemical in the future need not apply for assessment. However, manufacturers and importers need to be aware of their duty to provide any new information to NICNAS, as required under section 64 of the Act.

For the purposes of Section 78(1) of the Act, copies of Assessment Reports for New and Existing Chemical assessments may be inspected by the public at the library of the National Occupational Health and Safety Commission (NOHSC). Summary Reports are published in the *Commonwealth Chemical Gazette,* which are also available to the public at the NOHSC library.

Copies of this and other Priority Existing Chemical reports are available on the NICNAS website. Hardcopies are available from NICNAS either by using the prescribed application form at the back of this report, or directly from the following address:

GPO Box 58

Sydney

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AUSTRALIA

Tel: +61 (02) 9577 9437

Fax: +61 (02) 9577 9465 or +61 (02) 9577 9465 9244

Other information about NICNAS (also available on request) includes:

- NICNAS Service Charter;
- information sheets on NICNAS Company Registration;
- information sheets on Priority Existing Chemical and New Chemical assessment programs;
- safety information sheets on chemicals that have been assessed as Priority Existing Chemicals;
- subscription details for the NICNAS Handbook for Notifiers; and
- subscription details for the Commonwealth Chemical Gazette.

More information on NICNAS can be found at the NICNAS Web site:

http://www.nicnas.gov.au

Other information on the management of workplace chemicals can be found at the website of the National Occupational Health and Safety Commission:

http://www.nohsc.gov.au

Overview

Ammonium, potassium and sodium persulfate (CAS Nos. 7727-54-0, 7727-21-1 and 7775-27-1, respectively) were declared Priority Existing Chemicals for full assessment on 7 April 1998. The declarations were made due to concern about their widespread use as ingredients in bleaches used in the hairdressing industry and the prevalence of skin disease and asthma in that profession, and that the available information on the hazard warnings was inadequate. The declaration of these chemicals in hairdressing was limited to occupational health and safety and public health assessment.

The volume of persulfates imported for formulation into hair bleaching products is approximately 6.5 tonnes per year of which approximately 4.5 tonnes per year is formulated into consumer products. The import volume of formulated products for consumer use amounts to approximately 3.4 tonnes per year and for salon use approximately 127 tonnes per year. There are at least 13 home-use consumer products and approximately 40 hairdressing salon products available in Australia. Home-use products vary in persulfate content from 45% to 82.5% while the persulfate content of salon products varies from 22% to 88%.

The is no information on the kinetics and metabolism of persulfates in humans or any animal species.

In laboratory animals, the persulfate salts are harmful by ingestion following a single dose. They are skin, respiratory and eye irritants and skin and respiratory sensitisers. There are indications of mainly local effects on repeated exposure. Effects in humans include immediate and delayed contact hypersensitivity, contact urticaria, rhinitis, bronchitis and asthma (early and late onset). The persulfates are not mutagenic or carcinogenic.

Occupational exposure can occur through inhalation and skin contact to workers in formulation plants and to professional hairdressers.

Occupational control measures such as local exhaust ventilation and the use of personal protective equipment are used in formulation plants. No engineering controls are in place at salons. It is likely that less that 50% of hairdressers wear gloves for bleaching and special mixing areas may only be common in larger salons. Dust-free formulations are readily available within Australia which will reduce inhalation exposure. However, at the present time, few bleach boosters specifically formulated as creams are available.

The general public can be exposed to persulfate salts while performing do-it-yourself hair bleaching at home or as clients of hairdressers.

The main health hazards for professional hairdressers are rhinitis, bronchitis, asthma, and irritant and allergic contact dermatitis. The risk of respiratory effects is likely be low amongst hairdressers using effective dust-free formulations but considerably higher amongst those using common powder formulations and ineffective dust-free formulations. However, dermatitis of the hands can be quite common with frequent exposure to irritants such as water and shampoo and exposure to other allergens. Dermatitis attributable to persulfates is likely to affect up to 5% of hairdressers. Members of the general public with respiratory or skin conditions attributable to persulfates are likely to be uncommon.

Because ample safe, effective formulations are available, it is recommended that non dust-free formulations be removed from the market. Cream preparations are preferred, or as a next preference, effective dust-free formulations. Formulations that are not effectively dust-free need to be removed from the market.

The ammonium and potassium salts are currently in the NOHSC *List of Designated Hazardous Substances* [NOHSC:10005(1999)] and classified as harmful via the oral route, irritant to eyes, skin and respiratory system and as skin and respiratory sensitisers. They are assigned the risk phrases R22: Harmful if Swallowed, R36: Irritating to Eyes, R37: Irritating to Respiratory Systems, R38: Irritating to Skin, R42: May Cause Sensitisation by Inhalation and R43: May Cause Sensitisation by Skin Contact. In addition to this classification, the risk phrase R8: Contact with combustible material may cause fire and the designation “O” for oxidising are assigned. It is recommended that sodium persulfate be included in the NOHSC *List of Designated Hazardous Substances* with the same classification and risk phrases.

Current MSDS and labels for salon products were generally inadequate, for example, no salon products included the required risk phrase for respiratory sensitisation. Under the *Trade Practices (Consumer Product Information Standards) (Cosmetics) Regulations*, consumer cosmetics must be labelled with their ingredients and this was the case for the 13 consumer products assessed.

Suppliers of the pure chemicals and hair bleaching products need to update their MSDS and labels to be consistent with the above classification. As persulfate salts are hazardous chemicals, employers are required to conduct a risk assessment of their individual workplace and, where necessary, implement appropriate control measures and health surveillance. Recommendations are also made regarding improving training for salon workers and to establish an occupational exposure standard.

Ammonium, potassium and sodium persulfate for use in hair preparations have been listed in Schedule 6 of the Standard for the Uniform Scheduling of Drugs and Poisons. Company MSDS and product labels must be amended to reflect the Schedule requirements with respect to first aid instructions, warning statements and safety directions.

Contents

APPENDICES

LIST OF TABLES

Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ADG	Australian Code for the Transport of Dangerous Goods by Road and Rail
AHR	airway hyperresponsiveness
aq	aqueous
bw	body weight
CAS	Chemical Abstracts Service
CIR	Cosmetic Ingredient Review
CTFA	Cosmetic, Toiletry, and Fragrance Association (USA)
CTFAA	Cosmetic, Toiletry, and Fragrance Association of Australia
DNA	deoxyribonucleic acid
EASE	Estimation and Assessment of Substance Exposure
EINECS	European Inventory of Existing Commercial Chemical Substances
fMLP	formyl-methionyl-leucyl-phenylalanine
g	gram
h	hour
IUCLID	International Uniform Chemical Information Database
kg	kilogram
LC_{50}	median lethal concentration
LD_{50}	median lethal dose
LOAEL	lowest-observed-adverse-effect level
LTB_4	Leukotriene B_4
µg	microgram
mg/m^3	milligram per cubic metre
mg/kg	milligram per kilogram
mL	millilitre
MSDS	Material Safety Data Sheet
NDPSC	National Drugs and Poisons Schedule Committee
NOAEL	no-observed-adverse-effect level

NOHSC	National Occupational Health and Safety Commission
PMN	polymorphonuclear neutrophil
ppm	parts per million
RAST	radio-allergosorbent
SUSDP	Standard for the Uniform Scheduling of Drugs and Poisons
TWA	time-weighted average

Glossary

bleach	an agent or product designed to remove colour from the hair by oxidation of coloured pigments
bleaching	the process of removing colour from the hair. It includes lightening and colour removal
bleach booster	a substance that enhances the bleaching action of an oxidant
colour removal	bleaching of the natural or artificial hair pigment
damp consistency	the texture of a powder following the addition of oil, or other liquid agent, in order for it to form loose aggregates
highlighting	an effect created by bleaching only portions of the hair
lightening	a bleaching process that involves a limited colour change to the hair
off-scalp	a treatment that involves the distal portions of the hair shaft
on-scalp	a treatment that includes the full length of the hair shaft
retouching	bleaching of hair that has re-grown since prior bleaching
streaking	a technique that results in the bleaching of a limited number of hair strands

1. Introduction

1.1 Declaration

Ammonium, potassium and sodium persulfate (CAS Nos. 7727-54-0, 7727-21-1 and 7775-27-1, respectively) were declared Priority Existing Chemicals for full assessment on 7 April 1998. The declarations were made due to concern about their widespread use as ingredients in bleaches used in the hairdressing industry and the prevalence of skin disease and asthma in that profession, and that the available information on the hazards warnings was inadequate. The declaration of these chemicals in hairdressing was limited to occupational health and safety and public health assessment.

In accordance with the Act, persons introducing ammonium, potassium or sodium persulfate or products containing these persulfates into Australia were required to apply for assessment whilst they remained priority existing chemicals. As ammonium, potassium or sodium persulfate are not manufactured in Australia, applications were limited to importers.

1.2 Purpose of assessment

The purpose of this assessment with respect to persulfates in hair bleaching formulations is to:

- characterise the current and potential occupational and public exposure;
- characterise the human health hazards;
- determine the risk of adverse effects to workers and the public;
- review the conditions of use and labelling requirements; and
- consider the basis for a national exposure standard, if required.

1.3 Data collection

In accordance with the Act, importers of persulfates used in hairdressing, and who wished to continue importing the chemicals whilst they were priority existing chemicals, were required to apply for assessment and supply information. This included suppliers of the pure chemicals, formulators and importers of formulated products. In addition, information was obtained via a literature search. Toxicological data and human case studies attributed to persulfate exposure have been reviewed recently (CIR, 1998; BG Chemie, 1996; BIBRA International, 1997). Summaries of toxicological data were obtained from sponsors identified in the International Unified Chemical Information Database (IUCLID) reports for ammonium and sodium persulfate.

Data supplied by applicants included the amount of persulfates imported in pure form and in formulated products, customer lists, MSDS and labels, formulation and use details and occupational health and safety data.

A site visit to a hairdressing salon, the proprietor of which represents a group of salons called the Australian Hairdressers Cooperative, involved discussion of a number of issues relevant to current practice in salons. Site visits were also made to two companies involved in the formulation of persulfates and to a number of retail outlets.

2. Background

2.1 History

Persulfates were used in the baking industry to improve flour. At present, they do not play a major role in the baking industry due to replacement with potassium bromate.

2.2 International perspective

Persulfates are used extensively in Europe and the US for hair lightening and decolourising (CIR, 1998). Information on the use of persulfates in hair product formulations used in the US (submitted to the Food and Drug Administration in 1998) was published in the Cosmetic Ingredient Review (CIR) of these substances (CIR, 1998). Established in 1976, the CIR program was set up by the US-based Cosmetic, Toiletry, and Fragrance Association (CFTA) to provide an independent review of cosmetic ingredients. The CIR assessment of persulfates was undertaken to determine their safety when used as oxidising agents in hair colourants and lighteners. This information is presented in Table 1.

Table 1 - Hair bleaching preparations in the USA containing persulfates

Product Category	No. of Formulations	Percentage of Formulations Containing Persulfate		
		Ammonium	Potassium	Sodium
Hair Straighteners	63	0	1.6	1.6
Hair Dyes and Colours	1572	0.06	0.12	0.12
Hair Bleaches	113	20.4	23.9	18.6
Hair Lighteners with Colour	6	0	16.7	16.7
Other Hair Colouring Preparations	59	8.5	8.5	1.7
Other Skin Care Preparations	692	0.14	0	0

Product formulation data has been gathered by the US-based CTFA (CIR, 1998). The concentrations of persulfates used in two common hair treatment procedures are shown in Table 2.

One of the data sources for the CTFA submission further stated that concentrations of persulfates up to 60% are used in some hair bleaching formulations (CIR, 1998). The CIR (1998) also added that product formulation data submitted to the FDA in 1984 indicated that all three persulfates were used at concentrations greater than 50%.

Table 2 - Typical concentrations of persulfate salts used during common hair bleaching procedures in the USA

Type of treatment	Concentration of persulfates during use	Concentrations of the various salts during use[1]		
		Ammonium	Potassium	Sodium
Consumer Products				
On scalp	≤ 12%	≤ 4%	≤ 8%	-
Highlighting hair strands (off scalp)	≤ 25%	≤ 10%	≤ 15%	-
Professional Products				
On scalp	≤ 25%	≤ 5	≤ 15	≤ 5
Highlighting hair strands (off scalp)	10% to 18%	ns[2]	ns	ns

[1] based on two data submissions; [2] ns = not stated (CIR, 1998).

2.3 Australian perspective

A recent review of the incidence of contact dermatitis amongst hairdressers in South Australia together with some risk assessment and recommendations for risk management was undertaken on the basis of the high level of claims for work-related injury (Daly, 1996).

New South Wales WorkCover has produced guidance material for hairdressers on conducting workplace assessments and on risk management.

WorkSafe Western Australia has produced an online and printed guide for young people preparing to enter various industries including hairdressing.

The National Occupational Health and Safety Commission in 1989 developed a national strategy for the prevention of occupational skin disorders and has funded a study on the prevention of occupational skin disease in the hairdressing industry in Australia (Nixon et al., 1999). The results of the study are presented and discussed in Sections 13 and 14 of this report .

3. Applicants

Following the declaration of persulfates as priority existing chemicals, 29 companies importing persulfates or products containing them or with an interest in persulfate importation applied for assessment of the chemicals. In accordance with the *Industrial Chemical (Notification and Assessment) Act 1989*, NICNAS provided the applicants with a draft copy of the report for comments during the correction/variation phase of the assessment. Data for assessment were also provided by 2 companies which purchase persulfates locally in Australia and formulate it into various products.

Agfa-Gevaert Pty Ltd
372-394 Whitehorse Road
NUNAWADING VIC 3131

Alberto Culver Australia
14 Loyalty Rd
NORTH ROCKS NSW 2151

Amtrade International Pty Ltd
2/570 St Kilda Rd
MELBOURNE VIC 3004

Australian Council of Trade Unions
393 Swanston Street
MELBOURNE VIC 3000

BASF Australia Ltd
500 Princes Hwy
NOBLE PARK VIC 3174

Bio-Rad Laboratories
PO Box 210
REGENTS PARK NSW 2143

Bio-Scientific Pty Ltd
28 Monro Ave
KIRRAWEE NSW 2232

Bristol-Myers Squibb Australia Pty
320 Victoria Rd
RYDALMERE NSW 2116

Cosmetic Products Pty Ltd
1 Wella Way
SOMERSBY NSW 2250

Degussa-Huels Australia Pty Ltd
17Raglan Street
SOUTH MELBOURNE VIC 3205

Deltaplus Pty Ltd
121 Wheatsheaf Rd
GLENROY VIC 3046

Fernz Specialty Chemicals
70 Marple Ave
VILLAWOOD NSW 2163

G & T Hairdressing Supplies
Unit 4 No. 5 Deadman Rd
MOOREBANK NSW 2170

Goldwell Cosmetics (Australia) Pty
103 Yerrick Rd
LAKEMBA NSW 2195

Hairtech Australia Pty Ltd
5/150 Canterbury Rd
BANKSTOWN NSW 2200

ICN Biomedicals Australasia
12/167 Prospect Hwy
SEVEN HILLS NSW 2147

Laporte Organics
20-22 MacPherson St
BANKSMEADOW NSW 2019

M & U Imports Pty Ltd
660a South Rd
MOORABIN VIC 3189

Marigny (A'sia) Pty Ltd
266 Bay Rd
SANDRINGHAM VIC 3191

Matrix Essentials Australia
Unit 3/5-15 Epsom Rd
ROSEBERRY NSW 2018

Merck Pty Ltd
207 Colchester Rd
KILSYTH VIC 3137

Redox Chemicals Pty Ltd
30-32 Redfern St
WETHERILL PARK NSW 2164

Sabre Corporation Pty Ltd
75 South Creek Rd
DEE WHY NSW 2099

Schwarzkopf Pty Ltd
20 Rodborough Rd
FRENCHS FORREST NSW 2086

Selby-Biolab
2 Clayton Rd
CLAYTON VIC 3168

Semal Pty Ltd
52-62 Waterview Close
HAMPTON PARK VIC 3976

Sigma Aldrich
2/14 Anella Ave
CASTLE HILL NSW 2154

Swift and Company
PO Box 600
ABBOTSFORD VIC 3067

Turnleys (Aust.) Pty Ltd
9 Gertrude St
FITZROY VIC 3065

4. Chemical Identity and Composition

4.1 Ammonium persulfate

4.1.1 Chemical name (IUPAC)

peroxydisulfuric acid, diammonium salt

4.1.2 Registry numbers

CAS No	7727-54-0

EINECS No. 231-786-5

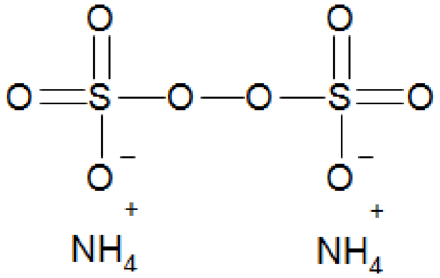
4.1.3 Trade names

Ammonium persulfate; Diammonium persulfate

4.1.4 Molecular formula

$(NH_4)_2S_2O_8$ (ammonium salt)

4.1.5 Structural formula



4.1.6 Molecular weight

228.2

4.2 Potassium persulfate

4.2.1 Chemical name (IUPAC)

peroxydisulfuric acid, dipotassium salt

4.2.2 Registry numbers

CAS Number	7727-21-1
EINECS Number	231-781-8

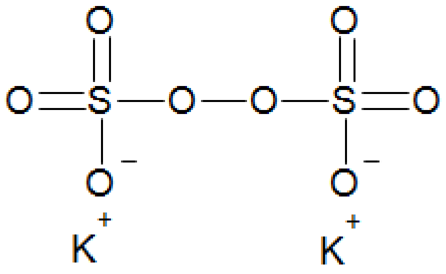
4.2.3 Trade names

Potassium persulfate; Dipotassium persulfate

4.2.4 Molecular formula

$K_2S_2O_8$ (potassium salt)

4.2.5 Structural formula



4.2.6 Molecular weight

270.3

4.3 Sodium persulfate

4.3.1 Chemical name (IUPAC)

peroxydisulfuric acid, disodium salt

4.3.2 Registry numbers

CAS number	7775-27-1
EINECS Number	231-892-1

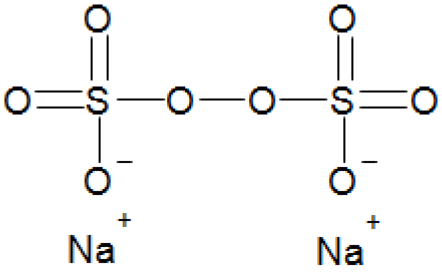
4.3.3 Trade names

Sodium persulfate; Disodium persulfate

4.3.4 Molecular formula

$Na_2S_2O_8$ (sodium salt)

4.3.5 Structural formula



4.3.6 Molecular weight

238.1

5. Physical and Chemical Properties

5.1 Ammonium persulfate

5.1.1 Physical state

Ammonium persulfate consists of colourless, white monoclinic crystals (Sax & Lewis, 1996).

5.1.2 Physical properties

Table 3 - Physical properties of ammonium persulfate

Property	Value	Reference
Melting point	decomposes at 120°C	Sax & Lewis (1996)
Boiling point	Not applicable	
Flash point	Not applicable	
Ignition temperature	Not applicable	
Density	1 982 kg/m^3	Budavari (1996)
Vapour pressure	Not identified	
Active oxygen content	6.94%	Degussa AG (1998a)
Water solubility	559 g/L at 20°C 740 g/L at 50°C	Degussa AG (1998a) BG Chemie (1996)
Partition coefficient	Not identified	

The particle size of imported ammonium persulfate is > 1000 µm (minimum 95%) (Degussa AG, 1998a).

5.1.3 Chemical properties

Ammonium persulfate is a powerful oxidiser that can react vigorously with reducing agents. Mixtures of sodium peroxide with aluminium and water or zinc and ammonia are explosive. A violent reaction occurs with iron or solutions of ammonia and silver salts (Sax & Lewis, 1996). Ammonium persulfate decomposes in the presence of moisture, gradually liberating ozone-containing oxygen; decomposition on heating liberates oxygen and forms ammonium disulfate ($(NH_4)_2S_2O_7$). Aqueous solutions of ammonium persulfate are acidic (pH of a 1% solution is 4 to 6 (CIR, 1998)) and decompose slowly at room temperature; at higher temperature decomposition is rapid liberating oxygen and forming ammonium bisulfate (NH_4HSO_4). When heated to decomposition it emits toxic fumes of SO_x, NH_3 and NO_x (Sax & Lewis,1996).

5.1.4 Composition

The purity of ammonium persulfate for commercial use is greater than 98% with the moisture content of approximately 0.5% or less.

5.1.5 Conversion factors

1 ppm = 9.35 mg/m^3 at 101.3 kPa and 25°C.

5.2 Potassium persulfate

5.2.1 Physical state

Potassium persulfate is a white crystalline powder (Sax & Lewis, 1996).

5.2.2 Physical properties

Table 4 - Physical properties of potassium persulfate

Property	Value	Reference
Melting point	Decomposes at 100°C	Sax & Lewis (1996)
Boiling point	Not applicable	
Flash point	Not applicable	
Ignition temperature	Not applicable	
Density	2 477 kg/m^3	Sax & Lewis (1996)
Vapour pressure	Not identified	
Active oxygen content	5.86%	Peroxid-Chemie (1998)
Water solubility	Moderately soluble in water	Sax & Lewis (1996)
Partition coefficient	Not identified	

The particle size of imported potassium persulfate was not available.

5.2.3 Chemical properties

Potassium persulfate is a powerful oxidiser and is flammable when exposed to heat or by chemical reaction. It can react with reducing materials and liberates oxygen above 100°C when dry or at about 50°C when in solution. When heated to decomposition it emits toxic fumes of oxides of sulfur (SO_x), persulfate (S_2O_8) and potassium oxide (K_2O) (Sax & Lewis, 1996).

5.2.4 Composition

The purity of potassium persulfate for commercial use is greater than 98% with the moisture content of approximately 0.5% or less.

5.2.5 Conversion factors

1 ppm = 11.08 mg/m^3 at 101.3 kPa and 25°C.

5.3 Sodium persulfate

5.3.1 Physical state

Sodium persulfate is a white crystalline powder (Sax & Lewis, 1996).

5.3.2 Physical properties

Table 5 - Physical properties of sodium persulfate

Property	Value	Reference
Melting point	Decomposes at 180°C	Degussa AG (1998b)
Boiling point	Not applicable	
Flash point	Not applicable	
Ignition temperature	Not applicable	
Density	1 103 kg/m^3	Redox Chemicals Pty Ltd (1999)
Vapour pressure	Not identified	
Active oxygen content	6.65%	Degussa AG (1998b)
Water solubility	556 g/L at 20°C	Degussa AG (1998b)
Partition coefficient	Not identified	

The particle size of imported sodium persulfate is >1000 µm (minimum of 70%) (Degussa AG, 1998b).

5.3.3 Chemical properties

Sodium persulfate is a powerful oxidiser and can cause fires. It decomposes in alcohol. When heated to decomposition it emits toxic fumes of oxides of sulfur (SO_x) and sodium (Na_2O) (Sax & Lewis, 1996).

5.3.4 Composition

The purity of sodium persulfate for commercial use is greater than 98% with the moisture content of approximately 0.5% or less.

5.3.5 Conversion factors

1 ppm = 9.76 mg/m^3 at 101.3 kPa and 25°C.

5.4 General chemical reactions of persulfates

The decomposition of the persulfate anion in aqueous solution involves the reactions:

$$S_2O_8^{2-} + H_2O \rightarrow 2HSO_4^- + \tfrac{1}{2} O_2 \quad (1)$$

$$H_2S_2O_8 + H_2O \rightarrow H_2SO_5 + H_2SO_4 \quad (2)$$

$$H_2SO_5 + H_2O \rightarrow H_2O_2 + H_2SO_4 \quad (3)$$

In alkaline, neutral and dilute acid solutions persulfate decomposes according to reaction (1) while in strongly acid solutions reactions (2) and (3) occur (Kolthoff & Miller 1951).

Under the conditions of use in the cosmetics industry, persulfates are mixed in combination with hydrogen peroxide resulting in the liberation of oxygen. The overall process is described in reaction 4 (House, 1962):

$$S_2O_8^{2-} + H_2O_2 \rightarrow 2HSO_4^{-} + O_2 \qquad (4)$$

6. Methods of Detection and Analysis

6.1 Identification

Reaction with iron (II) sulfate and back titration with potassium permanganate is used for the identification of persulfates (Degussa Australia Pty Ltd, 1999).

6.2 Atmospheric monitoring methods

Two methods have been used to monitor atmospheric persulfate concentrations. In the first method (Leino et al., 1999), airborne dust was collected on a cellulose acetate filter (Millipore AAWP 0037) with a stationary membrane pump. Persulfates were extracted in 10 mL water in a boiling water bath and hydrolysed sulfates were determined with an ion chromatograph. In the analysis, a 50 µL sample was injected into a IC-PAK A (Waters, USA) column, and 1.3 mM borate-gluconate eluent was pumped at 1.2 mL/min and detected with a conductivity detector Waters model 430 (Waters, USA).

In the second method (Merget et al., 1996), personal samples of dust were collected using a Du Pont Alpha 1 pump (flow rate 3.5 L/min) and a dust sampling head (sucking velocity 1.25 m/s) provided with a glass fibre filter (diameter 37 mm, Macherey-Nagel). Area samples were taken with a high volume collector (Gravicon VC25, Stroehlein, Kaarst, Germany) at a flow rate of 22.5 m^3/h and a sucking velocity of 1.25 m/s. Total dust was collected on glass fibre filters with a diameter of 150 mm (Macherey-Nagel). The amount of persulfates in the dust was analysed as sulfur by inductively coupled plasma emission spectrometry.

6.3 Biological monitoring methods

None known.

7. Use, Manufacture and Importation

7.1 Manufacture and importation

Ammonium, potassium and sodium persulfate are not manufactured in Australia. Overseas, ammonium and potassium persulfate are manufactured by electrolysis of concentrated solutions of ammonium and potassium sulfate, respectively (Lewis, 1997). Sodium persulfate is made by membrane cell electrolysis of sodium sulfate and sulfuric acid (Ashford, 1994).

Within Australia, several products are formulated from imported persulfates. Pure persulfates are imported from Germany in 25 or 50 kg polyethylene bags or in larger bags of 1000 kg capacity. In addition, a number of companies import pre-formulated hair bleaching products for salon use or for retail sales to consumers. The products imported for salon use can be sold as is or repackaged. All identified imported and locally formulated products containing persulfate salts are listed in Appendix 1.

7.2 Formulation of products

Two companies in Australia (De Lorenzo Hair & Cosmetic Research Pty Ltd and D.F.C Thompson Australia Pty Ltd) formulate hair bleaching powders from pure persulfates. One company receives < 1000 kg of ammonium persulfate per annum (20% to 30% of product) and < 1000 kg of potassium persulfate per annum (30% to 40% of product) for blending into two products. The other company formulates two consumer products from ammonium persulfate received from a second company, one product containing up to 50%, the other up to 70% ammonium persulfate, and packs the first of these. A contract packer packs the second product. Both products are sold to the retail market by another company. The annual import volume of ammonium persulfate for both products is < 4500 kg.

7.3 Uses

Persulfates are used as oxidising agents in hair bleaches, hair colouring preparations and hair lighteners with colour (Wenninger & McEwen, 1997).

Natural hair contains two pigments, melanin and pheomelanin. Melanin is black to dark brown in colour while pheomelanin varies from red to yellow (Menon et al. 1983). Hair bleaching involves the controlled oxidation of these two pigments. Melanin is easily oxidised while pheomelanin is more resistant to oxidation. The bleaching process takes the hair through several intermediate shades of colour typically described as black, brown, red, orange, gold, yellow and pale yellow. The term lightening is generally applied when only a few shades of colour change are required. Hydrogen peroxide is the primary oxidising agent in hair bleaches but is slow in acting at concentrations suitable for hair use. The addition of persulfate salts to these bleaches boosts the oxidation process as they liberate activated oxygen in the presence of hydrogen peroxide, which results in faster oxidation of the hair pigments.

The persulfate-containing booster powders are supplied separately packaged and are mixed with aqueous hydrogen peroxide just prior to use, to create a liquid, gel or slurry which is applied to the hair with a tinting brush. Within the hairdressing industry, persulfate salts are used solely as bleach boosters and not for any other purpose.

Within this assessment, the term hair bleach is used to include products used for hair bleaching, lightening, streaking and certain colouring effects. In order to accomplish certain hair colouring effects it is first necessary to remove either the natural or artifical hair colour by bleaching the hair before the final colour can be achieved.

While the majority of bleach products on the Australian market are for professional use in hairdressing salons a small number of products are for home use (see Appendix 1).

7.4 Non-cosmetic uses

Persulfates are used in industrial processes as oxidising agents, in metal etching and as oxidising agents for dyes and prints in the textile industry. In addition, they are also used in the rubber and adhesive, paper and paperboard industries (Fisher & Dooms-Goosens, 1976). Persulfates are used to deodorise and bleach oils, as depolarisers in batteries and in photography (Lewis, 1997).

8. Exposure

Occupational exposure of workers in Australia can occur during the transport and storage of pure persulfates, during the formulation of hair bleaching powders and during the transport, storage, or application of hair bleaching powders themselves.

In the assessment of occupational exposure to chemicals, it is generally necessary to evaluate intake from all routes of exposure, i.e. ingestion, inhalation and dermal (including ocular) exposure. While ingestion of large quantities of persulfates is unlikely during occupational use, some ingestion may occur due to inhalation of airborne persulfate particles. The major routes by which workers may be exposed to persulfates are by the inhalation and dermal routes.

Inhalation exposure to persulfates can occur at various stages in the product cycle. For use of the pure chemicals in product formulation, the particle size is above the inspirable range (particle size for persulfates is at least 420 μm) so inhalation exposure is likely to be low. However, during milling and subsequent operations, inhalation exposure to persulfates in hair bleaching powders is potentially high as the particle size approaches the inspirable and respirable range (see Figure 1). Use of hair bleaching powders in salons is also a potential source of inhalation exposure.

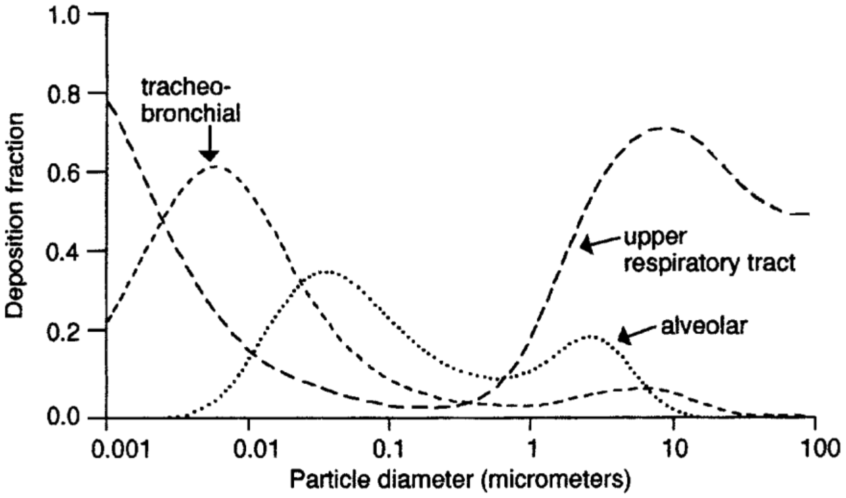


Figure 1. Deposition of particles of various size in the respiratory tract (after Snipes, 1994).

Dermal exposure to persulfates can occur at several stages of hair bleaching powder formulation and also during salon use.

For the assessment of occupational exposure to hazardous substances good quality measured data for various work scenarios are desirable. When such data are unavailable or inadequate, mathematical modelling is used. The EASE (Estimation and Assessment of Substance Exposure) model (ver 2.0) developed by the UK Health and Safety Executive (HSE) (EC, 1997) was used to estimate exposure.

EASE is a knowledge-based electronic data system designed to facilitate the assessment of workplace exposure. It is a predictive model for workplace exposure assessments and predicts exposure as ranges in the form of conventional 8-h time weighted average (TWA). Dermal exposure is assessed by EASE as the potential exposure rate predominantly to the hands and forearms (approximately 2000 cm^2).

8.1 Exposure during formulation of hair bleaching powders

8.1.1 Transport and storage

Persulfates are imported in 25 or 50 kg polyethylene bags or in larger bags of 1000 kg capacity and transported by road, unopened, to formulators of persulfate products.

During transport and storage of the pure persulfates, exposure is unlikely except in the case of accidental breakage of, or spillage from, the packaging in which they are contained.

8.1.2 Formulation and packing

Process

As noted above, formulation within Australia is carried out by 2 companies. The formulation process by company number 1, which produces two persulfate-containing products, is as follows:

The ammonium persulfate (available in particle sizes of $\geq$ 1000 µm, 95% minimum) is received in 25 kg woven polyethylene bags. For all formulation processes, local exhaust ventilation is employed to remove dust.

Fifteen batches of one product and 4 batches of another are produced annually. Therefore the average batch size for one product would be < 300 kg and for the other product, < 200 kg. Blending is performed by 2 workers for 3 h. Each ingredient of the formulation (which can include persulfates, fillers, emulsifiers, chelators and dye) is weighed into a stainless steel drum. The drum is then hoisted above a vibrating sieve and the flow control opened. Dust is contained by means of a heavy duty polyethylene hood connecting the drum and sieve. The sieved material (particle size $\leq$ 420 µm and $\leq$ 840 µm for products one and two) is collected in another stainless steel drum which is subsequently hoisted above a ribbon blender and the contents loaded to the blender. The blender is closed and blending takes place for 15 to 40 minutes. The blender is not airtight. Although it is expected that some particle size reduction does take place during the blending process the company indicated that there were no particle size measurements available following blending. A storage bag is positioned under the discharge valve which is opened and the product is discharged. The remaining product in the blender is scraped out. A sample is then removed for testing at the customer site prior to sealing of the bag for storage.

When the batch is deemed suitable for packaging, the storage bag is positioned on to a screw conveyor. The bottom ties of the bag are released and the product is fed into a filling machine via the screw conveyor. A bottle is held under the filling head and a metered dose added to the bottle. A cap is placed on the bottle by hand

and machine tightened. The bottle is then labelled and packed. Filling of four batches per annum occupies five workers for approximately four hours per batch.

One of the products is filled by a contract packer. Two workers load received 200 L open top drums onto a mezzanine floor beside the holding hopper. A heavy duty polyethylene hood is attached to the head of the drum and the hopper creating a sealed system. The drum is lifted and tilted with a drum lifter to transfer product to the holding hopper. The holding hopper feed is controlled by a level probe in an auger hopper which is part of the sachet filling machine under the mezzanine floor. The connection between the holding hopper and the auger hopper is with a sealed tube. The sachet machine forms, fills and seals the sachets which are then packed into cartons. The packing company does not perform particle size measurements.

At the second formulating company, where a further two persulfate-containing products are produced, the persulfates are received in 50 kg containers (particle size ≥ 700 μm) and approximately 15 batches of bleach powder are formulated per annum.

The persulfates and other ingredients (including fillers, dispersants, emulsifiers, binder and chelators) are weighed manually by scooping into a container on a scale under dust extraction prior to being manually dispensed under dust extraction into a roller mill. The roller mill is a closed system and milling involves slow to moderate rotation for approximately 24 h. The formulation process is carried out by 2 persons. Milling is conducted until at least 75% of the particles have a size less than 180 μm.

Quality control is conducted by one person who checks the particle size by sieve analysis and bleach performance testing. Samples to be tested are removed with a scoop under dust extraction and placed in a container, the contents of which are allowed to settle prior to particle size measurement and bleach testing on a swatch of hair. Bleach testing is conducted under the conditions which would be used in a typical salon. Dispensing of the final product into 500 g polyethylene tubs is conducted manually by scooping the product out of the mill under dust extraction.

Exposure during formulation

Site visits were conducted at each of the formulation plants. At each plant two workers perform blending of bleaching powders. Dermal exposure to the persulfates is possible while scooping the powered persulfate into weighing vessels and during transfer to the blending machines. However, each company provides its workers with gloves and appropriate long sleeved coveralls or dustcoats which aid in minimising dermal exposure. Inhalation and ocular exposure from dust generation at this stage is likely to be low due to the use of local exhaust ventilation and because the particle size of the persulfates is predominately greater than 420 μm. Dust masks and safety goggles are provided to workers to further minimise inhalation and ocular exposure. Only one of the two companies formulating bleaching powders produce a product designed to be dust-free.

Although one of the machines used for blending was not airtight, the use of local exhaust ventilation would be expected to minimise inhalation and ocular exposure during blending/milling.

At one company, at the completion of a batch, the equipment is washed and air-dried prior to re-use of the equipment or for maintenance. During such times, the room containing the equipment is subject to dust extraction. At the other company, a dedicated mill is used for formulating persulfates. The potential for inhalation, dermal and ocular exposure is expected to be infrequent given that at one plant 8 batches and at the other, 15 batches are produced annually.

Following powder blending or milling processes, quality control is performed on small samples, consequently total exposure should be low. During discharge of powders into bags for storage, inhalation and ocular exposure is controlled by the use of local exhaust ventilation and the use of heavy duty polyethylene dust hoods although dermal exposure is still possible. Dermal exposure is also possible during packaging but again inhalation and ocular exposure are controlled by local exhaust ventilation. During filling by a contract packer, the product is transferred from drums and packed into sachets via a sealed system so that exposure is expected to be low.

Exposure of workers to persulfate dust is controlled predominately by the use of local exhaust ventilation at each stage of the process and by the use of personal protective equipment including gloves, goggles, masks and protective clothing.

No measurements of atmospheric levels of persulfates have been made at either of the Australian sites where hair bleaching powders are formulated. However, estimates of dermal exposure and dust levels can be made using the EASE model (ver 2). With the assumptions of a process temperature of 25°C for a non-fibrous, non-aggregating solid subject to dry manipulation under conditions of local exhaust ventilation and exposure for two hours per day, dermal exposure is predicted to be very low and airborne dust levels are predicted to be 0.5 to 1.3 mg/m^3. Based on a persulfate content of 70% for a formulated product this would give a range of 0.35 to 0.91 mg/m^3 (TWA). As the formulation of persulfate products is intermittent (a maximum of 15 shifts/year), exposure is likely to be low. Currently, there are no Australian occupational exposure standards for the persulfate salts. Overseas, occupational exposure standards range from 0.1 to 5 mg/m^3 (see Table 11, Section 13.4).

8.2 Exposure during use

8.2.1 Import, transport and storage

Hair bleaching powders for salon use are imported in containers of up to 900 g in size although typical quantities are generally 500 g. Single use sachets are also imported and typically contain from 17 to 30 g of product. Although some repackaging can occur with imported products, this involves sealed packages being placed into new containers (for example, a plastic bag into a polyethylene tub) and no exposure to the powder results. Exposure during transport and storage is likely only in the event of accidental spillage.

8.2.2 Salon use

Hair bleaching is conducted at virtually all of the 12 000 salons in Australia several times a week. The mean number of workers per salon in metropolitan Melbourne is 4 (Nixon et al., 1999) so approximately 48 000 workers may be exposed to hair bleaching powders on a daily basis nationwide. Based on information supplied for this assessment by one distributor of hair-care products, less than 10% to 15% of a salon's business involves hair bleaching (personal communication).

The process of bleach preparation and use is similar for the majority of bleaching products examined. The process essentially consists of:

- shaking the container before use (generally required for products packaged in bulk tubs but not for those in plastic bags. One product packaged in sachets required shaking before use);
- transferring the required quantity of bleaching powder with the pre-measured scoop provided (one to four scoops or approximately 20 to 80 g from a bulk container) or one or two sachets (approximately 17 to 30 g) to a non-metallic bowl;
- add the required quantity of hydrogen peroxide solution, the strength dependent on the degree of bleaching required; and
- mixing the bleach powder and hydrogen peroxide solution to form a cream.

The application and bleaching process varies according to whether the hair has not been previously treated (virgin hair) or had a prior bleaching treatment (retouching application). The two processes are as follows:

The process for virgin hair (either full scalp or streaking procedure) is as follows:

- the dry unwashed hair is divided into sections. For the full scalp treatment the bleach is generally applied to each section with a brush to the full length of the hair. For some products, the bleach is initially applied 2 to 3 cm away from the scalp as heat from the scalp accelerates the bleaching process. Approximately half way through the bleaching process bleach is applied to the roots area to give full coverage to the hair shaft. For streaking the scalp is covered with a plastic cap through which lengths of hair are pulled with a hooked needle prior to bleach application. An alternative method involves the use of foils on which the hair is placed for brushing on the bleach or in which the hair is wrapped to avoid bleach exposure. For both procedures, the darkest portions of the hair (generally at the back of the head) are treated first.
- development is allowed to proceed for 10 to 60 minutes depending on the strength of the bleach and the degree of bleaching required. Heat may be applied to speed the development of some salon products; and
- removal of the bleach by washing off and neutralising with a suitable shampoo.

The process for retouching is as follows:

- the dry unwashed hair is divided into sections;
- bleach is applied one section at a time to re-growth areas only;
- development is allowed to proceed for 30 to 60 minutes depending on the strength of the bleach and the degree of bleaching required; and
- removal of the bleach by washing off and neutralising with a suitable shampoo.

Inhalation exposure is greatest during bleach mixing, which includes opening and closing of the bleach package, and dust particles may persist in the atmosphere following the mixing procedure. Dermal exposure is dependent on glove use although it may also occur due to contamination of surfaces with fine dust resulting from the mixing procedure. Nixon et al. (1999) found that hairdressers use gloves mainly to avoid staining of the hands with hair dyes. Nevertheless, even if gloves are used, removal of fine bleaching powder from its container can lead to skin contact and its collection under jewellery and watch bands can lead to prolonged exposure. Eye contact would be expected to occur through secondary transfer from the hands and from dust in the atmosphere.

Hair bleaching powders are currently produced as fine powders or as so-called "dust-free" preparations. Dust-free preparations can be produced either as a granulated product (two identified on the Australian market) or be of a damp consistency (14 identified). The damp consistency is produced by the addition of a small quantity of oil or other binding agent to the bleach powder which results in aggregates forming that are less likely to disperse into the air. While approximately 50% of the bleaching products identified for this assessment were labelled as "dust-free" (see Appendix 1), it is unknown how the efficacy of the claim was determined.

An examination of several products labelled as dust-free revealed the formation of visible clouds of dust that dispersed into the workplace atmosphere upon opening and closing of the container or during dispensing of the product with the scoop provided. Consequently, not all hair bleaches labelled as dust-free can be considered to be truly dust-free.

Of all the importers/formulators, only one was able to provide detailed information on the particle size distribution of its products, one a standard "dusty" preparation and one dust-free. The particle size data for four products obtained during assessment are provided in Table 6.

Table 6 - Particle size for some standard bleaches and dust-free preparations

Sample	% < 10 μm	% <180 μm	Max (μm)	mean (μm)
Dust-free 1	-*	60 – 75%	-	-
Dust-free 2	2.2%	-	180	124
Standard 1	-	61 – 80.5%	-	-
Standard 2	35.6%	-	10	15.4
Standard 3	8.9%	-	15	44.3

* = data not available

In general, normal bleach powders can contain up to approximately 40% of particles with a size less than 10 μm. The single dust-free preparation for which detailed particle size information is known (Dust-free 2, Table 6) nevertheless has the potential for deposition in the upper respiratory (nasopharyngeal) tract. Ocular exposure and dermal exposure to powders with a high level of fine particles is possible from dust cloud formation, from direct contact and from accumulation of dust on work surfaces. However, the formation of dust clouds as a result of normal use of dust-free preparations is expected to be much reduced or absent provided the product is effectively dust-free. At present there are no standards by which the effectiveness of dust-free claims can be measured.

There are few published workplace assessments of hairdressing salons. In one study of the use of bleaching powders in salons it was stated that the closing of the plastic bags in which the bleaching powder is supplied produces a visible cloud of particles (Daly, 1996). When the powder is removed with the supplied plastic scoop and placed in a bowl for mixing there is also potential for dust cloud generation with consequent, skin, eye and respiratory exposure. Dermal exposure can occur when the hands contact the inside of the bag, which is covered in bleach. It has been noted that jewellery and watch straps were often left exposed to catch dust, even when gloves are worn (Daly, 1996). Therefore, there is potential for dermal, ocular and respiratory exposure to the bleach dust when removing bleaching powder from its packaging.

When containers of persulfates are shaken prior to opening there is potential for dust cloud formation. Further contamination of the workplace can occur when bleach powder and hydrogen peroxide solution are vigorously stirred to form a paste, minor spillage can occur and remain on the floor and work surfaces. When this contamination is removed, commonly with a dry towel or tissue, airborne dust can be liberated (Daly, 1996). During mixing of hair bleach with a wide brush and application to hair there is potential for eye exposure from projectiles of bleach launched from the bristles. This potential can be minimised by the use of a viscous hydrogen peroxide preparation for mixing.

Two companies provided information on bleach formulations (DecoCream by HSA Laboratories distributed by G & T Hairdressing Supplies and Wella Blondor Special Cream distributed by Cosmetic Products Pty Ltd) which supplied the persulfate-containing bleach booster as a cream and is mixed with hydrogen peroxide in the usual manner. Due to the physical properties of these products both inhalation and ocular exposure should be minimised although there is potential for dermal contact.

Following bleach application, the clean up and rinse out procedures have the potential to expose the skin to persulfates. In addition, aluminium foil and other masks, which are used to create effects, are potential sources of exposure unless disposed of adequately and promptly. If a number of clients are being serviced at the same time, contamination of work surfaces may allow accumulation of persulfate-contaminated material leading to greater potential for mainly dermal exposure.

Dermal exposure is possible during mixing and application of hair bleach although exposure can be largely avoided by the use of a “no touch” technique (Nixon et al., 1999). This involves the use of gloves and applicator sticks during the preparation and bleaching process so that the skin of the operator does not come into contact with persulfate.

8.2.3 Exposure data and estimates

Use in salons

Overseas data

Studies of atmospheric measurements of persulfates in hairdressing salons are limited to one study. In a random sample of 20 salons in Finland, the average dust concentration in small salons was 133 μg/m^3 and in large salons, 66 μg/m^3. The persulfate concentration in the small salons was 2.9 μg/m^3 and in the large salons 0.9 μg/m^3 determined as the time-weighted average of two shifts. During the mixing of bleaching powder, the persulfate concentration in the breathing zone rose to 30 μg/m^3. The personnel in less ventilated salons (air exchange rate ≤ 3.6 L/h) complained of discomfort and ill health caused by dust and chemicals to a greater degree than workers in the better ventilated salons (Leino et al., 1999). The frequency of persulfate use, the presence of local exhaust ventilation during bleach mixing and the proportion of salons using dust-free products was not stated in the report.

Estimated Australian data

In the absence of monitoring data and the uncertainties involved in the study of Leino et al. (1999), the EASE model has been used to estimate exposure levels in Australian hairdressing salons. In the absence of local exhaust ventilation, the EASE model provides an estimate of between 5 to 50 mg/m^3 and 0.5 to 5 mg/m^3 (TWA) for a dusty and dust-free product respectively. Based on a maximum persulfate content of 70% for a formulated product this would give persulfate ranges of 3.5 to 35 mg/m^3 and 0.35 to 3.5 mg/m^3 (TWA) for the dusty and dust-free products respectively. Assuming an exposure time to airborne persulfate of 15 minutes during bleach preparation (i.e., each salon worker performs one bleaching service per day) exposures would range from 109.4 μg/m^3 to 1.09 mg/m^3 and 10.9 to 156.3 μg/m^3 for a dusty and dust-free product respectively.

8.3 Public exposure

8.3.1 Consumer use

Consumers can be exposed to persulfates either in the form of do-it-yourself products or in the form of products used by professional hairdressers. For home use, the products will be applied to the hair strands or to the hair roots, depending on product use, and it is likely there will be some contact with the scalp during product use, particularly by inexperienced users. Bleach preparations are normally left in contact with the hair for 10 to 60 minutes. The general bleaching process, including preparation of the bleach, is similar to that described for salon use (see Section 8.2) with the exception that heat is not applied during the development process. With do-it-yourself products, the bleach booster is generally supplied in sachets.

8.3.2 Consumer exposure

Consumers are likely to have inhalation and dermal exposure to persulfate salts although the latter will be the dominant route. Inhalation exposure by consumers is expected to be low, both from salon and home use, due to the small quantity of material involved, the infrequent use of the products and, in salons, the preparation of the bleach away from the client. The persulfate content of a number of identified consumer products (see Appendix 1) are as follows:

- one product contains 45% ammonium persulfate used at a concentration of approximately 12%;
- one contains 64% ammonium persulfate used at a concentration of approximately 8%;
- one contains 21% ammonium persulfate and 61.4% potassium persulfate used at a concentration of approximately 19% persulfates; and
- one contains 22% ammonium persulfate and 36% potassium persulfate used at approximately 29% on the hair.

Information obtained during this assessment shows that the persulfates are used in hair salon bleaches at a concentration of up to 70% (product formulation data submitted for assessment) for on- and off-scalp treatments. The final use concentration will depend on the desired result and the ratio of hydrogen peroxide developer and bleach booster used. These factors, in part, will determine the length of time the bleach is left on a client's hair.

While products used in salons in Australia can contain up to 70% persulfate salts most are used at approximately 20% persulfates on the hair with a minority of products used at concentrations up to 30% and some at 10% to 15%.

8.3.3 Exposure via environment

There will be some release to the environment of products containing persulfate salts once they are used by consumers. Used product containers and implements used to apply hair care products (plastic caps, plastic spoons, mixing bowls) will contain some residual persulfate salts which will either be disposed of in domestic garbage or rinsed off into domestic sewers. Under these conditions, the persulfate salts are expected to degrade rapidly.

9. Effects on Laboratory Mammals and Other Test Systems

Importers/formulators of persulfate salts or persulfate products were unable to provide any toxicological studies. Summaries of studies made available for assessment by overseas manufacturers of persulfates and relevant studies identified after extensive literature searches have been evaluated and are presented in this section. Where original studies were unobtainable, unpublished summaries or secondary sources, such as the International Unified Chemical Database (IUCLID), have been utilised for this assessment and have been acknowledged as such in the appropriate place.

9.1 Kinetics and metabolism

No information is available on the kinetics and metabolism of persulfates. However, based on the *in vitro* chemistry of persulfate compounds, they are expected to decompose under *in vivo* conditions to form hydrogen peroxide and the disulfate anion (Kolthoff & Miller, 1951). Micromolar concentrations of hydrogen peroxide are known to alter cellular function by altering intracellular redox status (Burdon, 1995) and to induce oxidative stress characterised by oxidation of many biomolecules including proteins and DNA and peroxidation of lipids (Kappus, 1987). Catalase and the peroxidases are intracellular enzymes which act to to eliminate hydrogen peroxide from cellular systems. Although catalase is ineffective against low micromolar concentrations of hydrogen peroxide (Makino et al., 1994) the peroxidases are more efficient (Suttorp et al., 1986). However, due to the intracellular nature of these enzymes they are not effective against extracellular hydrogen peroxide.

9.2 Acute toxicity

The acute lethality studies conducted with the persulfates via the oral, dermal, inhalation and intraperitoneal routes of administration are summarised in Tables 7 to 9.

The most significant clinical signs following oral administration of ammonium persulfate (LD_{50} = 495 mg/kg, rat females, Table 7) were tremors, oral discharge, lacrimation, pallor, abdominal gripping, splayed hindlimbs, leaning to one side, decreased locomotion, pale ears, walking on toes, recumbency and loss of muscle control. Recovery of surviving animals was essentially complete within 2 days of dosing and all signs of toxicity subsided by day 5 of the study. All rats appeared normal at necropsy.

Clinical signs observed after dermal application of ammonium persulfate included abdominogenital staining, chromorhinorrhea (red nasal exudate), chromodacryorrhea (red conjunctival exudate) and lacrimation together with erythema on 2 test sites.

Clinical signs of exposure following inhalation included respiratory distress, chromodacryorrhea, chromorhinorrhea, decreased faeces, decreased locomotion, dyspnea, nasal discharge, oral discharge, languid behaviour and squinted eyes. There were no treatment-related gross lesions.

Table 7 - Ammonium persulfate: Summary of acute lethality studies

Route	Species	Results	Reference
Oral			
	Rat (m)	LD_{50} = 820 mg/kg	Smyth et al. (1969)
	Rat (f)	LD_{50} = 495 mg/kg	FMC (1991a)
	Rat (m)	LD_{50} = 600 mg/kg	FMC (1979a)
Dermal			
	Rat	LD_{50} > 2 000 mg/kg	FMC (1991b)
	Rabbit (m)	LD_{50} > 10 000 mg/kg	FMC (1979a)
Inhalation			
	Rat	LC_{50} > 2.95 mg/L (4-h exposure, 97% dust particles < 10 μm)	FMC (1987a)
	Rat (m)	LC_{50} = 520 mg/L (1-h exposure)	FMC (1979a)

m = male; f = female

Following the oral administration of potassium persulfate no abnormal findings were observed at necropsy whereas on inhalation exposure enlarged livers and spleens were noted in all animals. Dermal treatment resulted in a number of haemorrhagic lesions at the sites of application (FMC, 1979b).

Table 8 - Potassium persulfate: Summary of acute lethality studies

Route	Species	Results	Reference
Oral			
	Rat (m)	LD_{50} = 1130 mg/kg	FMC (1979b)
	Rat	LD_{50} = 802 mg/kg	ACGIH (1986)
Dermal			
	Rabbit (m)	LD_{50} > 10,000 mg/kg	FMC (1979b)
Inhalation			
	Rat (m)	LC_{50} > 42.9 mg/L (1-h exposure)	FMC (1979b)

Clinical signs noted after oral administration of sodium persulfate (LD_{50} = 930 mg/kg rat males; 920 mg/kg rat females, Table 9), were sedation, ataxia, dyspnea, diarrhoea, muscular hypotonia and mydriasis. At necropsy, animals dying during the study exhibited pale discolouration of the liver and kidney parenchyma, haemorrhage and ulceration of the stomach and intestinal walls and a greenish-brown discolouration of the lungs.

Table 9 - Sodium persulfate: Summary of acute lethality studies

Route	Species	Results	Reference
Oral			
	Rat (m)	LD_{50} = 930 mg/kg	Degussa AG (1979)
	Rat (f)	LD_{50} = 920 mg/kg	Degussa AG (1979)
	Rat (m)	LD_{50} = 895 mg/kg	FMC (1979c)
Dermal			
	Rabbit (m)	LD_{50} > 10 000 mg/kg	FMC (1979c)
Inhalation			
	Rat	LC_{50} > 5.10 mg/L (4-h exposure)	FMC (1995)
	Rat	LC_{50} > 21.6 mg/L 17 – 19% dust particles < 5 μm (4-h exposure)	FMC (1987b)
	Rat (m)	LC_{50} > 191.7 mg/L 50% aqueous suspension (1-h exposure)	FMC (1979b)
Intravenous			
	Rabbit	Minimum Lethal Dose = 178 mg/kg	Spector (1956)
Intraperitoneal			
	Mouse	LD_{50} = 226 mg/kg	Nofre et al. (1963)

m = male; f = female

9.3 Irritation and corrosivity

9.3.1 Skin irritation

Ammonium persulfate

Three studies of the dermal irritation potential of ammonium persulfate have been conducted in rabbits (BG Chemie, 1996; IUCLID, 1996a). In two of the studies 0.5 g of ammonium persulfate was applied to the test site for 4 h. In the other study, the time of application was not specified. One of the studies, according to the IUCLID, was conducted according to OECD TG 404 and GLP principles. The maximum effect on intact skin was slight oedema which cleared within 24 h.

Two of the studies included an abraded skin site. In one of these studies no irritation was reported but in the other study moderate to severe erythema, moderate oedema together with scab formation was observed.

Potassium persulfate

One study submitted by industry (brief summary only) stated that potassium persulfate was non-irritating to intact and abraded rabbit skin (FMC, 1979b). No experimental details were provided.

Sodium persulfate

Summaries of a number of unpublished studies were available (IUCLID, 1996b). In two of these studies sodium persulfate was applied to both intact and abraded skin. The sites were scored by the Draize method after 24 and 72 h. The amount of sodium persulfate applied to the skin was not reported. Sodium persulfate was at most a slight skin irritant in rabbits.

9.3.2 Eye irritation

Ammonium persulfate

The eye irritation potential of ammonium persulfate was tested in rabbits, summaries of which have been published (CIR, 1998; BG Chemie, 1996; BIBRA International, 1997). In one study, ammonium persulfate was stated not to be irritating and in a second study exhibited slight to mild conjunctivitis and iritis. Severe conjunctival redness, chemosis and discharge were observed in a third study which disappeared within 72 h although corneal opacity persisted longer than 72 h. The investigators concluded that ammonium persulfate is slightly irritating to the eye.

Potassium persulfate

One study submitted by industry (brief summary only) stated that potassium persulfate produced marginal irritation to rabbit eyes. Draize scores were not determined (FMC, 1979b). No experimental details were provided.

Sodium persulfate

In a single unpublished study sodium persulfate was instilled into the eyes of 8 rabbits. Eyes were scored by the Draize method at 24, 48 and 72 h (IUCLID, 1996b) slight conjunctivitis only was noted at 48 h.

9.3.3 Respiratory Irritation

Sodium persulfate

Groups of 4 male ND4 Swiss Webster mice were exposed, head-only, to sodium persulfate dust for 30 minutes at concentrations of 0.26, 0.77, 1.38 or 3.22 mg/L. The mass median aerodynamic diameters for these concentrations were 9.0, 7.3, 11.7 and 16.0 μm, respectively. Sensory irritation was assessed by monitoring each animal's respiratory rate before and during exposure and during a 10-minute recovery period. For 7 days following exposure, animals were monitored for respiratory rate changes, body weight and clinical signs.

Mortality was observed in 1/4, 2/4 and 4/4 mice in the 0.77, 1.38 and 3.22 mg/L exposure groups, respectively, during the 7-day post-exposure period. Exposure-related clinical signs included decreased respiratory rate, blepharospasm, lacrimation, perinasal encrustation and unkempt fur. Abnormal gait and whole body tremors were observed in animals exposed to the highest concentration of dust (FMC, 1993).

Lengthening of the expiratory portion of the waveform of the respiratory cycle was observed with sodium persulfate indicating sensory irritation. The RD_{50}, the concentration of dust which produced a 50% decrease in respiratory rate, was 2.25 mg/L.

9.4 Sensitisation

9.4.1 Dermal

The full reports of optimisation tests with ammonium and sodium persulfate in guinea pigs were provided by Degussa-Hüls AG (Degussa AG, 1985a and Degussa AG, 1985b, respectively). Both studies were performed in accordance with OECD Test Guideline 406.

The method for both studies utilised 20 test and 20 control Pirbright White guinea pigs.

Induction was accomplished by injecting 0.1 mL of 0.1% test substance in physiological saline into the flank, back and neck on days 1, 3 and 5. Injections were continued on days 8, 10, 12, 15, 17 and 19 with an emulsion (1:1) of the test substance and Freund's Complete Adjuvant.

A first challenge involved injection of 0.1 mL of 0.1% test substance in physiological saline in the flank on day 36. Twenty-four hours later application sites were scored for erythema and oedema. A second challenge on day 50 was topical application of the test substance (1%) under occlusive patch on the back for 24 h. Sites were scored for erythema and oedema 24 and 48 h after patch removal.

Following intradermal challenge with ammonium persulfate all test animals were positive but none of the control animals; following topical challenge 16/20 test animals were positive compared to 3/20 control animals.

The corresponding figures for sodium persulfate were 18/20 test animals positive following intradermal challenge compared to 0/19 controls (1 animal died); following topical challenge the figures were 12/20 test animals positive versus 2/19 for the controls.

9.4.2 Inhalation

Ammonium and potassium persulfate

Ammonium and potassium persulfate have been tested in an animal model of occupational lung disease, namely, airway responsiveness to acetylcholine in rabbits (Mensing et al., 1995a; Mensing et al., 1995b; Mensing et al., 1998). Airway hyperresponsiveness (AHR) is regarded as an initial step in the development of obstructive lung disease (Vandenplas et al., 1996).

Ammonium persulfate at approximately 50 mg/m^3 for four hours induced AHR (Mensing et al., 1995a). Aerosolised hydrogen peroxide did not alter airway responsiveness to acetylcholine. Similar effects have been reported with hair bleaches containing ammonium and potassium persulfates together with hydrogen peroxide (Mensing et al., 1995b). In a more extensive study, AHR was induced after four hours of treatment with a hair bleach comprised of 11 mg/m^3 persulfates (6.8 mg/m^3 potassium persulfate and 4.1 mg/m^3 ammonium persulfate) together with approximately 1.4 mg/m^3 hydrogen peroxide (Mensing et al., 1998).

Although hydrogen peroxide at 37 mg/m^3 did not induce AHR, synergistic effects with the persulfates were not ruled out.

Sodium persulfate

Sodium persulfate was negative in an *in vitro* model for inhalation sensitisation via binding to a lysine-containing peptide (Wass and Belin, 1990). However, the study authors cautioned that a negative test result using the described protocol did not exclude the possibility that sensitisation may occur.

9.5 Repeated dose toxicity

Ammonium persulfate

28-Day Oral Feeding Study

Groups of 10 male CR-CD rats were fed ammonium persulfate in the diet at dosages of 0, 100, 300 or 600 ppm for 28 days. Neither mortality nor significant pathology at autopsy was observed but decreased relative adrenal weight was observed at the highest dose giving a NOAEL of 300 ppm (FMC, 1979a).

7-Day Inhalation Study

Groups of SD rats (6/sex) were exposed to 0, 1, 4, 9, 17 or 20 mg/m^3 of aerosolised ammonium persulfate (mass median aerodynamic diameter of 0.8 to 1.3 µm) 23.5 h/day for 7 days. At concentrations of 4 mg/m^3 and above a significant reduction in body weight gain and indications of pulmonary oedema and/or inflammation were observed (Last et al., 1982). The NOAEL in this study was 1 mg/m^3.

90-Day Inhalation Study

Sprague-Dawley rats (20/sex/group) were exposed to ammonium persulfate dust at concentrations of 5, 10.3 or 25 mg/m^3 (mass median aerodynamic diameters 2.5, 2.7 and 2.5 microns respectively) for 6 h/day, 5 days per week for 90 days. No exposure-related deaths occurred. Rales and an increase in respiration rate were noted in males and females in the 25 mg/m^3 group. A decrease in body weight gain and an elevation in lung weights occurred in the 25 mg/m^3 group compared to control animals. Irritation of the trachea, bronchi and bronchioles was noted in the high-dose group along with regenerative hyperplasia of the bronchial epithelium and excess mucus secretion and/or accumulation in the bronchi and alveoli. Rales occurred in 3/20 males and 10/20 females in the 10.3 mg/m^3 exposure group. The study was performed in accordance with GLP. The NOAEL was 5 mg/m^3 based on the occurence of rales (FMC, 1997).

Potassium persulfate

28-Day Oral Feeding Study

Groups of 10 weanling rats each were fed 0, 100, 316 or 1000 ppm of potassium persulfate in their diets for 28 days. No treatment-related deaths occurred and there were no significant pathological findings reported. The NOAEL was determined to be 1000 ppm (131.5 mg/kg bw/day) (FMC, 1979b).

Sodium persulfate

90-Day Oral Feeding Study

Groups of 10 CR-CD male rats were administered sodium persulfate in the diet at concentrations of 0, 100, 316 or 1000 ppm for 90 days. No effects were noted and there were no significant macroscopic findings (IUCLID, 1996b).

Groups of rats (10/sex, strain unspecified) were administered sodium persulfate in the diet at doses of 0, 300 or 3000 ppm for 90 days or 1000 ppm for 8 weeks followed by 5000 ppm for 5 weeks. No effects on body weight or clinical pathology were noted and the only microscopic effect was local damage to the gastrointestinal tract at 3000 ppm. This epithelial damage was not seen in the other treatment groups (Cascieri et al., 1981).

9.6 Reproductive toxicity

No studies investigating the reproductive effects of persulfates in animals have been reported.

9.7 Genotoxicity

Ammonium persulfate

Ammonium persulfate produced negative results in three studies of mutagenicity in bacteria. In *Salmonella typhimurium* strains TA 1535, TA 1537 and TA 1538 ammonium persulfate was not mutagenic in plate tests at concentrations up to 1 mg/plate in either the absence or presence of metabolic activation provided by rat liver S9 mix (Hossack et al., 1977). Two further studies used a 20 minute preincubation in pH 7.4 phosphate buffer prior to plating. Ammonium persulfate was not mutagenic in *S. typhimurium* strains TA 92, TA 94, TA 98, TA 100, TA 1535 or TA 1537 or in *Escherichia coli* strain WP2 *uvrA* at concentrations up to 5 mg/plate (Shimizu, 1985) or in strains TA 97 or TA 102 at concentrations up to 10 mg/plate (Ishidate et al., 1984) in the absence or presence of metabolic activation provided by rat liver S9 fraction.

Ammonium persulfate produced negative results in a chromosomal aberration test in CHL cells incubated at a concentration of 250 µg/mL for 48 h in the absence of metabolic activation (Ishidate et al., 1988).

Potassium persulfate

No studies were identified addressing genotoxicity due to potassium persulfate.

Sodium persulfate

Sodium persulfate produced negative results in a study of mutagenicity in *S. typhimurium* strains TA 98, TA 100, TA 1535, TA 1537 and TA 1538 at concentrations up to 10 mg/plate in the absence or presence of metabolic activation and was negative in a study of unscheduled DNA synthesis in rat hepatocytes at doses of 5 to 250 µg/mL without metabolic activation (IUCLID, 1996b).

ICR mice administered sodium persulfate by intraperitoneal injection at doses of 0, 85, 169 or 338 mg/kg did not exhibit induction of micronuclei (IUCLID, 1996b).

An *in vivo* study of unscheduled DNA synthesis in rats administered 0, 41, 164 or 820 mg/kg sodium persulfate for one day was negative (IUCLID, 1996b).

9.8 Carcinogenicity

Ammonium persulfate

51-Week Skin Carcinogenesis Study

Skin tumour promotion and carcinogenesis by ammonium persulfate were studied in female SENCAR mice by skin painting (Kurokawa et al., 1984). Tumour promotion was tested by pretreating 20 females with a single application of 20 nmol dimethyl benzanthracene (DMBA) in 0.2 mL acetone one week before beginning twice-weekly applications with 200 mg/mL ammonium persulfate for 51 weeks. To evaluate the complete skin carcinogenic potential of ammonium persulfate, the chemical was applied twice weekly in acetone to the skin of twenty mice for 51 weeks with control animals treated with acetone alone. The results of these experiments are presented in Table 10.

Table 10 - Ammonium persulfate: Summary of carcinogenicity testing

Treatment	Epidermal hyperplasia	Tumours
Tumour promotion		
Control (DMBA-treated)	0/15	0/15
ammonium persulfate-treated	1/20	3/20*
Complete skin carcinogenicity		
Control (acetone-treated)	0/15	0/15
ammonium persulfate-treated	2/20	2/20**

* one squamous cell carcinoma, two unspecified

** unspecified but neither was a malignant squamous cell carcinoma

There was some indication of dermal tumour formation attributable to ammonium persulfate but the small size of the groups and use of a single dose group do not allow a firm conclusion to be drawn.

Potassium persulfate

No studies were identified addressing the carcinogenicity of potassium persulfate.

Sodium persulfate

No studies were identified addressing the carcinogenicity of sodium persulfate.

9.9 Other studies

9.9.1 Release of inflammatory mediators histamine and leukotriene B_4

Ammonium persulfate

In a study investigating the release of inflammatory mediators (Koller et al., 1996), human polymorphonuclear neutrophils (PMN) were pre-treated with ammonium persulfate for 30 minutes. The ammonium persulfate was either washed out (priming) or not (co-incubation) prior to cellular activation by the calcium ionophore A23187, the chemotactic peptide formyl-methionyl-leucyl-phenylalanine (fMLP) or the G-protein activator sodium fluoride (NaF) for a further 20 minutes. With co-incubation, a dose-dependent inhibition of the inflammatory mediator leukotriene B_4 (LTB_4) formation was observed with doses of ammonium persulfate from 0.01 to 10 mM. Following priming, an increase in LTB_4 release was observed with fMLP and NaF but not with the calcium ionophore. Release was greater for fMLP than NaF and greater at 0.1 mM than at 1 mM ammonium persulfate. It was concluded by the authors that ammonium persulfate enhanced mediator release at low concentrations and decreased the molecular stability of leukotrienes at high concentrations. It was further concluded that the priming effects of ammonium persulfate were related to signal transduction upstream from a direct increase in intracellular calcium via receptor-mediated cell activation.

Similar conclusions were drawn from experiments with blood mononuclear cells (lymphocytes/monocytes/basophils). A weaker effect on LTB_4 release was observed with both sodium persulfate and ammonium sulfate. Histamine release from basophils by ammonium persulfate alone was observed at 1 mM (6% to 20%) and 10 mM (40%). When basophils were triggered subsequently with fMLP (co-incubation), a significant persulfate-induced increase in histamine release was obtained with 10 mM ammonium persulfate but not at lower ammonium persulfate concentrations.

9.9.2 Histamine release from skin and mast cells

Histamine release from skin and mast cells was investigated by taking slices of skin from Dunkin-Hartley guinea pigs, CFY rats and Rhesus monkeys. These were incubated with 1 to 1000 μg/mL ammonium persulfate for 15 to 30 minutes. Histamine release (20% to 24%) was observed only with rat skin at 1000 μg/mL (Mahzoon et al., 1977). In another study slices of guinea pig skin were incubated with 0.2 to 16 mg/mL ammonium persulfate at 37°C or 4°C. Ammonium persulfate caused histamine liberation in a dose-dependent manner up to a level of 14.4% at the highest dose at 37°C and 7.6% at 4°C. By comparison, the histamine liberator, compound 48/80, at 200 μg/mL and 37°C released 10.3% of the available histamine (Parsons et al., 1979).

Vascular permeability was measured following intradermal injection of ammonium persulfate and compound 48/80 in guinea pigs previously injected intravenously with Evans-Blue. The effect of 16 mg/mL ammonium persulfate was similar to that of 80 μg/mL 48/80 in terms of the size and intensity of the area of skin stained blue (Parsons et al., 1979).

Parsons et al. (1979) also investigated histamine release by isolated peritoneal mast cells from Wistar rats following treatment with ammonium persulfate. At 37°C ammonium persulfate caused dose-dependent histamine release up to about 25% of the total histamine content. At 4°C release was approximately 7% at 2.7 mg/mL. At this concentration, it was concluded that the histamine release was not caused by destruction of the mast cell membrane, but by degranulation of mast cells as the ammonium persulfate did not cause haemolysis of sheep erythrocytes.

9.9.3 Intracellular accumulation of calcium

Kaminishi et al. (1989) showed that ammonium persulfate and other oxidants, inhibited intracellular calcium uptake and accelerated calcium release in rat heart cells producing raised cytosolic calcium concentration and cell contracture.

10. Human Health Effects

This section includes the known health effects of ammonium, potassium and sodium persulfate on humans. While systematic studies of the health effects of these compounds are generally lacking, a substantial body of evidence is available from case reports and epidemiological studies relating to dermal and respiratory pathologies and are discussed below.

10.1 Irritant contact dermatitis

Standard 24/48-h patch tests with 2.5% or 5% persulfate are used to differentiate between irritant and allergic contact dermatitis. These tests have shown that 5% ammonium persulfate is irritant (Calnan & Shuster, 1963; Cronin, 1980) although a separate study found 1/20 people exhibited an equivocal response when tested with 5% to 10% persulfate (Forck, 1968).

Two cases of irritant reactions to hair bleach containing ammonium persulfate have been described (Cronin, 1980; Fisher & Dooms-Goossens, 1976) involving erythema of the scalp and forehead developing over several hours followed by weeping and crusting.

Skin rashes appearing within one month of beginning work in a factory manufacturing ammonium and potassium persulfates occurred in 20% to 70% of new employees (White et al., 1982). The early onset of the rashes was interpreted as evidence of an irritant response. Workers engaged in the manufacture of the potassium salt were the most likely to exhibit symptoms.

10.2 Allergic contact dermatitis and respiratory effects

Immediate inflammatory reactions are normally mediated by specific IgE and/or IgG4 binding to mast cells or basophils (Garssen et al., 1996). After first contact with the specific antigen, antibody producing cells will produce specific IgE and/or IgG4. Subsequent contact with the allergen will result in release of inflammatory mediators. No specific IgE antibodies have been found in subjects exhibiting immediate skin or pulmonary reactions to persulfates. The reactions, therefore, have been ascribed to a non-allergic mechanism such as chemical irritation (Mensing et al., 1994 cited in Yawalkar et al., 1999) or pseudoallergic mechanisms through the release of histamine or leukotriene B_4 by direct action on mast cells or neutrophils, respectively (Calnan & Shuster, 1963; Koller et al., 1996; Schwaiblmair et al., 1990). However, it was found that the radio-allergosorbent (RAST) test used to detect specific antibodies can give negative results in individuals positive in skin prick tests, in this case individuals who exhibited respiratory hypersensitivity to acid anhydrides (Drexler et al., 1993 cited in Kimber, 1996). The possibility that all three mechanisms contribute to immediate hypersensitivity has been raised.

Delayed contact hypersensitivity and late onset asthma appear to be T-cell-mediated responses but specific IgE antibodies may be important for triggering late-phase reactions and the chronic bronchial inflammation associated with asthma (Kimber, 1996).

Experimental Studies

Two unpublished studies of the sensitisation potential of persulfates in humans have been described. In the first study, two males and 44 females were treated with a lightener/developer mixture of ammonium, potassium and sodium persulfate at a concentration of 17.5% under occlusive patch for four hours. Patches were applied three times per week for three weeks. The first two applications were for four hours and the remaining seven for one hour as a result of irritant responses from the vehicle. For the last seven applications, skin sites were rotated on the same forearm. Following a 2-week recovery period, two challenge applications consisting of 0.2 mL of 2% of each persulfate under occlusive dressing were applied 48 h apart. The dressings were applied for 24 h to the right inner forearm and the sites examined at one and 48 h. The results were negative (CIR, 1998).

In a second study, subjects were treated with 0.001, 0.01 and 0.5% sodium persulfate (26 subjects/concentration) under occlusive patch four times per week for three weeks. After a 1-week recovery period, challenge was performed at each of the induction concentrations. No positive responses were observed when the two lower concentrations were used for challenge but challenge with 0.5% sodium persulfate resulted in 5/26 (19%) grade 4 skin reactions including: redness, induration, swelling, papules and vesicles. Following rechallenge with either 0.001% or 0.25% sodium persulfate for 24 or 48 h, one subject had reactions at the 0.001% site and two subjects had grade 4 reactions at the 0.25% site. The grade 4 reactions at the naïve sites were considered by the authors of the study to be indicative of sensitisation to sodium persulfate (E. I. Dupont de Nemours and Company, 1992).

Case Reports

A number of case studies of women exposed to persulfate-containing hair bleaches either self-administered or administered by a hairdresser were summarised in CIR (1998) as follows:

A 54-year-old woman developed itchiness of the face and became red and swollen on the upper part of her body within 30 minutes of having a hair bleach applied. She went into shock and had generalised erythema and urticaria. Patch tests with 2% ammonium persulfate were negative. However, direct application of a supersaturated solution of ammonium persulfate caused a 1+ response, and when the solution was rubbed in the skin a 4+ response. A freshly prepared hair bleach caused a response of 1+ when applied to the skin and a 2+ urticarial wheal when rubbed into the skin (Brubaker, 1972).

The face of a 49-year-old woman became red and oedematous immediately following exposure to a hair bleach containing a persulfate-peroxide mixture. This condition lasted for several hours. Generalised urticaria persisted for 24 h. Patch tests with 2% and 5% aq. ammonium persulfate were negative, but tests with 5% aq. ammonium sulfate were positive (Fisher & Dooms-Goossens, 1976).

A 46-year-old woman developed redness and slight crustiness on the anterior portion of the scalp and forehead one day after treatment with a hair bleach containing ammonium persulfate. Erythema and crusting were apparent on day 3.

Patch tests with 2% and 5% ammonium persulfate were negative. The authors believed that the reaction was due to "... excessive concentrations of ammonium persulfate producing a strongly irritating alkaline effect." (Fisher & Dooms-Goossens, 1976)

The face of a 49-year-old woman became red and oedematous, her eyelids could not be opened, and generalised urticaria developed immediately upon her first-time application of a persulfate-peroxide hair bleach. Oedema lasted for several hours and generalised urticaria persisted for 24 h. An open patch test with 2% aq. ammonium persulfate applied to the forearm produced a large urticarial wheal within 7 min for the woman but not in three controls. The author believed this was a severe histamine reaction since it was a first time exposure and that ammonium persulfate is not primarily urticariogenic because the controls did not have a reaction (Fisher, 1977).

A 45-year-old woman stated that on several occasions immediately upon application of ammonium persulfate hair bleach, a burning sensation and diffuse erythema developed on the forehead, back of the neck and upper back, followed by a mild crusted dermatitis of the scalp and back of the neck the next day. The use of prednisone and the antihistamine Chlor-Trimeton, prior to bleaching resulted in minimal symptoms (Fisher, 1977).

A 72-year old woman developed erythema and oedema of the face one hour following exposure to hair bleach containing 5% aqueous ammonium persulfate. The following day, her cheeks and forehead were sharply demarcated and she had marked oedematous urticaria on her face and forehead. When she was tested with 5% ammonium persulfate an immediate wheal was produced. However, a 48 h patch test with 2% aq. ammonium persulfate was negative (Fisher, 1985a).

A 70-year-old woman developed pruritic oedema on her cheeks and forehead three hours after the application of a hair bleach containing ammonium persulfate (Fisher, 1985a).

A 69-year-old woman experienced facial flushing following exposure to a hair bleaching formulation containing 2% ammonium persulfate. She reported a stinging and burning sensation of the scalp and her forehead and face were erythematous with no itching. This condition persisted for 48 h. Patch tests with 2% ammonium persulfate were negative (Fisher, 1993).

Case studies of people exhibiting reactions to persulfates following occupational exposure were also summarised by CIR et al. (1998) as follows:

A 29-year-old woman acquired rhinitis and asthma while working in a beauty salon. A scratch test performed using 1% aq. ammonium persulfate immediately produced a wheal, followed by a mild asthma attack (Fisher & Dooms-Goossens, 1976).

A 21-year-old hairdresser had a delayed asthmatic reaction to hair bleach containing persulfates. This type of reaction was reproduced by exposure to the bleach and was blocked by inhalation of beclomethasone dipropionate but not by sodium cromoglycate. Patch tests with potassium persulfate and the bleach were negative. The investigators noted that at the time of these tests, the subject had changed jobs and was no longer being exposed to the bleach (Pepys et al., 1976).

A 21-year-old hairdresser suffered from rhinitis and wheezing dyspnea during 5.5 years of employment when she was exposed to hair bleaches and hair dyes containing bleaches. She had elevated total IgE in allergy tests and a provocation test with 10 mg/mL histamine was positive. Exposure tests with a hair bleaching product and 1% ammonium persulfate caused wheezing and dyspnea three to four hours following exposure. These responses were partially inhibited when disodium cromoglycate was inhaled 15 min prior to exposure and completely inhibited when betamethasone was administered. The investigators concluded that the patient suffered from late onset bronchial asthma due to sensitivity to ammonium persulfate (Gamboa et al., 1989).

A hairdresser developed rhinoconjunctivitis and bronchial asthma associated with hair bleach containing persulfate after 2 years. A prick test was positive for the persulfate (Pankow et al., 1989).

A 21-year-old hairdresser developed rhinitis from exposure to commercial bleaches, had urticarial reactions when she applied the bleach to her own hair, and eventually developed conjunctivitis and oedema of the eyelids. Patch tests were positive for potassium and sodium persulfate, and inhalation tests with the hair bleach produced an immediate asthmatic reaction within 1 min (Pepys et al., 1976).

A 23-year-old hairdresser developed acute pruritus and rashes on her hands and forearms after using hair bleach containing ammonium persulfate. An open test with 5% aq. ammonium persulfate caused slight reddening and pruritus after 20 min. A scratch test with 1% aq. ammonium persulfate caused erythema and wheal formation after 5 min. A closed patch test with 2% aq. ammonium persulfate was positive at 72 h (Widstrom, 1977).

A hairdresser who developed cutaneous and respiratory symptoms after 1 year of employment was tested in clinical and immunological studies. Skin prick tests with 1:5 w/v potassium and sodium persulfate were positive but were negative with 10 control subjects. The hairdresser had no reaction to a 2% concentration of either of the persulfates in an open patch test. Hyperreactivity was observed in a methacholine-inhalation test. A bronchial provocation test with 1:50 w/v potassium persulfate elicited a delayed asthmatic response, which was followed by a recurrent nocturnal fall in airflow that was resolved after 3 days. Plethysmography indicated air trapping due to increased airway resistance. Histamine release tests were not conclusive and determinations of specific immunoglobins against persulfate salts were negative (Parra et al., 1992).

Two industrial workers developed dermatitis, rhinitis, bronchitis, and asthma following occupational exposure to the dust of persulfate salts. Patch tests induced late cutaneous reactions and occupational exposure at the workplace for eight hours induced a pathological increase in airway resistance (Baur & Fruhmann, 1979).

Other case studies reported in the literature are as follows:

A 24-year-old female hairdresser experienced episodes of dry cough, usually beginning one to two hours following exposure to bleaching powder and aggravated during the night, together with eczematous lesions on both sides of her hands and forearms. Skin prick and patch tests with 1% and 5% ammonium persulfate were negative at 15 minutes but a papule reproducibly developed at the prick site after 24 h in a dose-dependent manner. A lymphocyte transformation analysis using heparinised blood reproducibly demonstrated a significant dose-dependent proliferation of T cells to bleaching powder. It was suggested that the cutaneous and pulmonary responses had a common T-cell-mediated mechanism (Yawalkar et al., 1999).

A 35-year-old female beautician with a 4-year history of increasing difficulty with cough, chest tightness, congestion, and dyspnea was negative to methacholine bronchoprovocation. Bronchoprovocation testing was performed in a simulated work environment with frosting agents and hair bleach (containing 30% persulfates) with the latter giving a positive response 30 minutes after exposure (Schwartz, 1989).

The U.K. Health and Safety Executive (HSE) have published an assessment of the evidence for persulfates as asthmagens (Health and Safety Executive, 1997). They have pointed out that well-conducted studies have been performed in which hairdressers with work-related asthmatic symptoms have undergone specific bronchial challenge tests, performed blinded. In a number of these studies, controls that were either non-asthmatic or asthmatic for reasons unrelated to work in the hairdressing industry were used. The studies include Blainey et al. (1986), Parra et al. (1992), Pankow et al. (1989) and Schwartz (1989) described elsewhere in this section. The HSE document also cites a further study (Agustin et al., 1992) in which 2 hairdressers developed work-related rhinitis and conjunctivitis (one also had work-related asthma) and were positive following specific bronchial challenge: one showing late asthmatic symptoms, the other showing immediate severe nasal symptoms. The HSE document states that the well-conducted studies are supported by case reports where the challenges were not blinded and no controls were employed. These case reports include those of Pepys et al. (1976), Gamboa et al. (1989) and Schwaiblmair et al. (1990) described elsewhere in this section. The HSE document further cites two other studies; one with 5 cases of asthma (2 positive, 1 negative, 1 equivocal, 1 unknown at specific challenge) (Therond et al., 1989); another with 3 cases, 1 challenged and positive at specific challenge (Wallenstein et al., 1993). The HSE document stated that there was sufficient evidence to conclude that persulfate salts meet the revised EU criteria for classification as respiratory sensitisers.

A number of other studies were cited in a recent review of the toxicology of ammonium persulfate (BG Chemie, 1996). These studies reported cases of skin conditions and asthma (Blandin, 1970; Brun, 1975; Brun et al., 1966; Gaultier et al., 1966; Kleinhans & Ranneberg, 1989; Marks & Cronin, 1977; Meindl & Meyer, 1969; Schulz, 1967; Subiza-Martin, 1951; von Krogh & Maibach, 1981). A further study in the same vein (Reiffers et al., 1974) was cited in the review by BIBRA International (BIBRA International, 1997).

10.3 Epidemiological and multiple case studies

A number of large scale studies of hairdressers were summarised by CIR (1998) as follows:

Twelve of forty-nine hairdressers (24%) patch tested with 2.5% ammonium persulfate in petrolatum had positive reactions, compared to 1/118 non-hairdressers tested (Kellett & Beck, 1985).

Over a 5 yr period, 2320 patients with reactions to one or more allergens in a standard series were also tested with 2.5% pet. ammonium persulfate and 2% aq.

potassium persulfate. A total of 22 individuals had positive reactions to these persulfates. Retrospectively, 14 of these patients were hairdressers, of which 11 reacted to both persulfates and 3 reacted to only ammonium persulfate. Of the remaining 8 non-hairdressers, 5 reacted to both persulfates and 3 reacted to only ammonium persulfate. The investigators noted that the hand dermatitis of 4 of these non-hairdressers was exacerbated by their personal use of hair bleaches (Van Joost & Roesyanto, 1991).

A multicenter study was performed in Italy in order to evaluate the frequency and source of contact sensitisation in hairdressers. Of the 302 hairdressers studied, 11.3% tested positive to 2.5% pet. ammonium persulfate (Guerra et al., 1992).

Patch test results from 9 European centres were evaluated in order to determine the frequency of sensitisation among European hairdressers. Of the 809 hairdressers tested, 8% had positive patch test results with 2.5% pet. ammonium persulfate. Of 104 clients who were patch tested because of suspected contact sensitisation, none reacted to ammonium persulfate (Frosch et al., 1993).

Over a 5-yr period, 143 atopic and non-atopic hairdressers with hand eczema were patch-tested with a hairdressers and standard series of allergens. The subjects were divided into three groups: 45 were eczematous atopics, 32 were mucous membrane atopics, and 66 were non-atopic. Seven (16%), 4 (13%), and 10 (15%) of the subjects of each group, respectively, were sensitised to ammonium persulfate (Sutthipisal et al., 1993).

One hundred and three hairdressers were patch-tested with a number of allergens over a 4-yr period. Thirty-seven hairdressers reacted to 2.5% ammonium persulfate in petrolatum. One patient had a Type 1 reaction, with airways obstruction, in addition to allergic contact dermatitis (van der Walle & Brunsveld, 1994).

Over a 9-yr period, 106 hairdressers were patch-tested with a hairdressers and standard series of allergens. Nineteen subjects (17.9%) had a positive reaction to 2.5% ammonium persulfate in petrolatum (Katsarou et al., 1995).

Eleven of twenty-three employees of a hair salon complained of upper or lower respiratory tract symptoms. Four of six had asthma which was occupationally related. These subjects developed late type asthmatic reactions after exposure to bleach powder. Bronchial provocation tests with the components of the bleach indicated that potassium persulfate was the cause (Davies & Blainey., 1983).

Four of twenty-three employees of one hairdressing salon had occupational asthma due to inhalation of bleach powders containing persulfate salts. One of the four was positive in a skin prick test to persulfate salts. When specific bronchial provocation tests were conducted on 14 of the employees, as well as 8 other individuals, the investigators reported that only those with a history of work related asthma and bronchial hyperreactivity had positive reactions. They concluded that the response to the bleach powder was specific. Further studies indicated that the response was caused by changes in airway calibre rather than lung volumes and that mast cells may play a part in the pathogenesis of persulfate induced asthma (Blainey et al., 1986).

In a study of 98 hairdressers in Tainan City, Taiwan, only one case of reaction to ammonium persulfate was observed (Guo et al., 1994).

A further study (Estlander, 1990) was described in the review by BIBRA International (BIBRA International, 1997) in which out of 1082 patients (not necessarily hairdressers) with occupational skin disease between 1974 and 1983, one case was attributed to ammonium persulfate.

Other large scale studies reported in the literature are as follows:

A retrospective study of 379 hairdressing workers who attended a dermatology clinic between 1980 and 1993 was reported (Conde-Salazar et al., 1995). Patch tests were performed with a number of chemicals in a hairdressing series with 7.9% (30/379) testing positive to ammonium persulfate (2.5% in petrolatum) and 3.4% (13/379) testing positive to potassium persulfate (2.5% in petrolatum). In a number of other studies cited in this paper, positive responses to persulfates were observed in 12.8% (total cases = 35) (Conde-Salazar et al., 1985), 8.5% (total cases = 70) (Gonzalez et al., 1992) and 6.8% (total cases = 268) (Baz Manchado, 1993) of cases.

Hairdressers in North Bavaria, Germany, with type IV (delayed) contact allergy apparently were separated into those with or without skin atopy. The percentage of those apparently reacting to ammonium persulfate was 22% (of 215) in the atopic patients and 26% (of 312) in the non-atopic patients (Coenraads & Diepgen, 1998).

Fifty-five hairdressers out of 1440 patients with suspected contact dermatitis were patch tested with two sets of hairdressing chemicals. Of thirty-four hairdressers tested with ammonium persulfate, 15% were positive (Holness & Nethercott, 1990).

Four of thirty-two hairdressers classed as having occupational dermatitis were positive when patch tested with ammonium persulfate (Shah et al., 1996).

A random sample of 500 female Finnish hairdressers was drawn from trade union membership registers. Of 355 interviewed, 130/189 who reported work-related skin or respiratory symptoms undertook a structured computer-aided occupational medical interview and physical examination. Of these 109 were suspected and 17 were clinically diagnosed to have occupational skin or respiratory disease. Ammonium persulfate was the causative agent in 10 cases: 3 of asthma (2 of these had allergic rhinitis), 6 of allergic rhinitis (1 of these had irritant contact dermatitis), 1 of irritant contact dermatitis, 1 of laryngitis, 1 of allergic contact dermatitis and 1 of contact urticaria. Ammonium persulfate caused 55% of the diagnosed skin and respiratory diseases and 90% of the respiratory diseases (Leino et al., 1998).

In a study of 405 hairdressers, 203 were diagnosed with dermatitis by a medical practitioner and 98 of these were stated to be allergic to one or more substances, including hair care products (38%). It was concluded that there was a marginally significant association ($0.1 < p < 0.15$) between the use of hair bleach and the occurrence of dermatitis when allergy and sex were controlled for. There was an increase, then a levelling, in the odds of dermatitis with increased use in both females and males. It was suggested this reflected susceptible individuals leaving hairdressing for other occupations (Stovall et al., 1983).

Large scale studies of workers other than hairdressers were also reported by CIR (1998) as follows:

Of 106 workers in a hydrogen-peroxide factory, 34% had eczematous dermatitis and 15% had asthmatic bronchitis thought to be occupational in nature. Patch tests with ammonium persulfate were positive in 32/46 workers. None of the workers had positive responses to potassium persulfate, sulfuric acid, or hydrogen peroxide. It was noted that inhalation tests with aerosolised ammonium persulfate exacerbated the symptoms. The investigators concluded that the observed reactions were allergic in nature (Barsotti et al., 1951).

A cross-sectional study of 52 employees of a plant that produced persulfates was performed; 12 subjects were directly involved in persulfate production, the remaining 40 subjects had indirect contact. Thirteen persons from the medical profession were used as controls. Questionnaires were administered, skin prick tests were performed with 1 and 5% (w/v) ammonium and potassium persulfate, atopy screening was done, and lung function was assessed. Three, 2, and 3 test subjects reacted to ammonium, potassium, and both ammonium and potassium persulfate, respectively; of these 8 subjects, only 3 had direct contact with persulfates. Six of the 8 subjects reported workplace-related breathing difficulties; 9/44 non-reactive test subjects also reported breathing difficulties. None of the controls reacted to the prick test. The mean total IgE was increased in 16 subjects; a Phadiatop test (screening of IgE antibodies against common inhalant allergens) reported positive results in 12 test subjects. Test subjects that had positive results to the prick test had decreased lung function values compared to those subjects that had negative results (Wrbitzky et al., 1995).

A cross-sectional study of 32 employees of a chemical plant that produced persulfates was performed. Eighteen workers at the plant that were not exposed to persulfates were used as the controls. Questionnaires were administered concerning symptoms, history of allergy and persulfate exposure. Skin prick tests were performed with 80 mg/mL buffered ammonium (pH 3.1) and sodium persulfate (pH 3.9), total IgE and specific IgE were measured and lung function and bronchial responsiveness to histamine were assessed. Work-related rhinitis was reported by 1 test subject, and work-related conjunctivitis and bronchitis were reported by 2 control subjects. Early and/or late skin reactions to persulfates were not observed for test or control subjects. Lung function, total IgE, and response to histamine were similar for test and control subjects. Bronchial hyperresponsiveness was present in 4 non-atopic test subjects and in 1 non-atopic and 1 atopic control worker. It was noted that 7/36 ex-workers left because of medical reasons; 6 had work-related contact dermatitis and 1 reported asthma (Merget et al., 1996).

Forty-two of four hundred bakers examined had positive patch test reactions to ammonium persulfate. However, only 1/150 individuals not in the baking industry reacted to this ingredient (Grosfeld, 1951).

Five bakers with occupational eczematous dermatitis were tested with a variety of baking ingredients using on-off and patch tests to determine the cause of their dermatitis. Two of the workers were sensitive to persulfates (Nava et al., 1983).

In summary, immediate and delayed contact hypersensitivity, contact urticaria, rhinitis, bronchitis and asthma (early and late onset) have all been observed in hairdressers as a result of exposure to hair bleaching powders containing persulfates.

11. Hazard Classification

Workplace substances are classified as ‘hazardous’ to health if they meet the NOHSC *Approved Criteria for Classifying Hazardous Substances* (*Approved Criteria*) [NOHSC:1008(1999)] and ‘dangerous’ in terms of physico-chemical hazards if they satisfy the *Australian Code for Transport of Dangerous Goods by Road and Rail* (ADG code) (FORS, 1998). This section evaluates the physico-chemical data, animal toxicity and adverse human health effects in order to classify the hazards of persulfate salts to humans.

11.1 Physicochemical hazards

The persulfate salts are strong oxidising agents and can cause combustible materials to ignite. They will increase the intensity of a fire. They are incompatible with acids, alkalis and halides.

Ammonium persulfate decomposes at 120°C and when heated to decomposition emits toxic fumes of sulfur oxides (SO_x), ammonia (NH_3) and nitrogen oxides (NO_x). It is an explosion hazard when mixed with finely powdered organic matter, metal powder (particularly aluminium plus water), sodium peroxide or reducing agents. Decomposition by moisture forms oxygen and ozone. It is shock sensitive.

Potassium persulfate is flammable when exposed to heat or by chemical reaction. It can react with reducing materials and liberates oxygen above 100°C when dry or at about 50°C when in solution. When heated to decomposition it emits toxic fumes of SO_x, S_2O_8 and potassium oxide (K_2O). Explosive reactions occur with chlorates and perchlorates at room temperature in the presence of water. Combustion occurs with sulfur when heated with percussion in the presence of moisture. It reacts with moisture to form ozone and sulfuric acid causing explosion in closed containers.

Sodium persulfate decomposes in alcohol. When heated to decomposition it emits toxic fumes of SO_x and sodium oxide (Na_2O).

Classification

Ammonium, potassium and sodium persulfate meet the ADG Code and are assigned to class 5.1: oxidising substances. Ammonium and potassium persulfate are on the *List of Designated Hazardous Substances* [NOHSC:10005(1999)] with the risk phrase R8: Contact with combustible material may cause fire. Sodium persulfate should also be placed on the *List of Designated Hazardous Substances* with the same risk phrase.

11.2 Health hazards

11.2.1 Acute lethal effects

A number of studies have been carried out with the persulfates via the oral, dermal and inhalation routes (ammonium and sodium salts, oral route only for the potassium salt) and via the intravenous and intraperitoneal routes for the sodium salt.

There are few details of the studies available beyond the lethal dose data and not all studies were conducted to GLP standards.

The LD_{50} values of the three persulfate salts in rats are similar. The ammonium salt appeared to be slightly more toxic with the LD_{50} ranging from 600 to 820 mg/kg in males and 495 mg/kg in females. The LD_{50} for the potassium salt was 802 mg/kg and the sodium salt was the least toxic with the LD_{50} ranging from 895 to 930 mg/kg in males and 920 mg/kg in females.

The dermal LD_{50} for the ammonium, potassium and sodium salts were greater than 10 000 mg/kg in rabbits and greater than 2000 mg/kg for the ammonium salt in rats.

The acute inhalation LC_{50} (4-h exposure) in rats for ammonium persulfate was > 2.95 mg/L (97% dust particles <10 µm), for potassium persulfate > 42.9 mg/L (1h) and for sodium persulfate was > 21.6 mg/L (17% to 19% dust particles < 5 µm).

Classification

Ammonium persulfate

According to the *Approved Criteria* and based on the above data, ammonium persulfate is classified as Harmful (Xn) via the oral route and assigned the risk phrase R22: Harmful if Swallowed. Ammonium persulfate does not meet the *Approved Criteria* to be classified as a hazardous substance in relation to acute dermal or inhalation toxicity.

Potassium persulfate

According to the *Approved Criteria* and based on the above data, potassium persulfate is classified as Harmful (Xn) via the oral route and assigned the risk phrase R22: Harmful if Swallowed. Potassium persulfate is not classified as a hazardous substance in relation to acute dermal or inhalation toxicity.

Sodium persulfate

According to the *Approved Criteria* and based on the above data, sodium persulfate is classified as Harmful (Xn) via the oral route and assigned the risk phrase R22: Harmful if Swallowed. Sodium persulfate does not meet the *Approved Criteria* to be classified as a hazardous substance in relation to acute dermal or inhalation toxicity.

11.2.2 Irritation

The data for acute irritant effects in humans suggests that irritant responses can be observed following treatment with 5% ammonium persulfate (Calnan & Shuster, 1963; Cronin, 1980).

Cronin (1980) reported bleach applied for too long or in too high a concentration in humans produced erythema of the scalp and forehead with weeping and crusting a few hours later.

Most of the animal studies reported no skin irritation in rabbits; where irritation to rabbit skin did occur following the application of ammonium or sodium persulfate, it was considered slight. Data in humans clearly show skin irritation potential by the three persulfate salts.

Eye irritation by ammonium persulfate in rabbits varies from slight irritation to severe irritation with corneal opacity persisting beyond 72 h (CIR, 1998; BG Chemie, 1996; BIBRA International, 1997; IUCLID, 1996a). Sodium persulfate was a slight eye irritant in rabbits (IUCLID, 1996b). In humans, one case of corneal burns from potassium persulfate was reported and irritant effects of persulfates are said to include pain in the eyes with conjunctivitis (BIBRA International, 1997).

A decrease in respiratory rate was observed in mice exposed head-only to sodium persulfate dust for 30 minutes. Sodium persulfate was concluded to be a sensory irritant and the RD_{50} was 2.25 mg/L.

Classification

Ammonium persulfate

Ammonium persulfate meets the *Approved Criteria* for skin, eye and respiratory irritation and is assigned the risk phrases R36: Irritating to Eyes, R37: Irritating to the Respiratory System and R38: Irritating to Skin.

Potassium persulfate

There are only limited data from animals exposed to potassium persulfate with respect to skin, eye or respiratory irritation. However, data are available for humans for skin, eye and respiratory effects, therefore, potassium persulfate meets the *Approved Criteria* for skin, eye and respiratory irritation and is assigned the risk phrases R36: Irritating to Eyes, R37: Irritating to the Respiratory System and R38: Irritating to Skin.

Sodium persulfate

Sodium persulfate meets the *Approved Criteria* for skin, eye and respiratory irritation and is assigned the risk phrases R36: Irritating to Eyes, R37: Irritating to the Respiratory System and R38: Irritating to Skin.

11.2.3 Sensitisation

Two experimental studies of skin sensitisation were conducted in humans (CIR, 1998). In the first study induction with 17.5% persulfates (the three persulfates together in a lightener/developer mix) was negative on challenge. In the second study induction and subsequent challenge with 0.5% sodium persulfate produced positive results in 5 of 26 subjects.

In humans, persulfates have been linked to a variety of skin and respiratory complaints indicative of sensitisation, namely, immediate and delayed contact hypersensitivity, contact urticaria, rhinitis, bronchitis and asthma (early and late onset). These complaints have been described in numerous case studies, large scale studies and prevalence studies as described in Section 11.

Skin and respiratory sensitisation for persulfates has been demonstrated in experimental animals. Skin sensitisation in guinea pigs was demonstrated in an optimisation study. All test animals reacted positively following a challenge by intradermal injection of 0.1% ammonium persulfate and 80% of the animals were positive following a dermal challenge with 1% ammonium persulfate 10 days later (CIR, 1998; BG Chemie, 1996; BIBRA International, 1997).

Ammonium persulfate and hair bleaches containing ammonium and potassium persulfates were shown to induce airway hyperresponsiveness to acetylcholine in rabbits (Mensing et al., 1995a; Mensing et al., 1995b; Mensing et al., 1998).

Classification

Ammonium persulfate

Based on the human and animal data, ammonium persulfate meets the *Approved Criteria* and is classified as Harmful (Xn) and assigned the risk phrases R42: May Cause Sensitisation by Inhalation and R43: May Cause Sensitisation by Skin Contact.

Potassium persulfate

Based on the human and animal data, potassium persulfate meets the *Approved Criteria* and is classified as Harmful (Xn) and assigned the risk phrases R42: May Cause Sensitisation by Inhalation and R43: May Cause Sensitisation by Skin Contact.

Sodium persulfate

Based on the human and animal data, sodium persulfate meets the *Approved Criteria* and is classified as Harmful (Xn) and assigned the risk phrases R42: May Cause Sensitisation by Inhalation and R43: May Cause Sensitisation by Skin Contact.

11.2.4 Repeated dose toxicity

A single 7-day inhalation study in rats exposed to ammonium persulfate (mass median aerodynamic diameter of 0.8 to 1.3 μm) for 23.5 h/day for 7 days resulted in indications of pulmonary oedema or inflammation at doses of 4 mg/m^3/day and a reduction in body weight gain. A well conducted 90-day inhalation study with exposures of 6 h/d 5 days per week resulted in inflammation of the airways and reduced body weight gain with increased absolute and relative lung weights at 25 mg/m^3. Rales occurred at 10.3 mg/m^3. A NOAEL of 5 mg/m^3 was identified based on the effects seen at the LOAEL of 10.3 mg/m^3.

Although oral repeated dose studies have been conducted with ammonium, potassium and sodium persulfates, full reports are not available and none of the studies appear to have been conducted to GLP standards. Therefore, the results of these studies are of limited use for the purpose of classification

Classification

Based on the limited oral data available for assessment, ammonium, potassium and sodium persulfate are not classifiable with regard to serious damage to health by prolonged oral exposure. Based on the 90 day inhalation study, ammonium persulfate does not meet the *Approved Criteria* and is not classified as hazardous with regard to severe effects after repeated/prolonged inhalation exposure.

11.2.5 Mutagenicity

Ammonium persulfate was negative in mutagenicity tests in bacteria and in a chromosomal aberration test in CHL cells *in vitro.* Sodium persulfate was negative in a mutagenicity test in bacteria, in a mouse micronucleus assay and in the test for unscheduled DNA synthesis in primary rat hepatocytes.

Classification

Ammonium persulfate

Ammonium persulfate does not meet the *Approved Criteria* for mutagenic effects.

Potassium persulfate

Data on mutagenicity testing for potassium persulfate were not identified. However, based on the known activity of the ammonium and sodium salts, potassium persulfate is not classified for mutagenic effects.

Sodium persulfate

Sodium persulfate does not meet the *Approved Criteria* for mutagenic effects.

11.2.6 Reproductive toxicity

No epidemiological studies investigating the effects of persulfates on fertility or developmental toxicity in humans have been reported. No animal studies have been conducted on reproductive or developmental toxicity of persulfates.

Classification

Ammonium persulfate

No data were available to classify ammonium persulfate for reproductive toxicity.

Potassium persulfate

No data were available to classify potassium persulfate for reproductive toxicity.

Sodium persulfate

No data were available to classify sodium persulfate for reproductive toxicity.

11.2.7 Carcinogenicity

The carcinogenicity of ammonium persulfate was studied in SENCAR mice in a skin painting assay but no strong evidence either of induction or promotion was found.

Classification

Ammonium persulfate

Ammonium persulfate does not meet the *Approved Criteria* for carcinogenic effects.

Potassium persulfate

Data on carcinogenicity testing for potassium persulfate were not identified. However, based on the known activity of the ammonium salt, potassium persulfate is not classifiable for carcinogenic effects.

Sodium persulfate

Data on carcinogenicity testing for sodium persulfate were not identified. However, based on the known activity of the ammonium salt, sodium persulfate is not classifiable for carcinogenic effects.

Table 11 - Summary of data availability for end-point classification

End-point	Ammonium persulfate	Potassium persulfate	Sodium persulfate
Acute lethal			
oral	+	+	+
dermal	+	+	+
inhalation	+	+	+
Irritation			
eye	+	-[a]	+
dermal	+	+[a]	+
respiratory	-	+	+
Sensitisation			
skin	+	+	+
airway	+	+	+
Repeated dose toxicity	i	i	i
Mutagenicity	+	-[b]	+
Reproductive toxicity	-	-	-
Developmental toxicity	-	-	-
Carcinogenicity	+	-[b]	-[b]

+ = adequate data; - no data available; i = inadequate data; [a] = human data; [b] = testing not required as adequate data from other persulfates available.

12. Risk Characterisation

In this section, the results of the health hazard and occupational exposure assessments have been integrated to characterise the risk of adverse effects to workers potentially exposed to persulfate salts.

Results from the risk characterisation process provide the basis for health risk management strategies (i.e., methods to reduce exposure and/or increase worker awareness of potential hazards and safe handling of persulfate salts).

12.1 Methodology

The risk to human health from exposure to persulfate salts has been characterised using margin of exposure methodology commonly adopted in international assessments (EC, 1994; OECD, 1994).

For health effects caused by repeated or prolonged exposure, risk(s) have been characterised as follows:

1. Identification of the critical effect(s).

2. Identification of the most appropriate/reliable NOAEL (if available) for the critical effect(s).

3. Where appropriate, comparison of the NOAEL with the estimated human dose or exposure (EHD), to provide a margin of exposure (MOE), that is:

$$MOE = \frac{NOAEL}{EHD}$$

   Where actual exposure monitoring data are unavailable or insufficient, the EHD may be determined using exposure assessment models, such as the UK EASE model.

4. Characterisation of risk, by evaluating whether the MOE indicates a concern for the human population under consideration.

The MOE provides a measure of the likelihood that a particular adverse health effect will occur under the conditions of exposure. As the MOE increases, the risk of potential adverse effects decreases. In deciding whether the MOE is of sufficient magnitude, expert judgment is required. Such judgments are usually made on a case-by-case basis, and should take into account uncertainties arising in the risk assessment process, such as the completeness and quality of the database, the nature and severity of effect(s) and intra/inter species variability.

12.2 Occupational risk

12.2.1 Critical health effects

Acute effects

The critical effects from acute exposure to persulfates are skin and eye irritation. Although the persulfate salts are harmful via the oral route in rats, the critical effects, in terms of organ toxicity were not identified at necropsy. This potential for acute toxicity was not observed via the inhalation or dermal routes in general, although there was an indication of acute inhalation toxicity by sodium persulfate in the study of sensory irritation in mice. In this study the approximate LC_{50} was 1.38 mg/L.

Respiratory irritation caused by sodium persulfate was indicated by sensory irritation in mice, the RD_{50} being approximately 2.25 mg/L following a 30 minute exposure.

Effects due to repeated exposure

Repeated dose toxicity measurements have been conducted via the oral, inhalation and dermal routes. For ammonium persulfate in the diet of rats at a dosage of 600 ppm for 28 days, an increase in relative adrenal weight was observed. The NOAEL was 300 ppm. However, for potassium and sodium persulfate in the diet, no systemic effects or changes in organ weights were observed at dosages of 1000 ppm or 3000 ppm for 28 or 90 days respectively, or 1000 ppm for 8 weeks followed by 5000 ppm for 5 weeks for the sodium salt. As this level (equivalent to approximately 250 to 500 mg/kg/day) is approaching the acute oral LD_{50} there is an indication that chronic toxicity is not a significant aspect of the toxicological profile for persulfates.

In a sub-chronic inhalation study in rats, indications of pulmonary oedema and/or inflammation and reduced body weight gain were observed at concentrations of ammonium persulfate aerosols of 4 mg/m^3 and above for 7 days, 23.5 h/day.

A chronic 90-day inhalation study of ammonium persulfate revealed evidence of inflammation of the airways and reduced body weight gain in addition to increased lung weights, compared to control animals, at 25 mg/m^3.

The persulfates are capable of inducing skin and respiratory sensitisation in both animals and humans. Ammonium persulfate is a strong skin sensitiser in guinea pigs. Airway hyperresponsiveness (AHR) to acetylcholine in rabbits was induced by both ammonium persulfate and a hair bleach mixture. AHR is proposed as an indicator of asthmagenicity.

The conclusions from the animal studies are supported by observations in hairdressers and one of two studies involving patch testing in human volunteers. In the sensitisation study with sodium persulfate in humans a maximum induction dose of 0.5% was employed and sensitisation in 5/26 subjects was observed.

The major chronic effects of persulfate exposure observed in humans are immediate and delayed contact hypersensitivity, contact urticaria, rhinitis, bronchitis and asthma (early and late onset). All of these effects have been observed in hairdressers and occasionally skin and respiratory reactions occur in the same subject.

Hairdressing products generally contain a combination of two or, in some cases, three of the persulfate salts (see Appendix 1). As the individual persulfate salts are assigned the same hazard classification, the health effects will be additive, that is, based on the total persulfate concentration of the product.

12.2.2 Risk estimate(s)

Risks from physicochemical hazards

The persulfates are powerful oxidisers and can react vigorously with reducing agents. The use of metal bowls for mixing persulfate-containing bleaches with hydrogen peroxide solutions is not recommended by bleach suppliers presumably because metal ions will reduce bleach efficacy or lead to overheating of the mixture. A number of the suppliers' MSDS refer to the possibility that bleach mixtures can become hot enough to warrant immediate removal from clients' hair.

During hair bleaching powder formulation, overheating of the mixing vessel can occur although neither of the formulators referred to in Section 7 reported problems with overheating or fire.

The persulfates can produce toxic fumes on heating to decomposition, including ammonia (ammonium salt) and oxides of sulfur, sodium or potassium (depending on the salt) and nitrogen (ammonium salt). During normal use these would most likely be liberated in the event of a fire. Fires can occur if the persulfates come in contact with combustible materials and can be enhanced by the liberation of oxygen.

Risks during formulation

Acute effects

Although the persulfates are harmful via the oral route, the likelihood of exposure by ingestion is expected to be low as is the overall risk of acute oral effects. Similarly, the overall risks of acute dermal and inhalation effects are expected to be low given that both the acute toxicities and likelihood of exposure during formulation are expected to be low.

The risk of skin and eye irritation due to normal formulation procedures is expected to be low given that local exhaust ventilation is used at each of the points persulfates are potentially liberated and build-up of dust in the workplace should be minimal. Nevertheless, there is the possibility of spillage during formulation given that manual handling procedures are employed during some phases of the formulation process. Consequently, there is potential for skin, eye and respiratory irritation during clean-up.

Adverse effects due to repeated exposure

The formulation of products containing persulfates is essentially an open process. However, given the use of local exhaust ventilation at all stages of the process and the intermittent nature of the process (8 and 15 batches/year for the two formulators) airborne levels of persulfate salts are expected to be low. The are no monitoring data for Australian conditions, however, the EASE model predicts, under the conditions described, persulfate exposure levels of between 2 to 5 mg/m^3. Given the assumptions outlined in Section 8.1.2, this is equivalent to an intake of 0.01 to 0.03 mg/kg/day. Based on the available data for ammonium persulfate

($NOAEL_{(oral)}$ = 300 ppm or 300 mg/kg) this will provide a MOE of 30 000 to 10 000 by the oral route. Consequently, although it has not been possible to classify persulfates in terms of the systemic effects of repeated or prolonged exposure according to the *Approved Criteria,* within the limitations of the data available, the risk of systemic effects by the oral route at this dosage level is expected to be low.

Available inhalation data for ammonium persulfate from a well conducted 90-day study of rats gives a $NOAEL_{(inhalation)}$ of 5 mg/m^3 (for 6 h/d, 5d/wk exposures) for local effects. The EASE model (see Section 8.1.2) predicts a daily exposure to persulfate of between 0.35 to 0.91 mg/m^3. Therefore, MOE of 14.3 to 5.5 are expected. However, given that the formulation of persulfate-containing products is intermittent (8 to 15 batches per year) and exposure occurs for two h/day, MOE of 57.2 to 22 would be expected.

There are examples of respiratory and/or skin sensitisation in workers involved in persulfate production in overseas facilities. However, the two formulation plants and one contract packer involved in the formulation of hair bleaching powders in Australia have stated that no adverse health effects have been reported by workers.

Risks during use in hair salons

Acute effects

The risk of skin irritation to hairdressers from acute exposure to persulfates is difficult to judge given the inconsistencies in the available data. The risk of skin irritation from the hair bleaching powder itself is likely to be low. However, if the powder is allowed to collect under jewellery or watches on the hands or wrists, or under gloves, there may be a risk of skin irritation, particularly if the skin is moist.

The preparation of a hair bleaching mixture for application to one client typically involves between 15 to 30g of bleach powder (or a maximum of 10.5 to 21g of persulfate salts). If the mixed hair bleach containing persulfates and hydrogen peroxide is irritating to skin then home users or clients receiving on the scalp treatments would be expected to have lodged complaints with suppliers but complaints are relatively rare (CIR, 1998). As the hairdressers should be in contact with the mixed bleach for a shorter time than their clients, it is reasonable to assume that the risk of irritation from acute exposure is low. While in most cases acute toxicity due to acute exposure is not likely, nearly all workers in salons will have chronic exposure to persulfate salts.

There is a risk of eye irritation for hairdressers from acute exposure to persulfates following contact with airborne persulfate particles or secondary transfer from hands or gloves. Similarly, there is a risk of respiratory irritation from atmospheric dust. Estimates based on the EASE model indicate persulfate levels of 5 to 50 mg/m^3 (TWA, 8 h) without local exhaust ventilation. However, based on the small quantity of material used and the intermittent nature of the use exposure levels are likely to be substantially less. One study of 20 hair salons in Finland indicated a maximum peak airborne exposure of 30 µg/m^3 although this result represents only two work shifts (Leino et al., 1999).

In addition to normal usage, acute exposure of hairdressers to persulfates in hair bleaching powders may occur following accidental spillage. Persulfates are available for salon use in single-use sachets (approximately 30g) to bulk containers (500g) and the amount of persulfate salts in these preparations can typically range from 15 to 350g. Therefore, for those powders in the form of a fine dust, exposure could be significant especially via inhalation. However, the risk of acute toxic effects should still be low given the low acute inhalation toxicity.

Adverse effects due to repeated exposure

In one study of hairdressing salons, a peak atmospheric concentration of persulfate was estimated to be 30 μg/m^3 (Leino et al., 1999). Under conditions where local exhaust ventilation is absent and dry manipulation of persulfates is undertaken the EASE model predicts airborne levels of persulfates of between 3.5 to 35 mg/m^3 and dermal exposure to be 0.7 to 3.5 mg/cm^2/d.

Using the assumptions for working conditions given in Section 8.2.3, this would be equivalent to exposure levels of 109.4 µg/m^3 to 1.09 mg/m^3 and 10.9 to 156.3 µg/m^3 for a dusty and dust-free product respectively. Consequently, MOE of 45.7 to 4.6 for dusty products and MOE of 459 to 32 for dust-free products would be expected.

Most of the studies on the occurrence of persulfate-induced skin or respiratory effects in humans involve hairdressers or, more rarely, their clients, presenting for treatment. There are few cross-sectional studies. Nevertheless, there are estimates of the prevalence of contact dermatitis from all causes amongst hairdressers and there is a considerable body of data on the proportion of hairdressers with contact dermatitis who are positive in patch tests with persulfates, usually to ammonium persulfate.

In a study in London and south-east England, questionnaires were returned from 66 hair stylists (Rivett & Merrick, 1990). Twenty (30%) reported a skin condition of the hands that was better away from work. In the Netherlands in 1991, 26% (486/1869) of dropouts from hairdressing schools reported that hand dermatitis was their reason for leaving (van der Walle & Brunsveld, 1994).

Van der Walle (1994) reported that 16/45 (36%) hairdressers from 7 salons showed moderate to severe hand dermatitis and 12 others (26%) reported having suffered from hand dermatitis, especially in winter. It was stated that, based on the author's experience in the Center for Occupational Dermatology over previous years, many visits to hairdressing salons, discussions with hundreds of employers and as consultants to the Dutch work employers' organisation of hairdressers, the estimated prevalence of hand dermatitis amongts hairdressers was 10% to 20%.

A dropout rate of 20% from a hairdressing school was found in another Netherlands study (Majoie et al., 1996). In this study, 51% of hairdressers (26/51) followed for 8 years from the beginning of their apprenticeship developed hand eczema. A recent Australian study (Nixon et al., 1999) of 193 students and 184 hairdressers included a skin examination on the day of a questionnaire concerning various aspects of health and safety. In this study, 28% of students and 17.4% of hairdressers had clinical dryness in addition to 4.7% of students and 8.1% of hairdressers with moderate/severe changes. In the questionnaire, 58% of students and 61.4% of hairdressers said they had experienced skin problems associated with their hands.

The percentage of hairdressers with skin complaints who are positive in patch tests with persulfates varies from 6.8% to 36% in various studies If the figures are combined, approximately 15% of hairdressers with skin complaints test positive to persulfates. Therefore, if the prevalence of occupational skin disease is 10% to 20%, the prevalence of occupational skin disease due to persulfates could vary from approximately 1.5% to 3%. If about 50% of hairdressers experience occupational skin disease during their working lives it may result from exposure to persulfates in 7.5% of cases.

In a Finnish study (Leino et al., 1998), of 355 hairdressers chosen randomly, 189 indicated during interview that they had work-related skin or respiratory symptoms. One hundred and thirty of these came to further examinations. In 17 of these a causative agent was identified. Ammonium persulfate caused 55% of the diagnosed occupational skin and respiratory diseases and 90% of the occupational respiratory diseases. The overall prevalence was 2.8% for occupational dermatoses, 1.7% for occupational rhinitis and 0.8% for occupational asthma.

In a large retrospective cohort study of Finnish hairdressers (Leino et al., 1997), a self-administered questionnaire was used to assess the risk of developing asthma. The risk of developing asthma for hairdressers was approximately double that of a reference group. The incidence rate of asthma in 1980 through 1995, in cases per 1000 person-years, was 2.2 for hairdressers and 1.3 for the reference group.

In a study of 55 hairdressers with a clinical history of job-related rhinitic and/or asthmatic symptoms, 9 subjects out of 38 (with asthma) exhibited a positive response to bleaching powder although over two thirds of the subjects reported having respiratory symptoms during contact at work (Schwaiblmair et al., 1997).

In two studies of all the hairdressers from certain salons, 4/23 had late asthmatic responses to potassium persulfate (Davies & Blainey, 1983) and 4/23 had specific asthmatic responses to bleach powder (Blainey et al., 1986).

12.2.3 Areas of concern

For workers involved in the formulation of bleaching powders, the applicants stated that no health effects have been reported. For each of the 2 factories involved, there are only a small number of batches produced per year. This, together with the use of local exhaust ventilation has apparently prevented adverse skin or respiratory complaints. A mitigating factor may be the size of persulfate particles in the atmosphere. Certainly, the levels of persulfates in salons appear to be low (a maximum of approximately 30 $\mu g/m^3$ in one small study) when compared to levels reported in a factory producing persulfates overseas (1 mg/m^3) and yet the 33 workers in the persulfate factory had a low level of skin or respiratory complaints despite long service of many of the employees (mean length of service, 14 years) (Merget et al., 1996).

Clearly, in certain salons or groups of salons the incidence of job-related skin and/or respiratory complaints can be high and a significant proportion of these complaints can be attributed to exposure to persulfates. A number of factors are expected to contribute to the observed level of occupational skin and respiratory complaints, including atmospheric levels of persulfates, general ventilation of the workplace, the use of dust-free formulations, the use of personal protective equipment, waste disposal, cleaning of work surfaces and equipment and the use of protective hand creams. In addition, effects of season and numbers of clients having bleaching performed may influence the expression of latent conditions.

The progression from irritant contact dermatitis to allergic contact dermatitis has been remarked upon by several authors. It is common for apprentices or trainees to spend a considerable proportion of their working day shampooing hair and this leads to dry and cracked skin which is thought to allow easier penetration of allergens. Presumably synergistic effects are possible and there are a small number of cases of hairdressers with multiple allergies.

12.2.4 Public health risk

Public exposure to persulfate salts in hair bleaching products is high. The results of a substantial number of case studies indicate a high potential for varying degrees (mild to severe) of allergic and irritant reactions to occur in consumers and hairdressers' clients exposed to hairdressing products containing persulfate salts. However, the frequency of reports of these reactions is relatively low. For the allergic reactions, this is presumably attributable to the fact that exposure to persulfates is infrequent. It has been pointed out by the CTFA that the frequency of consumer complaints during the years 1990 to 1993 for hair lighteners sold over the counter or used in salons was 8.79/ million units sold (CIR, 1998).

12.2.5 Uncertainties in risk characterisation

Uncertainties arise in any risk characterisation process due to factors such as inadequate information, assumptions made during the process and variability in experimental conditions. These uncertainties need to be considered when deciding if an estimated exposure is of concern. Examples of uncertainties inherent in the assessment of health risk for persulfates are as follows:

Inadequate information

- lack of representative atmospheric monitoring data;
- lack of adequate particle size measurements for most hair bleaching powders;
- unexplained variability in irritation studies;
- inadequate repeated dose studies;
- inadequate carcinogenicity study;
- inadequate prevalence data for human health effects: bias introduced by selection of study groups, incomplete data, low percentage of workers followed up from an initial group, unknown effects of workers leaving the hairdressing profession because of a medical condition caused by persulfate exposure

Assumptions in the assessment process

- that dose-response relationships are likely to be similar in laboratory animals and humans;
- exposure scenarios have changed little over the years;
- persulfates are moderately irritant rather than severely irritant on short term exposure.

The estimates of the risk of acquiring skin and respiratory complaints from exposure to bleaching powders from the various studies exhibit some variability. In the study of Van der Walle and Brunsveld (1994), a number of sources of variability were discussed. Their survey of 45 hairdressers from 7 salons exhibited some of these and was stated to be biased because it was conducted in salons that requested help in reducing their dermatitis problem and because of a likely seasonal variation in dermatitis incidence. The authors suggested that differences in patch test data between studies may be explained by variation in exposure and variation in patch test materials as experience and product ingredient modifications require adaptation of test allergens.

The so-called healthy worker effect (Wen et al., 1983) also may have an impact on the nature of the study group. This effect applies to those who have contracted a disease or who, for some reason, do not feel comfortable in their job, finding a new occupation or leaving the labour market altogether. In a Finnish study of 3471 hairdressers and 3263 women in commercial work the relative risk of hairdressers leaving the profession because of hand eczema and asthma was 3.5 times as great as the control group in the period 1980 to 1995.

13. Risk Management

In this section, measures currently employed and/or recommended in the management of human health risks from occupational exposure to persulfates and products containing persulfates are discussed.

The key elements in the management of risks discussed in this section include:

- workplace control measures;
- hazard communication;
- atmospheric monitoring;
- regulatory controls; and
- emergency procedures.

13.1 Assessment of current workplace control measures

According to the NOHSC *National Model Regulations for the Control of Workplace Hazardous Substances* [NOHSC:1005(1994)] (the Model Regulations), exposure to hazardous substances should be prevented or, where this is not practicable, adequately controlled, so as to minimise risks to health and safety. The NOHSC *National Code of Practice for the Control of Workplace Hazardous Substances* [NOHSC:2012(1994)] provides further guidance in the form of a hierarchy of controls strategies, namely:

- elimination;
- substitution;
- isolation;
- engineering controls;
- safe work practices; and
- personal protective equipment.

13.1.1 Elimination and substitution

Elimination is the removal of a chemical from a process and should be the first option considered when minimising risks to health. Although a number of consumer bleaching products are available which do not contain persulfates, rapid or extensive bleaching of hair currently requires their use and suitable alternatives either have not been identified or are not used.

Using an effective dust-free powder, cream or granular bleach formulation would reduce or eliminate respiratory sensitisation, asthma, rhinitis and bronchitis caused by atmospheric persulfate particles. These forms are marketed by a number of suppliers and used in many salons. Use of these particular formulations would also be expected to reduce any dust build-up on work surfaces, equipment, fittings or storage areas and eliminate any secondary effects from the accumulated dust. Also use of viscous preparations reduces the likelihood of accidental spillage. At a salon visited where a dust-free formulation was used a minimal amount of dust was observed on opening the container. Cream formulations would generate no dust during use unless allowed to dry onto surfaces.

13.1.2 Isolation

Isolation involves separation of the process from people by distance or use of barriers to prevent exposure.

Formulation of bleach powders

No special procedures appear to be in place to isolate the formulation process although weighing out and packaging operations are conducted in a separate section of the plant.

Salon use

There is little published information on how hair bleaching powders are handled in salons. A single survey suggests that, in the Netherlands separate mixing areas for bleach are the exception (van der Walle & Brunsveld 1994). No data were identified for Australian salons to indicate whether separate or dedicated mixing areas are used.

13.1.3 Engineering controls

Engineering controls are plant or processes which minimise the generation and release of hazardous substances. They include enclosure or partial enclosure, local exhaust ventilation and automation of processes.

Formulation of bleach powders

Local exhaust ventilation is employed at the formulation plants during weighing out, milling and packing of the finished product and filling of sachets is an automated process.

Salon use

There is no published information on the frequency of use of local exhaust ventilation in salons in any country. In most salons, ventilation would be expected to be provided by air conditioning but specific engineering controls are unlikely to be used. In a study of indoor air quality in 20 randomly selected salons in Helsinki, Finland, it was noted that the air exchange rate in large salons (volume, 233 to 837 m^3) had a mean of 4.6 L/h compared to 2.7 L/h for small salons (volume, 42 to 168 m^3). This did not significantly reduce the level of discomfort reported by hairdressers although there was a trend in that direction.

13.1.4 Safe work practices

Safe work practices are administrative practices which require people to work in safe ways. They are important in reducing exposure to persulfates in crystalline or dust forms or when mixed with hydrogen peroxide in a watery, paste or viscous mixture. Information obtained during the assessment indicates that safe work practices followed at some of the work sites are:

Formulation of bleach powders

Safe work practices employed during formulation include:

- prompt clean up and disposal of spills; the potential for spillage is highest during manual dispensing of the final product and sampling for quality control testing; in one of the plants samples taken for quality control are allowed to settle before testing; and
- in one of the plants ammonium persulfate is handled under conditions of less than 50% relative humidity and 25°C; should the blend become hot, it is moved to a well ventilated area.

Salon use

Safe work practices associated with the use of persulfates in salons include:

- use in a well ventilated area;
- use of a disposable bench liner or towels during the preparation of persulfate-containing hair products;
- trying to avoid creating dust;
- correct disposal of contaminated foils, caps and mixing utensils; and
- prompt clean up and disposal of spills.

13.1.5 Personal protective equipment

The use of personal protective equipment as a control measure should be limited to situations where other control measures are not practicable or where personal protective equipment is used in conjunction with other measures to increase protection.

Formulation of bleach powders

Data provided for this assessment indicate that head gear, mask, eye protection, gloves and long sleeve dustcoat are employed by workers weighing the finished powder into 500 g polyethylene tubs. Workers blending and packing products are reported to wear gloves, goggles and dust masks.

Salon use

It appears that in Australia, dust masks are seldom, if ever, worn during mixing of hair bleach (Daly, 1996).

Gloves are worn by less than 50% of hairdressers during use of persulfate-containing bleaches, the commonly used ones being latex and rubber. In a questionnaire given to 193 students and 184 practising hairdressers in an Australian study (Nixon et al., 1999), 43% of the students and 54% of the hairdressers stated that they wore gloves for bleaching. However, the authors suggested, on the basis of anecdotal evidence, that these rates of glove use may be overestimates. Furthermore, although 74% of students and 65% of hairdressers “always” or “usually” wore gloves for various tasks, approximately 58% of respondents experienced problems. The main problems described were: *difficult to work with*: 36%; *hands sweat too much*: 30%; *take too long to put on*: 23% and *gloves too easily damaged*: 20%. Client complaints were a problem in only 8% of responses.

In the study of Nixon et al. (1999) it was found that 73% of respondents wore disposable latex gloves, 25% wore rubber gloves and 21% wore disposable vinyl gloves. Latex gloves are used by health workers for protection from bodily fluids but can cause allergy in these workers and in hairdressers (Guerra et al., 1992; van der Walle & Brunsveld, 1995).

13.2 Hazard communication

13.2.1 Assessment of labels

Hazardous substances used in the workplace should be labelled in accordance with the NOHSC *National Code of Practice for the Labelling of Workplace Substances* (the Labelling Code) [NOHSC:2012(1994)]. According to the current NOHSC *List of Designated Hazardous Substances* [NOHSC:10005(1999)], formulations containing more than 1% ammonium or potassium persulfate are designated hazardous substances. Listed risk and safety phrases are:

- R8 Contact with combustible material may cause fire
- R22 Harmful if swallowed
- R36 Irritating to eyes
- R37 Irritating to respiratory system
- R38 Irritating to skin
- R42 May cause sensitisation by inhalation
- R43 May cause sensitisation by skin contact

- S2 Keep out of reach of children
- S22 Do not breathe dust
- S24 Avoid contact with skin
- S26 In case of contact with eyes, rinse immediately with plenty of water and seek medical advice
- S37 Wear suitable gloves

This assessment indicates the above risk phrases and following safety phrases should apply:

- S3 Keep in a cool place
- S7 Keep container tightly closed
- S17 Keep away from combustible material
- S51 Use only in well ventilated areas

Other requirements are the presence of the signal word Hazardous; product name; details of the concentration and identity of individual persulfate salts; emergency instructions; first aid statements; supplier details; reference to MSDS; ADG Code and U.N. number.

Under the NOHSC *National Model Regulations and Code of Practice for the Control of Workplace Hazardous Substances* [NOHSC:1005(1994)] and the corresponding State and Territory legislation, suppliers of industrial chemicals are obliged to provide labels in accordance with the NOHSC Labelling Code.

Labels received from applicants were assessed against the Labelling Code, the *List of Designated Hazardous Substances* [NOHSC:10005(1999)] and the ADG Code (FORS, 1998). The results of the assessment are presented in Table 12.

Mixtures are assigned the risk phrase R22 if they contain persulfates at a concentration at or above 25%. The corresponding concentrations for R36/37/38 and R42/43 are 20% and 1% respectively.

Table 12 - Assessment of labels on hair bleaching products used in salons

Information[1]	**Proportion of Labels**	**Comments**
R22	4/32	
R36/37/38	6/32	no reference to respiratory in one of the six
R42	6/32	
R43	0/32	
S2	15/32	
S22	10/32	
S24	7/32	
S25	10/32	
S37	14/32	
Signal Word: Hazardous	1/32	one label had the word POISON
Product name	32/32	
Disclosure of ingredients	28/32	
Concentrations of persulfates	0/32	
Emergency instructions	0/32	
Supplier details	20/32	
Reference to MSDS	1/32	
ADG Code	1/32	
UN No. 3215 (Inorganic persulfates N.O.S)	1/32	
<u>First Aid Statements (or equivalent phrases)</u>		
If swallowed rinse mouth with water; give water to drink; do NOT induce vomiting; seek medical attention without delay	1/32	

Information[1]	**Proportion of Labels**	**Comments**
If skin contact occurs, wash contaminated area thoroughly with water, remove contaminated clothing; if irritation persists seek medical attention	4/32	
If eye contact occurs, immediately flush with water for at least 15 minutes while holding eyelids apart; seek immediate medical attention	14/32	
If inhaled, remove subject to fresh air; if required, seek medical attention	0/32	

[1] for ammonium, potassium and sodium persulfates.

In addition to the safety phrases listed in the NOHSC List, some labels contained the following safety phrases: S3, S7, S17 (see above for what these phrases are), S25 (Avoid contact with eyes) and S39 (Wear eye/face protection).

Unless one of the ingredients is listed on the SUSDP, cosmetic products for consumer end-use have to comply only with the ingredient labelling requirements in the *Trade Practices (Consumer Product Information Standards) (Cosmetics) Regulations*. These regulations are enforced by the Australian Competition and Consumer Commission through surveys conducted at regular intervals (Department of Industry Science and Tourism, 1998). Each of the consumer products listed the ingredients in the correct manner. However, during the preparation of this assessment the SUSDP was amended to include ammonium, potassium and sodium persulfate for hair dressing products in Schedule 6. Consequently, subsequent labelling of persulfate-containing hair dressing products for consumer use will need to reflect the new labelling requirements (see Section 13.6) .

13.2.2 Assessment of MSDS

MSDS are primary sources of information for the safe handling of chemical substances. Under NOHSC *National Model Regulations for the Control of Workplace Hazardous Substances* [NOHSC:1005(1994)] and corresponding State and Territory legislation, suppliers are required to provide MSDS to their customers for all hazardous substances. Employers must ensure that a MSDS for any hazardous substance used in the workplace is readily accessible to employees with potential for exposure to the substance and is prepared in accordance with the *National Code of Practice for the Preparation of Material Safety Data Sheets* [NOHSC:2011(1994)].

Each of the companies formulating hair bleaching powders in Australia use persulfates of a single grade from a single source. Therefore, one MSDS for each of the persulfate salts was received. The results of the MSDS assessment are presented in Appendix 3. In general, the MSDS did not state that the persulfates can cause skin and eye irritation following acute exposure and failed to state that skin and respiratory sensitisation can be a consequence of chronic exposure. Information relating to treatment of spills and disposal of persulfates was inadequate.

MSDS for products containing various combinations of the persulfate salts were received from a number of applicants. In addition, some applicants chose to use a generic MSDS written by the Working Party of the Cosmetic, Toiletries and Fragrance Association of Australia (CTFAA) and representatives of supplier companies.

The total concentration of persulfates in all products exceeds 25%. Therefore, the health effects of the products from the persulfate content alone will not be different from the health effects of the pure persulfates when calculated from the concentration cut-offs described in the *Approved Criteria*.

Of the applicants who provided specific MSDS, 4 provided overseas MSDS and 3 provided Australian versions. For the overseas MSDS the emergency telephone number is irrelevant, therefore, the emergency telephone number is considered to be non-existent. The results of the assessment of MSDS for products are presented in Appendix 4. The major findings of the product MSDS assessment were that the hazardous nature of the products and their ability to cause skin and respiratory sensitisation and irritant contact dermatitis were not stated in many cases. There was also a general failure to adequate information on safe handling.

Assessment of the generic MSDS prepared by the CTFAA revealed some deficiencies as follows:

- No UN No. or Dangerous Goods Class were listed;
- The powder was incorrectly stated to be miscible with water: it dissolves in water;
- No mention of the use of a mask was included under Personal Protection;
- Under Storage and Transport no mention was made of the need to keep containers closed, protect contents from moisture, not returning unused product to original container and not loading with the various incompatible ADG classes for transport (see table 14);
- Under Spills and Disposal no mention was made of the need to keep unnecessary personnel from the area of the spill, use of personal protective equipment during clean-up, not returning contaminated material to containers of the pure product, mixing with combustible materials such as sawdust or removing material completely from combustible contaminated surfaces.

13.3 Education and training

Guidelines for the induction and training of workers exposed to hazardous substances are provided in the National Commission's Model Regulations (NOHSC, 1994a). Under these regulations employers are obliged to provide training and education to workers handling hazardous substances.

The Model Regulations stipulate that training and induction should be appropriate for the workers concerned. It is important that each workplace implement a program that is suitably designed to accommodate the needs of different workers.

Training should be given to the workers at induction and repeated at regular intervals to reinforce the information. Training and education needs for workers should be reviewed on a regular basis.

The main education and training providers for hairdressing in Australia are Recognised Training Organisations (RTOs) which are registered by State/Territory Training Authorities as nationally recognised for the provision of training products and services. Within the vocational education and training (VET) sector nationally recognised qualifications may be issued as follows: Certificate I – IV, Diploma and Advanced Diploma. Under the Australian Qualifications Framework, qualifications issued in the VET sector must lead to the achievement of a package of competencies.

The National Training Framework includes the Australian Recognition Framework providing recognition of training organisations and products, and Training Packages which integrate nationally available training products with competency standards. Until the Training Package for the hairdressing industry is fully developed, nationally accredited courses will continue to provide apprentices and trainees with the main method of obtaining nationally recognised qualifications.

Competency standards describe the skills and knowledge required for a person to operate effectively in the workplace. The competency standard for hairdressing comprises a number of units. Unit 1, entitled "Maintain a safe, clean and efficient work environment" includes references to "storage and use of hazardous substances", "use of chemicals" and "dangerous goods and substances identified, handled and stored according to salon policy and occupational health and safety regulations".

In addition to training provided by RTOs, cosmetic companies provide training during the introduction of new products. This training mainly focuses on techniques of use of the products.

The effectiveness of education and training in the use of hazardous substances in salons was addressed by Nixon et al. (1999) who surveyed 184 hairdressers and 193 students in Melbourne, Victoria, Australia. Approximately 10% of students could not recall learning about skin problems and 95% of students did not understand the term *allergy*. Approximately 4% of students said they had received no occupational health and safety training, 49% had received "some" and 46% said they had received "quite a bit" or "a lot". The study identified a number of areas where the training of hairdressers in colleges was deficient. These included knowledge relating to: skin disorders, damaging substances used in hairdressing, how substances damage the skin and understanding MSDS and appropriate glove use.

13.4 Occupational monitoring and regulatory controls

13.4.1 Monitoring

Atmospheric monitoring for persulfates is not conducted at the two plants which formulate hair bleaching powders in Australia and is unlikely to be conducted at any of the salons around Australia. There is currently no Australian exposure standard (see below).

Under the National Commission's Model Regulations, employers need to carry out an assessment of the workplace for all hazardous substances, with methodology for the assessment provided in the *Guidance Note for the Assessment of Health Risks Arising from the Use of Hazardous Substances in the Workplace* (National

Occupational Health and Safety Commission (NOHSC), 1994). When the assessment indicates that the risk of inhalation exposure is significant, atmospheric monitoring should be conducted to measure persulfate concentrations in the workplace. Monitoring provides an indication of the effectiveness of the control measures in place and whether there is a need to improve measures to reduce worker exposure. Atmospheric monitoring should be repeated if any changes are made to the process or equipment.

13.4.2 Exposure standards

There is no current Australian exposure standard for any of the persulfates.

Table 13 lists the exposure standards for persulfates in various countries.

Table 13 - International exposure standards for persulfate salts

Country	persulfates	ammonium salt	sodium salt	potassium salt
Canada – Alberta[a]	4 mg/m^3 STEL			
Canada – Alberta[a]	2 mg/m^3 TWA			
Canada – Ontario – OHSA[a]	5 mg/m^3 TWA			
USA – ACGIH[b]	0.1 mg/m^3 TWA			
United Kingdom[b]	1 mg/m^3 TWA			
Denmark[a]			2 mg/m^3 TWA	
The Netherlands[b]	1 mg/m^3 TWA			
Poland[b]				0.1 mg/m^3 TWA
Ireland[b]	1 mg/m^3 TWA			

[a] source: Tomes CPS® (1999), Micromedex Inc.

[b] source: ACGIH (1998) TLVs and Other Occupational Exposure Values, American Conference of Industrial Hygienists, OH, USA.

13.5 Health surveillance

Health surveillance is not routinely conducted for workers exposed to persulfates.

Persulfates are not listed in schedule 3 of the National Commision's *National Model Regulations for the Control of Hazardous Substances* (1994) as a substance requiring health surveillance. However, health surveillance is required for employees where the workplace assessment has shown that there is a likelihood of an identifiable disease or health effect occurring under the particular conditions of work following exposure to a hazardous substance. The employer is responsible for providing health surveillance.

13.6 Public health regulatory controls

At the time of this assessment, none of the persulfate salts in hair dressing preparations were listed on the Standard for the Uniform Scheduling of Drugs and Poisons (SUSDP) (Australian Health Ministers' Advisory Council, 1999). After consideration of the draft assessment report on ammonium, potassium and sodium persulfate, the National Drugs and Poisons Scheduling Committee (NDPSC) listed the three persulfate salts for use in hairdressing products in Schedule 6 of the SUSDP. The NDPSC also established appropriate First Aid Instructions, Warning Statements and Safety Directions for each of the persulfate salts.

13.7 Emergency procedures

For any hazardous chemical an emergency response plan is an essential component of occupational health and safety risk management. In the event of a substantial leak, spill, release or fire, a written procedure is necessary for workers and emergency services. Although such plans were not submitted for assessment, the following emergency procedures have been described in available MSDS:

- contain spillage; collect spillage in clean plastic containers with loose fitting lids;
- small quantity (of spills) to be flushed to drain; approval may be required from the relevant authorities; for larger quantities, consult local Trade Waste Authority; consult company for further advice;
- neutralise persulfate by careful reduction with acidic sodium thiosulfate solution, bisulfate or ferrous salts. When reaction complete, bring to neutral pH with soda ash or hydrated lime slurry;
- fire fighting procedures: drench residues with water to eliminate heat from decomposition as a potent source of re-ignition;
- unusual fire and explosion hazards: when subjected to heat from combustion of other materials will decompose to liberate oxygen; this may cause other materials to burn more fiercely; under confinement may cause pressure bursts to release gases of decomposition; and
- hazardous decomposition products: oxygen gas increases fire hazard; heating can cause slight development of sulphur dioxide, sulphur trioxide, and ozone.

With regard to the storage and handling of oxidising agents AS 4326-1995 provides guidance on emergency procedures.

14. Discussion and Conclusions

14.1 Current use and occupational exposure in Australia

Formulation of bleaching powders

Approximately 5000 kg of ammonium persulfate and 473 kg of potassium persulfate are imported into Australia for formulating products. Approximately 2000 kg of the ammonium persulfate is used in two consumer products and the remainder is used in one salon product together with the potassium salt. The consumer products contain between 45% or 64% ammonium persulfate.

Formulation of hair bleaching products in Australia involves a low number of workers for relatively short periods over the year. Although persulfates are harmful via the oral route following acute exposure of rats, ingestion is an unlikely route of exposure and no systemic effects are expected. It was specifically stated that no irritant or sensitising effects have occurred in workers at the formulation plants. This is presumably because of the high standard of control measures employed at these plants and the low volume of persulfates processed for hair bleaching powders per year.

Salon use

Approximately 40 products are imported for salon use in Australia. The approximate import volume of persulfates contained in these products is 130 tonnes per year. Typical product formulations contain 0% to 23% ammonium persulfate, 10% to 60% potassium persulfate and 0% to 44% sodium persulfate. The total persulfate content varies from 22% to 88% with the majority of products having a persulfate content above 50%.

While systemic toxic effects to salon workers from acute exposure or repeated or prolonged exposure to persulfates are not expected due to the low level of exposure, irritation and sensitisation of the skin and respiratory tract in hairdressers is well documented. In addition to the additive effect of the three persulfate salts, it is possible that synergistic effects can occur with other chemicals used in the workplace and that frequent immersion of the hands in water and shampoo can induce irritant contact dermatitis which predisposes to allergic contact dermatitis.

Public use

Approximately 13 consumer products are imported, containing an estimated 3500 kg of persulfates, each year. These products can contain up to 80% persulfate salts. Systemic toxicity is not expected due to intermittent use but dermatological and respiratory effects similar to those documented in the hair salon industry are expected. Prior to this assessment, persulfate salts in consumer products were not scheduled by the NDPSC. As a result of this assessment, scheduling (S6) has occurred and consumer products are consequently required to display the appropriate warning, first aid and safety directions.

Exposure standard

There is no Australian exposure standard for ammonium, potassium or sodium persulfate. Several overseas countries have adopted exposure standards. Overseas exposure standards for persulfates currently include 0.1 mg/m^3 TWA (ACGIH) and 1 mg/m^3 TWA (UK). This assessment concludes that while repeat dose toxicity is not expected at 0.91 mg/m^3, there is no threshold for the sensitisation effects of the persulfates. Given the expected exposures in the formulation and hairdressing industry, 0.1 mg/m^3 (TWA) is considered both achievable and desirable to minimise the risk of sensitisation.

14.2 Health effects

Several oral acute toxicity studies in rats indicate that ammonium, potassium and sodium persulfate are to be considered harmful by the oral route (LD_{50} > 495 mg/kg for the ammonium salt with comparable values for the potassium and sodium salts). However, the persulfates appear to exhibit low acute dermal toxicity (LD_{50} > 2000 mg/kg for the ammonium, potassium and sodium salts). Similarly, the persulfates exhibit low acute inhalation toxicity (LC_{50} > 2.95 and 5.10 mg/L for ammonium and sodium salts respectively (4 h exposures) and 42.9 mg/L for potassium persulfate (1 h exposure)).

Full reports of all tests for skin and eye irritation were not available for assessment. A number of skin irritation tests were conducted with ammonium and sodium persulfates. In general, the persulfates were either not irritating or slightly irritating to rabbit skin. However, on the basis that skin irritation has been observed in humans patch tested with ammonium, potassium and sodium persulfate and in some hairdressers' clients, the persulfates are considered to be skin irritants. Persulfates also appear to be skin irritants following repeated exposure as shown by the development of irritant contact dermatitis in hairdressers.

The summaries of eye irritation studies on test animals following challenge with ammonium persulfate have reported equivocal results. In the absence of the full reports and taken together with isolated instances in humans, the persulfates should be considered eye irritants.

A full report on sensory irritation in mice was available from which sodium persulfate was judged to be a respiratory irritant. Similarly, full reports on skin sensitisation by ammonium and sodium persulfate in guinea pigs demonstrated a strong skin sensitisation potential. This evidence supports a large body of human case study data suggesting that the persulfates are both skin and respiratory sensitisers and induce a number of health complaints with an allergic basis. Dermatological conditions include the development of pruritus (itching), erythema, oedema, urticarial lesions and crust formation. Respiratory conditions can include rhinitis, dyspnea and asthma. A number of case studies have shown the concurrent development of dermal and respiratory symptoms following the use of persulfates.

Although a number of repeated dose studies have been conducted using persulfates, full reports of the oral studies were not available. Therefore, although there were indications that the persulfates did not induce severe effects after repeated administration in the diet of rats at 3000 ppm for 13 weeks, this could not be confirmed.

A published 7-day repeated dose inhalation study with ammonium persulfate suggested that local effects (pulmonary oedema and inflammation) predominated at doses of 4 mg/m^3 and above administered to rats for 23.5 h/day. Systemic effects were characterised by a reduction in body weight gain. However, a well conducted (unpublished) 90-day inhalation study, produced a NOAEL of 5 mg/m^3.

A number of short term genotoxicity tests have been performed with ammonium and sodium persulfate. All studies are either published in the literature or have been performed to GLP standards. The persulfates were not mutagenic in bacteria and were negative in tests for induction of chromosomal aberrations, micronuclei or unscheduled DNA synthesis.

There have been no studies of the effects of persulfate salts on reproduction.

A published study of carcinogenicity by twice-weekly skin painting of mice for 51 weeks was not conclusive due to the small group size.

Therefore, it is concluded that the persulfates are harmful via the oral route following acute exposure but are of low dermal or inhalation toxicity. They are considered to be skin, eye and respiratory irritants and skin and respiratory sensitisers. They are not considered to be genotoxic.

14.3 Control measures

Australian formulation plants use local exhaust ventilation at all points where dust is generated in the handling of persulfates. In addition to the segregation of formulation activities, workers wear protective clothing, goggles and dust mask while formulating and packing the bleaching powder into containers. Consequently, worker exposure to the persulfate salts is minimised.

In contrast, few Australian hairdressing salons are likely to employ local exhaust ventilation. While it is likely that larger salons use separate mixing areas it is estimated that less than 50% of hairdressers use gloves when preparing and applying hair bleach. The frequency with which protective measures are employed, such as the use of moisturising cream which can reduce dermal irritation due to chemical exposure, is unknown (Nixon et al., 1999). In general, the study of Nixon et al. (1999) provides a strong case for a workplace assessment covering a number of salons involving persulfates and other hazardous chemicals.

Of 49 persulfate-containing bleach products identified during this assessment, 16 were stated to be dust-free. One was available as a cream and two were granulated. The cream formulation was reported by the supplier to produce an effect comparable to a powder bleach and was similarly priced. Therefore, it appears that a cream bleach could be substituted for powder bleach for most applications. The advantages of a cream bleach are that spills are less likely, contamination of hands and work surfaces is more easily avoided and inhalation exposure minimised. The remaining 15 dust-free products were described as dust-free powders. Of 13 bleaching products identified for home use, none were formulated to be dust-free.

Dust-free formulations will minimise inhalation exposure but as they need to be removed by a scoop from their container spills can still occur. As discussed in Section 8.2.2, there are no criteria for determining the effectiveness of dust-free claims and an examination of several bleach samples provided by a number of companies revealed that the effectiveness of certain dust-free powders was questionable. One product in particular, although labelled as dust-free, produced a quantity of fine dust on removal and replacement of an internal plastic lid while others produced a fine dust on removal of the outer lid or on opening and closing inner plastic liners. During removal of the product by means of a supplied scoop a fine dust was observed to form which dispersed into work environment. Similar concerns were noted on examination of one granulated formulation. While the bulk of the product was in granular form, a fine dust was also present which may have formed due to abrasion of particles during transport and handling. At present, there are no standards by which dust-free claims can be substantiated.

It is noteworthy that the instructions for use on a number of bulk hair bleach containers required users to shake the container vigorously prior to opening. As these were not all dust-free formulations, this instruction would appear to promote the risk of dispersal of persulfate-containing dust in salons rather than minimising it.

The primary potential exposure is to the hands and suitable gloves should be worn when mixing and applying bleach. Vinyl or nitrile rubber gloves are considered suitable and an adequate supply should be maintained in the workplace. Workers should be aware that gloves should also be worn for shampooing hair as the resultant dryness and damage to skin may predispose to either irritant or allergic contact dermatitis from subsequent contact with persulfates.

The MSDS and labels for salon use products revealed a large number of deficiencies in a number of areas. The main deficiencies in the MSDS were: no statement of hazardous nature, failure of almost all to mention skin and respiratory sensitisation and major deficiencies in spills/disposal, storage and transport and fire hazard sections. The main deficiencies in the labels were a lack of most of the risk and safety phrases, no signal word, no concentration details, emergency instructions or reference to the MSDS. Not one product of the 32 surveyed included the required risk phrase for respiratory sensitisation.

14.4 Data gaps

There are no repeated dose toxicity studies for sodium and potassium persulfate known to have been conducted to GLP standards and in accordance with OECD guidelines which can be used for hazard classification. The majority of salon users of persulfate bleaches in Australia are females of reproductive age (Nixon et al., 1999), however, it is noteworthy that there are no studies relating to reproductive toxicity of the persulfate salts.

14.5 Conclusions

This assessment of persulfate salts in hair bleaching preparations has identified the following health and safety issues:

- persulfate salts in hair bleaching preparations are hazardous chemicals and all the products available for consumer and salon use are harmful if swallowed, irritant to the skin and eyes and able to cause allergic responses such as dermatitis and asthma;
- the majority of formulations are not optimal for minimising exposure due to dust formation;

- most of the MSDS and labels for salon products are deficient in several areas;
- most hair salons would benefit from a workplace assessment and health surveillance program; and
- the training of salon workers in the safe use of chemicals used in hairdressing appears inadequate.

15. Recommendations

Recommendation 1: Safer product formulation

This assessment has found that the risks arising from exposure to dusty formulations of persulfate-containing bleaches used in the hairdressing industry are significant, and that adequate alternatives exist.

It is recommended that non dust-free formulations for hairdressing use in salons be phased-out.

Not all persulfate-containing bleaches with dust-free claims were in fact sufficiently dust-free.

No national or international standard for "dust-free" formulations, relevant to these products, was identified. It is recommended that the Cosmetics, Toiletries and Fragrances Association of Australia investigate this further, with a view to developing guidance to industry on this issue.

Should, after a sufficient period of time (12 to 18 months), voluntary industry approaches to the above fail, regulatory actions should be considered by the occupational health and safety jurisdictions.

Recommendation 2: Improved packaging

The following recommendations on packaging measures are made to industry for formulators/importers and re-packagers of powered persulfate bleaches:

- formulate and/or package persulfate bleaches supplied in bulk for salon use in a manner so that the container does not need to be shaken prior to use;
- package plastic scoops for dispensing the bleach separately to the bleach; and
- products should not be packaged with inner plastic "snap" lids as these promote the dispersal of dust particles on opening/closing and dermal contact with persulfates.

Recommendation 3: Hazard classification

The existing NOHSC hazard classification for ammonium and potassium persulfate for the workplace is confirmed.

Sodium persulfate, which is presently not classified by NOHSC, should have the same classification as the ammonium and potassium compounds. This classification, which appears below, should be included in the NOHSC *List of designated hazardous substances,* and on product labels, as soon as possible.

• R22	Harmful if swallowed
• R36/37/38	Irritating to eyes, respiratory system and skin
• R42/43	May cause sensitisation by inhalation and skin contact

- R8 Contact with combustible material may cause fire, with the designation O for oxidising
- S3 Keep in a cool place
- S7 Keep container tightly closed
- S17 Keep away from combustible material
- S51 Use only in well ventilated areas

The concentration cut-offs for ammonium, potassium and sodium persulfate and for mixtures containing the persulfate salts at which the above risk phrases need to be included on labels are > 25% for R22, > 20% for R36/37/38 and > 1% for R42/43.

Recommendation 4: Hazard communication

This assessment has found that compliance with the MSDS and labelling requirements for substances to be used in the workplace is generally poor, to the extent that adequate health effects information is not provided in many cases. It is recommended that the state/territory occupational health and safety regulatory authorities undertake compliance action to improve industry performance. A reasonable period of 6 months for industry to achieve self-compliance is suggested before occupational health and safety jurisdictions undertake investigations.

A sample MSDS for ammonium persulfate is provided at Appendix 5. MSDS for potassium and sodium persulfate should be modified as appropriate.

Recommendation 5: Workplace controls

The following recommendations on control measures are made for **formulators/importers and re-packagers** of persulfate bleaches:

- promptly clean spills in a way to minimise dust generation and place contaminated materials in correctly labelled containers for disposal;
- during formulation ambient temperature and humidity should be monitored as well as the temperature of the blend. If the blend becomes hot, it should be moved to a well ventilated area to cool;
- samples for quality control should be allowed to settle before testing; and
- that approved protective clothing, goggles, gloves and respiratory protection (dust mask) be worn during weighing out, quality control testing, transferring chemical or product, while in the area of the milling machine and during filling/packaging.

The following recommendations are made for **hairdressing salons** using persulfate-based bleaches:

- retain all open packages and materials used for mixing in the designated mixing area. Contaminated materials used in bleaching (foils, plastic caps, etc) should be placed in a designated area prior to disposal;
- plastic scoops for dispensing bulk persulfates are not to be stored in the same container as the persulfates in order to minimise dermal contact;

- remove jewellery and watches before commencing work with bleach powders as the dust has the potential to collect under jewellery and watch bands thus increasing dermal exposure;
- use a moisturising cream as a preventative measure on the hands. Dryness between the fingers should be recognised as an early warning sign of contact dermatitis; and
- wear gloves suitable to the task being performed when handling persulfate bleaches.

Recommendation 6: Health surveillance

Exposure to persulfate salts can lead to occupational contact dermatitis and asthma and these conditions do occur in the hairdressing industry with a greater frequency than in the general population.

It is recommended that employers conduct a workplace health surveillance program if workers experience skin or respiratory problems following the use of persulfate-containing products. Employers need to refer to the NOSHC *Guidelines for health surveillance.*

Recommendation 7: Training and education

In addition to the standard training required to become a qualified hairdresser, student and apprentice hairdressers need to be trained in the safe use of chemicals and to develop an understanding of their health effects. This training should include how to read MSDS and labels and an understanding of the risk and safety phrases they may encounter.

NICNAS will prepare a Safety Information sheet aimed at workers, which conveys the key messages from this report.

Recommendation 8: Exposure standard

It is recommended that NOHSC assign exposure standards for ammonium, potassium and sodium persulfate based on their ability to cause skin and respiratory irritation, skin and respiratory sensitisation, irritant and allergic contact dermatitis, and asthma.

The ACGIH standard of 0.1 mg/m^3 TWA is recommended as appropriate for the hairdressing use of these substances, based on exposure and health effects information in this report. Noting that this standard would apply for all uses, the practicability of the standard for other industry sectors would need to be considered by NOHSC.

Recommendation 9: Public health and safety

Following consideration of the draft assessment report and in recognition of the serious health consequences to consumers and professional hairdressers following the use of products containing persulfate salts, ammonium, potassium and sodium persulfate for use in hair preparations have been listed in Schedule 6 of the SUSDP. The requirements for the first aid instructions, warning statements and safety directions should be strictly adhered to.

First aid instructions

- a – If poisoning occurs, contact a doctor or Poisons Information Centre. *Phone (e.g. Australia 13 1126; New Zealand 03 4747000);
- c – If swallowed, do NOT induce vomiting. Give a glass of water; and
- s – If in eyes, hold eyes open, flood with water for at least 15 minutes and see a doctor.

Warning statements

- 5 – Irritant;
- 21 – WARNING – This product contains ingredients which may cause skin irritation to certain individuals. A preliminary test according to accompanying directions should be made before use. This product must not be used for dyeing eyelashes or eyebrows; to do so may be injurious to the eye; and
- 25 – Do not use on broken skin. Wash hands thoroughly after use.

Safety directions

- 1 – Avoid contact with eyes;
- 5 – Wear protective gloves when mixing or using;
- 12 – Do not allow product to come into contact with other chemicals, especially acids;
- 13 – Do not allow product to come into contact with combustible material such as paper, fabric, sawdust or kerosene; and
- 23 – Keep away from heat, sparks and naked flame.

Recommendation 10: Further information

As products containing persulfate salts are applied to human skin and operator exposure occurs during salon bleaching procedures, it is recommended that industry fill the toxicity data gaps for repeat dose and reproductive toxicity.

16. Secondary Notification

Under Section 65 of the Act, the secondary notification of a chemical may be required, where an applicant or other introducer (importer) of a chemical, becomes aware of any circumstances which may warrant a reassessment of its hazards and risks. Specific circumstances include

- The function or use of a chemical has increased, or is likely to change, significantly;
- The amount of a chemical introduced into Australia has increased, or is likely to increase significantly;
- Manufacture of a chemical has begun in Australia; or

Additional information has become available to the applicant/notifier as to the adverse health and/or environmental effects of a chemical.

In the case of persulfates, a secondary notification may be required if significant new information about its health effects becomes available. In addition, should the amounts imported increase greatly, notification will be required.

The Director (Chemicals Notification and Assessment) must be notified within 28 days of the manufacturer/importer becoming aware of any of the above or other circumstances prescribed under section 65 of the Act.

Appendix 1

Hair Bleaching Formulations Containing Persulfates

Product	NH_4^+	K^+	Na^+	Labelled Dust-free[a]	Use
Affinage Lite Blue Bleach	✎	✎	✎	Y	Salon
Affinage Lite White Bleach	✎	✎	✎	Y	Salon
Blondex Dust-Free	✎	✎	–[b]	Y	Salon
Blondex Swiftly Blonde	✎	✎	–	N	Salon
Clairol Born Blonde 3	✎	✎	–	N	Home
Clairol Frost & Tip	✎	✎	–	N	Home
Coy Ultra Blue	✎	✎	✎	N	Salon
Coy Ultra White	✎	✎	✎	N	Salon
De Lorenzo Novalite Bleach Powder	✎	✎	–	N	Salon
De Lorenzo Novalite Bleach Powder D/F	✎	✎	–	Y	Salon
Decore Blonding Crème 4 Ultimate Blonde	✎	–	–	N	Home
Decore Lights Highlight & Streaking Kit	✎	–	–	N	Home
Decore Lights Streaking & Frosting Kit	✎	–	–	N	Home
Goldwell Oxycur Platin Dust-Free	✎	✎	–	Y	Salon
Goldwell Oxycur Platin Ultra	–	✎	–	N	Salon
Hairtech Ultra Bleach Blue	✎	✎	✎	N	Salon
Hairtech Ultra Bleach White	✎	✎	✎	N	Salon
Hi Lift Blonde Highlighter	–	✎	✎	Y	Salon
HSA DecoCream Silky	✎	✎	✎	N/A[c]	Salon
HSA Nouvelle Polvere Decolorant	✎	✎	✎	N	Salon
Indola Dust-Free Bleach	✎	✎	–	Y	Salon
Indola Rapid Blonde	✎	✎	✎	N	Salon
Indola Rapid White	✎	✎	✎	N	Salon
Laboratoires Garnier Blonding Contrasts	–	✎	✎	N	Home
Laboratoires Garnier Blonding Highlights	–	✎	✎	N	Home
Laboratoires Garnier Nutrisse Pre-Lightener	–	✎	✎	N	Home
L'Oréal Blondys	–	✎	✎	N	Salon
L'Oréal Efassor	–	✎	✎	N	Salon
L'Oréal Platinclair	–	✎	✎	N	Salon
L'Oréal Super Blonde	–	✎	✎	N	Home
L'Oréal Frost and Design	–	✎	✎	N	Home
Linea Ricerca Bleaching Powder	✎	✎	✎	N	Salon
Linea Ricerca Bleaching Powder	✎	✎	✎	Y	Salon
Matrix Essentials Colorease Permanent	✎	✎	✎	Y	Salon
Matrix Essentials Colorgraphics Powder Bleach	✎	✎	✎	N	Salon
Matrix Essentials Le Bleach Frosting &	✎	✎	–	N	Salon
Matrix Essentials Light Exposure	✎	✎	✎	Y	Salon
Matrix Essentials Logics Light Reaction	✎	✎	✎	Y	Salon
Matrix Essentials Logics Special Effects Powder	ns[d]	ns	ns	Y	Salon

Product	**NH_4^+**	**K^+**	**Na^+**	**Labelled Dust-free[a]**	**Use**
Matrix Essentials Socolor Crème Scalp Bleach	✎	✎	✎	N	Salon
Napro Nordic Colors Lightening Crème	✎	–	–	N	Home
Napro Nordic Colors Streaking Kit	✎	✎	–	N	Home
Redken Lift 5-15	–	✎	✎	N	Salon
Redken Shades EQ Lightening D/T	✎	✎	✎	N	Salon
Salon Signature Super Blondes	✎	✎	✎	Y	Salon
Schwarzkopf Igora Brilliant Blonde Plus	✎	✎	–	N	Salon
Schwarzkopf Igora Vario Blonde Plus	✎	✎	–	Y	Salon
Selecta Dust Free Bleach	✎	✎	–	Y	Salon
Verocolor Verolight Bleach Powder	✎	✎	–	N	Salon
Wella Bellady Blonde	✎	–	–	N	Home
Wella Blondor Special	✎	–	✎	N	Salon
Wella Blondor Special Cream	✎	✎	✎	N/A	Salon
Wella Blondor Special Dust Free	✎	✎	–	Y	Salon

[a] Y = yes, N = no; [b] - = not present in product; [c] N/A = not applicable;
[d] ns = information not supplied

Appendix 2

Estimating Occupational Exposure to Persulfate Salts

(i) Inhalation exposure to dust

The daily dose due to absorption of dust by inhalation is given by:

$$D = \frac{C \times R \times E \times B}{BW} \quad \text{mg/kg bw per day}$$

where C = concentration of substance in air (mg/m^3),

R = inhalation rate (m^3/h),

E = exposure duration (h/day),

B = bioavailability of the substance across the lungs (1= 100%),

BW = average body weight of worker (kg).

For male workers the average body weight is taken to be 70 kg and for females 60 kg. For males and females the inhalation rate during light work is taken to be 1.3 m^3/h (Organisation for Economic Co-operation and Development 1993).

Appendix 3

Assessment of MSDS for the Pure Persulfates

Information	ammonium salt	sodium salt	potassium salt
Statement of hazardous nature	✎	✎	✎
Emergency telephone no.	✎	✎	✎
Product Identification			
Major uses	✎	✎	✎
UN number, ADG class, Hazchem code	✎	✎	✎
Ingredients			
Identity	✎	✎	✎
Proportion	✎	✎	✎
Physical description/properties	✎	✎	✎
Health Hazard Information			
Acute effects			
Harmful if swallowed	incorrectly stated to be corrosive to skin, eye and if swallowed		
Skin irritant, can cause contact urticaria and irritant contact dermatitis			
Eye irritant			
Respiratory irritant	✎	✎	✎
Chronic effects			
Skin sensitiser, can cause allergic contact dermatitis	–	–	–
Respiratory sensitiser, can cause asthma, allergic rhinitis and bronchitis	–	–	–
May cause pulmonary oedema or inflammation	–	–	–
First Aid statements			
If swallowed rinse mouth with water; give water to drink; do NOT induce vomiting; seek medical attention without delay	✎	✎	✎
If skin contact occurs, wash contaminated area thoroughly with	✎	✎	✎

Information	ammonium salt	sodium salt	potassium salt
water, remove contaminated clothing; if irritation persists seek medical attention			
If eye contact occurs, immediately flush with water for at least 15 minutes while holding eyelids apart; seek immediate medical attention	✏	✏	✏
If inhaled, remove subject to fresh air; if required, seek medical attention	✏	✏	✏
First Aid Facilities: Eye wash and safety shower should be available in the workplace where this product is used	✏	✏	✏
Advice to Doctor: Treat symptomatically	✏	✏	✏
Precautions for use			
Exposure standards			
No specific NOHSC exposure standard has been established	✏	✏	✏
Engineering controls			
Use local exhaust ventilation	✏	✏	✏
Personal protection			
Eye protection (full face shield, chemical goggles); mention of contact lenses: irritant absorption by soft lenses, irritant concentration by all lenses	✏	✏	✏
Hand protection (PVC, synthetic or natural rubber gloves)	✏	✏	✏
Respiratory protection (an approved half facepiece suitable for dusts)	✏	✏	✏
Protective clothing	✏	✏	✏
Flammability			
Not combustible	✏	✏	✏
Safe handling information			
Storage and transport			
Store in cool place away from heat	✏	✏	✏
Store in dry place	✏	✏	✏
Keep container tightly closed			
Protect product from moisture	✏	✏	✏
Store in polyethylene lined containers	✏	✏	✏

Information	ammonium salt	sodium salt	potassium salt
Do not return unused product to original container	✎	✎	✎
Store away from sources of heat or ignition, combustible materials (eg wooden pallets or cardboard), reducing agents, strong acids or alkalis. Do not allow to come into contact with rust, metal ions or metal salts	✎	✎	✎
Transport in accordance with the Australian Dangerous Goods Code. Not to be loaded with class 1, 2.1, 2.3, 3, 4, 5.2, 6, 7, 8, 9 or substances other than dangerous goods capable of combustion	✎	✎	✎
Spills and disposal			
Keep unnecessary personnel from the area of the spill	_	_	_
Personnel involved in clean-up should wear PPE to prevent skin, eye and respiratory exposure	_	_	_
Collect spilled material without generating dust eg/ by using a shovel	_	_	_
Collect in plastic containers with tight fitting lids	_	_	_
Do not return spilled contaminated material to containers with pure material	_	_	_
Do not mix with combustible materials such as sawdust	_	_	_
Ensure any contaminated surfaces made from combustible materials such as wood or cardboard have the chemical completely removed or neutralised	_	_	_
Wash contaminated area with excess water	_	_	_
Dispose of in accordance with Local, State or Federal government regulations	_	_	_
Neutralise by careful reduction with acidic sodium thiosulfate solution, bisulfite or ferrous salts; after	_	_	_

Information	ammonium salt	sodium salt	potassium salt
reaction has finished carefully neutralise the aqueous solution with soda ash or hydrated lime slurry			
Fire/explosion hazard			
Extinguishing media: water jet, water fog, fine water spray	–	–	–
Firefighting procedures: firefighters to wear full body protective clothing and SCBA	–	–	–
Unusual fire or explosion hazards: may accelerate burning when involved in a fire; may decompose explosively when involved in a fire; containers may explode when heated; may ignite combustibles; if safe to do so remove containers from path of fire, otherwise cool fire exposed containers from a safe distance	✎	✎	✎
Hazardous decomposition products: oxides of sulfur, sulfuric acid, ammonia (ammonium salt), Na_2O (sodium salt), K_2O (potassium salt), ozone, oxygen (increases fire hazard)	✎	✎	✎
Contact point			
Title	✎	✎	✎
Telephone number	✎	✎	✎

Appendix 4

Assessment of MSDS for Hair Bleaching Formulations for Salon Use

design element**Information**	**Number of MSDS**	**Comments**
Statement of hazardous nature	6/12	
Emergency telephone no.	6/12	
Product Identification		
UN No.	4/12	
Use	5/12	
Ingredients		
Identity	12/12	
Proportion	12/12	
Physical description/properties		
Health Hazard Information		
Acute effects		
Harmful if swallowed	11/12	
Skin irritant	9/12	
Can cause contact urticaria and irritant contact dermatitis	0/12	
Eye irritant	8/12	
Respiratory irritant	10/12	
Can cause symptoms of rhinitis, bronchitis and/or asthma	8/12	
Chronic effects		
Skin sensitiser, can cause allergic contact dermatitis	4/12	
Respiratory sensitiser, can cause asthma, allergic rhinitis and bronchitis	4/12	
May cause pulmonary oedema or inflammation	0/12	
First Aid statements		
If swallowed rinse mouth with water; give water to drink; do NOT induce vomiting; seek medical attention without delay	9/12	

Information	**Number of MSDS**	**Comments**
If skin contact occurs, wash contaminated area thoroughly with water, remove contaminated clothing; if irritation persists seek medical attention	12/12	
If eye contact occurs, immediately flush with water for at least 15 minutes while holding eyelids apart; seek immediate medical attention	12/12	
If inhaled, remove subject to fresh air; if required, seek medical attention	12/12	
Advice to Doctor: Treat symptomatically	3/12	
Precautions for use		
Exposure standards		
Adequate information on the exposure standards	6/6	only for the Australian MSDS
Engineering controls		
Use local exhaust ventilation	6/12	some stated that use of general ventilation to keep dust level below TLV was adequate control
Personal protection		
Eye protection: safety glasses	9/12	
Mention of contact lenses: irritant absorption by soft lenses, irritant concentration by all lenses	1/12	
Hand protection (PVC or nitrile rubber gloves preferred)	12/12	
Respiratory protection (an approved half facepiece suitable for dusts)	3/12	
Protective clothing	3/12	
Safe handling information		
Storage and transport		
Store in cool place	11/12	
Store in dry place	5/12	
Keep container tightly closed	1/12	
Protect product from moisture	1/12	
Do not return unused product to original container	0/12	

Information	Number of MSDS	Comments
Store away from sources of heat or ignition, combustible materials (eg wooden pallets or cardboard), reducing agents, strong acids or alkalis. Do not allow to come into contact with rust, metal ions or metal salts	10/12	most MSDS had incomplete instructions in this section
Transport in accordance with the Australian Dangerous Goods Code. Not to be loaded with class 1, 2.1, 2.3, 3, 4, 5.2, 6, 7, 8, 9 or substances other than dangerous goods capable of combustion	3/12	
Spills and disposal		
Keep unnecessary personnel from the area of the spill	0/12	
Personnel involved in clean-up should wear PPE to prevent skin, eye and respiratory exposure	1/12	
Collect spilled material without generating dust eg/ by careful use of a dust pan and brush	3/12	
Collect in plastic containers with tight fitting lids	4/12	
Do not return spilled contaminated material to containers with pure material	0/12	
Do not mix with combustible materials such as sawdust	1/12	
Ensure any contaminated surfaces made from combustible materials such as wood or cardboard have the chemical completely removed or neutralised	1/12	
Wash contaminated area with excess water	5/12	
Dispose of in accordance with Local, State or Federal government regulations	10/12	
Fire/explosion hazard		
Extinguishing media: water jet, water fog, fine water spray	4/12	
Firefighting procedures: wear respiratory and eye protection	4/12	if the fire is major involving the whole salon firefighters will need to wear SCBA and protective clothing

Information	**Number of MSDS**	**Comments**
Unusual fire or explosion hazards: may accelerate burning when involved in a fire; may decompose explosively when involved in a fire; containers may explode when heated; may ignite combustibles; if safe to do so remove containers from path of fire, otherwise cool fire exposed containers from a safe distance	4/12	
Hazardous decomposition products: oxides of sulfur, sulfuric acid, ammonia (ammonium persulfate), Na_2O (sodium persulfate), K_2O (potassium persulfate), ozone, oxygen (increases fire hazard)	11/12	
Other information		
Mixtures of bleach powders and solutions containing hydrogen peroxide (9 and 12%) may produce heat when applied to hair. This may be further enhanced by the presence of metallic impurities such as aluminium in glitter sprays or other forms. Should a reaction occur remove mixture from the hair by rinsing at the basin. Do not mix with perm lotions	0/12	
Contact point	6/6	Australian MSDS only
Title	6/6	“
Telephone number	6/6	“

Appendix 5

SAMPLE MATERIAL SAFETY DATA SHEET

AMMONIUM PERSULFATE

Page x of Total y

Date of Issue

Ammonium persulfate is classified as Hazardous according to the National Occupational Health and Safety Commission’s *Approved Criteria for Classifying Hazardous Substances* [NOHSC:1008(1999)].

COMPANY DETAILS

Company Name:

Address:

Telephone Number:

Emergency Telephone Number:

Telex and Fax Numbers:

IDENTIFICATION

Chemical Name: Ammonium persulfate

Other Names: Peroxydisulfuric acid ($[(HO)S(O)_2]_2O_2$), diammonium salt;

Peroxydisulfuric acid (((HO)S(O)2)2O2), diammonium salt Ammonium peroxydisulfate;

Ammonium peroxodisulfate;

Diammonium peroxydisulfate;

Diammonium persulfate;

Bis(ammonium) peroxodisulfate

Manufacturer's Product Code:

UN Number: 1444

Dangerous Goods Class: 5.1

Subsidiary Risk:

Hazchem Code: 2W

Page x of Total y

Date of issue

Poisons Schedule Number: 6.

Packaging Group: III

Use: Oxidising agent in hair bleaches, hair colourants and hair lighteners.

PHYSICAL DESCRIPTION/PROPERTIES

Appearance: White or colourless crystalline solid, odourless

Odour: None

Melting Point: 120 deg C (decomposes)

Specific Gravity: 1.982 (water=1)

Vapour Pressure: not relevant

Flashpoint: not relevant

Flammability Limits: not relevant

Solubility in Water: 559 g/L at 20°C; 740 g/L at 50°C

OTHER PROPERTIES

Strong oxidising agent, can cause combustible materials to ignite. Can react vigorously with reducing agents.

Decomposes in the presence of moisture, gradually evolving ozone-containing oxygen; Decomposition on heating evolves oxygen and forms ammonium disulfate.

Aqueous solutions of ammonium persulfate are acidic (pH of a 1% solution is 4 – 6) and decompose slowly at room temperature; at higher temperature decomposition is rapid evolving oxygen and forming ammonium bisulfate.

Ammonium persulfate is shock sensitive.

INGREDIENTS

Chemical Entity	CAS Number	Proportion
Ammonium persulfate	7727-54-0	

Page x of Total y

Date of issue

HEALTH HAZARD INFORMATION

Acute

Low acute toxicity in animal studies.

Inhalation: Respiratory irritant. Symptoms may include shortness of breath, coughing, wheezing, tight chest.

Swallowed: Harmful if swallowed, based on acute oral studies in animals.

Eye: Eye irritant.

Skin: Skin irritant, can cause contact urticaria and irritant contact dermatitis. Symptoms may include itchiness, dryness or cracking, flushing, burning sensation, inflammation, erythema (redness), oedema (swelling). Symptoms may range from mild to severe.

Chronic

Skin sensitiser, can cause allergic contact dermatitis;

Respiratory sensitiser, can cause asthma, allergic rhinitis and bronchitis.

May cause pulmonary oedema or inflammation.

FIRST AID

Inhaled: If inhaled, remove subject to fresh air; if required, seek medical attention

Eye: If eye contact occurs, immediately flush with water for at least 15 minutes while holding eyelids apart; seek immediate medical attention

Skin: If skin contact occurs, wash contaminated area thoroughly with water, remove contaminated clothing; if irritation persists seek medical attention

Swallowed: If swallowed rinse mouth with water; give water to drink; do NOT induce vomiting; seek medical attention without delay

First Aid Facilities: Eye wash and safety shower should be available in the workplace where this product is used

Page x of Total y

Date of Issue

ADVICE TO DOCTOR

Treat symptomatically

PRECAUTIONS FOR USE

Exposure Standards: No Australian exposure standard has been allocated. The American Conference of Governmental Industrial Hygienists (ACGIH) have allocated a threshold limit value of 0.1 mg/m^3 TWA.

Engineering Controls: Use local exhaust ventilation. Avoid generating dust. During formulation ambient temperature and humidity should be monitored as well as the temperature of the blend. If blend becomes too hot remove to well ventilated area to cool.

Personal Protection:

Avoid contact with skin;

Wear protective gloves;

Wear an approved half face mask suitable for dusts;

Wear a face shield or chemical goggles;

Wear protective clothing; and

Do not wear contact lenses as they may trap irritant particles and cause irritation to eyes.

Flammability

Not flammable, however contact with combustible materials may cause fire.

Page x of Total y

Date of issue:

SAFE HANDLING INFORMATION

Storage and Transport

Store in a cool and dry place away from source of heat or ignition. Keep away from combustible materials (eg wooden pallets or cardboard), reducing agents, strong acids or alkalis. Do not allow to come into contact with rust, metal ions or metal salts.

Keep container tightly closed. Protect product from moisture. Do not return unused product to original container.

Store in polyethylene lined containers.

Store in accordance with Dangerous Goods (Storage and Handling) Regulations and AS 4326 Storage and Handling of Oxidising Agents

Do not store scoops in the same container to minimise skin contact.

Correct shipping name: Ammonium persulfate

Dangerous Goods Class 5.1.

Packaging Group III

Transport in accordance with the Australian Dangerous Goods Code.

Shock sensitive – protect from shock.

Spills And Disposal

Keep unnecessary personnel from the area of the spill.

Remove any ignition source that may ignite combustible materials contaminated with ammonium persulfate.

Personnel involved in clean-up should wear PPE to prevent skin, eye and respiratory exposure.

Collect spilled material without generating dust eg/ by using a shovel.

Collect in plastic containers with tight fitting lids.

Do not return spilled contaminated material to containers with pure material.

Do not mix with combustible materials such as sawdust.

Ensure any contaminated surfaces made from combustible materials such as wood or cardboard have the chemical completely removed or neutralised.

Wash contaminated area with excess water.

Page x of Total y

Date of issue:

Neutralise by careful reduction with acidic sodium thiosulfate solution, bisulfite or ferrous salts; after reaction has finished carefully neutralise the aqueous solution with soda ash or hydrated lime slurry.

Dispose of in accordance with Local, State or Federal government regulations.

Fire/Explosion Hazard

May ignite combustibles; explosion hazard when mixed with reducing agents, finely powdered organic matter, metal powder (particularly aluminium plus water), or sodium peroxide. A violent reaction occurs with iron or solutions of ammonia + silver salts.

May accelerate burning when involved in a fire; may decompose explosively when involved in a fire; containers may explode when heated; if safe to do so remove containers from path of fire, otherwise cool fire exposed containers from a safe distance.

Extinguishing media: water jet, water fog, fine water spray

Firefighting procedures: firefighters to wear full body protective clothing and SCBA

Hazardous decomposition products: oxides of sulfur (SO_x), oxides of nitrogen (NO_x) ammonia (ammonium salt), oxygen (increases fire hazard).

Hazchem code: 2W

OTHER INFORMATION

Oral LD_{50} range of 600-820 mg/kg.(male rat)

Oral LD_{50} = 495(female rat)

Dermal LD_{50}>2,000 mg/kg (rat);

Dermal LD_{50}>10,000 mg/kg (rabbit)

Inhalation LC_0 = 2.95 mg/L (4-hr exposure, 97% dust particles<10μm)(male rat);

Inhalation LC_{50}=520 mg/L (1-hr exposure) (rat)

Inhibits intracellular calcium uptake and accelerates calcium release in rat heart cells producing raised cystolic calcium concentration and cell contracture.

CONTACT POINT

Title:

Telephone Number:

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