HEALTH RISK ASSESSMENT: DISHWASHER POWDER

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by

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GLOSSARY

Acute toxicity	1. *Adverse effects* of finite duration occurring within a short time (up to 14 d) after administration of a single *dose* (or *exposure* to a given *concentration*) of a test substance or after multiple doses (exposures), usually within 24 h of a starting point (which may be exposure to the *toxicant*, or loss of reserve capacity, or developmental change, etc.) 2. Ability of a substance to cause *adverse effects* within a short time of dosing or *exposure*
Adverse effect	A change in biochemistry, physiology, growth, development morphology, behaviour, or lifespan of an organism which results in impairment of functional capacity or impairment of capacity to compensate for additional stress or increase in susceptibility to other environmental influences
Alkaline	The property of having a pH of greater than seven (pH7)
Alkali	Inorganic compounds, which are water soluble hydroxides of the group 1 metals; or ammonium hydroxide.
Carcinogenicity	The ability to produce cancer
Caustic	Burning or corrosive; destructive to living tissues
Chronic toxicity	Ability of a substance to cause *adverse effects* after repeated *exposure* over a long period
Corrosive	Producing gradual destruction of tissues by the action of a strong acid or alkali
Critical effect level	A defined point on the dose-response curve for an adverse effect, such as a no observed adverse effect level or a LD_{50}
Dermal	Cutaneous, pertaining to the skin
Developmental toxicity	The ability to cause of adverse effects on a developing organism attributed to exposure to a substance before conception, *in utero*, after birth, or during sexual maturation
Dose	Total amount of a substance administered to, taken up, or absorbed by an organism, organ, or tissue
Dose response	Association between dose and the incidence of a defined biological effect in an exposed population
Dose response assessment	Analysis of the relationship between the total amount of an agent administered to, taken up by, or absorbed by an organism, system, or (sub)population and the changes developed in that organism, system, or (sub)population in reaction to that agent, and inferences derived from such an analysis with respect to the entire population. Dose–response assessment is the second of four steps in risk assessment
Erythema	Redness of the skin due to congestion of the capillaries

Exposure assessment	Evaluation of the exposure of an organism, system, or (sub)population to an agent (and its derivatives). Exposure assessment is the third step in the process of risk assessment.
Gastrostomy	Surgical procedure involving inserting of a tube through the abdominal wall into the stomach
Genotoxicity	Causing damage to DNA
Hazard identification	The identification of the type and nature of adverse effects that an agent has an inherent capacity to cause in an organism, system, or (sub)population. Hazard identification is the first stage in hazard assessment and the first of four steps in risk assessment.
Hyperplasia	Abnormal increase in the number of normal cells in an organ or tissue, which increases its volume
Hypertrophy	Enlargement or overgrowth of an organ or part due to increase in size of its constituent cells
Hypocalcaemia	Abnormally low levels of calcium in the circulating blood
Incidence	Number of occurrences of illness commencing, injury, or of persons falling ill, during a given period in a specific population usually expressed as a rate
Irritant	Producing inflammation or irritation
LC_{50}	The average concentration of a substance in air that is capable of killing half of the test animals exposed by inhalation under specific test conditions
LD_{50}	The average dose of a substance that is capable of killing half of the test animals exposed under specific test conditions
Margin of exposure	Ratio between a defined point on the dose-response curve for an adverse effect and the human exposure
Mutagenicity	The ability to cause genetic mutation (permanent changes to DNA)
Necrosis	Morphological changes indicative of cell death
Nephrocalcinosis	Precipitation of calcium phosphate in the renal tubules
No observed adverse effects level (NOAEL)	Greatest concentration or amount of a substance, found by experiment or observation, that causes no alterations of morphology, functional capacity, growth, development, or life span of target organisms distinguishable from those observed in normal (control) organisms of the same species and strain under the same defined conditions of exposure
Ocular	Pertaining to the eye
Oedema	Abnormal accumulation of fluid in the interstitium, which are locations beneath the skin or in one or more cavities of the body, presenting as swelling

Oesophageal	Of or relating to the oesophagus
Oral	Pertaining to or via the mouth
Reproductive toxicity	The ability to cause an adverse effect on the reproductive system, including changes in fertility, pregnancy outcomes or modification of functions that depend on reproductive integrity
Risk characterisation	The qualitative and, wherever possible, quantitative determination, including attendant uncertainties, of the probability of occurrence of known and potential adverse effects of an agent in a given organism, system, or (sub)population, under defined exposure conditions. Risk characterization is the fourth step in the risk assessment process.
Sensitisation	To make hypersensitive or reactive to a substance, particularly by repeated exposure
Toxicological endpoints	An observable or measurable biological event or chemical concentration (e.g., metabolite concentration in a target tissue) used as an index of an effect of a chemical exposure
Tracheostomy	Creation of an opening through the neck into the trachea

EXECUTIVE SUMMARY

The purpose of this report is to develop a generic health risk assessment for automatic dishwasher powder. This report will only consider domestic, non-occupational, routine and incidental exposure to automatic dishwasher powder. In some instances, occupational exposure information will be used to contextualise non-occupational exposures, specifically in terms of adverse health outcomes and critical exposure levels.

Exposure to dishwasher powder does not appear to be a major cause of poisoning in New Zealand. While a series of hospitalised child cases was reported in New Zealand prior to 2006, the introduction of a Group Standard in 2006, under the Hazardous Substances and New Organisms Act 1996, restricting the pH of dishwasher powders, appears to have impacted on the occurrence of poisonings.

Internationally there appears to be little evidence that dishwasher powders are a major cause of poisonings. The comprehensive information provided from the United States over a long period of time found that dishwasher powder or tablets were responsible for only 0.2-0.25% of exposure incidents. Severe outcomes from exposure to these products were extremely rare.

While a very wide range of chemical ingredients may be present in dishwasher powders, it appears that the ingredients most commonly present that may be of health concern are sodium carbonate, sodium tripolyphosphate (STPP), sodium percarbonate and alcohol ethoxylates (AEs).

Scenarios for acute oral ingestion and inhalation exposure were formulated and systemic exposure assessments for young children (1-2 years) and adults were assessed by margin of exposure (MoE) analysis against acute critical effect levels derived from animal lethality data for dishwasher powder. Margins of exposure for inhalation of dust from dishwasher powder were all in excess of 20 million, suggesting that adverse health effects due to this route of exposure under normal use conditions are unlikely. However, margins of exposure for the scenario of direct oral ingestion of dishwasher powder by a young child were less than five, suggesting potential for severe adverse health effects due to this route of exposure.

While there is the potential for chronic oral exposure to dishwasher powder residues, due to material remaining on washed dishes, the estimated exposures are well below the maximum tolerable daily intake (MTDI; 550 mg/kg bw) for dishwasher powder, derived from the MTDI for STPP.

There is little evidence to suggest that exposure to the dishwasher powder will result in severe local effects to the skin or eyes, although there is potential for serious eye injury from dishwasher powders containing high levels of sodium percarbonate. It should be noted that high sodium percarbonate concentrations appear to be associated with tablet-type formulations and eye contact with these products appears less likely than for powdered products.

1. INTRODUCTION

The purpose of this report is to develop a generic health risk assessment for automatic dishwasher powder. This report will only consider domestic, non-occupational, routine and incidental exposure to automatic dishwasher powder. In some instances, occupational exposure information will be used to contextualise non-occupational exposures, specifically in terms of adverse health outcomes and critical exposure levels. Exposure scenarios will be developed for the most common or likely exposure events to assess the health risk for vulnerable groups.

1.1. Consumer Products Description – Dishwasher Powder

For the purpose of the current report 'dishwasher powder' will be taken to mean dishwasher detergent preparations in either powder or tablet form, but does include gel-based formulations. Gel-based products do not appear to be common in New Zealand.

Dishwasher powders may contain a large range of chemicals, included to breakdown, remove and prevent redeposition of food residues on dishes. Major components will usually be alkaline 'builder' salts, chlorine-contributing compounds (bleach), surfactants and enzymes.

The major dishwasher powder brands in New Zealand are Finish (manufactured by Reckitt Benckiser) and Active (a New Zealand brand manufactured by Quantum Pacific). Reckitt Benckiser New Zealand Ltd is leading the overall category with a value share of 39% in 2012, solely driven by the Finish brand operating in the automatic dishwashing powders, tablets and additives categories. Finish was ranked first in dishwashing tablets with a value share of 83% (Euromonitor International 2013). Publicly available information on the composition of major dishwasher products available in New Zealand is summarised in Table 1. It should be noted that for most brands compositional information was not available and the information in Table 1 should not be viewed as comprehensive.

Table 1: Ingredient composition of dishwater powders and tablets commonly used in New Zealand

Brand name	Manufacturer	Ingredients	Proportion (%)	Function
Finish® powder[1] (pH = 10.8)	Reckitt Benckiser	Sodium carbonate	30-60	Complexing agent
		Sodium sulphate		Solvent
		Sodium citrate		Complexing agent
		Water		Diluent
		Sodium silicate	1-5	Complexing agent
		Sodium carbonate peroxide	1-5	Bleaching agent
		Alcohol ethoxylates		Surfactant
		Sodium polyacrylate		Anti-redeposition agent
		Tetracetylethylenediamine		Bleach activator
		Fragrance		Fragrance
		Subtilisin	<0.01	Enzyme
		Kaolin		Solvent
		Titanium dioxide		Solvent
		Polyethylene glycol		Solvent
		Microcrystalline cellulose		Polymer
		Amylase		Enzyme

Brand name	Manufacturer	Ingredients	Proportion (%)	Function
Finish® Powerball tablets[1] (pH = 9.5)	Reckitt Benckiser	Sodium carbonate	20-40	Complexing agent
		Sodium bicarbonate		Complexing agent
		Sodium carbonate peroxide	10-20	Bleaching agent
		Polyethylene glycol		Solvent
		Sodium polyacrylate		Anti-redeposition agent
		Tetracetylethylenediamine		Bleach activator
		Alcohol polyglycolether		Surfactant
		Trisodium Dicarboxymethyl alaninate		Complexing agent
		Microcrystalline cellulose		Polymer
		Citric acid		Complexing agent
		Tetrasodium etidronate		Complexing agent
		Sucrose		Sweetener
		Sodium silicate		Complexing agent
		Subtilisin	<1	Enzyme
		Starch		Filler
		Glycerin		Humectant
		Manganese oxalate		Bleach activator
		Titanium dioxide		Solvent
		Water		Diluent
		Hydroxypropyl methyl cellulose		Binder
		Fragrance		Fragrance
		CI pigment blue 29		Colourant
		Alcohol ethoxylates		Surfactant
		CI pigment red 57		Colourant
		Magnesium stearate		Organic
		Benzotriazole		Preservative
		Kaolin		Solvent
		Sodium sulphate		Solvent
		Acid blue 182		Colourant
		Amylase	<0.1	Enzyme
Finish® Powerball Quantum tablets[1] (pH = 10.5)	Reckitt Benckiser	Sodium carbonate	20-40	Complexing agent
		Sodium carbonate peroxide	20-30	Bleaching agent
		Sodium citrate	10-20	Complexing agent
		Polyvinyl alcohol, partially hydrolysed	2.5-10	Adhesive
		Alcohols ethoxylated propoxylated	2.5-10	Surfactant
		2-propenoic acid, telomer with sodium hydrogen sulphite		Polymer
		Ethylene/propylene oxide copolymer		Polymer
		Tetracetylethylenediamine		Bleach activator
		Sodium polycarboxylate		Anti-redeposition agent
		Sorbitol		Humectant
		Polyvinyl alcohol		Dissolvable film
		Propylene glycol		Solvent
		Sucrose		Sweetener
		Trimethylolpropane		Organic
		Sodium silicate		Complexing agent
		Water		Diluent
		Starch		Filler
		Tetrasodium etidronate		Complexing agent
		Subtilisin	0.1-1	Enzyme
		Polyethylene glycol		Solvent
		Proprietary inert filler		Filler

Brand name	Manufacturer	Ingredients	Proportion (%)	Function
		Titanium dioxide	0.1-1	Solvent
		Polydimethylsiloxane		Filler
		Fragrance		Fragrance
		Hydroxypropyl methyl cellulose		Binder
		Alcohol ethoxylate		Surfactant
		Amylase	<0.1	Enzyme
		Octadecanamide		Lubricant
		Calcium stearate		Organic
		Silica		Inorganic
		Kaolin		Solvent
		Sodium sulphate		Solvent
		Microcrystalline cellulose		Polymer
		Zinc stearate		Organic
		Calcium carbonate		pH adjustor
		CI pigment violet 75		Colourant
		CI acid red 18		Colourant
		Carbonyl diamine		pH adjustor
Ecostore auto dish powder[2]	Ecostore Company Limited	Sodium carbonate Sodium citrate Sodium bicarbonate Sodium percarbonate Alcohols, ethoxylated and propoxylated Sodium polyaspartate Protease Amylase Fragrance		
Ecostore auto dishwash tablets[2]	Ecostore Company Limited	Sodium carbonate Sodium citrate Sodium bicarbonate Sodium percarbonate Sodium disilicate Sorbitan sesquioctanate Tetracetylethylenediamine Amylase Protease Sodium polyaspartate Glycerin Polyvinyl alcohol Fragrance		

[1] http://www.rbnainfo.com/productpro/ProductSearch.do?brandId=16&searchType=CAT&template=1
[2] http://www.ecostore.co.nz/

Until July 2007, New Zealand regulations permitted the sale of highly caustic formulations of dishwashing powders. Since then the Cleaning Product (corrosive) Group Standard (2006) provisions of the Hazardous Substances and New Organisms (HSNO) Act (1996) has come into effect, which prohibits the sale of powders with a pH of greater than 12.5. While this removed very caustic powders from New Zealand homes, automatic dishwashing powders with pH less than 12.5 remain caustic substances that may cause potentially life-threatening injuries (Safekids New Zealand 2007).

This report only considers domestic, non-occupational routine and incidental exposure to dishwasher powder. Exposure scenarios have been developed for the most common or likely exposure events to assess the health risk for vulnerable groups.

2. HAZARD IDENTIFICATION

2.1. Dishwasher Powder

The alkalinity of the ingested dishwasher product strongly determines the severity of resulting injuries. The degree of tissue injury depends on pH, concentration, physical state, and duration and volume of exposure (Bertinelli et al 2006; Kikendall 1991). It has been demonstrated that solutions at pHs <11.5 have no damaging effects on the oesophagus (Atug et al 2009). At pH 11.5 or higher, the damage was both time- and pH-dependent. Dishwasher detergents containing silicate or metasilicate were most alkaline and thus most corrosive, whereas products containing enzymes and oxygen bleaches were found to keep the pH at lower and hence safer levels (Bertinelli et al 2006).

2.1.1. Previous assessments

No previous assessments of formulated dishwasher powders were found.

2.1.2. Relevant toxicological studies

No toxicological information was found for formulated dishwasher powders.

2.1.3. Observations in humans

Case reports

A case of reactive airway dysfunction syndrome (RADS) caused by acute exposure to dishwater detergent containing sodium metasilicate and sodium dichloroisocyanurate has been described (Hannu et al 2012). A 43-year-old apprentice cook developed respiratory symptoms immediately after exposure to a cloud of detergent powder that was made airborne by vigorous shaking of the package. The diagnosis of RADS was based on the concurrent emergence of persistent respiratory symptoms, chronic occurrence of mild bronchial obstruction (both obstruction and restriction) and persistent bronchial hyper-reactivity in follow-up lung examinations.

Incident surveillance and epidemiological studies

New Zealand

In New Zealand, data on hazardous substance exposure incidents is collated in the Hazardous Substances Surveillance System (HSSS) by the Massey University Centre for Public Health Research (CPHR). For the period 2006 to 2011, 5,827 incidents were reported to HSSS. None of these unambiguously identified dishwasher products as the causal agent. Descriptors such as ‘soaps and detergents’ (n = 120) may include cases related to dishwasher powder, but this could not be confirmed.

Information was provided by the New Zealand National Poisons Centre (NPC)[1] on the 20 substances accounting for most calls to the centre for each year during the period from 2008 to 2012. Finish® dishwasher powder was in this 'top 20' list for 2008 (24 enquiries) and 2009 (50 enquiries), but not in subsequent years. Active dishwasher powder accounted for 40 enquiries in 2011. This contrasts with earlier NPC data, that between January 2003 and January 2005, 610 dishwasher powder ingestions were reported, with 88% relating to children less than two years old (Bertinelli et al 2006).

No fatalities due to ingestion of dishwasher powder were reported in coronial data in New Zealand in the period 2006 to 2009.

Of 23 children admitted to Starship Children's' Hospital from January 2003 to January 2005 following caustic ingestion, 11 were identified as having ingested dishwasher powder (Bertinelli et al 2006). The mean age of the 11 cases was 17.5 months. Five (45%) of children were admitted to the paediatric intensive care unit. Two children needed tracheostomy. Three of the 11 children (27%) required repeated oesophageal dilatation, and two underwent gastrostomy formation. One brand of dishwasher detergent and container type was implicated in over half of the cases. The pH of the products involved in most of these cases was very high (13.3-13.4). It should be noted that, subsequent to this study, the Cleaning Products (Corrosives) Group Standard 2006, issued under the Hazardous Substances and New Organisms Act 1996, does not allow sale to the public of automatic dishwashing products with pH greater than 12.5 (Environmental Risk Management Agency 2010).

A survey carried out in 2012 found that only one of 19 automatic dishwashing products had a measured pH (500 g/L solution) of greater than 12.5 (Consumer NZ 2012).

A 10-year review of eye trauma cases at Waikato Hospital found that 61 of 821 (7.4%) cases were due to chemical exposures (Pandita and Merriman 2012). The majority of chemical eye injuries (82%) occurred at work and involved NaOH or sodium hypochlorite. Chemical injuries in the home (18%) were usually due to cleaning agents. However, no details of the types of cleaning agents involved were given.

Australia

A case series (n = 50) of paediatric caustic ingestion cases at Children's Hospital, Westmead was reviewed (Riffat and Cheng 2009). Overall, 74% of causative agents were alkali, with major contributors being dishwashing powder, disinfectants, oven cleaner and degreasers.

A retrospective case series study of caustic ingestion cases was carried out at the Royal Children's Hospital, Melbourne, covering the period 1993-2003 (Turner and Robinson 2005). Of the 32 incidents of caustic ingestion, dishwashing tablets/powder accounted for 10 incidents (31%). The median age of cases of dishwasher powder poisoning was 20 months, compared to an overall median for all poisonings of 31

[1] http://www.poisons.co.nz/index.php Accessed 23 January 2014

months. Cases were predominantly male (8/10). While symptoms and outcomes were described, it was not possible to relate these to particular causative agents.

Canada

Case histories of children (*n* = 80) presenting at the Department of Otolaryngology, The Hospital for Sick Children, Toronto with caustic burns of the aerodigestive tract between 1965 and 1995 were reviewed (de Jong et al 2001). Ages ranged from 1 to 15 years, with 78% of cases between one and three years. Dishwasher powder was not mentioned as a major causative agent. The most common causative agent was drain cleaner (29 cases). The majority of burns (54%) were confined to the oral cavity, with only one case with documented gastric injury.

United States

The American Association of Poison Control Centers (AAPCC) supports the United States network of 56 poison centres.[1] The association publishes an annual report including summary statistics of all exposures reported to the poison centres during a calendar year. Table 2 summarises the data for granular (powdered) or tablet automatic dishwasher products for the period 2002-2011.

Some distinct patterns of dishwasher product poisoning incidents are apparent from this table:

- Granular or tablet dishwasher products are involved in approximately 0.20-0.25% of all exposure events reported to US poison centres;
- The majority of those involved in dishwasher product exposure incidents (approximately 85%) are children less than six years of age;
- The vast majority (>97%) of reports of dishwasher product exposure relate to unintentional exposure. Of the more than two million total exposures reported each year, intentional exposures account for approximately 15% of exposures, with suicidal intent suspected in approximately two-thirds of intentional exposures;
- Most dishwasher product exposures result in minor or no injury. Less than 0.1% of exposures result in major injuries and only one death was reported in the 10-year period covered.

A retrospective case series (*n* = 633) of consecutive cases of chemical eye injury presenting at the emergency department at a large eye hospital in Alabama between January 2006 and December 2009 was reviewed (Blackburn et al 2012). The most common class of agents involved in chemical eye injuries were household cleaning agents (28.6% of cases). While this category included six cases of injury due to 'dishwashing soap', it is uncertain whether this included any cases due to dishwasher powder. Chemical eye injuries due to household cleaning products involved cases with an average age of 32.8 years.

[1] http://www.aapcc.org/ Accessed 25 November 2013

Table 2: Incidents of dishwasher powder poisoning reported to US poison centres 2002-2011

Year[1]	Exposures reported		Age (years)					Reason				Treated in healthcare facility	Outcome[3]				
	Total	**Dishwasher powder**	**<6**	**6-12**	**13-19**	**>19**	**Unknown**	**Unint**	**Int**	**Other**	**Adv Rxn**		**None**	**Minor**	**Mod**	**Major**	**Death**
2002	2380038	Granular 4450 Tablet 789	3733 728	137 13		565 47		4411 786	18 2	14 1	6 0	204 29	1398 296	697 89	41 1	3 0	0 0
2003	2395582	4310 787	3638 714	117 17		537 54		4270 786	22 0	11 0	5 1	177 23	1389 271	626 101	46 4	1 0	1 0
2004	2438644	4480 1738	3765 1635	138 25		559 77		4446 1731	14 4	16 3	3 0	187 53	1461 610	588 241	30 10	1 0	0 0
2005	2424180	4755 1504	4008 1420	133 22		597 58		4702 1501	25 2	21 0	4 1	165 48	1499 552	552 203	25 4	0 0	0 0
2006[2]	2403539	4606 1472	3811 1368	152 32		448 50		4494 1454	15 3	24 7	7 0	155 61	1357 480	566 194	21 8	0 0	0 0
2007	2482041	4013 1826	3330 1717	113 22		416 62		3919 1812	17 2	19 2	5 0	143 63	1126 525	460 252	20 5	0 0	0 0
2008	2491049	3600 1866	3015 1742	90 33		335 63		3502 1843	14 3	15 4	5 3	118 67	1008 565	459 245	20 1	1 0	0 0
2009	2479355	3567 1765	2992 1654	44 14	39 11	365 58	84 17	3489 1749	15 3	15 2	4 0	114 62	902 418	347 182	22 5	0 0	0 0
2010	2384825	3041 1552	2454 1439	44 11	39 12	373 58	87 18	2954 1532	14 2	24 4	4 0	119 45	720 397	344 189	21 1	1 0	0 0
2011	2334004	2760 1928	2285 1799	43 16	33 12	282 77	74 10	2679 1910	17 3	15 1	3 0	93 70	684 468	322 249	14 7	0 0	0 0

Unint = unintentional exposures, including passive environmental exposure, occupational exposure, therapeutic error or unintentional misuse

Int = intentional exposures, including suspected suicide and improper or incorrect use of a substance for a purpose other than its intended purpose

Adv Rxn = adverse reaction, an adverse event occurring with normal, prescribed, labelled, or recommended use of the product, as opposed to overdose, misuse, or abuse, including allergic, hypersensitive and idiosyncratic reactions

Mod = moderate

[1] Report references: (Bronstein et al 2007; Bronstein et al 2008; Bronstein et al 2009; 2010; Bronstein et al 2011; Bronstein et al 2012; Lai et al 2006; Watson et al 2003; Watson et al 2004; Watson et al 2005)

[2] From 2006 onwards there was a change in the way demographic information was reported; the ‘Alkaline Drain Cleaner’ exposure count represents all recorded exposures, but the counts in subsequent columns report single substance exposures only. Over all exposures, single substance exposures account for just over 90% of all exposures

[3] Minor = The patient developed some signs or symptoms as a result of the exposure, but they were minimally bothersome and generally resolved rapidly with no residual disability or disfigurement. A minor effect is often limited to the skin or mucus membranes.

Moderate = The patient exhibited signs or symptoms as a result of the exposure that were more pronounced, more prolonged, or more systemic in nature than minor symptoms. Usually, some form of treatment is indicated. Symptoms were not life-threatening, and the patient had no residual disability or disfigurement
Major = The patient exhibited signs or symptoms as a result of the exposure that were life-threatening or resulted in significant residual disability or disfigurement

Denmark

Case information for children less than 16 years (*n* = 102) admitted for caustic ingestion during the period 1976-1991 in the county of Aarhus, Denmark was reviewed (Christesen 1994). The age of cases showed a peak at 19 months, with 94% of cases less than 5 years of age. All ingestions were accidental and male cases outnumbered female cases by 1.5:1. Automatic dishwasher detergent accounted for 32 incidents (31.1%).

Finland

A retrospective analysis was carried out of children hospitalised due to acute poisoning at the Oulu University Hospital, Finland between 1991 and 2010 (Hoikka et al 2013). Of 334 hospital admissions, dishwasher powder was responsible for 31 cases (9.3%) and was the most common non-pharmaceutical cause of acute poisoning. However, the number of acute poisoning cases due to dishwasher powder decreased from 19 cases in 1991-1995, to eight cases in 1996-2000, and to three cases in 2001-2005. Only one case of acute poisoning due to dishwasher powder was recorded for the period 2006-1010. The study authors suggested that this decrease may have been due to the introduction of child-resistant packaging (CRP) and reformulation of products to make them more irritant, but less corrosive. The move to less corrosive products in Finland is consistent with the changes made in New Zealand as part of the Cleaning Products (Corrosives) Group Standard 2006, issued under the Hazardous Substances and New Organisms Act 1996, restricting the pH of automatic dishwashing products to less than 12.5

Spain (Galicia)

Case histories of children (*n* = 743) presenting at the Paediatric Department of the General Hospital of Galicia over the period January 1981 to December 1990 for suspected ingestion of caustic substances were reviewed (Casasnovas et al 1997). The mean age of cases was 27 months, with 85% of cases less than three years of age. Cases were approximately twice as likely to be male as female. Dishwasher powder was the caustic substance ingested in 3% of cases, with bleach being the most commonly ingested substance (73%). Most ingestions were of liquid products. However, ingestion of solids was more likely to result in oesophageal burns. While only 20% of all cases resulted in oesophageal burns, 59% of dishwasher powder ingestion cases resulted in burns. This was the highest proportion of burns for any product type.

Turkey

Case histories of children (*n* = 75) managed in Yuzuncu Yil University, School of Medicine, Van, Turkey for corrosive substance ingestion were reviewed (Melek et al 2008). The mean age of cases was 3.5 years, with 82% of cases less than five years of age. Three cases were described as being due to ‘dishwasher polisher’, but this seems unlikely to equate to dishwasher powder. The most commonly ingested corrosive substance was bleach (45% of cases). Ingested volumes of corrosive substance were in the range 1 to 100 ml.

A retrospective study of children (*n* = 320) referred to the Pediatric Emergency Department of Eskisehir Osmangazi University Hospital in 2009 for acute poisoning was conducted (Sahin et al 2011). Drugs were the most common cause of intoxication, followed by corrosive substances (23.1%). Corrosive ingestion cases were more likely to be under 4 years of age, but no specific substances were identified.

Cases (*n* = 182) admitted to the Department of Emergency Medicine, Dokuz Eylul University Hospital in Izmir due to caustic and household detergent exposure between 1993 and 2008 were reviewed (Arıcı et al 2012). Caustic exposures accounted for 8.5% of childhood cases and 4.1% of adult cases. Most of the cases were unintentional (96% of child cases, 76% of adult cases). Alkaline substances accounted for 58% of cases, with dishwasher detergents the causative agent in 16 cases (8.8%), although it is uncertain whether these were powders or liquid products.

United Kingdom

A prospective survey of accidental childhood poisonings (*n* = 2043) was carried out through nine accident and emergency departments and five paediatric departments, between July 1982 and February 1984 (Wiseman et al 1987). Most cases (75%) were two and three year olds, with 56% being males. Household products were responsible for 37% of cases. The most commonly reported household products involved in childhood poisonings were bleach, detergents, disinfectants and petroleum distillate. Insufficient detail was provided to determine if detergents included dishwasher powders.

Between 1 March 2008 and 30 April 2009, the United Kingdom National Poisons Information Service (NPIS) prospectively collected 5939 telephone enquiries related to household cleaning products (Williams et al 2012). The majority of enquiries (65.5%) concerned children 5 years or less. Dishwasher products accounted for 399 enquiries (6.7%). The severity of outcomes was assessed using a poisoning severity score (PSS), ranging from zero (no outcome) to three (severe outcome) (Persson et al 1998). Dishwasher product incidents only accounted for 1.3% of moderate outcomes (PSS = 2) and no serious outcomes (PSS = 3). In other words, all but one of the dishwasher product incidents resulted in minor outcomes (PSS = 1) or no outcome (PSS = 0).

Chemical eye injuries presenting to the Croydon Eye Unit during a 14-month period (1 January 1985 to 28 February 1986) were analysed (Morgan 1987). Of 180 cases, 47 were due to exposure to alkalis. However, a breakdown of these injuries by product type did not identify dishwasher products as a significant contributor.

Iran

A prospective case series of caustic substance ingestion cases admitted to the emergency ward of the Loqman-Hakim hospital, Tehran was examined (Yeganeh et al 2009). Of 1260 cases admitted between April 1999 and January 2006, 62 fatalities occurred (42 men, 20 women). Fatal cases were in the age range 15 to 107 years. Dishwasher products were not reported as a cause of any fatality.

Israel

Records for cases admitted to the Hadassah Hebrew University Hospital, Jerusalem between 1988 and 2003 due to ingestion of caustic substances were reviewed (Arevalo-Silva et al 2006). Of the 50 cases identified, 25 were children under 5 years of age. All childhood cases involved accidental ingestion, while approximately two-thirds of the adult cases were attempted suicides. Alkaline substances were the most common agents involved. Injuries were more serious in cases of attempted suicide and incidents involving ingestion of acidic substances. Injuries to children were predominantly first degree (57%) or second degree (36%), with no fourth degree injuries.[3]

South Africa

Childhood poisoning incidents (*n* = 2,872) presenting to the Red Cross War Memorial Children's Hospital (RCWMCH) in Cape Town, South Africa, from 2003 to 2008 were reviewed (Balme et al 2012). Household cleaning products contributed the fourth largest number of incidents, after paraffin, drugs and pesticides. There were 299 incidents associated with household cleaning products. However, dishwasher powder was not specifically mentioned and the products contributing most often to this category of incidents were bleach, oven cleaner, drain cleaner and floor cleaner. Poisonings due to household cleaning products were general of low severity, with no fatalities reported.

Summary

Exposure to dishwasher powder does not appear to be a major cause of poisoning in New Zealand. While a series of hospitalised child cases was reported in New Zealand prior to 2006 (Bertinelli et al 2006), the introduction of a Group Standard in 2006, under the Hazardous Substances and New Organisms Act 1996, restricting the pH of dishwasher powders, implemented controls that appear to have impacted on the occurrence of poisonings.

Internationally, there appears to be little evidence that dishwasher powders are a major cause of poisonings. The comprehensive information provided from the United States over a long period of time found that dishwasher powder or tablets were responsible for only 0.2-0.25% of total reported exposure incidents. Although the vast majority of these cases were children, severe outcomes from exposure to these products were extremely rare.

Across the various studies summarised, it appears that accidental ingestion of dishwasher powders and related products is more likely to involve the very young, while eye injuries seem to be more prevalent amongst adults.

[3] In this study oesophageal damage was graded as; first degree – mucosal erythema, second degree – erythema with circumferential exudates, third degree – circumferential exudates, and fourth degree – circumferential exudates with oesophageal wall perforation

2.2. Individual Components of Dishwasher Powders

No previous assessment or toxicological information was found for formulated dishwasher powders. Therefore, the toxicity of these products must be considered in terms of the toxicity of their component chemicals.

Dishwashing powders may contain a wide range of chemicals and it is not possible, within the scope of the current project, to assess the potential impact of all possible ingredients. Analysis of ingredients identified in material safety data sheets (MSDSs) for a range of dishwashing powders from different manufacturers identified four ingredients that were present in most formulations. These were; sodium carbonate, sodium tripolyphosphate, sodium percarbonate, and alcohol ethoxylates/ propoxylates.

2.2.1. Sodium carbonate

Sodium carbonate (CAS 497-19-8; soda ash, carbonic acid disodium salt, or disodium carbonate) is used as a builder in detergent powders and tablets. Builder compounds increase the detergency of the product through various mechanisms. Sodium carbonate contributes to the action of the product by softening water through the precipitation of calcium and magnesium, as their respective carbonates. Dishwasher powders or tablets usually contain between 10% and 60% sodium carbonate (Reckitt-Benckiser 2014).

Sodium carbonate is a strong alkaline compound with a pH of 11.6 for a 0.1M aqueous solution (Johnson and Swanson 1987). When sodium carbonate comes into contact with body fluids it dissociates into carbonate and sodium ions. The carbonate ions will react with water, establishing equilibrium between the carbonate and bicarbonate ions.

$$CO_3^{2-} + H^+ \leftrightarrow HCO_3^-$$
$$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$$

Carbon dioxide is the dominant species in solution at low pH, while the carbonate ion is the dominant species at pHs greater than 10.33 (OECD-SIDS 2002). The bicarbonate ion is the dominant species at intermediate pH.

The New Zealand Environmental Protection Agency (NZEPA) has classified sodium carbonate as acutely toxic by the oral (classification 6.1E) and inhalation (6.1D) routes of exposure, and irritating to the skin (6.3A) and the eyes (6.4A) (NZEPA 2014b).

Previous assessments

Sodium carbonate has been assessed by the Organization for Economic Co-operation and Development (OECD) (OECD-SIDS 2002). It was concluded that sodium carbonate is of low acute toxicity and has no or a low skin irritation potential, but it is considered irritating to the eyes. No studies have been published on skin sensitisation by sodium carbonate. Due to its alkaline properties, irritation of the respiratory tract is also possible.

No valid animal data are available on repeated dose toxicity by oral, dermal, inhalation or other routes for sodium carbonate. A repeated dose inhalation study in rats, which was not reported in sufficient detail, revealed local effects on the lungs which could be expected based on the alkaline nature of the compound. Under normal handling and use conditions neither the concentration of sodium in the blood nor the pH of the blood will be increased and therefore sodium carbonate is not expected to be systemically available in the body. Sodium carbonate is not expected to reach the foetus or male and female reproductive organs, indicating no risk for developmental or reproductive toxicity. This was confirmed in developmental studies with rabbits, rats and mice (FDA 1974 reported in OECD-SIDS 2002). Sodium carbonate was administered in solution by intubation on days 6-15 of gestation. An *in vitro* bacterial mutagenicity test was negative (Olivier and Marzin 1987) and, based on its structure, no genotoxic effects are expected due to sodium carbonate.

Sodium carbonate was also assessed under the Human and Environmental Risk Assessment on ingredients of household cleaning products (HERA) initiative (HERA 2002a). The HERA assessment reached very similar conclusions to the OECD assessment and stated that “the only critical endpoint for sodium carbonate seems to be local irritation”.

A US Environmental Protection Agency (USEPA) assessment concluded that sodium carbonate was a mild skin irritant and a mild-moderate eye irritant (US Enviromental Protection Agency 2006). Concentrated solutions may cause necrosis of mucous membranes, such as the gastrointestinal and respiratory tracts.

Sodium carbonate was granted full generally recognised as safe (GRAS) status by the US Food and Drug Administration (US Food and Drug Administration 1975).

Relevant recent toxicological studies

Scientific literature searches were carried out in Scopus[4] and PubMed[5]. Search terms included the chemical name and any common variants and the wildcard term ‘toxic*’.

No relevant toxicological studies, additional to those reviewed in the assessments summarised in the previous section, were found in the recent (last five years) scientific literature.

Observations in humans

No cases of acute human poisoning due to sodium carbonate ingestion have been reported and it has been suggested that this may be due to sodium carbonate being neutralised in the acidic environment of the stomach (OECD-SIDS 2002).

Patch tests on humans (0.2 g of 98% sodium carbonate for up to 4 hours) showed no skin reactions (York et al 1996). Application of a solution of 50% w/v sodium

[4] http://www.scopus.com/

[5] http://www.ncbi.nlm.nih.gov/pubmed

carbonate to the skin of volunteers for 4 hours produced no skin reactions on intact skin, but erythema and oedema occurred on abraded skin of 2 of 6 volunteers (Nixon et al 1975).

2.2.2. Sodium tripolyphosphate

Sodium tripolyphosphate (STPP, CAS 7758-29-4; $Na_5P_3O_{10}$, pentasodium triphosphate, triphosphoric acid, pentasodium salt) is a solid inorganic compound widely used in automatic dishwashing detergents (powder, liquid, tablets, gel). STPP provides a number of functions: sequestering of 'water hardness' to enable surfactants to function effectively, pH buffering, and dissolving and dispersing dirt particles. The STTP content of automatic dishwashing detergents ranges from 10% to 60%, with typical concentrations between 25-40% in powder, 24-30% in liquid, 20-51% in tablet and 15-30% in gel formulations (HERA 2003).

STPP is very water-soluble and is able to form complex salts with metals such as calcium, magnesium and iron (Watters 1957). Several studies indicate that polyphosphates can be hydrolysed *in vivo* by enzymes with the formation of monophosphates, which are absorbed (JECFA 1982).

NZEPA has classified STPP as acutely toxic by the oral (classification 6.1E) route of exposure, and irritating to the eyes (6.4A) (NZEPA 2014c).

Previous assessments

STPP has been assessed under the HERA initiative (HERA 2003). It was concluded that STPP is of low acute toxicity by ingestion and dermal application. At the maximum possible concentration of STPP in air that could be generated, no significant toxicity was observed except reactions consistent with exposure to an irritant dust (FMC 1990 reported in HERA 2003).

STPP is irritating to intact skin or to the eyes when tested neat or in aqueous solutions. Data for detergent formulations containing STPP showed no skin contact sensitisation potential under typical use conditions. There have been no reports of skin sensitisation associated with STPP exposure in consumers.

Based on available data, STPP does not appear to be mutagenic or genotoxic. A long-term (2-year) oral toxicity study in rats did not show any evidence of carcinogenicity. There was no evidence of reproductive or developmental toxicity in the three generation rat study.

No repeated dose toxicity studies were available in animals for the dermal or inhalation route of exposure. However, repeated dose oral toxicity studies in rats showed that STPP at high doses induced retarded growth, anaemia and renal calcification. The top dose administered in these studies was either 5 or 10% in the diet (Hodge 1964). In a 2-year study, no toxic effect was observed at the doses of up to 0.5%, which was used to estimate a systemic no observed effect level (NOEL) of 225 mg/kg/day. The effects induced by STPP were similar to those reported for other condensed inorganic phosphates.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) established a maximum tolerable daily intake (MTDI)[6] for humans for phosphoric acid and phosphate salts, including STPP, of 70 mg/kg body weight/day, expressed as phosphorus (JECFA 1982). The MTDI is based on the chronic impact of high phosphorus exposure on calcium absorption and resultant hypocalcaemia and potential for bone loss and calcification of soft tissues, particularly the kidneys.

STPP was granted full generally recognised as safe (GRAS) status by the US Food and Drug Administration (US Food and Drug Administration 1975).

Relevant recent toxicological studies

No relevant toxicological studies, additional to those reviewed in the assessments summarised in the previous section, were found in the recent (last five years) scientific literature.

Observations in humans

Few case reports of adverse health effects in humans were found. A woman experienced asthma-like symptoms after her carpets and upholstery had been cleaned with a solution containing 90-95% STPP (Lynch 2000). The incident was ascribed to the irritant action of STPP.

Patch tests in ceramic workers (*n* = 190), using 2% solutions, reported one positive reaction to STPP (Motolese et al 1993)

2.2.3. Sodium percarbonate

Sodium percarbonate (CAS 15630-89-4; sodium carbonate peroxide) is an addition compound of hydrogen peroxide and sodium carbonate. Based on the molecular formula, the pure substance sodium percarbonate contains 32.5% hydrogen peroxide and 67.5% sodium carbonate, on a weight basis.

Sodium percarbonate rapidly dissolves in water or body fluids, dissociating into hydrogen peroxide, carbonate and sodium ions which are all naturally present in the human body.

$$2\ Na_2CO_3{\cdot}3H_2O_2 \rightarrow 4\ Na^+ + 2\ CO_3^{2-} + 3\ H_2O_2$$

For hydrogen peroxide, a high degradation capacity is present in the blood and tissues, with concentrations controlled by a number of mechanisms, including the enzymes catalase and glutathione peroxidase (European Chemicals Bureau 2003; OECD-SIDS 2005).

[6] This figure represents the maximum tolerable daily intake (MTDI) of phosphates. The MTDI is expressed as phosphorus and it applies to the sum of phosphates naturally present in food and phosphorus-containing food additives.

In machine dishwashing products, sodium percarbonate is mainly used as a bleaching chemical. The content in dishwasher powders and tablets typically is about 21% (ranging from 3% to 21%) and 8.5%, respectively (HERA 2002b).

NZEPA has classified sodium percarbonate as acutely toxic by the oral (classification 6.1D) route of exposure, and irritating to the eyes (6.4A) (NZEPA 2014a).

Previous assessments

Sodium percarbonate has been assessed by OECD (OECD-SIDS 2005). Due to sodium percarbonates rapid dissociation and metabolism in the body, it was not considered likely that sodium percarbonate would be systemically toxic.

Sodium percarbonate is of low acute toxicity, with effects seen due to local, rather than systemic toxicity. In animal tests, sodium percarbonate is slightly irritating to skin, but highly irritating to the eye (rabbit, not rinsed). Sodium percarbonate is not a skin sensitiser. Most of the acute and local effects can be explained by the release of hydrogen peroxide.

Although a repeated dose study is not available for sodium percarbonate, it is expected that repeated dose toxicity of sodium percarbonate will mainly be mediated by hydrogen peroxide. A 90-day oral study with hydrogen peroxide in catalase-deficient mice demonstrated a dose-related incidence of reversible duodenal mucosal hyperplasia at doses up to 3000 mg/L in distilled drinking water (FMC 1997 reported in OECD-SIDS 2005).

No data on the mutagenicity of sodium percarbonate are available, but available studies on hydrogen peroxide do not suggest significant genotoxicity or mutagenicity. While hydrogen peroxide exhibits a local carcinogenic effect in the duodenum of a catalase-deficient mouse strain, an underlying genotoxic mechanism is not considered likely. It is likely that the mucosal hyperplasia observed is due to inflammatory processes.

No developmental or reproductive toxicity studies are available for sodium percarbonate. However, it was considered that the rapid breakdown into normal components of the body would make it unlikely that sodium percarbonate or any of its components would reach the reproductive organs or the developing embryo or foetus.

The HERA initiative also carried out an assessment of sodium percarbonate and concluded that “the only critical endpoint for sodium percarbonate seems to be local irritation” (HERA 2002b).

While sodium percarbonate has not been assessed by the United States Food and Drug Administration, hydrogen peroxide is generally recognised as safe (GRAS) when used as a bleaching agent in foods and in cotton and cotton fabrics for dry food packaging (US Food and Drug Administration 1979).

Relevant recent toxicological studies

No relevant toxicological studies, additional to those reviewed in the assessments summarised in the previous section, were found in the recent (last five years) scientific literature.

Observations in humans

No case reports of human toxicity due to sodium percarbonate exposure were found.

2.2.4. Alcohol ethoxylates

Alcohol ethoxylates (AEs) are non-ionic surfactants which are often used in dishwasher detergents. Although the proportion in dishwasher detergent products is usually <1%, it has been reported that this type of product may contain up to 14.5% AEs (HERA 2009). The AEs family can be defined to be of the basic structure $C_{x-y}AE_n$ (HERA 2009). The carbon chain length is most commonly 8 to 18 while the ethoxylated chain is usually 3 to 12 ethylene oxides long in household detergent products. The HERA document lists approximately 80 different CAS numbers for individual AEs.

NZEPA has not classified a number of the AEs are potentially present in dishwasher powder formulations. All individual AEs that have been classified are considered to be acutely toxic by the oral route (classification 6.1D or 6.1E). Some are skin irritants (6.3B), some are eye irritants (6.4A), while a few are corrosive to the eyes (8.3A) (NZEPA 2014d).

Previous assessments

The toxicity of AEs has been assessed under the HERA initiative (HERA 2009). AEs are of low acute toxicity by oral, dermal or inhalation route of exposure. AEs are not contact sensitisers. Neat AE are irritating to eyes and skin, but the irritation potential of aqueous solutions of AEs depends on concentrations.

In repeat dose oral studies (90 days to 2 years, all conducted on rats) the effects observed were restricted to changes in organ weights with no histopathological organ changes with the exception of liver hypertrophy. This was considered to be indicative of an adaptive response to metabolism rather than a toxic effect.

Based on *in vivo* and *in vitro* studies, there is no evidence that AEs are genotoxic, mutagenic or carcinogenic, or cause adverse reproductive or developmental effects.

Relevant recent toxicological studies

No relevant toxicological studies, additional to those reviewed in the assessments summarised in the previous section, were found in the recent (last five years) scientific literature.

Observations in humans

Skin irritation tests on human volunteers suggest that humans are less susceptible to the effects of AEs than the animal models (HERA 2009). Patch tests (4 hours, 0.2 ml undiluted, upper outer arm) produced no response that would warrant classification of AEs as skin irritants. Longer exposures (24 hour, 0.1% solutions) produced only slight reddening that resolved quickly. A further 24 hour exposure study with undiluted or 20% AEs applied to the skin of volunteers (*n* = 20) produced only mild reversible erythema in a small proportion of volunteers.

2.3. Special Susceptibility of Children

While the epidemiological evidence suggests that young children are more likely to be involved in reported incidents of dishwasher powder exposure, the toxicological evidence does not suggest any particular susceptibility to the effects of the constituent substance amongst children.

3. DOSE-RESPONSE INFORMATION

In the absence of toxicological information on formulated dishwasher powders, it is necessary to infer the toxicity of these powders from the toxicity of the component ingredients.

3.1. Theoretical Composition of Dishwashing Powders

Information on dishwashing powders available in New Zealand provided the following compositional ranges for the chemical of interest. Figures in brackets are ranges given in HERA publications for automatic dishwashing powders (HERA 2002a; 2002b; 2003; 2009):

Sodium carbonate	20-60%	(<30->90%)
Sodium tripolyphosphate		(20-51%)
Sodium percarbonate	1-30%	(3-21%)
Alcohol ethoxylates	2.5-10%	(0.0-14.5)

For the current exercise percentages of 60%, 51%, 30% and 14.5% will be used for sodium carbonate, STPP, sodium percarbonate and alcohol ethoxylates, respectively. While this combination of percentages is obvious nonsensical for a single product, it is adequate for exposure assessment purposes.

It should be noted that sodium percarbonate is made up of 67.5% sodium carbonate and 32.5% hydrogen peroxide (HERA 2002b). This means that a dishwashing product containing 30% sodium percarbonate will contain 9.75% hydrogen peroxide.

3.2. Combined Dose-Response from the Mixture as Formulated

With the exception of a maximum tolerable daily intake derived for phosphates, including STPP, no health based exposure limits have been confirmed for any of the major components of formulated dishwasher powders. Therefore, it is necessary to derive a toxicological critical effect level for the combination of ingredients that can be used to assess exposure estimates.

3.2.1. Acute toxicity

The only available measures of the acute toxicity of dishwasher powder ingredients are LD_{50} (for oral or dermal exposure) or LC_{50} estimates. The LD_{50}/LC_{50} are doses or concentrations that are lethal to 50% of test animals. While these dose levels relate to an extreme toxicological endpoint (death), they do provide a consistent metric to assess the acute toxicity of dishwasher powders.

The United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS) provides guidelines for classifying the acute toxicity of mixtures, based on the acute toxicity of the components in the mixture (United Nations 2009). The approach uses dose additivity without consideration of organ systems affected or the mechanism of toxicity. Mixture acute toxicity is calculated according to formula (1).

$$\frac{100}{ATE_{mix}} = \sum_{i=1}^{n} \frac{C_i}{ATE_i} \quad (1)$$

Where the mixture is made up of *n* components with concentrations (expressed as percentages) equal to C_i and acute toxicity estimates ATE_i. ATE_{mix} is the acute toxicity estimate for the mixture. Appropriate LD_{50} or LC_{50} values can be used to derive the ATE.

Under the GHS protocols, the preferred test species for evaluation of oral or inhalation acute toxicity is the rat, while the rat or rabbit are the preferred species for acute dermal toxicity evaluation (United Nations 2009).

Acute toxicity estimates for sodium carbonate, STPP, sodium percarbonate and AEs and derived acute toxicity estimates for dishwasher powder are shown in Table 3. Where more than one measure of toxicity is available for the same chemical, preference was given to studies in the recommended species and complying with good laboratory practice (GLP). If more than one study meets these criteria then the lowest reported toxic dose was used. It should be noted that for some chemicals only single dose studies have been carried out. Provided that no excess mortality was observed at this single dose, then that dose or concentration was used as the dose metric.

Table 3: Estimated acute toxicity of dishwasher powder, based on acute toxicity of its major ingredients

Chemical	**Exposure route**	**Species**	**Dose metric**	**Dose (mg/kg bw or mg/m^3)**[1]	**Reference**
Sodium carbonate	Oral	Rat	LD_{50}	2800	(OECD-SIDS 2002)
STPP	Oral	Rat	LD_{50}	2000[2]	(HERA 2003)
Sodium percarbonate	Oral	Rat	LD_{50}	1034	(OECD-SIDS 2005)
AEs	Oral	Rat	LD_{50}	1000[3]	(HERA 2009)
Dishwasher powder (derived)			**LD_{50}**	**1720**	
Sodium carbonate	Dermal	Rabbit	LD_{50}	2000[2]	(OECD-SIDS 2002)
STPP	Dermal	Rabbit	LD_{50}	4640[2]	(HERA 2003)
Sodium percarbonate	Dermal	Rabbit	LD_{50}	2000[1]	(OECD-SIDS 2005)
AEs	Dermal	Rat	LD_{50}	2000[2]	(HERA 2009)
Dishwasher powder (derived)			**LD_{50}**	**2460**	
Sodium carbonate	Inhalation	Rat	LC_{50}	2300	(OECD-SIDS 2002)
STPP	Inhalation	Rat	LC_{50}	390[2]	(HERA 2003)
Sodium percarbonate	Inhalation	Rat	LC_{50}	4580[2,4]	(OECD-SIDS 2005)
AEs	Inhalation	Rat	LC_{50}	1500[5]	(HERA 2009)
Dishwasher powder (derived)			**LC_{50}**	**890**	

STPP = sodium tripolphosphate; AEs = alcohol ethoxylates; LD_{50} = Lethal dose: amount of material, which causes the death of 50% of test animals; LC_{50}= Lethal concentration: concentration of material, which causes the death of 50% of test animals

[1] Units of 'mg/kg bw' apply to oral and dermal exposure, while units of 'mg/m^3' apply to inhalation exposure

[2] Limit (single dose) study or highest study dose. No mortality was observed at this dose

[3] A large number of acute toxicity studies have been carried out on AEs of varying chain length. This was the lowest LD_{50} for a study following OECD procedures and employing GLP

[4] Little information is available on this study

[5] No studies reported mortality at concentrations below the saturated vapour concentrations for AEs. This value is the lowest LC_{50} reported for studies that generated a mist or aerosol of AEs

3.2.2. Chronic systemic toxicity

To understand the combined toxicity of the individual components of automatic dishwasher detergents when considered as a mixture, an understanding of the mode(s) of action (MoA) and target organ(s) is required. Available information for the major ingredients of concern in dishwasher powders is summarised in Table 4.

Table 4: Mode of action and primary target organs for major constituents of dishwasher powder

Compound	Primary target organs	Mode of action	Reference
Sodium carbonate (Na_2CO_3)	None identified	Not applicable	(OECD-SIDS 2002)
Sodium tripolyphosphate ($Na_5P_3O_{10}$)	Some evidence of renal effects	Excess phosphorus and calcium load on the kidneys	(HERA 2003; JECFA 1982; Weiner et al 2001)
Sodium percarbonate ($2Na_2CO_3 \cdot 3H_2O_2$)	None identified. Hydrogen peroxide may affect the gastrointestinal mucosal lining	Duodenal mucosal hyperplasia probably due to local irritant action of hydrogen peroxide. Only seen in sensitive (catalase-deficient) rodents	(OECD-SIDS 2005)
Alcohol ethoxylates	Effects observed in the liver were considered to be adaptive, rather than adverse. Only seen in some studies	Not applicable	(HERA 2009; Roberts and Marshall 1995)

No specific target organs are identified as common for more than one of the compounds listed above. Therefore, there is no basis from which to consider the combined risk from mixtures of these ingredient chemicals and the chronic toxicological risks due to dishwasher powder exposure can be considered in terms of the chronic toxicity of the constituent chemicals.

In the absence of common modes of action for any of the components of dishwasher powder, the chronic toxicity of dishwasher powder can be considered in terms of the most sensitive endpoint for the component ingredients, after consideration of their dilution in the formulated products. The only endpoint relevant to chronic systemic toxicity is nephrocalcinosis due to STPP. A maximum tolerable daily intake of 70 mg/kg bw, expressed as phosphorus, has been derived for this endpoint (JECFA 1982). This would equate to 280 mg/kg bw/day of STPP or 550 mg/kg bw/day of dishwasher powder containing a worst case 51% STPP.

3.2.3. Skin irritation/corrosion

GHS provides guidelines for classifying the skin irritation/corrosion potential of mixture, based on the skin irritation/corrosion potential of the components in the mixture (United Nations 2009). As for acute toxicity, effects are treated as being additive.

None of the component chemicals of dishwasher powder were corrosive to the skin, even when chemicals were applied undiluted and for long periods of time (HERA 2003; 2009; OECD-SIDS 2002; 2005). Sodium carbonate and STPP are, at worst, mild skin irritants, with most studies concluding they are non-irritant. The irritant effect of sodium percarbonate is considered to be due to the hydrogen peroxide component of the compound. In the European Union solutions of hydrogen peroxide with concentrations ≥ 35 % are labelled as irritating to skin, while concentrations ≥ 50 % are labelled as corrosive. The hydrogen peroxide content of a dishwasher powder containing 30% sodium percarbonate would be approximately 10%. The skin irritant potential of AEs appears to be complex, but in general terms undiluted materials were moderate to severe skin irritants, whereas 1% aqueous solutions were mildly irritating and 0.1% to 0.5% aqueous solutions were usually not irritating.

While there is insufficient information to calculate an additive effect for the components of dishwasher powder, the AE content of these products suggests that they have the potential to be irritant, but not corrosive to skin. It should be noted that the irritant action of AEs appears to be completely reversible (HERA 2009).

3.2.4. Eye irritation/corrosion

GHS provides guidelines for classifying the eye irritation/corrosion potential of mixture, based on the eye irritation/corrosion potential of the components in the mixture (United Nations 2009). As for acute toxicity, effects are treated as being additive.

All of the dishwasher powder ingredients considered have the potential to cause eye irritation. For sodium carbonate and STPP most studies report mild eye irritation (HERA 2003; OECD-SIDS 2002). For sodium percarbonate and AEs eye irritation ranged from mild to severe in different studies (HERA 2009; OECD-SIDS 2005). In particular, in the European Union concluded that solutions of hydrogen peroxide with concentrations ≥ 5 % are labelled as irritating to eyes, concentrations ≥ 8 % are labelled with “risk of serious damage to eyes” and concentrations ≥ 50 % are labelled as corrosive (OECD-SIDS 2005). The hydrogen peroxide content of dishwasher powders, due to the presence of sodium percarbonate, may be as high as 10%.

While there is insufficient information to calculate an additive effect for the components of dishwasher powder, the sodium percarbonate content of these products, and the associated hydrogen peroxide content, suggests that they have the potential to cause serious eye damage.

4. EXPOSURE ASSESSMENT

The ranking of exposure routes for dishwasher detergents was assumed to be similar to exposure routes for household cleaning products in general. Results of an UK study, analysing data from 2008-2009 (Williams et al 2012) are shown in Table 5.

Table 5: Exposure routes of household cleaning products[1]

Exposure route	Number of reported cases (*n*)	Proportion attribution (%)
Ingestion	4616	75.8
Eye contact	513	8.4
Inhalation	420	6.9
Skin contact	187	3.1
Total reported	**5736**	**94.2[2]**

[1] (Williams et al 2012)
[2] The remaining 5.8% is split between a number of other exposure routes which are proportionately less significant.

Since the introduction of regulations to limit the alkalinity of dishwasher powders, there has been little evidence of adverse health effects due to these products in New Zealand.

4.1. Exposure Scenarios for Dishwasher Powder in New Zealand

In the following sections exposure scenarios are defined for dishwasher powder.

4.1.1. Oral exposure (ingestion)

Oral exposure to dishwasher detergent is predominantly seen as occurring through accidental ingestion by infants and children. Occasions of deliberate ingestion in adults may also occur. Accidental ingestion of dishwasher detergent by infants and children is assumed for the purposes of this report as the most significant route for acute exposure amongst the New Zealand population. It has been noted that children may ingest dishwasher powder either directly from the packet, from the detergent dispenser on the dishwasher machine door, or from post-cycle ‘sludge’ (residue remaining in the dispenser or on interior surfaces of the dishwasher) (Bertinelli et al 2006).

Age distribution data received from the New Zealand National Poisons Centre for household chemical exposure incidents (specifically dishwasher powder) to children between July 2007 and June 2012 showed peaks at 12 and 24 months (1-2 years), although this may partially be due to variability in age-reporting formalities at the time of each enquiry. Direct ingestion of dishwasher powder was assessed for children aged 1-2 years.

Few data on quantities of dishwasher detergent accidentally consumed by infants and children have been identified. Additionally in the reporting of case studies and through national poison centre databases the brand name of the ingested detergent and/or the actual composition does not appear to be always recorded. It has been suggested that no more than 5 g of powder detergent or 20 ml of dishwashing liquid would be swallowed (HERA 2009). The current assessment is only concerned with dishwashing products in powdered or tablet form. Ingestion quantities of 5 and 10 g were assessed, with the higher figure representing a 'worst case' scenario.

For all age groups, there is potential for exposure to dishwasher powder material due to persistence of residues on washed dinnerware and utensils. Exposure from this source was modelled for a 1-2 year child (the youngest age when children are likely to be regularly using dinnerware and utensils) and an average adult (15+ years).

4.1.2. Dermal exposure

Dermal exposure of adults to dishwasher powder is likely to be restricted to exposure of the hands during loading of the dishwasher and is likely to be of short duration.

For children there is potential for greater exposure due to spilling dishwasher powder on themselves, although the form these products are in means that clothing will be an effective barrier in such instances.

While no specific exposure scenarios will be assessed, local dermal effects due to dishwasher powder will be discussed under risk characterisation.

4.1.3. Eye exposure

There is potential for eye exposure to dishwashing powder during the process of loading the dishwasher and similarly for children spilling dishwashing powder on themselves.

While no specific exposure scenarios will be assessed, local eye effects due to dishwasher powder will be discussed under risk characterisation.

4.1.4. Inhalation

While dishwashing powder and its ingredients are largely non-volatile, there is potential for aspiration of dust during loading or spilling. Two scenarios were assessed:

- Adult exposure to dishwasher powder dust during loading of the dishwasher; and
- Child (1-2 years) exposure to dishwasher powder dust due to spilling the contents of a container of the product.

4.2. Exposure – Ingestion (Oral)

4.2.1. Children – accidental ingestion

Scenario: Accidental oral ingestion of dishwasher powder was calculated using the equation:

$$Ingestion\ exposure\ dose = \frac{C \times IR \times EF}{BW}$$

Where:
C = contaminant concentration in mg/g
IR = ingestion weight (g)
EF = exposure factor (proportion of ingested dose absorbed)
BW = body weight in kilograms

Body weights (5th and 50th percentile, 8.9 kg and 11.3 kg) for a 1-2 year child (males and females combined) were taken from the USEPA child specific exposure factors handbook table 8-3 (US Environmental Protection Agency 2008). Calculations were performed for ingestion weights of 5 g and 10 g of formulated dishwasher powder. As exposure to the formulated dishwasher powder is being considered, C will equal one. EF has been assumed to be one.

Table 6: Ingestion exposure dose following accidental ingestion of dishwasher powder (5 or 10 g) by a 1-2 year child

	Ingestion Exposure Dose (mg/kg bw)			
	Ingested weight = 5 g		Ingested weight = 10 g	
Body weight, kg (percentile)	8.9 (5th)	11.3 (50th)	8.9 (5th)	11.3 (50th)
Dishwasher powder	560	442	1120	880

bw = body weight

4.2.2. Adults and child – exposure due to residues on dinnerware and utensils

Scenario: Exposure to dishwasher powder components remaining on washed dinnerware and utensils was calculated according to the equation:

$$Ingestion\ exposure\ dose = \frac{F \times C \times Qw \times SA \times Ft \times n \times EF}{BW}$$

Where:

F = fraction of the ingredient of interest in the dishwashing powder product (1, as dishwasher powder being considered)

C = product concentration in the dishwash solution that can remain on the surface of the washed item. European data, based on 50 g of product per wash and 18 litres of water, gave a value of 2.77 mg/ml for this parameter (HERA 2003)

Q_w = amount of water left on dishes after washing and rinsing. It has been estimated that the dish surface in contact with food and used by one individual per day is 5400 cm^2. The amount of wash water left on this surface area of unrinsed dishes has been estimated at approximately 3 ml or 0.00055 ml/cm^2. If a factor of 10 is applied to account for rinsing, the volume of wash water remaining on the surface of dishes is 0.000055 ml/cm^2 (HERA 2003)

SA = surface area of dishes in contact with food and used by one individual per day (5400 cm^2, from above)

F_t = weight fraction of dishwasher powder ingredients transferred from the dish surface to food. It was assumed that 100% transfer would occur

n = number of exposure events per day. As SA has been estimated for a day, this factor will be one

EF = exposure factor, weight percent of product ingredient absorbed. Complete absorption was assumed

BW = body weight, in kilograms. Body weights (5th and 50th percentile) for a 1-2 year child were taken from USEPA data (8.9 kg and 11.3 kg) (US Environmental Protection Agency 2008). Body weights for any average New Zealand adult (15+ years, 5th and 50th percentile) were taken from the 2009 Adult Nutrition survey (52.7 kg and 77.1 kg) (University of Otago and Ministry of Health 2011).

Estimates of exposure to dishwasher powder due to residues remaining on dishes are summarised in Table 7.

Table 7: Ingestion exposure dose for dishwasher powder residues remaining on dishes by a 1-2 year child and a 15+ years adult

	Ingestion Exposure Dose (mg/kg bw/day)			
	Child, 1-2 years		Adult, 15+ years	
Body weight, kg (percentile)	8.9 (5th)	11.3 (50th)	52.7 (5th)	77.1 (50th)
Dishwasher powder	0.092	0.073	0.016	0.011

bw = body weight

4.3. Exposure - Inhalation

Inhalation exposure to dishwasher powder is likely to be negligible, as consumer products consist largely of crystals or 'clumps' and there is little dust generated. While no information specific to dishwashing powder was identified, it has been reported that powdered laundry detergents release approximately 0.00027 mg (0.27 μg) of dust per cup of detergent product (van de Plassche et al 1999). If it is assumed that all dust generated will be inhaled and that all inhaled material will be systemically available, inhalation exposure can be calculated from the equation:

$$Inhalation\ exposure\ dose = \frac{F \times C \times W \times EF \times n}{BW}$$

Where:

F = fraction of the ingredient of interest in the dishwashing powder product (1 for dishwasher powder)
C = quantity of dishwasher powder dust products per kilogram of product handled. The density of dishwasher powder is approximately 0.9 kg/L. If 0.27 μg of dust are produced per cup (200 mL) of product, then 1.5 μg of dust will be produced per kilogram of powder handled
W = weight of dishwashing powder handled. A dishwashing load has been reported to require approximately 50 g of dishwasher powder (HERA 2003)
EF = exposure factor, weight percent of product ingredient absorbed. Complete absorption was assumed
n = number of exposure events per day.
BW = body weight, in kilograms. Body weights (5th and 50th percentile) for a 1-2 year child were taken from USEPA data (8.9 kg and 11.3 kg) (US Environmental Protection Agency 2008). Body weights for any average New Zealand adult (15+ years, 5th and 50th percentile) were taken from the 2009 Adult Nutrition

survey (52.7 kg and 77.1 kg) (University of Otago and Ministry of Health 2011).

4.3.1. Adult incidental exposure

Scenario: It was assumed that an adult of either median body weight (77.1 kg) or low body weight (5th percentile, 52.7 kg) may load a dishwasher up to three times per day, using 50 g of dishwashing powder each time. The resultant exposure to dishwashing powder is summarised in Table 8.

Table 8: Inhalation exposure dose for dishwasher powder by a 15+ years adult loading an automatic dishwasher three times per day

	Inhalation Exposure Dose (mg/kg bw/day)	
	Adult, 15+ years	
Body weight, kg (percentile)	52.7 (5th)	77.1 (50th)
Dishwasher powder	0.000005	0.000003

bw = body weight

It should be noted that for dishwashing products in tablet format these negligible exposures will be further reduced.

4.3.2. Child accidental exposure

Scenario: Dishwasher powders currently sold in New Zealand are mainly sold in one or two kilogram packs. However, these are generally of design that would make it difficult for the entire contents to be emptied out at once. For the current study, it was assumed that a 1-2 year child would empty 500 g of dishwashing powder and inhale all of the resulting dust. The quantity of dust released was based on the findings of van de Plassche et al (1999) and for 500 g of dishwashing powder will equate to 0.75 μg of dust. Inhalation exposure estimates are summarised in Table 9.

Table 9: Inhalation exposure dose for dishwasher powder by a 1-2 year child upsetting a container of dishwashing powder

	Inhalation Exposure Dose (mg/kg bw)[1]	
	Child, 1-2 years	
Body weight, kg (percentile)	8.9 (5th)	11.3 (50th)
Dishwasher powder	0.000085	0.000067

bw = body weight
[1] Based on the child inhaling all dust resulting from accidentally dispensing 500 g of dishwasher powder

It should be noted that for dishwashing products in tablet format these negligible exposures will be further reduced.

5. RISK CHARACTERISATION

5.1. Acute Exposure

Risks associated with acute exposure scenarios were assessed using a margin of exposure (MoE) approach. The MoE is calculated from the animal critical effect level divided by the estimated human exposure (EFSA 2005). For the acute exposure scenarios in the current study a derived LD_{50} has been used as the acute critical effect level.

While two inhalation exposure scenarios have been defined, the parameters of these scenarios do not allow an inhalation concentration to be calculated for comparison with the derived LC_{50} for dishwasher powder. Instead, these scenarios have been assessed in terms of oral ingestion of dishwasher powder.

Margins of exposure for acute exposure scenarios are summarised in Table 10.

Table 10: Summary of acute exposure scenarios for dishwasher powder and associated margins of exposure

Exposure scenario	Estimated exposure (mg/kg bw)	Benchmark dose (mg/kg bw)	Margin of exposure
Direct ingestion of dishwasher powder by 1-2 year child	442-1120	1720	1.5-3.9
Inhalation exposure for a 15+ year adult, from loading dishwasher	0.000003-0.000005	1720	340-570 million
Inhalation exposure for a 1-2 year child, from upsetting a container of dishwasher powder	0.000067-0.000085	1720	20-26 million

bw = body weight

The information in Table 10 suggests incidental inhalation of dishwasher powder is highly unlikely to be a toxicological concern, due to the extremely large margins of exposure. However, the margins of exposure for direct ingestion of dishwasher powder by an infant are very low considering the seriousness of the toxicological point of departure (50% mortality in test animals).

5.2. Chronic Exposure

Chronic exposure due to the persistence of dishwasher powder residues on dishes was assessed. As a maximum tolerable daily intake (MDTI) is available for the toxicological endpoint of concern (nephrocalcinosis), exposures were assessed against this MTDI by derivation of a hazard quotient (HQ). The HQ is the ratio between the estimated exposure and the MTDI. A hazard quotient greater than one indicates the potential for adverse health effects. Exposure estimates and associated HQs are summarised in Table 11.

Table 11: Summary of chronic exposure scenarios for dishwasher powder and associated hazard quotients

Exposure scenario	**Estimated daily exposure (mg/kg bw)**	**Hazard quotient**
Maximum Tolerable Daily Intake (Dishwasher powder) = 550 mg/kg bw		
Ingestion of residues on dishes by 1-2 year child	0.073-0.092	0.00013-0.00017
Ingestion of residues on dishes by an adult (15+ years)	0.011-0.016	0.00002-0.00003

bw = body weight

The HQs in Table 11 suggest that ingestion of dishwasher powder residues remaining on dishes is unlikely to cause adverse effects.

5.3. Local (Concentration-based) Effects

5.3.1. Skin effects

Dermal exposure to dishwasher powder has the potential to cause skin irritation, but not corrosion. Irritation is most likely to be due to the AE content of the dishwasher powder and animal studies suggest the effects are completely reversible.

5.3.2. Eye effects

Dishwasher powder is highly likely to cause irritation if it comes in contact with the eyes. For powders containing the maximum potential content of sodium percarbonate there is potential for serious eye injury, due to the action of hydrogen peroxide.

6. CONCLUSIONS

While a very wide range of chemical ingredients may be present in dishwasher powders, it appears that the ingredients most commonly present that may be of health concern are sodium carbonate, STPP, sodium percarbonate and AEs.

Scenarios for acute oral ingestion and inhalation exposure were formulated and systemic exposure assessments for young children (1-2 years) and adults were assessed by MoE analysis against an acute critical effect level (based on animal LD_{50} data) derived for dishwasher powder. Margins of exposure for inhalation of dust from dishwasher powder were all in excess of 20 million, suggesting that adverse health effects due to this route of exposure are very unlikely. However, margins of exposure for the scenario of direct oral ingestion of dishwasher powder by a young child were less than five, suggesting potential for severe adverse health effects due to this route of exposure.

While there is the potential for chronic oral exposure to dishwasher powder residues, due to material remaining on washed dishes, estimated exposures due to this route of exposure are well below the maximum tolerable daily intake (550 mg/kg bw), derived for dishwasher powder. None of the reported ingredients in dishwasher powder are known or suspected carcinogens, reproductive or developmental toxicants, or sensitisers.

There is little evidence to suggest that exposure to the dishwasher powder will result in severe local effects to the skin or eyes, although there is potential for serious eye injury from dishwasher powders containing high levels of sodium percarbonate. It should be noted that high sodium percarbonate concentrations appear to be associated with tablet-type formulations and eye contact with these products appears less likely than for powdered products.

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