National Research FLAGSHIPS
Water for a Healthy Country

CSIRO

www.csiro.au

Sources of contaminants in domestic wastewater: nutrients and additional elements from household products

Grace Tjandraatmadja, Chris Pollard, Chris Sheedy and
Yesim Gozukara

February 2010

Smart Water Fund

REPRESENTED BY

City West Water
Melbourne Water
South East Water
Yarra Valley Water
Department of Sustainability and Environment

Our Water Our Future

Victoria The Place To Be

Water for a Healthy Country Flagship Report series ISSN: 1835-095X

Citation: Tjandraatmadja G, Pollard C, Sheedy C, Gozukara Y 2010. Sources of contaminants in domestic wastewater: nutrients and additional elements from household products. CSIRO: Water for a Healthy Country National Research Flagship

Cover Photograph:
From CSIRO's ScienceImage: www.scienceimage.csiro.au
File: BUR6243.jpg
Description: Algal scum on treated wastewater at Perth treatment works.Perth, WA.
CSIRO Land and Water
Photographer: Willem van Aken

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The authors would like to thank:

- the Smart Water Fund and water authorities from the Source control strategy group for sponsoring this project,
- the members of the Reference group, Lidia Harvey, John Dennis, Adam Kazi, Michelle Carsen, Mick Anderson, Hieu Dang, and Robina Westblade for their input and guidance.

ABBREVIATIONS

CCL	Cumulative contaminant loading
Cl	Chloride
Co	Cobalt
$Conc_{measured}$	Concentration of element determined experimentally
$Conc_{product}$	Concentration of element in product
Cr	Chromium
f	Frequency of use per week
F	Fluoride
IC	In-cistern
ICP-AES	Inductively coupled plasma with atomic emission spectroscopy
ICP-MS	Inductively coupled plasma mass spectroscopy
K	Potassium
L	Litre
LOD	Limit of detection
LTV	Maximum concentration for long term irrigation (100 years)
μg	microgram
$M(i)_{week}$	Weekly mass load for element I for a selected product category
Mproduct	Mass of product tested
Mo	Molybdenum
N	Nitrogen
na	Not applicable
Na	Sodium
$NaHClO_3$	Sodium hypochlorite
nd	Not determined
ng	nanogram

pe	person
PET	Poly(ethylene terephthalate)
Sb	Antimony
Sb_2O_3	Antimony trioxide
Se	Selenium
STV	Maximum concentration for short-term irrigation (20 years)
TF	Toilet freshener
TKN	Total Kjeldahl nitrogen
TP	Total phosphorus
Vs	Sample volume analysed
WWi	Combined wastewater stream for household

EXECUTIVE SUMMARY

Context and purpose

Understanding the origin of contaminants in wastewater is important in developing strategies for sustainable wastewater treatment and reuse of water and biosolids. However, limited information exists on the contribution that households make towards contaminants other than nitrogen (N), phosphorus (P) and carbon (solids), and how they are generated.

In an earlier report, the contribution of household products to the quantity of heavy metals and inorganic elements discharged into wastewater, and, thus subsequently impacting effluent and biosolids reuse, was evaluated (Tjandraatmadja *et al* 2008). In this report, the evaluation is extended to additional elements: antimony (Sb), chloride ions (Cl), chromium (Cr), cobalt (Co), fluoride ions (F), molybdenum (Mo), nitrogen (N), phosphorus (P) and selenium (Se), all of which are of interest to water authorities because of their chronic public health or environmental impact.

This report is part of the Smart Water Fund project Round 3 – Project 5 *Household sources of priority contaminants in domestic wastewater.* The overall project aims to understand the origins of contaminants in domestic wastewater and to evaluate strategies for their reduction at source.

The aim of this report is to evaluate the contribution that household and personal care products make to Sb, Cl, Cr, Co, F, Mo, N, P and Se in domestic wastewater and the implications to source control and wastewater management.

Research method

A range of 156 household and personal care products used in the bathroom, laundry, kitchen and toilet were analysed using standard water and wastewater analytical methods (APHA/AWWA 2008) to determine:

(a) The concentration of antimony, cobalt, chromium, chloride, fluoride, molybdenum, selenium, nitrogen (as total Kjeldahl nitrogen) and phosphorus (as total phosphorus), and

(b) The loads and distribution of such elements within the wastewater streams (bathroom, laundry, kitchen and toilet) in a household. The loads of household products were evaluated for a one person household and an average frequency of product use (Roberts 2005) and compared to the typical elemental load from human excreta.

For each product category, when possible a “private” or “supermarket” brand and a brand with an “environmental friendly” label were included in the analysis.

Key findings

Frequency of detection

The elements most frequently detected in household products were phosphorus, nitrogen, chloride and chromium, which were respectively detected in 97%, 84%, 80% and 64% of the products analysed. Molybdenum, fluoride, cobalt and selenium were detected in less than 30% of the products and antimony was detected in less than 10% of household products.

Phosphorus, nitrogen, chloride, fluoride and selenium were part of compounds disclosed in a number of product formulations, whilst the other elements, detected in trace amounts originate from contaminants in the raw materials, through the manufacturing or packaging process.

Traces of fluoride were also detected in some brands of hair colouring, dishwashing and laundry detergents although they had not been disclosed in the product formulation, and most probably originate from raw materials and/or contamination during manufacturing.

Elemental Loads in households

Household products contribute to the overall elemental load in residential wastewater, with the actual mass load contribution partly influenced by the product category, specific brand formulation, and the amount of product used.

Elemental concentration varied markedly within product categories and among brands within the same category. For instance, a large difference was verified between the median and the maximum concentrations for brands within a product category for elements such as phosphorus and selenium. Environmental label brands analysed typically had a low concentration of phosphorus compared to the mean of a product category, but the same was not always true for the other elements.

The adoption of "environmental label" brands and products of low element concentration assisted in reducing the load of chromium, cobalt, chloride, fluoride, selenium and particularly phosphorus discharged by a household.

However, the impact of their adoption was less significant when the contribution from the product category to the overall household load was small, as in the case of antimony and molybdenum, which were often below detection in household products, or when non-product sources have a more significant contribution, such as nitrogen which comes mainly from human excreta or fluoride which is also supplied by fluoridated tap water.

Source identification

Within a household individual wastewater streams, such as laundry, kitchen, bathroom shower and sinks, and toilets contributed different amounts to the overall element load.

Chromium and cobalt were discharged in all household wastewater streams (kitchen, laundry, bathroom and toilet). However, most elements had one or two dominant sources responsible for the majority of the load within the household. The laundry and the bathroom were each major sources for six of the elements of interest, including Cl, F and Se, whilst the toilet and the laundry were each major sources for two elements, P and Mo.

The mass load from product use was compared to the load from human excreta (anthropogenic load) for a one person household:

- Nitrogen: household products have a limited influence on the load of nitrogen; their load was equivalent to less than 7% of the anthropogenic load. The largest loads were discharged from the bathroom and the laundry.
- Phosphorus: the product load ranged between less than 1% to up to 80% more than the anthropogenic load. The major loads from products were discharged from the laundry, the kitchen and the bathroom.
- Selenium: the product load was up to 60% of the anthropogenic load. The major loads were discharged from the bathroom and the laundry.
- Molybdenum: the product load was up to 97% of the anthropogenic load. The major loads were discharged from the laundry and the toilet.

- Fluoride: the product load ranged from less than 9% to approximately 6 times the anthropogenic load. The load originated mainly from the bathroom and were determined by the type and brands of product used.
- Chromium: products generated a load that much larger than the anthropogenic load. Depending on the product type and brands adopted, loads from products were equivalent to less than 50% to 276 times the anthropogenic load. Loads were distributed across the various household sources and varied with product type and brand. The load from selected product brands was comparable to that from human excreta, being for instance approximately 50% higher. Whilst for other products the load from human excreta was insignificant compared to the load derived from product use.
- Chloride: products created a load ranging from less than one third to five times the anthropogenic load and median loads were equivalent to a third of the anthropogenic load. The load was dependent on the products used for each household activity and originated either from the bathroom, the laundry or the toilet. The products with the highest Cl concentration were laundry products.
- Cobalt: products could contribute between less than one quarter to thirteen times the anthropogenic load. Their origin within the household was dependent on the brands adopted for each activity.
- Antimony: the product contribution varied markedly, ranging from nil to 95 times the anthropogenic load. The median load from products was equivalent to 9% of the anthropogenic load. The laundry or the kitchen were responsible for the largest product loads.

Implications to contaminant management

Source control through product selection has potential to change the amount of contaminants discharged into the sewer or the concentrations in greywater diverted into gardens in residential areas. This control strategy is feasible for contaminants, such as phosphorus, chloride, fluoride and selenium, which are sourced predominantly from products; but less effective for nitrogen, molybdenum and cobalt; as their main source is anthropogenic waste.

Elements which are in the formulation of a product can be more easily traced and quantified. However, most of the elements of interest were not disclosed in the product formulation and were also present in trace amounts; hence identifying the source of contamination would require more extensive investigation.

Householders could change the quality of wastewater by using products with low elemental content. However, product selection by householders is limited by access to information and knowledge about product formulation. Labels typically used in products such as “biodegradable”, “low P” or “environmentally friendly” are typically based on biodegradability and the environmental impact of phosphorus on surface waters, and do not provide sufficient information on the environmental impacts associated with current patterns of greywater and wastewater reuse, which are based on land application, impacting soil and plant health.

The data presented here will fill a current gap in the understanding of contaminants in wastewater. The data from the analysis of elemental content in the products can be used by water authorities and researchers to simulate a wide range of product combinations, demand management or source control strategies and to evaluate their impact on wastewater quality both at single property scale or for larger catchments. In addition this work could be furthered to evaluate the potential impacts on other aspects of the systems, such as infrastructure, treatment, etc.

1. INTRODUCTION

Traditionally the onus of wastewater treatment in urban areas has been relegated to a sewage treatment plant located remotely, followed by disposal of effluent to sea and biosolids to landfill. However, the challenges of urban population growth are leading to the realisation that reuse of water streams for different end purposes is necessary to fulfil the demand in urban centres and that biosolids stockpiling is unsustainable as a long-term strategy.

Interest in wastewater management strategies other than the sole reliance on end-of-line solutions is growing. As reuse strategies such as greywater diversion at households and effluent recycling for irrigation and non-potable water supply are implemented, the quality of wastewater, the type and amount of contaminants it carries, play a significant role on the cost of treatment and the fate of effluent and biosolids.

In this new context, pollution management focuses on understanding the ingress of pollution into the water cycle and in particular on the identification of sources of contaminants, before streams are mixed or diluted, to identify effective strategies for pollution control. Whilst trade waste monitoring is a routine activity for water authorities and the focus of regular monitoring, less information is available on domestic wastewater, in particular the origin of contaminants in it.

The Smart Water Fund project Round 3 – Project 5 *Household sources of priority contaminants in domestic wastewater* aimed to identify residential sources and their contribution to contaminants in wastewater. The knowledge generated is expected to assist in the development of effective contaminant reduction strategies.

To achieve such objectives, the project focused on understanding the various contaminant sources, estimated loads and their release pattern in residential settings through (i) review of the scientific literature, (ii) assessment of typical wastewater discharge patterns by household appliances, (iii) characterisation of wastewater inputs and streams within a household and (iv) modelling of source control scenarios. The summary of the project structure is shown in Figure 1.

Outcomes from the project include the following reports:

- Sources of critical contaminants in domestic wastewater: a literature review (Tjandraatmadja and Diaper 2006);
- Sources of priority contaminants in domestic wastewater: contaminant loads from household products (Tjandraatmadja *et al* 2008);
- Sources of emerging organic contaminants in wastewater: an assessment based on the literature review (Shareef *et al* 2008);
- Sources of contaminants in domestic wastewater: contaminant loads from household appliances (Diaper *et al* 2008);
- Characterisation of priority contaminants in residential wastewater (Tjandraatmadja *et al* 2009a);
- Investigation of seasonality effects on domestic wastewater quality (Tjandraatmadja *et al* 2009b);
- Impact of source management strategies on quality and loads in residential wastewater: scenario analysis (Cook *et al* 2010).

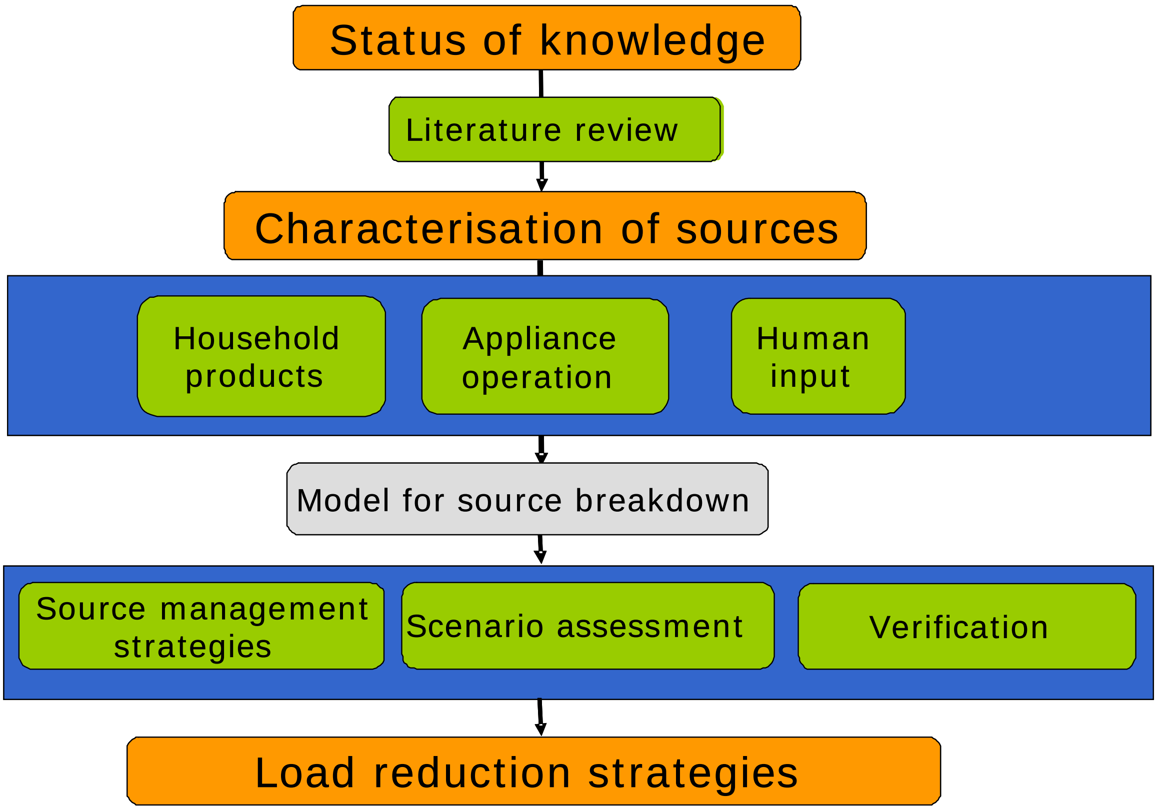

Figure 1: Summary of "Sources of contaminants in domestic wastewater" project

In an earlier report in this series, the contribution of household and personal care products to priority contaminants (arsenic, boron, cadmium, copper, iron, lead, manganese, mercury, nickel, sodium, tin, zinc, total dissolved solids and colour) was evaluated and loads to wastewater streams were estimated (Tjandraatmadja *et al* 2008). The data generated was used to model contaminant loads associated with selected product consumption patterns.

In that particular report the data was used to identify the potential loads derived from different wastewater streams in a household and to compare the load contribution of different products towards each stream.

In this report, the analysis of household products is extended to a new range of parameters identified by water authorities. The new parameters are:

(a) Nitrogen (N) and phosphorus (P), which are essential nutrients to biological metabolism and parameters regulated in sewage treatment plant discharges by the EPA;

(b) Antimony (Sb), which is present in low concentrations in the environment, and its presence in wastewater is attributed mainly to human related activities;

(c) Chloride (Cl): when effluent is used for irrigation, high concentrations of Cl can increase the uptake of Cd by plants, cause foliage burns and impact soil health;

(d) Cobalt (Co) and molybdenum (Mo) are micro-nutrients which can impact the growth of plants;

(e) Chromium (Cr), which is toxic at relatively low concentrations, can be detrimental to aquatic and land vegetation.

(f) Fluoride (F), is typically added to the water supply in urban areas, however, the contribution from households is expected to be minimal, but high concentrations can cause fluoridosis.

(g) Selenium (Se), is an essential element in small doses, but it can be toxic to plants and animals at high concentrations.

With the exception of nitrogen and phosphorus, there is limited data on the distribution of these other elements in residential wastewater streams.

This report aims to evaluate:

(a) The concentration of antimony (Sb), cobalt (Co), chloride (Cl), chromium (Cr), fluoride (F), molybdenum (Mo), nitrogen (N) and phosphorus (P) in common household and personal care products.

(b) The potential loads derived from the typical use of such products and their sources in residential households.

The data generated is intended to assist water authorities to understand the origins of such elements in domestic wastewater in the current Australian context thereby allowing them to better manage the treatment process, or generate policies that may influence guidelines on the use and disposal of certain products.

2. CONTAMINANTS OF INTEREST

The elements, antimony, chloride, cobalt, chromium, fluoride, molybdenum, selenium, nitrogen and phosphorus, were selected by a consultative process between water authorities and CSIRO researchers. Nitrogen (N) and phosphorus (P) are essential nutrients and key parameters used to establish the treatment requirements in sewage treatment plants. Chromium (Cr) antimony (Sb), cobalt (Co), selenium (Se) and molybdenum (Mo) are micro elements that depending on their concentrations can promote or inhibit plant development and impact aquatic systems. Chloride (Cl) is a common element in biological processes, widely present in the human diet and in industrial and household applications. Cl contributes to total dissolved solids in wastewater and can also cause adverse effects to aquatic biota, soil and plant health at high concentrations. Whilst fluoride (F) commonly added to the water supply for the prevention of dental caries is an element of interest to water authorities.

A summary of the elements of interest in this report and the concentrations at which plant toxicity is detected is shown in Table 1.

Table 1: Recommend water quality parameters for water used in irrigation and general use (ANZECC/ARMCANZ 2001)

	Guidelines for irrigation water			*Comment*	*Environmental impact (Asano et al 2007)*
Element	*LTV*(mg/L)*	*STV*(mg/L)*	*CCL(kg/ha)*		
Sb	na	na	na		n.a
Cl	<175 (sensitive crops – stone fruit)	175-350 (moderately sensitive – pepper, tomato, potato)	350-700 (moderately tolerant major crops)	>700 (tolerant)	Risk of foliar injury
	0-350 (low)	350-750 (medium)	<750 (high)		Risk of Cd uptake
Co	0.05	0.1	nd	Upper soil background level 27mg/kg	Toxic to tomatoes at 0.1mg/L in nutrient solution
F	1	42	nd	Inactivated by neutral and alkaline soils	Toxicity is dependent on plant species.
Mo	0.01	0.05	nd	Upper background level 1mg/kg	Not toxic to plants at concentrations found in soil and water. But can accumulate in plants and become toxic to grazing animals.
Se	0.02	0.05	10	Upper background level 0.5mg/kg	Essential elements in low concentrations. Toxic to plants at >0.025mg/L and to grazing animals fed with fodder grown in soils with high concentration of Se.
N	5	25-125	na	Based on maintaining	Nitrate contamination of

				crop yield, minimising off-site impacts	groundwater supply
P	0.05	0.8-12	na	Based on minimising off-site impacts	Run-off can cause excess algae growth

Note: * STV is the maximum concentration of a contaminant that can be allowed in the irrigation water assuming 20 years of irrigation and LTV is the maximum concentration of contaminant that can be allowed in the irrigation water assuming 100 years of irrigation. Both limits assume an annual application of 1000 mm water, retention of inorganic contaminants in the top 150 mm of soil, and a soil bulk density of 1300 kg/m^3. Cumulative contaminant loading limit (CCL) is the maximum element loading for a heavy metal in soil.
Na – not applicable, nd – not determined.

2.1. Antimony

Antimony (Sb) is a metalloid from the same group and period as As, P and N. Sb as a naturally occurring compound is found in parts per billion (ppb) levels in the environment (air, water and soil). Sb in soil is usually bound to iron, manganese and aluminium particles and frequently found in association with As (Ashley *et al* 2003).

Sb is used in the manufacture of lead alloys, including metal and cable sheeting, solder, pipes, brake linings (Maher 2009), metal bearings, ammunition, semi-conductors, ceramic enamels, pottery, glass, lead-acid batteries in automotives and as a catalyst in the production of PET bottles (Westerhoff *et al* 2008). Antimony trioxide (Sb_2O_3) is widely used as a fire retardant in plastics, textiles, rubbers, paper, adhesives and pigments (Stephenson 1987, Maher 2009, US EPA 2009). Sb is also used in the treatment of parasitic diseases and it is emitted into the air by coal and fuel combustion.

Sb has no biological function, but interest on its impact on the environment has increased in recent years, due to the increase of its concentration in the environment associated with human activity since the industrial revolution, and also due to the limited scientific knowledge available on its chemistry and its long term environmental impact.

Typical concentrations of Sb in the environment range between less than 1ng/m^3 to 170ng/m^3 in the air, and between 0.3 to 8.6 mg/kg in soil (USEPA 2009, Tschan *et al* 2009), in sea water the average concentration is 0. 2μg/kg (Tschan *et al* 2009) and less than 2 to 25 mg/kg dry weight for sediment (ANZECC and ARMCANZ 2001). A maximum concentration for Sb in fresh water has not been established (ANZECC and ARMCANZ 2001, Ashley *et al* 2003).

Sb concentrations in drinking water range between 0.6 to 4.0μg/L, with a mean of 1.87 μg/L (USA data) (Health Canada 1997). The Australian drinking water recommended guideline for Sb is a maximum of 3 μg/L (NHMRC and NRMMC 2008). Overseas studies reported 0.01 μg/L Sb in domestic wastewater (Palmquist and Hanaeus 2005). In drinking water and wastewater sampled from Melbourne suburbs in 1994 and in 2006, Sb was below the respective detection limits of 1μg/L and 5μg/L in majority of samples from each of the respective studies (Connor and Wilkie 1995, CWW 2006).

In urban areas, the major sources of Sb to the environment are attributed to air pollution from human activities, particularly to the wear of brake linings (Månsson *et al* 2009, Ijima *et al* 2009 in Maher 2009), in addition waste incineration (e.g. in Japan) (Ijima *et al* 2009 in Maher 2009) and flame-retarded goods have also been identified as potentially important sources (Månsson *et al* 2009 in Maher 2009). Surface run-off is considered a predominant source of Sb to the wastewater stream in urban environments, particularly in combined sewers (Patriarca *et al* 1999).

There is limited data on Sb within households. Palmquist and Hanæus reported Sb concentrations ranging from 0.28 to 0.68 μg/L and 0.22 to 0.33 μg/L for greywater and blackwater sampled from Swedish households (Palmquist and Hanæus 2005). In Canada, Le Blanc and colleagues measured concentrations of less than 1 μg/L to 16 μg/L Sb in shampoos and conditioners, with less than 1 μg/L in the majority of products (LeBlanc *et al* 1999).

Toxicity

The toxicity of Sb is not well understood (Maher 2009). Sb has a similar chemical behaviour as arsenic (As), but it displays less toxicity on a molar basis (Maher 2009). Evidence of Sb bioaccummulation in plants and toxicity to animals has been reported in the literature, e.g. animals fed on forage grown in Sb contaminated soil (Tschan *et al* 2009, Westerhoff *et al* 2008) and for plants cultured in nutrient solution (Foy *et al* 1978). Tschan *et al* have also shown that plant uptake of Sb increases as the concentration of Sb in a solution increases and with the soluble Sb portion in soil. Mutagenic activity was evidenced on bacteria and cultured mammalian cells exposed to pentavalent and trivalent ammonium salts (NHMRC and NRMMC 2008). Carcinogenicity of some Sb compounds is suspected, but it has not been confirmed (USEPA 2009).

Evidence of direct toxicity to humans at current concentrations is limited (USEPA 2009). Acute toxicity effects occur generally by inhalation or skin contact (USEPA 2009). However, oral absorption has also been shown to affect the gastrointestinal tract following short-term chronic exposure, and, the nervous systems in the long-term in animal studies (Westerhoff *et al* 2008).

2.2. Chloride

Chloride (Cl^-) is an anion that originates from the dissolution of natural salt deposits or from contamination by human activity.

Cl is widely used in industrial, commercial and domestic applications. Industrial applications include the manufacture of food (NaCl), fertilisers (KCl), water treatment ($FeCl_3$), disinfection ($NaHClO_3$), chemicals (solvents, degreasing agents, adhesives, insecticides, herbicides), detergent industry, plastic manufacture (vinyl chloride), including pipes, flooring, medical supplies, personal care products, cosmetics, etc.

Chloride is found in food and water, including vegetables and processed food.

Surface waters in Australia typically contain less than 10mg/L Cl, but concentrations vary depending on location and pollution (NHMRC and NRMMC 2008). Reticulated water typically contains less than 350mg/L, with the Australian Drinking Water Guidelines (ADWG) value of 250mg/L based on the human taste threshold (NHMRC and NRMMC 2008). Domestic wastewater reaching the treatment plant has on average between 30 and 90mg/L Cl, but concentrations can be much higher for industrial wastewater (Metcalf and Eddy 2003)

In mixed greywater a wide range of Cl concentrations, from 31 to 136mg/L, have been reported in the literature (Hypes 1974, Rose *et al* 1991, NRMMC/EPHC/AHMC 2006). Concentrations for domestic wastewater reported in the literature vary, partly because of differences in tap water quality and household habits across the globe. For instance, in Israel, which is supplied by high salinity groundwater, Friedler reported concentrations ranging from 166 to 450 mg/L for the bathroom and laundry greywater, whilst, in Melbourne, which is characterised by soft water, Christova-Boal *et al* reported concentrations of 9 to 88 mg/L for greywater from those same sources (Friedler 2004, Christova-Boal *et al* 1996).

Toxicity

Chloride is an essential element for human beings and animals. It is non-toxic at the typical concentrations found in the environment, however at elevated concentrations it can have adverse effects on biota in freshwater environments (NRMMC/EPHC/AHMC 2006).

High levels of chloride in irrigation water (30 - 100 mg/L) can increase salinity of soil. Irrigation with concentrations greater than 140 mg/L can cause decline in plant yield depending on soil characteristics and irrigation frequency (ANZECC and ARMCANZ 2001).

In addition, water with more than 400 mg/L Cl increases the concentration of $CdCl_n^{2-n}$ complexes in soil, which is more labile resulting in greater overall uptake of Cd from the soil by plants (McLaughlin *et al* 1997 in ANZECC and ARMCANZ 2000).

Foliar injury to crops also results when solutions containing high chloride levels are sprayed directly onto leaves. Concentration thresholds vary with plant species. Tobacco leaves, for instance, have a threshold of 40 mg/L (ANZECC and ARMCANZ 2001).

High chloride concentrations in water can also cause corrosion of metal pipes and water distribution infrastructure (NRMMC/EPHC/AHMC 2006).

In humans, chloride is absorbed via the gastrointestinal tract mainly via the ingestion of NaCl from food. There is no evidence of carcinogenic or genotoxic effects and limited evidence of adverse effects following the prolonged intake of large amounts of chloride (NRMMC/EPHC/AHMC 2006).

2.3. Cobalt

Cobalt (Co) is a common element found in 0.0025% of the earth's crust. It is often found in combination with sulfides, arsenides, sulfoarsenides, hydrates and oxides, and in association with copper or nickel (Kim *et al* 2006).

The major industrial application of Co is in the manufacture of alloys (steel, welding material, magnets). Co is also used as a catalyst in the petrochemical, plastic and detergent industry (Kim *et al* 2006), in the manufacture of pigments, inks and glass production (Stephenson 1987), in phosphate fertilisers, petrol, coal and fuel oil at concentrations of less than 0.001 mg/kg, 5 mg/kg and between 0.001 - 10 mg/kg, respectively.

Co is found in the air, in surface waters, in soil, in groundwater, in wastewater sludge and in leachate from landfill. It is released to the environment by a number of diffuse sources, such as burning of fossil fuels, sewage sludge, phosphate fertilisers, pollution from mining and smelting and by industries that use cobalt compounds in their processing. Typically it settles in sediment and has low uptake by plants remaining mainly in the root zone.

Co is naturally found in sea and surface waters, soil and rocks. Surface water and ground water contain less than 1-10 μg/L in urban areas. Unpolluted surface waters typically contain less than 1μg/L. The concentration in drinking water ranges from <1 to 2μg/L and in rainwater from 0.3 to 0.7 μg/L. The Australian guidelines recommend a long term concentration value of 0.05 mg/L and a short term value of 0.1 mg/L for irrigation water. As there is limited data on soil toxicity, no CCL values have been established (ANZECC and ARMCANZ 2001).

There is limited data on Co concentrations in wastewater. In 1995 Melbourne's wastewater had an average of 1.28μg Co/L, but concentrations ranged from less than 1 to 3μg/L (Wilkie *et al* 1996). Palmquist and Hanaeus reported grey and blackwater concentrations in the ranges of 1.19 to 1.59 μg/L and 0.48 to 1.20 μg/L, respectively, in Sweden (Palmquist and Hanaeus 2005). LeBlanc verified that shampoos and conditioners in the UK also contributed to the Co content in wastewater, with concentrations up to 12 μg/L verified in certain brands

(Le Blanc 1999). However, detection in wastewater was often rare even close to the point of discharge, as reported by the number of studies that reported Co to be either at or below the limit of detection (maximum 1.5 µg/L) in greywater (Hargelius *et al* 1996, NRMMC/EPHC/AHMC 2006).

Toxicity

Cobalt is a non-essential micronutrient for most plants, but it is essential in the nitrogen fixation process for legumes.

Evidence of direct toxicity to microorganisms and plants in soil is scarce, as Co tends to bind with soil particles into stable compounds. However plant toxicity has been verified in nutrient solutions, with concentrations greater than 0.06 mg/L reported to hinder plant growth (Kim *et al* 2006).

Co released into water tends to be adsorbed into particles or sediment and settle into the soil. However, in polluted waters, soluble organic complexes of Co are formed, these are bioavailable to plants and other organisms. Yet there is no evidence of biomagnification of cobalt in the food chain (Smith and Carson, 1981 in Kim *et al* 2006).

Concentrations of 0.08-0.5 mg/L Co have been verified to exert an inhibitory effect on pure cultures of *Nitrosomas sp* (Henze *et al* 2002), hence inhibition of the nitrification process during wastewater treatment could occur at specific Co concentrations.

Cobalt toxicity in aquatic systems has been verified for a range of species, at exposure limits ranging from 0.01 mg/L (EC50 for *Daphnia magna* 21d) to 1.1 mg/L (LC50(24-96h) for freshwater invertebrates) (WHO 2006). Adverse impact on higher order organisms requires much higher concentrations, for instance, earthworm and springtail reproduction are only affected at concentrations of 300-400mgCo/kg dry weight soil (WHO 2006).

Human toxicity has been verified at doses of 150 mg/day for periods of at least 22 days (Kim *et al* 2006). Toxicity symptoms include polycythaemia, increased hemoglobin and reduced lung capacity. Mortality is generally associated with occupational exposure, such as entry via the respiratory system with the onset of lung disease in the hard metal industry (Kim *et al* 2006).

2.4. Chromium

Chromium (Cr) is a naturally occurring element found in the soil, rocks, plants, living beings and volcanic emissions (EPA 1998). Soils typically contain 100 mg Cr/kg soil, but the concentration can range between 5 to 3,000 mg/kg (Asano *et a*l 2007). Chromium concentrations in surface water depend on the degree of pollution of the water body.

Cr is widely used in the manufacture of alloys for industrial equipment, machinery and building construction, in electroplating, in rust inhibitors, inks, pigments, preservatives (fungicides), glass manufacture, dyeing of textiles and tanning (Stephenson 1987, Icon 2001).

In Europe, commercial sources contribute between 30 – 60% of the total load reaching wastewater treatment plants, whilst domestic sources are assumed to contribute between 20-40% (Icon 2001). In Melbourne, 45.8% of the Cr load reaching the Eastern Treatment plant is estimated to come from trade waste (URS 2004). Among commercial sources, car washes have been identified as the major potential source in Europe (Sörme and Langkvist 2002).

Reticulated water in Australia may contain up to 0.03 mg/L Cr (ADWG 2008). In Melbourne the concentration in tap water was below the detection limit of 1 µg/L in the 1995 study by Wilkie *et al* (1996). Concentrations of Cr in Melbourne's residential wastewater were reported to range up to 8 μg/L, with an average of 3.2 μg/L according to the same study (Wilkie *et al* 1996).

Closer to the point of generation higher concentrations have been observed. Chromium concentrations for grey and blackwater range between 2.06 to 36 μg/L and up to 3.7 μg/L respectively (Palmquist and Hanaeus 2005, Eriksson *et al* 2002).

Toxicity

Chromium is present in the environment as a metal, in trivalent (III) or hexavalent (VI) states.

Cr (VI) in the soil is absorbed by plants, whilst Cr (III) remains immobile in the soil. Cr (VI) is toxic at concentrations ranging from 50 to 5,000 mg/kg, dependent on plant species and soil conditions (NRCC 1976 in ANZECC and ARMCANZ 2001). In biosolids Cr is typically present as Cr (III) which is immobile. Yet specific soil conditions can result in reduction of Cr (III) to Cr (VI).

Studies using nutrient solutions have shown lower crop yields at concentrations of 1-10 mg/L Cr (ANZECC and ARMCANZ 2001).

Trivalent Cr is an essential element for microorganisms, animals and human beings. On the other hand, hexavalent Cr is carcinogenic when inhaled, mutagenic to bacterial assays and corrosive on tissue, leading to long-term skin sensitisation and kidney damage (Metcalf and Eddy 2003).

Carcinogenic effects due to oral ingestion by humans have not been verified, although in mice dosages of 250-700 ppm Cr in drinking water impair foetus development.

Toxicity to heterotrophic microorganisms at treatment plants has also been verified at concentrations of 10 mg/L (Metcalf & Eddy 2003) and more than 0.25 mg/L for pure cultures of *nitrosomas sp* (Henze *et al* 2002).

Toxicity to zooplankton has been verified at concentrations from 0.016 to 0.70 mg/L Cr (Hart 1974).

2.5. Fluoride

Fluoride (F) is found in 0.07% of the earth's crust, mainly bound to metalloids. Concentrations found in the environment include: between less than 200 to 7,000 mg/kg in soil, 2 mg/L in freshwater (WHO 1970 in AANZMCC and ARMCANZ 2001), average of 1.4 mg/L in seawater and less than 2 mg/L in irrigation water.

Typical concentrations in soil are less than 400 ppm. In surface waters the concentration ranges from less than 0.1 to 0.5 mg/L, however higher content can be found in groundwater due to leaching from mineral rocks with high F content in certain parts of the world. Agricultural soil averages range from 150 to 360 mg/kg soil (McLaughlin *et al* 1996).

Trace amounts of F are also found in most food stuff, with specific food groups, such as tea leaves having high concentrations.

Inorganic F is used in aluminium production, in the manufacture of steel and glass fibre, in the production bricks, tiles and ceramics. Fluoride is also used in insecticides, rodenticides, floor polishes, petroleum, glass etching, timber preservatives, dietary supplements and toothpaste. Hydrogen fluoride/hydrofluoric acid is used in the semiconductor industry, manufacture of chemicals, solvents and plastics (WHO 2009). Fluoride is also found as a contaminant in phosphate rock, which is used in fertilisers and in some laundry powder formulations.

Fluoride in air is mainly caused by emissions, particularly in the proximity of industries such as steel, superphosphate, coal burning, glassworks and oil refineries. Typical concentrations in air are less than1.89 μg/m^3 (USA/Europe).

The Australian drinking water guidelines sets a maximum guideline value of 1.5 mg/L F (NHMRCC and NRMMC 2008). Fluoridated drinking water concentrations in Melbourne range between less than 0.05 to 1.1 mg/L, with annual averages of less than 1 mg/L. (YVW 2009, CWW 2009, SEWL 2009). Fluoride is not commonly analysed in household wastewater, but concentrations between 0.49 to 1.6 mg/L have been reported for greywater in the literature (NRMMC/EPHC/AHMC 2006).

Toxicity

Fluoride is an essential trace element to mammals, however at high concentrations toxicity has been verified.

In soil F is typically bound to soil particles and inert. Contamination of groundwater through irrigation and plant toxicity by fluoride from soil has not been evidenced (ANZECC and ARMCANZ 2001). However, uptake and toxicity to plants in nutrient solution has been observed at concentrations ranging between 1 mg/L to more than 100 mg/L, dependent on the ionic species and the plant species. The Australian irrigation guidelines recommend concentrations of 1.0 mg/L for long-term and 2.0 mg/L for short tem values (ANZECC and ARMCANZ 2001).

Fluoride is also absorbed by plants through deposition of airborne particles onto leaves, with long-term injury to plants resulting from concentrations greater than 0.2 $\mu g/m^3$. A detailed description of fluoride's impact on crops can be found in McLaughlin *et a*l (1996).

Concentrations of more than 1.5 mg/L have been shown to have negative impact on tooth mineralisation in children (NHMRCC and NRMMC 2008). Ingestion of 5 to 10 mg/kg body weight results in acute toxicity, and doses of more than 16 mg/kg may lead to death. Skeletal fluorosis has been verified at concentrations of more than 5 mg/d for sensitive human subjects (WHO 2000).

2.6. Molybdenum

Molybdenum (Mo) is used in the manufacture of steel and non-ferrous alloys, chemicals and ceramics, in catalysts, pigments, electrical contacts, screens, radio valves and lamp filaments, fertilisers and lubricants (Stephenson 1987, NHMRCC and NRMMC 2008).

Mo occurs naturally in Australian soils at concentrations ranging between 0.2 to 20 mg/kg with a median concentration of 1.0 mg/kg soil (ANZECC and ARMCANZ 2001). Concentrations in surface waters range between 0.03 and 10 μg/L in unpolluted freshwater (ANZECC and ARMCANZ 2001). The Australian drinking water guidelines for Mo recommend a maximum concentration of 0.05 mg/L. Mo is also present in most foods.

Information on Mo in wastewater is scarce (Icon 2001, Eriksson *et al* 2002). Wilkie *et al* (1996) analysed Melbourne's wastewater and detected less than 1 μg/L Mo in domestic wastewater catchments and an average of 3 μg/L for wastewater at the treatment plant. There is also limited data on Mo sources. In Canada, Le Blanc *et al* (1999) measured between 1 to 27 μg/L Mo in the formulation of shampoos and conditioners.

Toxicity

Molybdenum (Mo) is an essential trace element for living organisms in small concentrations.

Plants in soil have a high tolerance to Mo, with no adverse effects verified for soil concentrations greater than 100 mg/kg. There is also no evidence of phytotoxicity to crops from Mo in irrigation waters, but toxicity to plants grown in aqueous solution has been observed at concentrations larger than 0.5 mg/L Mo (ANZECC and ARMCANZ 2001).

Often, toxicity to livestock is evidenced before plant toxicity is observed. Livestock fed a daily intake of forage containing more than 5 mg/kg for cattle and more than 10 mg Mo/kg for sheep experience Cu deficiency (Dye 1962 in ANZECC and ARMCANZ 2001). Cattle fed on vegetables irrigated with water containing 0.01 mg/L Mo have also shown signs of molybdenosis (DWAF 1996a in ANZECC and ARMCANZ 2001). Thus, long and short term concentrations of 0.01 mg/L and 0.05 mg/L are specified for irrigation waters (ANZECC and ARMCANZ 2001).

For aquatic life, data on Mo toxicity is contradictory (Davies *et al* 2005). Acute toxicity has been reported for concentrations ranging from 0.73 to more than 90 mg/L for fish eggs and alevins and between 70 to 2,000 mg/L for various fish species, however results could not be confirmed in later studies (Davies *et al* 2005). In Canada a maximum concentration of 1mg/L is adopted for protection of aquatic life (Davies *et al* 2005). Whilst in Australia trigger values for aquatic ecosystems have not been set because of insufficient data.

There is insufficient evidence of toxicity to humans (NHMRCC and NRMMC 2008).

2.7. Selenium

Selenium (Se) is widely found in the environment, often in association with sulphide ores of copper, iron, zinc and in natural coal deposits. An essential trace element to humans and animals, it is also found in foodstuff (Icon 2001).

Industrial applications of Se include the electrical and electronics industry, the manufacture of semiconductors, rectifiers, ceramics, glass and pigments, alloys, catalysts, deodorants, lubricants, pesticides, anti-dandruff shampoo, cosmetics, pharmaceuticals, food supplements, animal feed and rubber industry (Stephenson 1987, Icon 2001, NHMRCC and NRMMC 2008). Release of Se into the air is most commonly attributed to the burning of coal and the production of alumina.

Selenium content in Australian soils ranges from 0.05 to 3.2 mg/kg, yet many Australian soils are Se defficient (ANZMCC 2000). In unpolluted waters concentrations are less than 0.1 μg/L. Australian reticulated water supplies contain in general less than 0.005 mg/L (NHMRCC and NRMMC 2008), which is also the trigger value for protection of 99% freshwater aquatic systems (ANZECC and ARMCANZ 2001).

In a 1995 study conducted in Melbourne by Wilkie *et al* Se was below the detection limit of 10 μg/L in domestic wastewater and at the treatment plant (Wilkie *et al* 1996). Studies of Se in household wastewater have also been few (Eriksson *et al* 2002), with reported concentrations mainly below detection in greywater (Christova-Boal *et al* 1996, Hypes 1974).

Toxicity

Se is recognised as a potentially toxic compound at low concentrations, but information on its long term effects is limited (Icon 2001).

Se is highly mobile and bioavailable. Toxicity is dependent on the specific Se compounds and on their concentration (NHMRCC and NRMMC 2008, O'Connor *et al* 2001).

Phytotoxicity is dependent on plant species (Terry *et al* 2000). Some plants, which are known to be Se accumulators, can absorb large amounts of Se with low phytotoxicity, whilst non-accumulators, experience stunted growth at a range of concentrations. Australian phytotoxicity was verified for Se at 1 mg/kg in soil and 0.7 mg/L in nutrient solution (Will and Suter 1994 in ANZECC and ARMCANZ 2001).

Aquatic toxicity has been evidenced mainly in environments polluted by industrial discharges, resulting in teratogenic and developmental defects in freshwater fish and in the cycling and accumulation of Se in aquatic environments, particularly in lakes (Lemly 2002).

Cattle requires between 0.03-0.1 mg/kg of Se as dietary supply. However domestic animals fed more than 5mg Se/kg feed can suffer from toxic effects such as "blind staggers" which results in paralysis and death due to respiratory failure.

The maximum recommended Se concentrations for waters used for growing feed for livestock are respectively 0.05 mg/L and 0.02 mg/L Se for short and long term irrigation. The CCL for Se is 10kg/ha (ANZECC and ARMCANZ 2001).

Selenium sulphide and selenite have been shown to cause tumours in mice and chromosome damage to mammalian cells (NHMRCC and NRMMC 2008). However, carcinogenicity to humans and animals has not been proven.

Se deficiency in humans is suspected to be associated with chronic heart disease and cancer, with the typical adult requiring on average 70 μg/d Se (Francesconi and Pannier 2004). Excess intake of Se, more than 1 mg/d over extended periods, is reported to cause nail deformities, gastrointestinal disturbance, dermatitis, dizziness, mental tiredness and breath odour (NHMRCC and NRMMC 2008). However, toxicity in humans is most often caused by occupational exposure.

2.8. Nitrogen

Nitrogen (N) is an essential nutrient for biological development of all major organisms.

Wastewater typically contains between 20 to 85 mg/L total nitrogen (WHO 2006). In Melbourne, concentrations up to 122 mg/L have been reported in domestic wastewater reaching sewage treatment plants (Wilkie *et al* 1996), whilst concentrations up to 500 mg/L have been reported in the trade waste of specific industries (Fox *et al* 2006).

In a household, over 85% of the nitrogen load originates from blackwater, with typical concentrations of total nitrogen in blackwater ranging between 130 to 180 mg/L (Palmquist and Hanæus 2005). Concentrations of TKN in greywater range from 1 to 5 0 mg/L in the literature (Eriksson *et al* 2002, Palmquist and Hanæus 2005, Tunaley *et al* 2004).

Toxicity

Nitrogen is reported as organic nitrogen, nitrate salts, and ammonium (NH_4^+). Nitrate, the end product of the oxidation of ammonium and organic nitrogen, is soluble in water and can be toxic to humans at high concentrations.

Excess nitrate (more than 50 mg /L NO_3) in drinking water causes methemoglobinemia in infants less than 3 months old and in animals, leading to asphyxiation. Conversion of nitrate into nitrosamine, a carcinogenic, in the human digestive tract has also been reported in the literature (NHMRCC and NRMMC 2008).

Excess nitrogen, at concentrations ranging from 0.1 to more than 1.6 mg/L, in surface waters can cause excessive algae growth (euthrophication), which depletes dissolved oxygen in water and impacts other aquatic species.

Ammonium is rapidly absorbed by the soil and available to plants. For irrigation waters, the maximum recommended concentration of nitrogen was established to protect groundwater and surface waters, with 5 mg/L and 25 to 125 mg/L as the short and long term maximum recommended concentrations for irrigation (ANZECC and ARMCANZ 2001).

2.9. Phosphorus

Phosphorus (P) is an essential nutrient for plant growth and for biological metabolism. In the environment, it is found as mineral phosphate deposits of tricalcium phosphate.

Industrial applications of phosphorous include the manufacture of fertiliser, food (including soft drinks, cheese processing, baking powder), flame-proofing chemicals, water conditioning, anti-corrosion agents for metals, detergent manufacture, insecticides, rodenticides, matches, as an additive in alloy manufacture, additives to gasoline and lubricating oil, plasticisers in plastic manufacture and more (Encyclopaedia Britannica 2009).

Toxicity

Phosphorus is not toxic. However excessive discharge into aquatic environments can result in excessive algae growth, eutrophication and the depletion of oxygen in water bodies, impacting aquatic life. The recommended STV and LTV for irrigation waters are 0.8 to 12 mg/L and 0.05 mg/L, respectively (ANZECC and ARMCANZ 2001).

2.10. Sources of pollutants to domestic sewage

A number of sources have the potential to contribute to the element loads in wastewater. Some of these are illustrated in Table 2. Nutrients such as nitrogen and phosphorus originate primarily from human excretion (Metcalf and Eddy 2003, Gray and Becker 2002). Information on the origin of other contaminants in domestic settings is more limited. Selenium, cobalt and molybdenum are also sourced from food, ending in human excreta. However a number of the elements can be found in common household products either as residual contaminants or as ingredients in product formulations.

Table 2: Domestic sources of elements in urban wastewater (adapted from Icon 2001)

Product type	***Co****	***Cr****	***Se****	***Cl***	***F***	***Sb***	***Mo***	***N***	***P***
Cleaning products		√		√				√	√
Cosmetics, medicated shampoos			√					√	√
Fire extinguishers		√							
Inks			√						
Lubricants		√							
Medicines and ointments	√		√					√	
Health supplements	√	√	√			√	√	√	
Food products	√		√	√				√	√
Paints and pigments	√	√	√						
Faeces and urine		√	√		√			√	√
Tap water		√			√				
Metal fittings		√					√		

Note: * potentially toxic

Human excreta has traces of all the contaminants detailed in this report, as elements are often ingested via daily food intake or via respiration. The rates of human intake and excretion reported in the literature vary depending on the characteristics of the sample population, including their age, gender, geographical location, diet and environmental pollution. A summary of the elemental loads in human urine and faeces reported in the literature is shown in Table 3.

.

Table 3: Typical amounts secreted by human body

Element	*Daily excretion* (mg. pe^{-1} .d^{-1} or as stated)	*Concentration in Faeces (range)* (μg. pe^{-1}.d^{-1} or as stated)	*Concentration in Urine (range)* (μg. pe^{-1}.day^{-1} or as stated)	*Perspiration or other* (μg.pe^{-1}. d^{-1} or as stated)
Antimony	2.51 [(m)]	0.3-0.9 [(a)] Sb (III)	1.61 [(b)] (Germany) (1.2-3.6) [(a)] Sb (VI) 0.063 (LOD – 0.57) [(c)]	
Chloride	210-500 μg.kg body wt $^{-1}$.d^{-1} [(5) in (c)] 4400 [(m)]	210-500 μg. kg body wt $^{-1}$. d^{-1} [(c)]	20 to 250 mEq. d^{-1} [(c)] 115 mEq. d^{-1} or 4.21g/L [(f)]	360-4680mg. L^{-1} [(c)]
Chromium	0.02 [(m)]	20 [(f)] 10.1 [(e)] Sweden	0.16± 0.02 [(e)] 0.158 (LOD – 1.0) [(n)]	
Cobalt	0.002-0.020 [(19) in (c)] 0.161 [(d)] 0.023 [(m)]		0.04-2μg.L $^{-1}$ [(p)] 0.387 (0.02-3.3) μg.L $^{-1}$ [(n)]	
Fluoride	3.14 [(m)]	74.56 [(h)]	671±373 (156-1990) (Spain 250 pe) [(g)]	100
Molybdenum	87±11μg. pe^{-1}.d $^{-1}$ [(j)]		(87 -187) (USA) [(c)] 38 (4-357) μg.L $^{-1}$ (Germany) [(n)]	20 [(i)] Hair (0.01μg/g hair) [(i)]
Selenium	1.4-14 for healthy adults [(k)] 0.085 [(m)]		14(3-60) μg.L $^{-1}$ [(n)]	

Element	Daily excretion (mg. pe^{-1} .d^{-1} or as stated)	Concentration in Faeces (range) (μg. pe^{-1}.d^{-1} or as stated)	Concentration in Urine (range) (μg. pe^{-1}.day^{-1} or as stated)	Perspiration or other (μg.pe^{-1}. d^{-1} or as stated)
Phosphorus	9.9 (7.1-20.0) μg.kg body wt $^{-1}$.d^{-1} [(10) in (c)] 2,700-4,500 (dry weight basis) [(l)] 3,200 [(m)]	0.7(0.1-1.7) g .pe^{-1} .d^{-1} (USA)[(o)] 1 g .pe^{-1} .d^{-1} (Sweden)[(f)]	1,500 [(f)]	32 mg/100mL saliva
Total nitrogen	0.8-2.5 g.pe^{-1}.d^{-1} [(20) in (c)] Average 13g .pe^{-1} .d^{-1} [(l)] Range 9-21.7g. pe^{-1}.d^{-1} (dry weight basis)(USA) [(l)]	2 (0.25-4.2) g. pe^{-1}. d^{-1} (USA) [(o)]	11 g. pe^{-1}. d^{-1} [(f)]	

[(a)] Health Canada (1997), [(b)]Gebel *et al* (1998), [(c)] Alltman and Dittmer (1972-74)[1], [(d)]Kim *et al* (2006), [(e)]Anderson *et al* (1997), [(f)] Vinneras, B (2001),

[(g)]Yadav *et al* (2007), [(h)] Based on Gropper *et al* (2008), [(i)]Gropper *et al* (2008), [(j)] Van Cauwenbergh *et al* (1997), [(k)] Adapted from Alaejos and Romero (1993) assuming a body weight of 70kg, [(l)]Metcalf and Eddy (2003), [(m)] Estimated from literature, [(n)] Heitland and Köster (2006), [(o)] Del Porto *et al* 2000 in Crockett *et al* 2003, [(p)]Ichikawa *et al* (1985) and Alexandersson (1988) in [(d)], [(q)] Fittschen and Hahn (1998) in [(f)] .

[1] Based on a dietary intake of 10g N per day and a body weight of 70kg.

3. METHODOLOGY

3.1. Product selection

A total of 156 products were purchased from major supermarkets in Melbourne, Australia, during the period of February to March 2008. For each brand, a single product sample was purchased. When available a private brand, a market leader brand and a brand with an “environmental friendly” or “natural“ label were included in the product category.

3.1.1. Cleaning products

The range of cleaning products selected included:

- 4 brands of toilet cleaner
- 4 brands of floor cleaners
- 7 brands of general purpose cleaners which included 4 disinfectants (including 1 bleach), 2 multi-purpose cleaners and 1 cream cleanser
- 3 brands of toilet bowl fresheners and 4 brands of in-cistern cleansers
- 8 brands of toilet paper, including 2 made of recycled paper.

3.1.2. Dishwashing products

The range of dishwashing products selected included:

- manual dishwashing: 6 brands of liquid detergent
- automatic dishwashers: 4 brands of dishwasher tablets and 5 brands of dishwasher powder detergents (the environment label detergent was only available as a powder in sachets)
- Rinse aid: 1 brand.

3.1.3. Laundry products

The range of laundry products selected included:

- 7 brands of fabric softener
- 13 brands of concentrate powder detergent
- 11 brands of liquid detergent (including 1 brand of wool wash liquid detergent)
- 2 brands of soakers.

3.1.4. Personal care products

The range of personal care products included:

- 4 brands of facial care creams/lotion

- 5 brands of body lotion
- 5 brands of deodorant in aerosol form
- 4 brands of deodorant in roll-on form
- 7 brands of sunscreen SPF30+
- 5 brands of mouthwash
- 9 brands of toothpaste
- 6 brands of hair colouring
- 5 brands of shaving foam (including 1 shaving stick)
- 10 brands of shampoo, including 2 anti-dandruff formulations
- 3 brands of conditioner
- 4 brands of shower gel, 6 brands of soap bars and 5 brands of hand wash
- 1 brand of facial cleanser, 1 brand of facial scrub and 1 brand of depilatory cream.

3.2. Analytical methodology

3.2.1. Metal analysis

Metal analysis was conducted using a Varian Liberty Series II ICP-AES with a 40 MHz free running RF generator and a 0.75 m Czerny- Turner monochromator and a Thermo X series ICP-MS for detection of antimony, cobalt, molybdenum and selenium. The limits of detection for the instruments are shown in Table 4.

Samples of low organic content were prepared by acid digestion of each product as received or diluted to 1:10v/v in deionised water. For products of high organic content, e.g. toilet paper, a 5-g sample was ashed prior to digestion and analysed in duplicate. Ashing was performed in covered crucibles in a muffle furnace at 450°C for 1 hour or until the sample weight had stabilised.

Acid digestion was conducted using high purity nitric acid (Fluka TraceSelect) and hydrochloric acid (BDH AnalaR) at 95°C. Acid was added in 5 mL increments as per method 3030E (APHA/AWWA 1998). The digested sample was transferred to a 100 mL volumetric flask and the volume completed with deionised water. Blanks were also prepared for each batch of 20 samples.

3.2.2. Chloride

Samples for chloride analysis were prepared as 100% aqueous solutions (5-10 g product in 100mL) with deionised water or as a 10% v/v isopropanol (analytical grade) solution for hydrophobic products and sent for analysis in a NATA accredited external lab using method WSL115.

3.2.3. Fluoride

Samples for fluoride analysis were prepared as a 100% aqueous solutions (2.5-10 g product per 100mL) with deionised water or as a 10%v/v isopropanol solution for hydrophobic products and sent for analysis in a NATA accredited external lab. Fluoride was analysed using method APHA 4500-F C (ion selective electrode) at a NATA accredited laboratory (APHA/AWWA 2008). The detection limit for the fluoride test was 0.1 mg/L for samples in aqueous solution.

3.2.4. Nutrients

Liquid products were analysed in their original state. Solid and viscous samples were diluted in deionised water for analysis.

Total Kjeldahl Nitrogen (TKN) was analysed using APHA method 4500-N Org, B (APHA/AWWA 2008) at a NATA accredited laboratory.

Total phosphorus (TP) was analysed using APHA method 4500 (APHA/AWWA 2008) at the CSIRO Highett laboratories.

Table 4 provides a summary of the detection limits of the methodology adopted.

Table 4: Detection limits for test methods

Element	***Standard LOD (mg/L or *μg/L)***
Antimony	5*
Chloride	1
Cobalt	0.5*
Fluoride	0.1
Molybdenum	0.5*
Selenium	4*
TKN	0.1
TP	0.05

3.2.5. Concentration in product

The concentration of an element in a product was determined using equation (1).

$$\mathbf{Conc_{product} = Conc._{measured} \times Vs \times Mproduct^{-1} \times 10^{3}} \qquad \text{(equation 1)}$$

Where: $Conc_{product}$ = concentration of element in product (mg/kg product)

$Conc_{measured}$ = concentration of element determined experimentally (mg/L)

Vs = volume analysed (L)

Mproduct = Mass of product tested (g)

The geometric mean and median concentrations for each category of products, e.g. shampoos, were determined as the geometric mean and median of the concentration of all brands tested in a product group.

$$\mathbf{Conc(average)_{product\ group}} = \sum_{i=1}^{n} \mathbf{Conc_{product\ i}} \qquad \text{(equation 2)}$$

3.2.6. Frequency of use

The frequency of product use and the amount of product adopted in each application were estimated for a single person household based on the average frequency of appliance use (Roberts 2005) and average product dosages for each category based on manufacturer's recommendations (Tjandraatmadja *et al* 2008). The assumed frequencies are shown in **Table 5**.

These assumptions were used to estimate the weekly mass load generated from product use.

$$M(i)_{week} = f \times dose \times Conc_{product}$$

Where: $M(i)_{week}$ = Weekly mass load for element I for a selected product category (mg/pe/wk);

f = frequency of use per week (times/week);

dose = typical product dose for the product category (kg)

Table 5: Assumptions for product dosages for household and personal care products for a single person household

Category	***Product type***	***Assumed dose per use (g)***	***Frequency of use per week***
Bathroom	Conditioner	10	5.3*
	Shampoo	5	5.3*
	Body wash	7	5.3*
	Handwash/ Soap	2	42
	Shaving foam	3	7
	Hair colorant	60	0.3
	Toothpaste	3	14
	Mouthwash	17	14
	Deodorant	0.2	7
	Sunscreen	10	7
	Body Lotion	10	7
	Facial cleanser	5	7
Kitchen	Dishwashing liquid	7	10.5
	Dishwasher tablet	20	1.8*
	Dishwasher powder	60	1.8*
	Rinse aid	1	1.8*
Laundry	Fabric softener	75	3*
	Laundry Powder	126	3*
	Laundry Powder concentrate	80	3*
	Laundry Liquid	90	3*
Toilet	Toilet paper	1	8.4
	Toilet freshener or in-cistern freshener	1	29.4*

Note: *Based on Roberts (2005).

4. RESULTS AND DISCUSSION

4.1. Elements in products

Figure 2 shows a summary of the frequency of detection of the elements of interest in the products analysed. The data values are shown in Table 17 in Appendix 1.

In 156 common household products, the elements most commonly detected in decreasing frequency were:

TP>TKN>Cl>Cr>Mo>F>Co>Se>Sb

As shown in Figure 2, phosphorus, nitrogen and chromium were among the four most common elements detected in household products, being respectively detected in 97%, 84% and 64% of the products analysed and in all cleaning and personal care product categories.

Chloride, the third most common element, was detected in 79.5% of the products analysed and in the majority of the household product categories, but not in toilet paper.

Molybdenum, fluoride, cobalt and selenium were detected in less than 30% of the products:

(a) Molybdenum was below the limit of detection in all hair colouring products;

(b) Fluoride was below the limit of detection in all shower products, deodorants, lotions, sunscreens and toilet paper; but it was commonly detected (f >75%) in hair dye and oral care products

(c) Cobalt was below the limit of detection in all hair colouring, oral care and deodorant products; and

(d) Selenium was below the limit of detection in hair colouring, toilet paper, dishwashing, sunscreen and lotions.

Antimony was the least detected element in household products, with a detection frequency of less than 10%. It was below detection among all brands of hair colour and deodorants analysed.

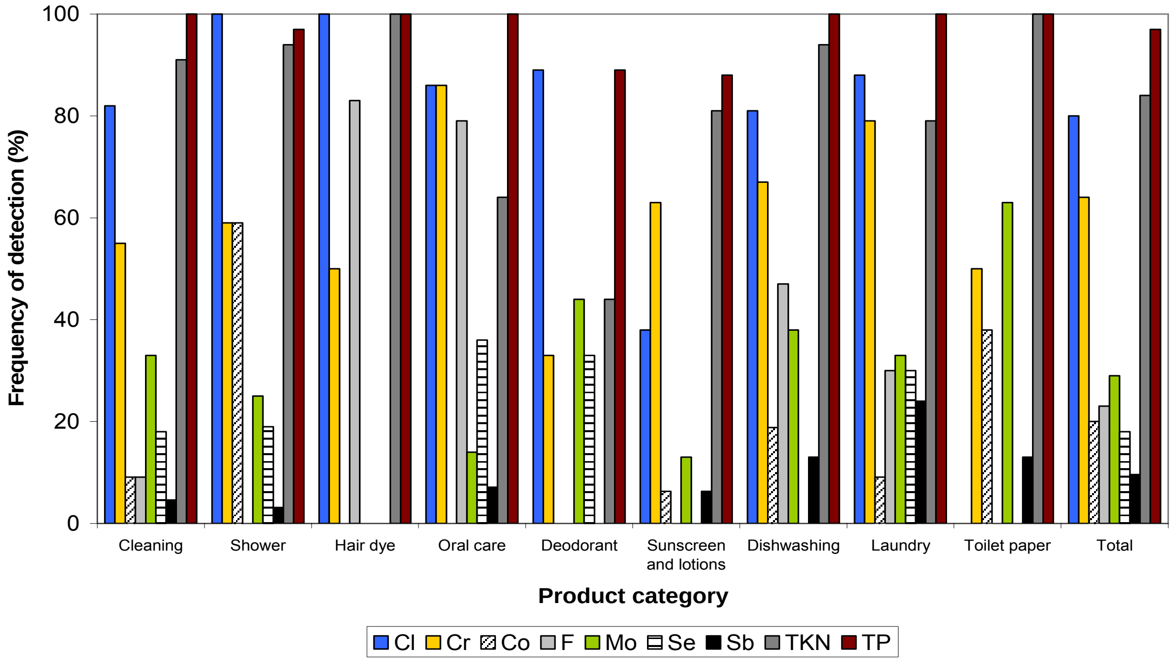

Figure 2: Frequency of element detection in household products analysed.

4.1.1. Antimony

Traces of Antimony (Sb) were detected in 9.6% of the 156 products analysed. Sb was detected in individual product brands, but not detected consistently in any class of products analysed.

The concentrations in products and the comparison of the corresponding loads from product use are shown in Table 6 and Figure 3, respectively.

Antimony was below the detection limit in majority of the cleaning products and personal care products (toilet cleaners, disinfectants, sunscreen, soap, handwash, laundry powder, shampoo, soap, etc).

Among the laundry products that contained Sb, the concentration range varied from 0.04 to 0.82 mg/kg product. The highest concentration, 0.82 mg/kg, was for a brand of dishwashing powder. The second highest concentration, 0.47 mg/kg, was for a brand of laundry powder.

Among the product categories, antimony was:

(a) detected in only two of four brands of dishwasher powders, and it was below detection in all brands of dishwashing liquids, tablets and in the rinse aid, and

(b) detected in 46% and 20% of the brands of washing powders and liquids, respectively, but it was below detection in all the remainder of washing aids (fabric softeners, soakers and wool wash).

Other individual products that contained Sb included one brand of floor cleaner (0.016 mg/kg), one brand of toilet paper (0.069 mg/kg) and one brand of toothpaste (0.147mg/kg).

The low Sb concentrations in the products would result in weekly loads of less than 0.18 mg/pe/wk per product assuming that the brand with the highest concentration was used as shown in Figure 3. The estimated mass loads are shown in Table 27 in Appendix 2.

In summary, Sb is a minor contaminant in household products.

Table 6: Concentration of Sb in household products

Product (number of brands)	***Concentration (mg/kg product)***
Toilet paper (1)	0.02
Floor cleaner (1)	0.07
Toothpaste (1)	0.15
Laundry detergent (8)	0.04, 0.12, 0.13, 0.19, 0.2 (x2), 0.41, 0.47
Dishwashing powder (2)	0.82, 0.10

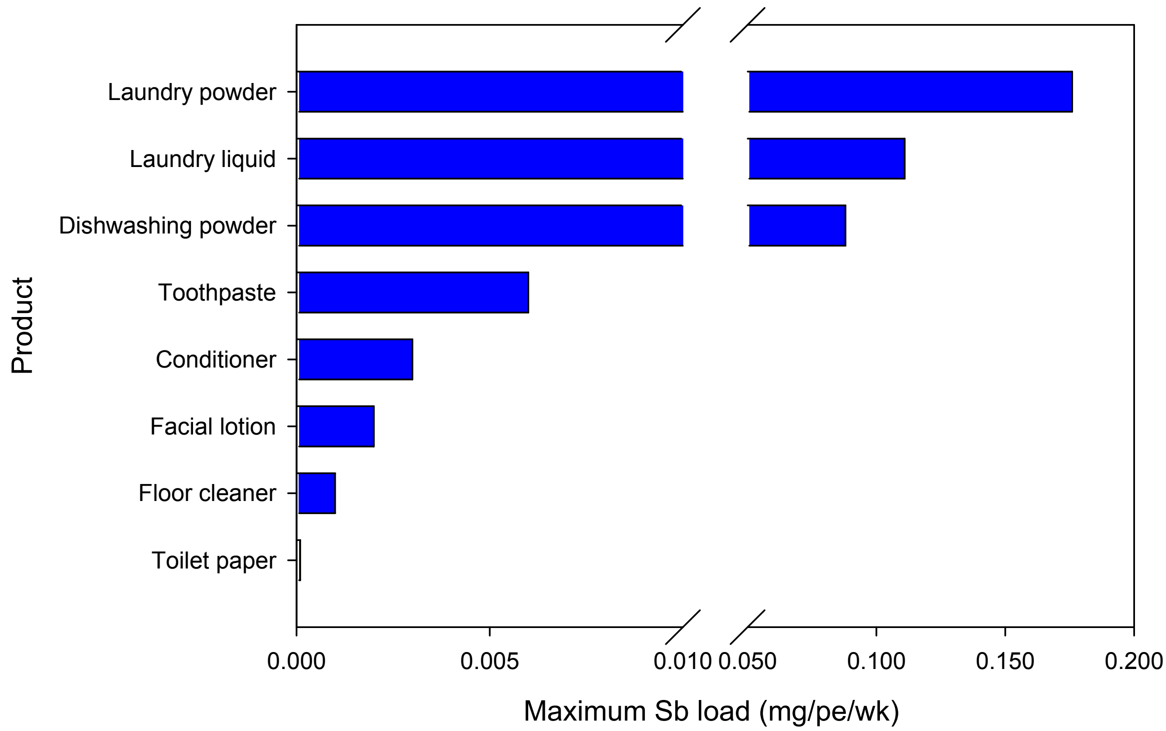

Figure 3: Antimony loads estimated from product use

4.1.2. Chloride

Chloride was the third most common element in this group detected in 79.5% of the household products analysed. The concentrations in products are shown in Table 7 and the corresponding loads from product use are compared in Figure 4. Table 28 in Appendix 2 shows the major Cl loads for each product category.

The concentrations in products ranged from below detection to 225 g/kg. Chloride was below the detection limit in toilet paper and body lotions, but it was detected in every other product category.

The highest chloride concentration in products was observed in the categories of soaps, deodorant and toilet freshener with means of 89, 67 and 53 g/kg for each product category, respectively (Table 7).

In cleaning products, chloride was detected in 86% of fourteen brands of cleaning products and concentrations ranged from 0.07 to 43 g/kg product. The highest concentrations were for two brands of disinfectants at 43 g/kg and 393 g/kg product.

In personal care products, which includes products used in the shower and bathroom, chloride was present in every product, with the exception of a few brands of creams, sunscreens and lotions.

Among dishwashing products, the highest median concentration in a product type was observed in liquid detergent at 6 g/kg product compared to 1.4 mg/kg and 2.4 g/kg for dishwasher tablets and powders. However, when individual brands were considered, the highest concentration (46 g/kg) was for a laundry powder.

In laundry products, the concentration of chloride ranged from 0.05 to 27 g/kg product, with fabric softeners and liquid detergents containing the lowest concentrations in the group and median concentrations equivalent to 6% and 58% of the median concentration for powder concentrates and soakers (Table 7).

The three largest weekly loads, 85, 34 and 16 g/pe/wk, from product use are expected to be generated from the use of laundry powder, toilet fresheners and bar soap (Figure 4). Loads derived from the remainder of products including the deodorants would release less than 2 g/pe/week into the sewer (Figure 4).

No trends were verified among the market leader, private and enviro label brands regarding the concentration of Cl.

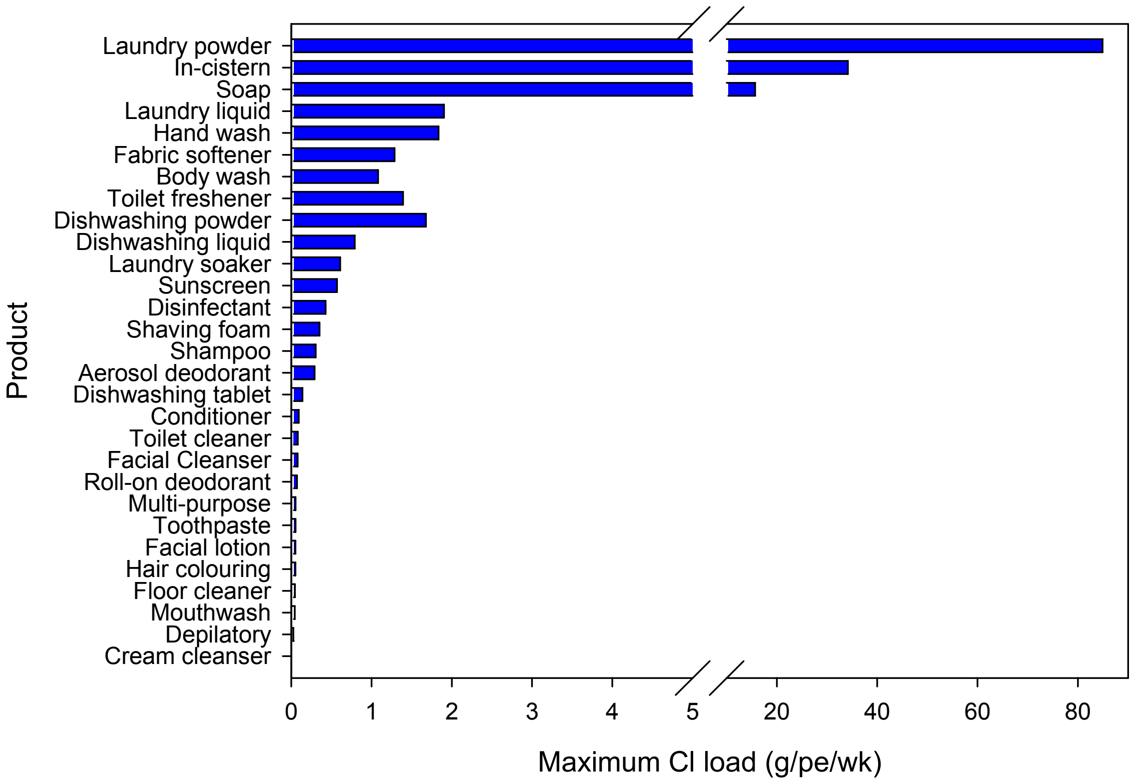

Figure 4: Chloride loads estimated from product use

Table 7: Chloride concentration in household products

		Concentration Cl (g/kg product)						
Product type	***Number of brands with detectable Cl***	***Minimum***	***Maximum***	***Median***	***Average***	***Leader***	***Enviro***	***Private***
Body wash	4/4	0.015	29	6.9	10.7	-	29	-
Conditioner	3/3	0.4	1.8	0.5	0.9	0.4	-	-
Cream cleanser	1/1		0.6					
Depilatory product	1/1		8.9			-	-	-
Hand wash	5/5	2.7	21.8	6.7	9.5	2.7	-	21.8
Multi-purpose	1/2		5.6			-		
Disinfectant	4/4	1.0	42.9	20.5	21.2	39.3		1.0

Toilet cleaner	3/4	0.07	5.6	0.2	1.5	0.3	5.6	<0.5
Floor and surface	4/4	0.7	3.1	0.3	1.75	1.5	3.1	-
Toilet fresheners	5/7	5.5	166	6.8	52.7	6.8(TF)	-	5.5(IC) 5.8(TF)
Shampoo	11/11	1.8	11.5	5.4	5.9	1.8	5.4	7.1
Soap bar	6/6	1.6	187	104	89.5	18.6	93	121
Face cleanser	1/2	<0.001	3.8			-	-	-
Shaving foam	5/5	0.2	16.8	4.4	7.9	0.2	-	4.4
Hair colouring	6/6	0.1	3.5	1.3	1.5	-	-	-
Mouth wash	5/5	0.02	0.19	0.08	0.08	0.02		0.19
Toothpaste	2/9	0.005	1.3	0.18	0.5	0.005	0.18	<0.03
Deodorant	8/9	0.09	210	52	67.4	126.2	-	210.5
Sunscreen	3/6	0.41	8.2	0.4	1.5	1.3	-	<0.025
Facial cream/lotion	2/4	0.007	0.77	0.004	0.19	0.77	-	<0.04
Dishwashing liquid	5/6	0.08	10.8	6.1	5.6	10.9	6.06	<0.02
Dishwasher tablet	3/4	1.2	3.9	1.4	1.7	<0.05	-	3.9
Dishwasher powder	5/5	0.2	46.6	2.3	12.9	2.7	0.18	46.6
Fabric softener	4/7	0.1	5.7	0.1	0.9	0.2	<0.2	0.1
Laundry powder	13/13	0.07	27.3	2.0	27.3	0.07	1.3	13.7
Laundry liquid	10/11	0.06	5.5	1.2	2.2	0.06	0.07	3.3
Soaker	2/2	2.0	2.3	2.1	2.1	2.0	-	-

4.1.3. Cobalt

A summary of the Co concentration in household products and the corresponding weekly mass loads are shown in Table 8 and Figure 5.

Cobalt was below detection in the majority of household products analysed. Cobalt was below detection in laundry powder, soaker and dishwasher detergents.

It was detected at low concentrations (in mg/kg product) in a few brands of cleaning products, shower and bathroom soap, dishwashing liquid and toilet paper (Table 8).

Personal care products used in the bathroom contained Co more often than any of the other product categories.

Cobalt was detected, in 67%, 73%, 80% and 100% of the brands of conditioners, shampoos, hand wash and body wash, respectively. Despite the high frequency of detection, the concentrations were low, ranging from 0.03 to 8 mg/kg product.

The resulting loads from individual products would have been less than 0.8 mg/pe/week as shown in Figure 5 and also in Table 29 in Appendix 2. The three largest product loads were 0.8, 0.56 and 0.49 mg/pe/week for a brand of in-cistern freshener, dishwashing and laundry liquid (Figure 5).

Table 8: Cobalt concentration in household products

		Concentration Co (mg/kg product)						
Product type	*Number of brands with detectable Cl*	*Minimum*	*Maximum*	*Median*	*Average*	*Leader*	*Enviro*	*Private*
Toilet fresheners	1/7		3.9			<0.02		3.9
Multi-purpose	1/2		0.12			<0.04		
Shampoo	8/11	0.03	1.4	0.26	0.51	0.26	0.43	<0.005
Conditioner	2/3	0.28	0.39	0.28	0.22	<0.005	-	-
Hand wash	4/5	0.33	2.5	0.36	0.81	<0.08	-	2.5
Body wash	4/4	0.35	4.9	3.35	2.99		2.2	
Sunscreen	1/7		0.20			<0.02		<0.01
Dishwashing liquid detergent	3/6	0.05	7.6	0.01	0.06	0.05	<0.005	1.4
Fabric softener	1/7		0.09			<0.01		0.09
Laundry liquid	2/11	0.10	1.8	0	0.17	<0.005	<0.01	1.8
Toilet paper	3/8	0.06	0.24			<0.005	0.24 <0.005	<0.005

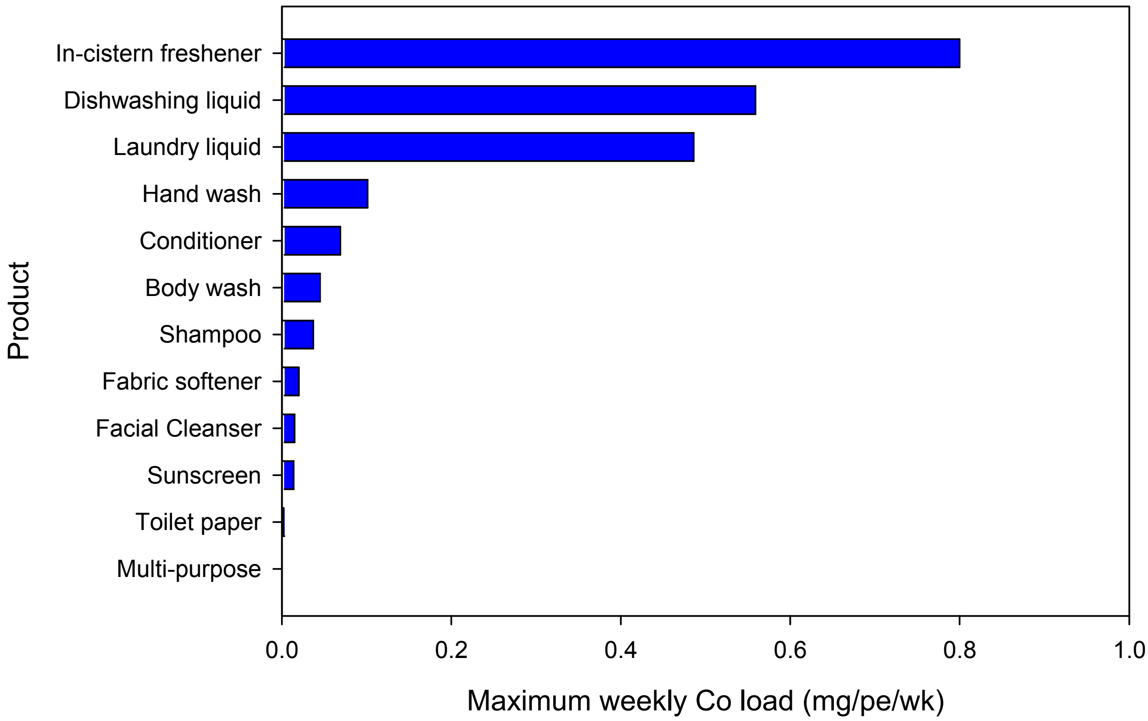

Figure 5: Cobalt loads estimated from product use

4.1.4. Chromium

A summary of the Cr concentration in household products and the estimated weekly mass loads are shown in Table 9 and Figure 6.

Chromium was detected at concentrations ranging from 0.002 to 6.2 mg/kg in 64% of the products analysed.

In shaving foam, soap bars, toilet cleaners and one brand of depilatory product, Cr was below the limit of detection. In other product categories, Cr was detected in individual brands, but not necessarily across all products within the category.

Majority of the products contained less than 0.5 mg/kg product. But concentrations could vary markedly across brands. For instance, concentrations in toilet fresheners ranged from 0.26 to 174 mg/kg.

The highest median concentrations were recorded in dishwashing powder, hair conditioners and laundry powder at 0.90, 0.88 and 0.57 mg/kg, respectively (Table 9).

When considering the frequency of use, the highest weekly load among all the household products, 35.8 mg/pe/week, was estimated from the use of a brand of in-cistern toilet freshener as seen in Figure 6. The remainder of the products were estimated to generate less than 0.95 mg/pe/week (Table 30 in Appendix 2).

Table 9: Chromium concentration in household products

		Concentration Cr(mg/kg product)						
Product type	*Number of brands with detectable Cr*	*Minimum*	*Maximum*	*Median*	*Average*	*Leader*	*Enviro*	*Private*
Cream cleanser	1/1					0.20		
Multi-purpose	1/2					0.01		
Disinfectant	2/4	0.07	0.11	0.04	0.04	0.07		0.11
Floor and surface	3/4	0.01	0.05			0.01	0.02	
Toilet fresheners	7/7	0.26	174			0.26		0.3
Shampoo	8/10	0.07	1.4	0.33	0.54	0.88	1.3	<0.001
Conditioner	2/3	0.88	1.3	0.88	1.09			
Hand wash	4/5	1	6.2			6.2		<0.007
Body wash	3/4	0.01	1.2				0.02	
Face cleanser	2/2	0.5	0.7					
Hair colouring	3/6	0.14	0.22					
Mouth wash	4/5	0.01	0.7	0.04	0.18	0.7		
Toothpaste	8/9	0.30	1.21	0.47	0.60	0.30	0.47	0.95
Deodorant	3/9	0.8	3.9	0	0.63	<0.3		
Sunscreen	6/7	0.01	0.11	0.03	0.04	0.11		0.08
Facial cream/lotion	3/4	0.002	0.35	0.003	0.09	0.35		<2
Body lotion	1/5		0.37					
Dishwashing liquid	3/6	0.02	0.19	0.01	0.06	0.19	<0.001	0.02
Dishwasher tablet	4/4	0.06	1.06	0.69	0.63	0.38		0.06
Dishwasher powder	4/5	0.08	1.80	0.90	1.14	1.8	0.08	0.9
Fabric softener	4/7	0.01	3.50	0.01	0.55	<0.06	<0.04	0.01
Laundry powder	13/13	0.13	1.20	0.57	0.59	1.1	0.28	0.18
Laundry liquid	7/11	0.03	3.50	0.06	0.51	<0.001	0.085	<0.007
Soaker	2/2	0.19	0.23	0.21	0.21	0.19		
Toilet paper	4/8	0.73	1.03	0.37	0.42	0.76	≤0.99	<0.90

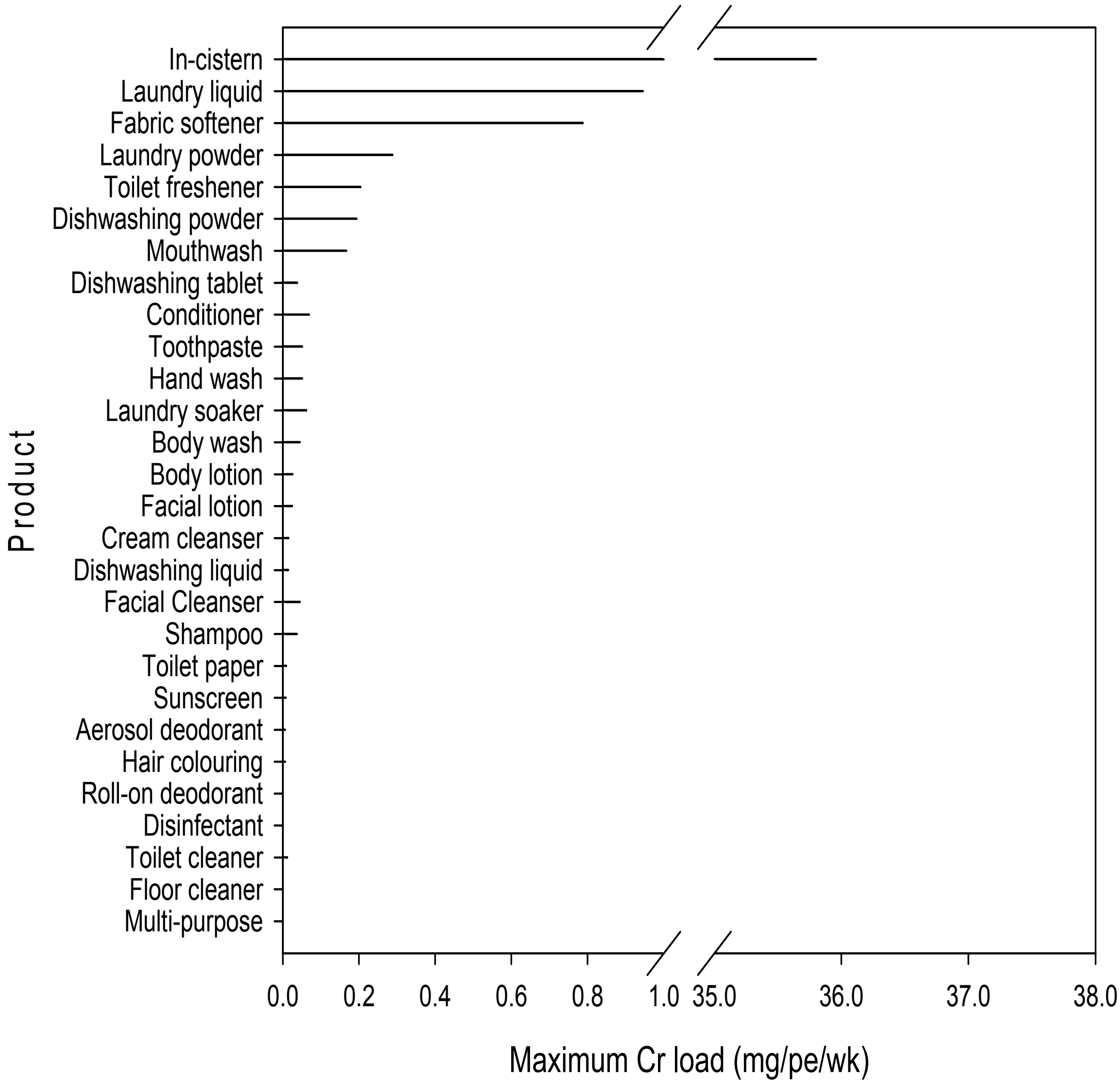

Figure 6: Chromium loads estimated from product use

4.1.5. Fluoride

Fluoride was detected in 22.7% of the household products analysed. The range of concentrations recorded and the estimated weekly loads are shown in Table 10 and Figure 6.

Fluoride in toothpaste and in some of the mouthwash formulations was detected at concentrations up to 1,098 mg/kg. In such products, fluoride originated from ingredients added to combat dental decay, such as sodium fluoride or sodium monofluorophosphate.

Fluoride was also detected in products used in the dishwasher and in the laundry and in hair colouring agents.

In laundry soakers and detergent powders fluoride concentrations ranged from 0.5 to 15 mg/kg. In laundry powder formulations the median and mean concentrations were 8 mg/kg and 6.5 mg/kg, whilst soakers had a mean of 0.8mg/kg (only two brands analysed).

For dishwasher tablets and powders median concentrations of 14.6 mg/kg and 11 mg/kg were recorded. The market leader tablet brand had 41 mg/kg. As mentioned in section 2.5, mineral phosphate can sometimes contain fluoride as a trace contaminant and F could also be introduced during the manufacture process through use of fluoridated water.

Five of the six hair colouring agents analysed contained fluoride, with concentrations ranging between 2.5 to 26.5 mg/kg and a median of 7.9 mg/kg.

The only other products with traces of F included one brand of floor cleaner that contained 5.5 mg/kg and one brand of toilet freshener that contained 39 mg/kg in its formulation.

The largest loads from product use would be expected to be generated through the consumption of toothpaste and mouthwash, resulting in a maximum combined load (toothpaste and mouthwash) of approximately 114 mg/pe/wk as shown in Figure 6. The other products generated weekly loads that were equivalent to less than 10% of that produced by oral products. For example, loads of 8 mg/pe/wk, 3.5 mg/pe/wk and between 1.5 to 1.7 mg/pe/wk would be generated from use of toilet freshener, laundry powder and the dishwasher detergents with the highest F concentrations (Table 31 in Appendix 2).

Table 10: Fluoride concentration in household products

		Concentration F (mg/kg product)						
Product type	*Number of brands with detectable Cl*	*Minimum*	*Maximum*	*Median*	*Average*	*Leader*	*Enviro*	*Private*
Floor and surface	1/4		5.5					
Toilet fresheners	1/7		39					
Hair colouring	5/6	2.5	27	8	10			
Mouth wash	3/5	0.8	287	0.8	101	<1		0.81
Toothpaste	8/9	0.3	1,098	180	415	1,098	<4.5	202
Dishwasher tablet	3/4	0.7	41	15	18	41		28
Dishwasher powder	4/4	0.5	17	11	9.8	5.6	0.5	17
Laundry powder	7/13	8.0	15	8.0	6.5	15	8	<87
Soaker	2/2	0.5	1.1	0.8	0.8	1.1		

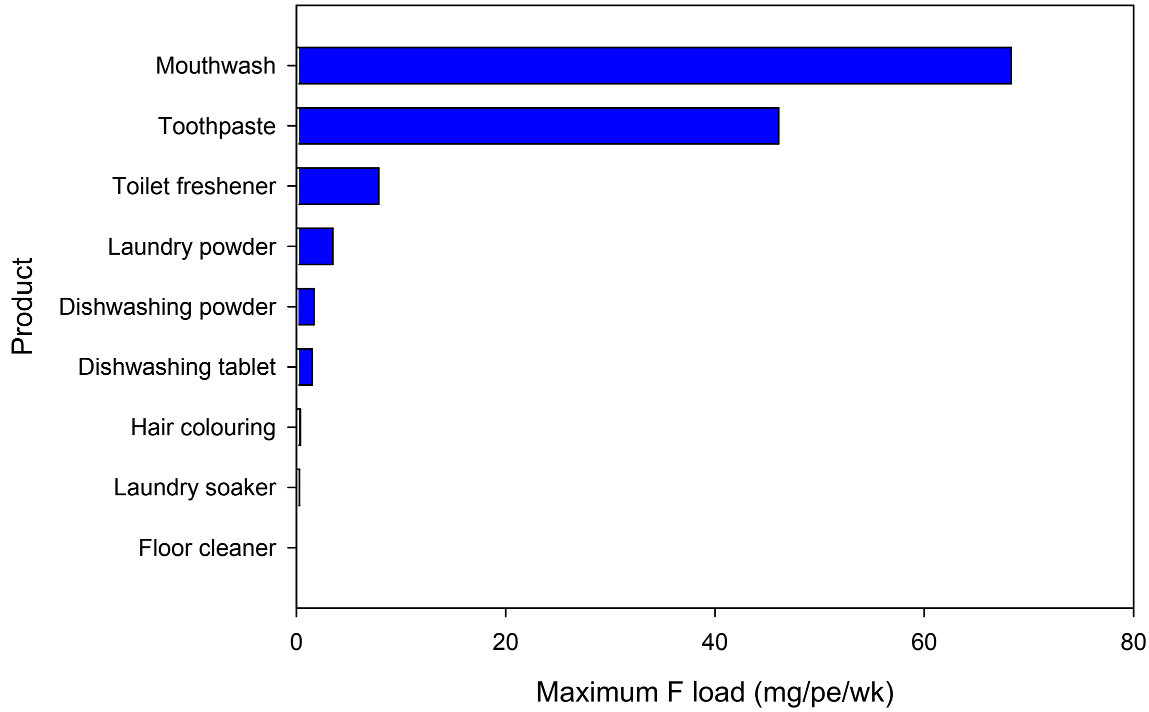

Figure 7: Fluoride loads estimated from product use

4.1.6. Molybdenum

The concentrations and maximum weekly mass loads from household products are shown in Table 10 and Figure 8. Molybdenum was detected in 29% of the products analysed. Mass loads of less than 0.33 mg/pe/week would have been generated from the use of such products as seen in Figure 8.

Molybdenum was detected in:

(a) 86% of toilet fresheners;

(b) 62.5% of toilet paper brands, including the two brands of recycled toilet paper;

(c) 62% of laundry powder concentrates;

(d) 50% of dishwasher products;

(e) 45% of shampoo and deodorant brands; and

(f) In individual brands of soaker, laundry liquid, fabric softener, conditioner, hand and body wash, toothpaste, sunscreen.

Loads from 0.001 to 0.34 mg/pe/wk were estimated from the use of individual products (Table 32 in Appendix 2). The three largest loads combined would release 0.74 mg/pe/wk into sewage, and would be caused by laundry powder concentrates and toilet fresheners (Figure 8). No trends were verified among market leader, private and enviro brands regarding Mo concentrations (Table 11).

Table 11: Molybdenum concentration in household products

		Concentration Mo (mg/kg product)						
Product type	*Number of brands with detectable*	*Minimum*	*Maximum*	*Median*	*Average*	*Leader*	*Enviro*	*Private*
Toilet cleaner	2/4	0.05	4	0.25	1.01	<0.01	0.05	4
Toilet fresheners	6/7	0.06	1	0.11	0.38	<0.03		0.09mg/L
Conditioner	1/3		0.05			0.05		
Hand wash	1/5		0.02			<0.08		<0.02
Body wash	1/4		0.02				<0.01	
Toothpaste	2/9	0.12	0.62	0	0.02	<0.15	<0.45	0.12
Deodorant	4/9	0.51	1.62	0	0.14	<2.7		<3.09
Sunscreen	2/7	0.03	0.13	0	0.02	0.13		<0.02
Shampoo	5/11	0.02	0.4	0.05	0.10	0.06	0.02	0.05
Dishwashing liquid detergent	2/6	0.08	0.21	0	0.05	<0.002	<0.03	0.21
Dishwasher tablet	2/4	0.16	0.47	0.08	0.16	<0.94		0.47
Dishwasher powder	2/4	0.16	0.2	0.08	0.09	0.16	<0.002	0.2
Fabric softener	1/7		0.05			<0.06	<0.04	<0.03
Laundry powder	8/13	0.54	1.35	0.56	0.52	0.54	<0.002	<0.001
Laundry liquid	1/11		0.05			<0.03	<0.002	<0.001
Soaker	1/2		0.06			<0.08		
Toilet paper	5/8	0.02	0.29	0.03	0.05	0.05	0.04 0.29	0.04

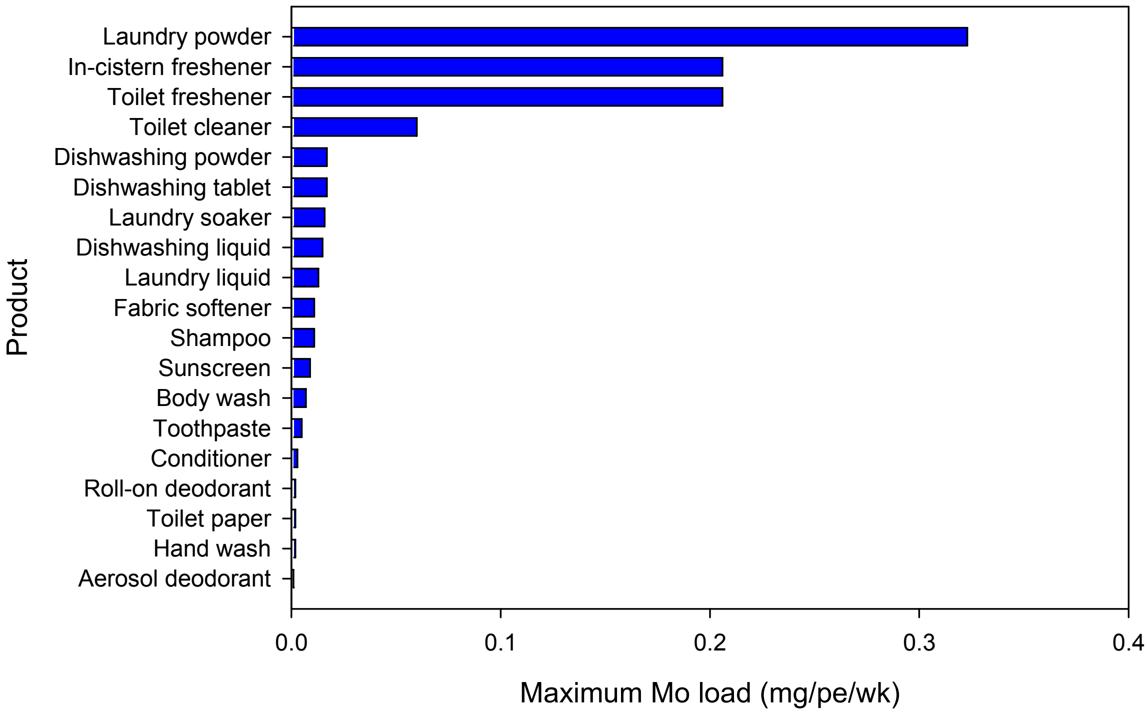

Figure 8: Molybdenum loads estimated from product use

4.1.7. Selenium

The concentrations and maximum mass loads for Se are summarised in Table 12 and Figure 9. Only 18% of the products analysed contained Se within the limit of detection. Se was detected in 30 of the 156 products analysed within the range of 0.01 to 4.6 mg/kg.

The highest concentration, 4.6 mg/kg, was in an anti-dandruff shampoo. Selenium compounds are used in some anti-dandruff shampoo formulations.

Se was detected in specific brands of cream cleanser, multi-purpose, floor and surface cleaners, soaps, oral care products, deodorant, dishwasher powder and laundry detergents. Concentrations were typically less than 1 mg/kg and the corresponding loads were less than 0.04 mg/pe/wk for each of those products.

The three largest weekly loads were attributed to laundry liquids, anti-dandruff shampoos and laundry powders and were respectively 0.15, 0.12 and 0.09 mg/pe/wk (Figure 9 and Table 33 in Appendix 2).

No correlations were verified among market leader, private and enviro brands regarding Se concentrations.

Table 12: Selenium concentration in household products

		Concentration Se (mg/kg product)						
Product type	*Number of brands with detectable Se*	*Minimum*	*Maximum*	*Median*	*Average*	*Leader*	*Enviro*	*Private*
Cream cleanser	1/1		0.03					
Multi-purpose	1/2		0.01					
Floor and surface	2/4	0.01	0.02	0.01	0.01	<0.01	<2	
Shampoo	3/11	0.2	4.6	0	2.3	<1	<0.03	<0.03
Soap bar	4/6	0.28	0.39	0.28	0.21	<1.8	0.28	0.33
Mouth wash	2/5	0.01	0.11	0	0.06	<0.02		<2
Toothpaste	3/9	0.04	0.09	0	0.02	0.09	<0.45	<2
Deodorant	3/9	0.12	0.62	0	0.13	<1.3		0.62
Dishwasher powder	1/4		0.85			<2		
Laundry powder	5/13	0.04	0.37	0	0.05	<1	0.04	0.08
Laundry liquid	4/11	0.01	0.57	0	0.07	0.57	<2	<2
Soaker	1/2		0.05			0.05		

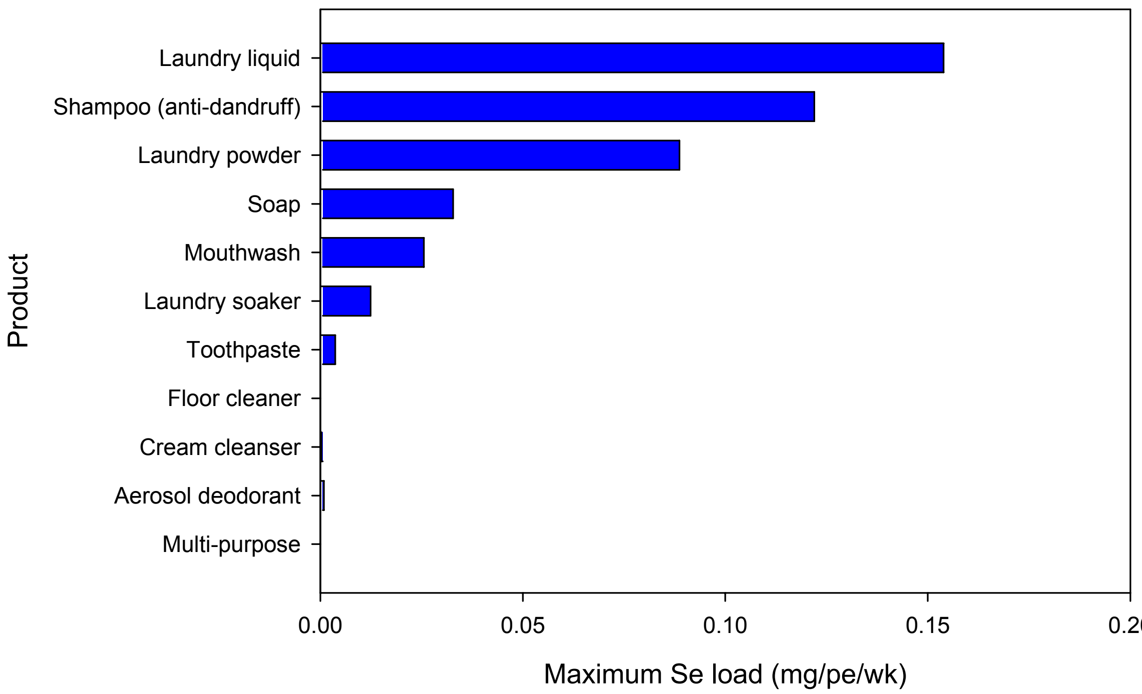

Figure 9: Selenium loads estimated from product use

4.1.8. Nitrogen

Nitrogen was detected in 84% of the household products evaluated. A summary of the TKN concentration in products is shown in Table 13, The equivalent mass loads are shown in Table 34 in Appendix 2 and compared in Figure 10, respectively.

Nitrogen was detected in:

(a) Cleaning products: in 91 % of all products, including all brands of surface and toilet cleaners, all toilet fresheners and in 50% of floor cleaners;
(b) Bathroom products: in 94% of shower and bathroom personal care products, including all brands of shampoos, conditioners, shower gels, shaving foam and hair colouring, 67% of soaps, 64% of oral care products.
(c) Personal care: in 44% of deodorants, 86% sunscreens and 78% of other skin care products.
(d) Kitchen products: all brands of manual and dishwashing detergents.
(e) Laundry products: in 79% of all products, including all fabric softeners, 80% of liquid detergents and 62% of laundry powder concentrates; and
(f) Toilet paper: 100% products.

Cleaning products

The TKN concentration in cleaning products varied over a wide range for different product categories and for individual brands within a category. For instance, toilet freshener brands contained between 0.001 to 269 g TKN/kg product (Table 13).

The median concentration of TKN in the majority of the cleaning products was less than 0.5 g TKN/kg product, with the exception of toilet fresheners and multi-purpose cleaners, which had 3 and 1.8 g TKN/kg product, respectively.

Toilet fresheners had the highest median concentrations of TKN among cleaning products at 3.07 g/kg. However the TKN concentration varied for individual toilet freshener brands from 0.001 to 269 g/kg.

The second largest TKN concentration was in multi-purpose cleaners with a median of 1.8 g /kg product. However, this should be seen with caution as only two brands of multi-purpose cleaners were analysed.

Bathroom and Personal care products

The largest median concentrations of TKN in household products were detected in personal care products, particularly in hair colouring and shampoos at 7.6 g/kg and 3.8 g/kg. Median TKN concentrations between 1 to 2 g/kg product were verified for hand wash, shower gel, shaving foams and face cleansers. Hair conditioners, soap, toothpaste, mouthwash, sunscreen and lotions had less than 1 g/kg TKN.

However, as observed in cleaning products, the TKN concentration varied significantly among individual brands. For instance, in the case of toothpaste the TKN ranged from 0 to 1.6 g/kg (Table 13).

Kitchen products

All brands of dishwashing detergents contained nitrogen in their formulations. But in the dishwasher aid the concentration was below the limit of detection.

The concentration of TKN in dishwashing products for manual and dishwasher detergents, ranged from 0.02 g/kg to 3.77 g/kg. Median concentrations for dishwashing powders, liquids and tablets were 1.4, 1.5 g/kg and 3.1 g/kg respectively. Enzymes are added to detergent formulations to assist in food removal and are a likely source of nitrogen.

Laundry products

The concentration of nitrogen (as TKN) in laundry products ranged from 0.002 to 14.6 g/kg. Overall, laundry powders and liquids had the lowest median concentrations of TKN at 0.03 and 0.06 g/kg whilst fabric softeners and soakers contained more TKN with median concentrations of 1 and 2.3 g/kg. Mean concentrations were 0.195, 1.95, 1.16 and 2.3 g/kg respectively.

Mass Loads

When frequency of product usage and the products with the highest nitrogen concentrations were considered, toilet fresheners were identified as the largest potential sources among household products with a maximum load of 4.0 g/wk for in-cistern fresheners (Figure 10). Laundry products were the next major sources with liquid detergent, soaker, fabric softeners and powder concentrates generating loads of 3.9, 1.1, 0.5 and 0.4 g/wk, respectively.

The loads for each of the remaining product groups analysed were estimated to be less than 0.3 g/pe/week (Table 34 in Appendix 2).

Table 13: Total nitrogen concentration in household products

		Concentration TKN (g/kg product)						
Product type	*Number of brands with detectable TKN*	*Minimum*	*Maximum*	*Median*	*Average*	*Leader*	*Enviro*	*Private*
Cream cleanser	1/1		0.08					
Multi-purpose	2/2	0.4	3.1	1.8	1.8	3.2		
Disinfectant	4/4	0.25	0.7	0.34	0.4	0.25		0.4
Toilet cleaner	4/4			0.15	0.86	0.13	3.03	0.1
Floor and surface	2/3	0.10	1.97	0.10	0.69	<0.04	1.97	
Toilet fresheners	7/7	0.001	268.8	3.07	45.76	0.32		3.1(TF) 268.8(IC)
Depilatory product	1/1		38.2					
Shampoo	11/11	1.0	9.0	3.8	3.8	7.4	3.8	4.9
Conditioner	3/3	0.3	1.3	0.5	0.7	1.3		
Soap bar	4/6	0.03	0.10	0.04	0.04	<0.0001	0.1	0.05
Hand wash	5/5	0.7	3.1	1.8	0.02	3.1		1.7
Body wash	4/4	1.7	3.4	2.2	2.4		3.4	
Face cleanser	1/2		1.8					
Shaving foam	5/5	0.09	9.0	2.1	3.0	4.2		2.0
Hair colouring	6/6	1.4	11.5	7.6	8.0			
Mouth wash	2/5	0.03	0.05	0	0.016	<0.025		<0.01
Toothpaste	7/9	0.16	1.6	0.36	0.5	<0.09	0.6	0.16
Deodorant	4/9	0.08	3.8	0	0.9	<0.003		0.08
Sunscreen	6/7	0.02	1.0	0.2	0.4	0.6		0.9
Facial cream/lotion	3/4	0.4	3.7	1.4	1.6	2.4		<0.0001
Body lotion	4/5	0.08	0.98	0.12	0.28	0.08		0.22
Dishwashing liquid detergent	6/6	0.27	3.7	0.84	1.47	0.27	3.70	0.84
Dishwasher tablet	4/4	0.02	3.77	3.09	2.40	3.77		3.22
Dishwasher powder	4/4	0.03	3.69	0.94	1.40	0.95	3.69	0.03

Fabric softener	7/7	0.47	2.35	1.03	1.16	2.35	1.30	0.47
Laundry powder	8/13	0.002	1.83	0.03	0.20	0.002	0.03	<0.03
Laundry liquid	9/11	0.01	14.57	0.06	1.95	0.09	2.78	14.57
Soaker	2/2	0.27	4.26	2.27	2.27	4.26		
Toilet paper	8/8	0.16	0.61	0.36	0.37	0.25	0.34/0.38	0.20

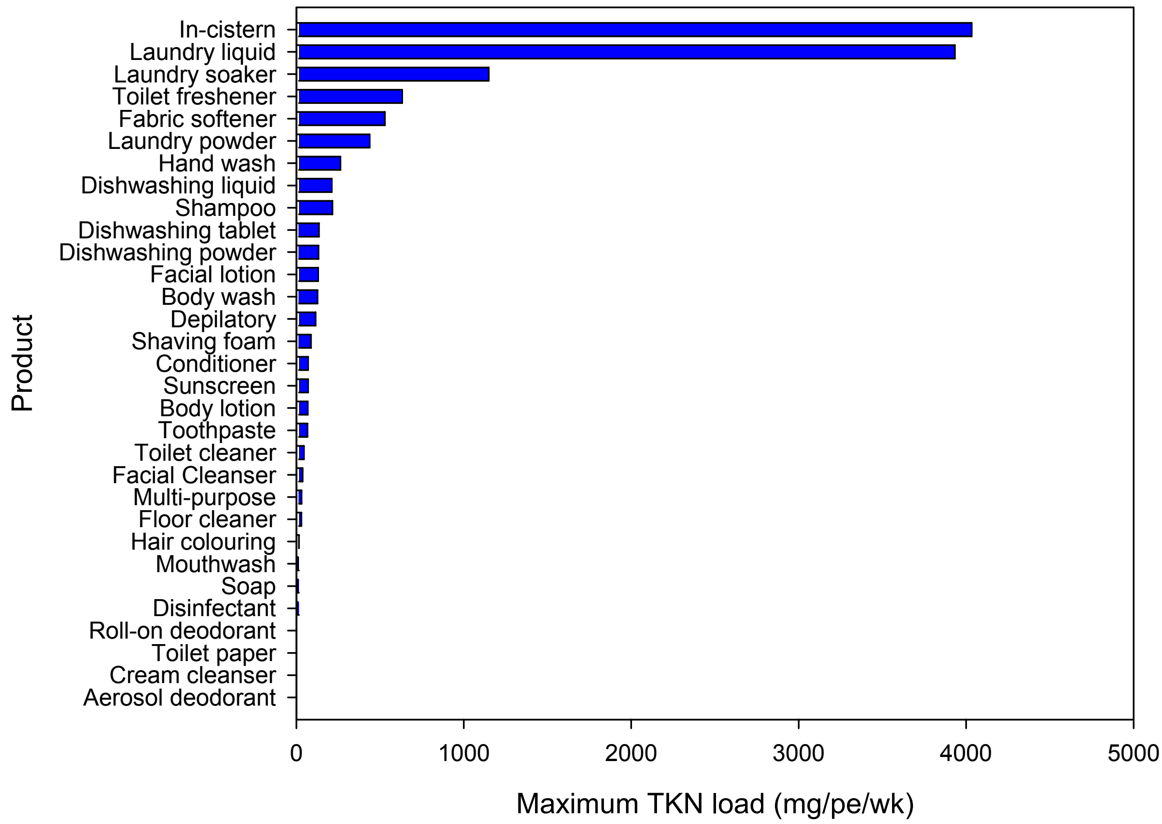

Figure 10: Total Kjeldahl nitrogen loads estimated from product use

4.1.9. Phosphorus

Phosphorus (as total phosphorus, TP) was detected in 97% of the household products evaluated, and is thus the most common element in this group of household products.

Phosphorus was detected in:

(a) All cleaning products, including all brands of surface and toilet cleaners, all toilet fresheners and floor cleaners;
(b) Bathroom products: 97% of shower and bathroom personal care products, including all brands of shampoos, conditioners, shower gels, shaving foam, soaps, hair colouring, oral care products and 75% of other personal care products,
(c) Personal care: 89% of deodorants, 71% sunscreens and all brands of other skin care products.

(d) Kitchen products: all brands of manual and dishwashing detergents.
(e) Laundry products: all products, including fabric softeners, liquid detergents and laundry powder concentrates.

A summary of the TP concentrations and the equivalent mass loads are shown in Table 14 and Figure 20, respectively.

The highest median concentrations of TP in household products were detected in dishwasher products, laundry powders, toothpaste and toilet paper (Table 14).

Most “enviro label” products had lower TP concentrations than the market leader brands (Table 14).

Cleaning products

TP in individual brands of cleaning products ranged from less than 0.001 g/kg to 7.4 g/kg product (Table 14). However, the overall concentration of TP in the cleaning product category was low, with mean and median concentrations of less than 1.9 g/kg and 0.3 g/kg product.

Median concentrations for disinfectants, toilet cleaners, floor and surface and toilet fresheners were respectively 0.036 g/kg, 0.013 g/kg, 0.010 mg/kg and 0.291 mg/kg.

The product categories with the largest spread in concentrations were floor and surface cleaners (range 0.4 to 7,428 mg/kg) and toilet fresheners (range 5 to 3,084 mg/kg).

A load of less than 0.11 g/pe/wk was estimated for individual product categories within this group based on the typical product usage by a single person household (Table 35 in Appendix 2). The largest mass loads from product use were attributed to floor cleaners, toilet fresheners and disinfectants at 0.11, 0.06 and 0.013 g/pe/wk, respectively. Mass loads of TP from all other products would be less than 0.001 g/pe/wk (Figure 20).

Bathroom and Personal care products

Concentrations of TP in personal care products range from nil to 78.5 g/kg product, with the highest concentrations detected in toothpaste (Table 14).

Toothpaste has the highest median concentration in this group, at 10.3 g/kg product. It was also the 4th highest in TP content among all products analysed.

Soaps, deodorants and shampoo had median TP concentrations of 0.90, 0.45 and 0.15 g/kg product. The remaining products in this category contained less than 0.1 g/kg product.

TP concentrations varied markedly for individual brands within each product category, particularly for shampoos, conditioners, soaps, hand wash, toothpaste, deodorant and sunscreen. For example, hand wash had minimum and maximum concentrations of 0.004 g/kg and 75 g/kg.

Kitchen products

All dishwashing detergents contained phosphorus in their formulations. The concentration range varied with the product category and with individual brands.

Median TP concentrations were 0.01, 29 and 22 g/kg for dishwashing liquid, dishwasher powder and tablets. Rinse aid had only 0.08 g/kg as shown in Table 14.

Dishwashing tablets had the highest concentration of TP among all household products, with concentrations ranging up to 98 g/kg; these were at least 85% higher than the ranges verified for the dishwashing powder and liquid detergents, which ranged between 0.01 to 53 g/kg and 0.002 to 1.5 g/kg, respectively.

Laundry products

The concentration of TP in laundry products ranged from 0.005 to 54 g/kg, as shown in Table 14.

The highest TP concentrations in laundry products were verified in powder concentrates with median and mean concentrations of 24.5 g/kg and 23.0 g/kg, but once again there was a wide spread from 0.1 to 54 g/kg product. Thus the TP content of individual brands within the category varies.

The data also shows that liquid detergents had a lower TP concentration than powder detergents. Laundry liquids displayed the second lowest median concentration as a category at 7.7 g/kg, but the second highest mean at 16.7 g/kg. But some individual products had high TP concentrations as verified in the spread in concentrations between 0.005 to 46 g/kg product and the mean of 17.6 g/kg product.

Fabric softeners had the least TP, with a mean concentration of 0.07 g/kg and a range of 0.01 to 0.189 mg/kg.

Two brands of soakers were analysed and the TP concentrations varied markedly between them. One had a TP concentration of 18 g/kg and the other only 1.1 g/kg product.

Mass Loads

When frequency of product usage and the products with the highest phosphorus concentrations were considered, the largest loads of TP were generated from the use of laundry powders and liquids, each of them generating approximately 13 and 12 g/pe/wk (Figure 20).

The following largest mass loads, between 1 to 6 g/pe/wk, would be generated from the use of dishwashing powder and tablets, hand wash, laundry soakers and toothpaste.

Whilst loads derived from the other household product categories would have been less than 0.2 g/pe/wk (Figure 11).

Table 14: Total phosphorus concentration in household products

		Concentration TP (g/kg product)						
Product type	Number of brands with detectable Cl	Minimum	Maximum	Median	Average	Leader	Enviro	Private
Cream cleanser	1/1		0.10					
Multi-purpose	1/2	0.004	0.08					
Disinfectant	4/4	0.01	1.30	0.04	0.35	0.03		0.013
Toilet cleaner	4/4	0.0007	0.03	0.01	0.015	0.001	0.03	0.009
Floor and surface	4/4	0.0004	7.43	0.01	1.86	7.43	0.006	
Toilet fresheners	7/7	0.005	3.08	0.29	1.17	0.19		0.005(F) 3.08(I)
Shampoo	11/11	0.001	1.73	0.15	0.45	0.01	0.198	0.001
Conditioner	3/3	0.006	1.93	0.019	0.65	0.006		
Soap bar	5/6	0.4	2.5	0.9	1.2	0.8	<0.001	1.0
Hand wash	5/5	0.004	75.0	0.06	15.0	75.0		0.1
Body wash	4/4	0.0001	0.040	0.006	0.013		0.002	
Face cleanser	1/2		0.12					
Shaving foam	5/5	0.006	0.08	0.02	0.03	0.006		0.022
Hair colouring	6/6	0.04	1.02	0.09	0.37			
Mouth wash	5/5	0.0	0.02	0.0001	0.005	0.003		0.0001
Toothpaste	9/9	0	78.5	10.3	19.6	78.5	0.05	0.86
Deodorant	8/9	3	1.1	0.35	0.45	0.08		0.59
Sunscreen	5/7	0.001	0.90	0.002	0.18	0.002		<0.0001
Facial cream/lotion	4/4	0.05	0.38	0.07	0.15	0.38		0.18
Body lotion	5/5	0.007	0.14	0.07	0.07	0.02		0.08
Dishwashing liquid detergent	6/6	0.002	1.45	0.01	0.25	0.002	0.02	1.45
Dishwasher tablet	4/4	0.0005	97.7	21.8	43.1	0.0005		95.7(brand 1) 97.7(brand 2)

Dishwasher powder	6/4	0.01	53.4	28.8	27.8	53.4	0.01	8.3
Fabric softener	7/7	0.01	0.19	0.04	0.07	0.05	0.02	0.01
Laundry powder	13/13	0.1	54.5	24.6	23.0	2.1	0.1	1.0
Laundry liquid	11/11	0.004	46.2	7.7	16.7	0.13	0.15	0.01
Soaker	2/2	1.1	18.2	9.6	9.6	1.1		
Toilet paper	8/8	0.001	0.03	0.01	0.01	0.02	0.001 (brand a) 0.017 (brand b)	0.03

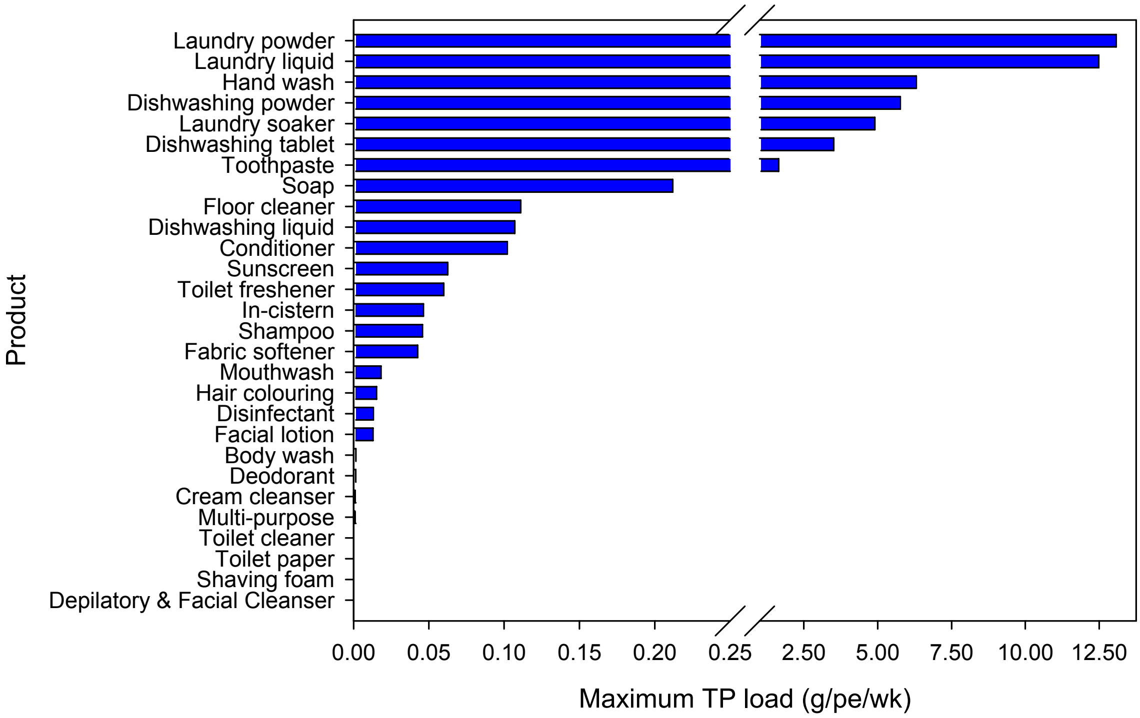

Figure 11: Phosphorus loads estimated from product use

5. ELEMENTAL LOADS IN HOUSEHOLD STREAMS

5.1. Methodology

The contribution of products to the contaminants in wastewater was examined by estimating the typical loads that would be discharged from various household outlets (bathroom, toilet, laundry and kitchen) in a one person household.

The wastewater mass loads for each outlet represent the load derived from combining all products that would typically be adopted by a householder at each location. The assumed product dosages and the frequency of product use were shown in **Table 5**. The estimates do not consider the contribution from tap water or human waste.

Thus it was assumed that (i) the bathroom discharged greywater from the shower and vanity unit, (ii) the toilet wastewater discharge contains toilet paper and toilet fresheners, but excludes urine and faecal matter, (iii) the kitchen wastewater contains either greywater from the kitchen sink or dishwasher, and that the laundry discharged greywater from the washing machine.

Variation in stream composition due to interchange of products was also considered. For instance, streams were calculated for either liquid hand wash or soap; laundry liquid or powder; toilet bowl freshener or in-cistern freshener; aerosol or roll-on deodorant and dishwashing powder, tablet or liquid.

The streams' were comprised of:

- Bathroom 1: soap, shampoo, conditioner, sunscreen, lotion, cleanser, shaving foam, toothpaste, mouthwash and aerosol deodorant;
- Bathroom 2: hand wash, body wash, shampoo, conditioner, sunscreen, lotion, cleanser, shaving foam, toothpaste, mouthwash and roll-on deodorant;
- Kitchen 1: liquid dishwashing detergent;
- Kitchen 2: dishwasher tablet and rinse aid;
- Kitchen 3: dishwasher powder and rinse aid;
- Laundry 1: powder detergent concentrate and fabric softener;
- Laundry 2: liquid detergent concentrate and fabric softener;
- Toilet 1: toilet paper and toilet bowl freshener
- Toilet 2: toilet paper and in-cistern freshener.

Loads derived from other cleaning products were not included in the evaluation because of their low frequency of use compared to the other products.

The individual stream loads were estimated under three scenarios. These assumed that a one person household adopted:

(a) Maximum: Product brands with the highest concentration of each element, thus providing a conservative or worst case scenario load;

(b) Median: The median concentration for each product category for comparison, to reflect the typical outcome from that category;

(c) Enviro: "Environmental label" products, or if not available, the brand with the lowest element concentration.

These loads were compared to those derived from anthropogenic waste (faeces and urine) reported in the literature.

The wastewater loads originating from individual locations in a household (bathroom, kitchen, laundry and toilet) are shown in Figure 12 to Figure 20.

5.1.1. Household wastewater

The individual outlet wastewater streams were also combined to generate the overall household load of an element to sewer. The permutations adopted for the household are shown in Table 15. The resulting wastewater streams are described as:

- Wastewater 1 (WW1): use of bar soap in the shower, dishwasher with powder detergent, laundry powder and toilet bowl freshener;
- Wastewater 2 (WW2): use of shower gel, manual dishwashing with liquid detergent, laundry liquid and toilet freshener;
- Wastewater 3 (WW3): use of environment friendly labels for bar soap, manual dishwashing with liquid detergent and laundry liquid and recycled toilet paper (no toilet freshener). When an environmental label product was not available, the product with the lowest concentration of the element of interest was adopted.

The combined streams are shown in the Appendix 2 and show how the overall load can vary with the product categories and brands adopted.

Table 15: Household streams adopted in the household wastewater load simulation

Source	*Wastewater 1 (WW1)*	*Wastewater 2 (WW2)*	*Wastewater 3 (WW3)*
Bathroom	Bathroom 1	Bathroom 1	Bathroom 1 with enviro label or least concentration products
Kitchen	Kitchen 1	Kitchen 3	Kitchen 1 with enviro label or least concentration products
Laundry	Laundry 1	Laundry 2	Laundry 1 with enviro label or least concentration products
Toilet	Toilet 1	Toilet 1	Recycled toilet paper

5.2. Analysis

Figure 12 to Figure 20 compare the mass loads for streams adopting the maximum, median and environmental label concentrations in products. The streams do not incorporate the contribution from water.

The results show that the mass loads generated in wastewater can vary markedly depending on the type and brands of products used in a household.

For instance, the difference between the loads estimated for wastewater from “Bathroom 1” using the maximum and median concentration products was 9.4 g/pe/wk for chloride (Figure 14) and 8.3 g/pe/wk for phosphorus (Figure 20).

Table 16 shows how the importance of each household wastewater source changes based on the type and brands of products selected. For instance, the laundry and the kitchen dishwasher are the two major source of Sb in the household when products with the highest

Sb concentrations are used, but when products of median Sb concentration are used, loads from products are much smaller and human excreta becomes the predominant source of Sb.

Each individual element in discussed in detail in the following sections.

Table 16: Major sources of contaminants in a household

Element	***Element concentration in products***	***Major sources***
Antimony	Maximum	Laundry> Kitchen (powder) > Human > Bathroom> Toilet
	Median	Human> Bathroom=Toilet> Laundry(powder)> Dishwasher
	Enviro	Human
Chloride	Maximum	Laundry (powder)> Toilet (in-cistern freshener)> Human> Bathroom > Laundry (liquid) >Kitchen (powder>manual>tablet)
	Median and Enviro	Human> Bathroom > Laundry (powder)> Kitchen(liquid)> Laundry(liquid) > Toilet
Chromium	Maximum	Toilet (In-cistern freshener) > Laundry > Bathroom > Toilet (freshener) > Kitchen > Human
	Median	Bathroom> Laundry(powder)> Kitchen (powder)>Toilet> Kitchen (tablet) > Laundry (liquid)> Human> kitchen(liquid)
	Enviro	Toilet> Laundry>bathroom> Human> kitchen(liquid)
Cobalt	Maximum	Toilet>Kitchen(liquid)>Laundry(liquid)>Bathroom>Human>Laundry (powder)
	Median	Human>Bathroom>Kitchen
	Enviro	Human>Bathroom
Fluoride	Maximum	Bathroom > Toilet > Human > Laundry (powder)> kitchen (powder and tablet)
	Median	Human>Bathroom>Toilet>Laundry (powder)>Kitchen(dishwasher)
	Enviro	Human>Laundry (powder)
Molybdenum	Maximum	Human > Laundry(powder) > Toilet > Bathroom > Kitchen
	Median	Human > Laundry (powder)> Toilet (in-cistern)>Kitchen (tablet)
	Enviro	Human>Laundry (powder)
Selenium	Maximum	Human > Bathroom (shampoo) > Laundry > Bathroom (Shower gel) > Toilet
	Median and Enviro	Human>Bathroom
Nitrogen	Maximum	Human > Laundry > Bathroom > Toilet (freshener) > Kitchen
	Median	Human>Bathroom>Laundry>Kitchen>Toilet
	Enviro	Human>Laundry>Bathroom≈kitchen
Phosphorus	Maximum	Human > Laundry > Bathroom > Kitchen (powder/tablet) >Toilet>kitchen (liquid)
	Median	Human>Laundry(powder)>Kitchen(dishwasher)>Bathroom>Toilet> Laundry(liquid)> Kitchen (liquid)
	Enviro	Human>Toilet>Laundry>Bathroom>Kitchen

5.2.1. Antimony

Figure 12 compares the mass of antimony (Sb) generated through product use in wastewater to the average mass load from urine and faeces.

The load of Sb from human excretion was assumed to be 0.02 mg/pe/wk (adapted from Health Canada 1997).

The largest Sb loads were produced in the laundry (maximum 0.18 mg/pe/wk for powder detergent) and in the kitchen when dishwasher powder was used (maximum 0.09 mg/pe/wk). These loads were 350% larger than the anthropogenic load (Figure 12).

In the bathroom, the maximum loads were equivalent to 50% or less of the anthropogenic load as seen in Figure 12.

When products of median concentration were adopted, the median loads generated were negligible. The one exception was the mass load discharged from the laundry (Laundry 1). In that stream the load generated, 0.002 mg/pe/wk, was equivalent to 10% of the anthropogenic load.

As mentioned in section 4.1.1, the majority of household products contained only trace amounts of Sb, which often amounted to less than 1 ppm Sb. Hence, for Sb loads from products to be noteworthy, would require the use of large amounts of product as was the case for washing powder.

Figure 12 also shows that the adoption of “enviro” and minimum concentration products resulted in Sb below detection in wastewater, even in the laundry. However, given the low concentrations in most products, adoption of enviro products had limited impact compared to the median.

The total Sb household load from products was equivalent to 0, 9 and 950% of the anthropogenic load when enviro label, median and maximum concentration products were adopted.

In summary, anthropogenic sources are expected to be a more important source of Sb in household wastewater compared to the majority of household products. However there are specific brands of laundry and dishwasher products that can generate loads at least four times larger than the anthropogenic load.

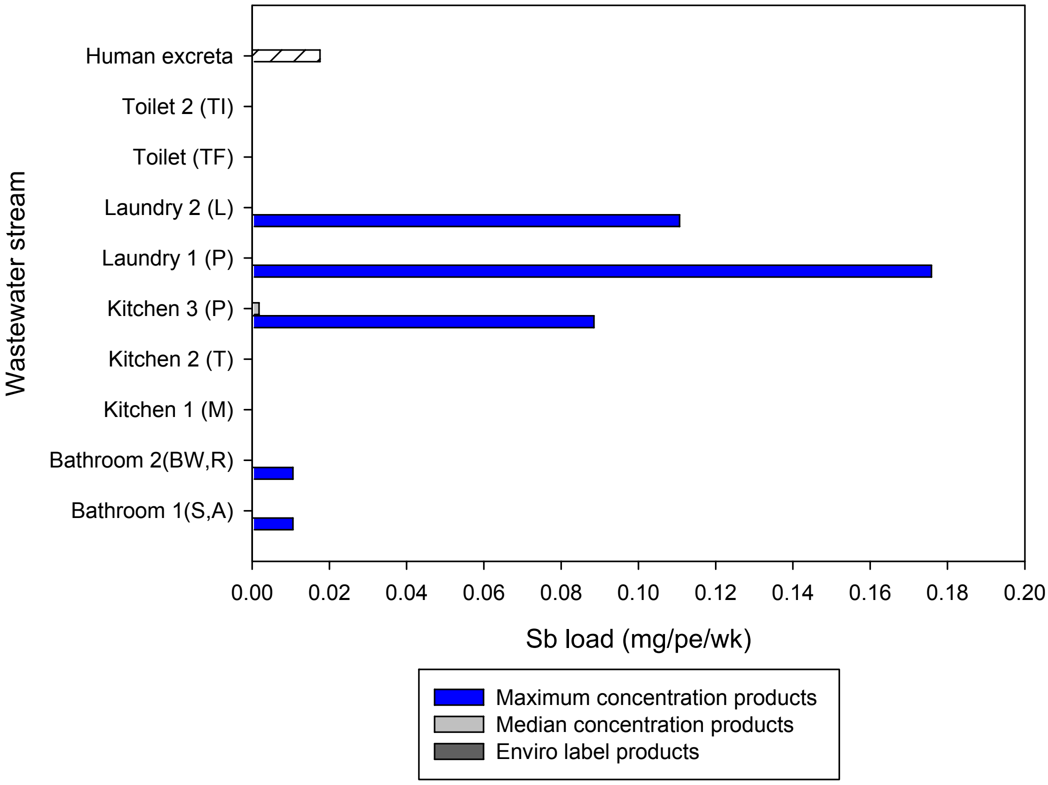

Figure 12: Antimony load from use of products with environmental labels, median and maximum antimony concentration products in household streams.

5.2.2. Cobalt

The average anthropogenic load of Co from urine and faeces was 0.161mg/pe/wk (Figure 13). When median concentrations in household products were considered, human excreta and bathroom products were the major sources of Co in the household. Median loads were 0.14 and 0.15 mg/pe/wk for bathroom 2 and 1, whilst the Co load from other sources was below detection.

However, when the maximum concentration products were adopted, the product loads from the toilet, the kitchen, the laundry and the bathroom were 398%, 247%, 214% and 46.6% larger than the anthropogenic load (Figure 13). In addition, different product types also produced markedly different loads, for example laundry powder and laundry liquid generated respectively 0.02 and 0.51 mg/pe/wk Co. Likewise larger loads were generated through the use of in-cistern toilet freshener and liquid dishwashing detergent than counterpart household products.

Thus product categories and individual brands impact the loads discharged in different household streams.

Adoption of green products reduced the Co load as shown in Figure 13. The figure shows that the Co load from majority of the streams would be undetected and that the load from the bathroom would decrease by 70%.

In summary, most of the Co would be likely to originate from bathroom products and anthropogenic waste, but wastewater from the kitchen, the laundry and the toilet can become significant sources when specific brands of dishwashing detergent, laundry liquid and in-cistern toilet fresheners are used. Adoption of "enviro" label and low Co products was verified to reduce the bathroom Co load by 70%.

The total product household load was equivalent to 26%, 96% and 1,300% of the anthropogenic load when enviro, median and maximum concentration products were adopted.

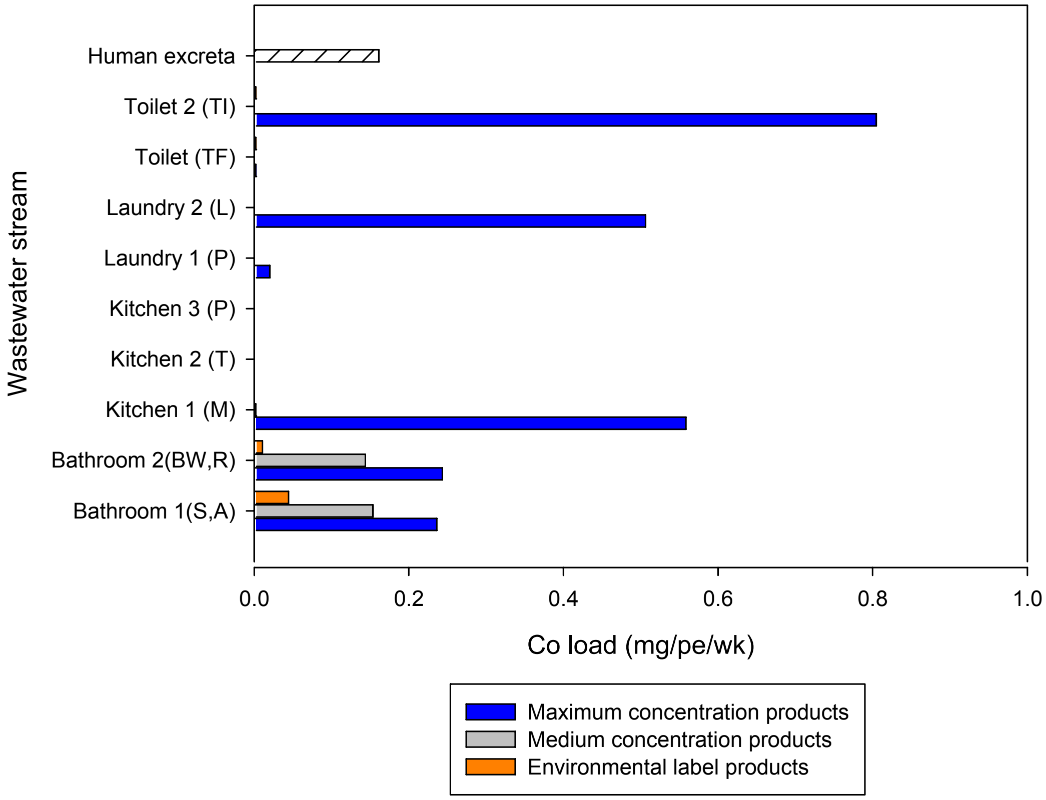

Figure 13: Cobalt load from use of environmental label, median and maximum cobalt concentration products in household streams.

5.2.3. Chloride

The product mass loads for chloride are compared in Figure 14. Chloride from household product use ranged from 10 to 141 g/pe/wk. When products with the enviro, median and maximum concentrations were adopted the overall product household loads were equivalent to 34%, 35% and 459% of the anthropogenic load, respectively.

The average anthropogenic load of 30.8 g/pe/wk was the predominant source of Cl when products of median concentration were used. The second and third largest loads, 9.9 g/pe/wk and 1.2 g/pe/week, were sourced from bathroom 1 and 2 streams respectively. Whilst the kitchen and the laundry generated less than 1 g/pe/wk each and products used in the toilet (toilet paper and fresheners) produce a negligible load.

However, when maximum loads were considered, as shown in Figure 14, the loads and the major sources changed markedly. The laundry became the predominant source generating

86 g/pe/wk (Laundry 1). The next largest loads originated from the toilet (with in-cistern freshener) at 34 g/pe/wk. This was comparable to the load of 31 g/pe/wk from human excreta. Furthermore, the maximum loads for the other streams were larger by 80% (for kitchen 1) to 570% (for kitchen 3) than the loads derived from median product concentrations (Figure 14).

The use of environment friendly label and low Cl products reduced the loads of some sources and increased the loads of others (Figure 14). The variation in loads for kitchen 1, bathroom 1 and 2, was -1%, -11% and +9% from the median loads. But, in the laundry a load reduction of -65% and -98% of laundry 1 and 2 median loads was achieved.

On the other hand, the load from kitchen 2 (dishwasher tablets) could decrease by 87% with selection of the tablet with the lowest Cl content (no environmental friendly tablets are available in the market). But for kitchen 3 the load increased by 24% with the adoption of "enviro label" product compared to the median.

In summary, product selection can have a significant effect on the loads of Cl in wastewater, being able to increase and decrease the loads significantly. Either way, the anthropogenic load is also a major source of Cl in domestic wastewater.

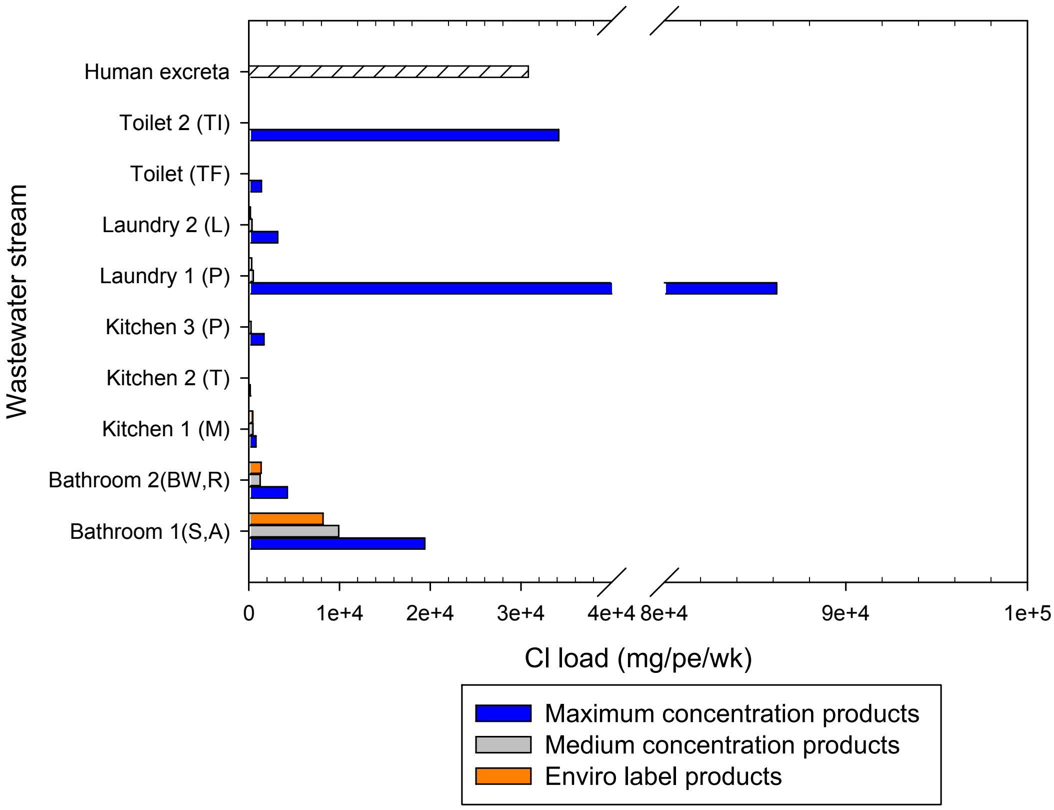

Figure 14: Chloride load from use of environmental label, median and maximum chloride products in household streams.

5.2.4. Chromium

The loads of Cr derived from product use at various locations in household are shown in Figure 15. The figures show that majority of the sources within a household contribute to the overall Cr load and that median and maximum loads in individual wastewater streams would range from 0.001 to 0.184 mg/pe/wk and from 0.014 to 35.8 mg/pe/wk, respectively.

The load derived from human excreta, 0.14mg/pe/wk, was of the same magnitude as the loads from product use (Figure 15). When median loads are considered the sources of Cr were ranked in decreasing order of priority as:

Bathroom (1 and 2) >Human>Laundry 1 >Kitchen 3 >toilet (1 and 2) > Kitchen 2 > Laundry 2 > kitchen 1.

In Figure 15, when median loads are considered, the bathroom, human excreta, the laundry and the dishwasher were the major sources of Cr contributing 0.184, 0.140, 0.123 and 0.113 mg/pe/wk. The smallest load came from the kitchen when liquid dishwashing detergent was used.

However, the maximum loads from the laundry, bathroom, kitchen (using dishwasher powder) and particularly the toilet could surpass the anthropogenic load. In such case, the largest load, 35.8 mg/pe/wk was generated when a specific brand of in-cistern toilet freshener was adopted, but this value was not necessarily representative of the typical output expected from such products as the Cr concentration in that brand was much larger than in any of the other toilet freshener products tested.

Environment label products and products with low Cr content reduce the Cr loads significantly as shown in Figure 15. The combined product household load was equivalent to 146%, 363% and 27 times the anthropogenic load when products of enviro label, median and maximum concentrations were adopted respectively.

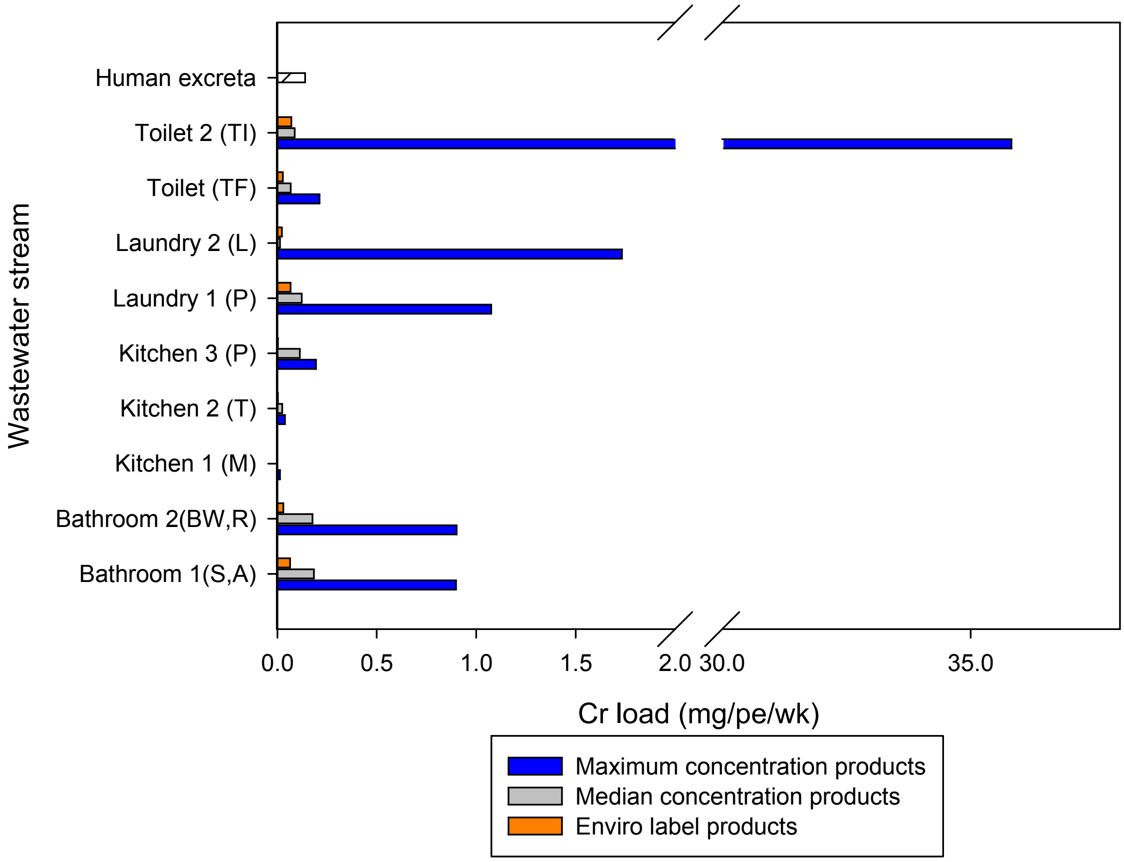

Figure 15: Chromium load from use of environmental label, median and maximum chromium concentration products in household streams.

5.2.5. Fluoride

The loads of fluoride (F) derived from product use at various locations in a household are shown in Figure 16.

Household products were an important source of F compared to the mean anthropogenic load. The anthropogenic load was 22 mg/pe/wk whilst the combined load from household products could be much larger, being up to 6 times the anthropogenic load when products with the maximum F concentration were considered.

Adoption of median concentration and environmental label products reduced the combined loads to 73% and 9% of the anthropogenic loads.

In Figure 16, the median and maximum loads for individual sources and products combinations vary markedly. The bathroom was a major source of F, but it was also subject to the largest variation in load from products, where a difference of approximately 100 mg/pe/wk was observed between the median and maximum loads.

Median loads from the different sources, including the bathroom, were lower than the load derived from human excreta, 22 mg/pe/wk. Likewise the adoption of environment label and low F products further reduced the F load for most streams, but for Laundry 1.

Tap water was not considered in this assessment, but as it contains 1 mg/L F, and it will be a predominant F source in a household.

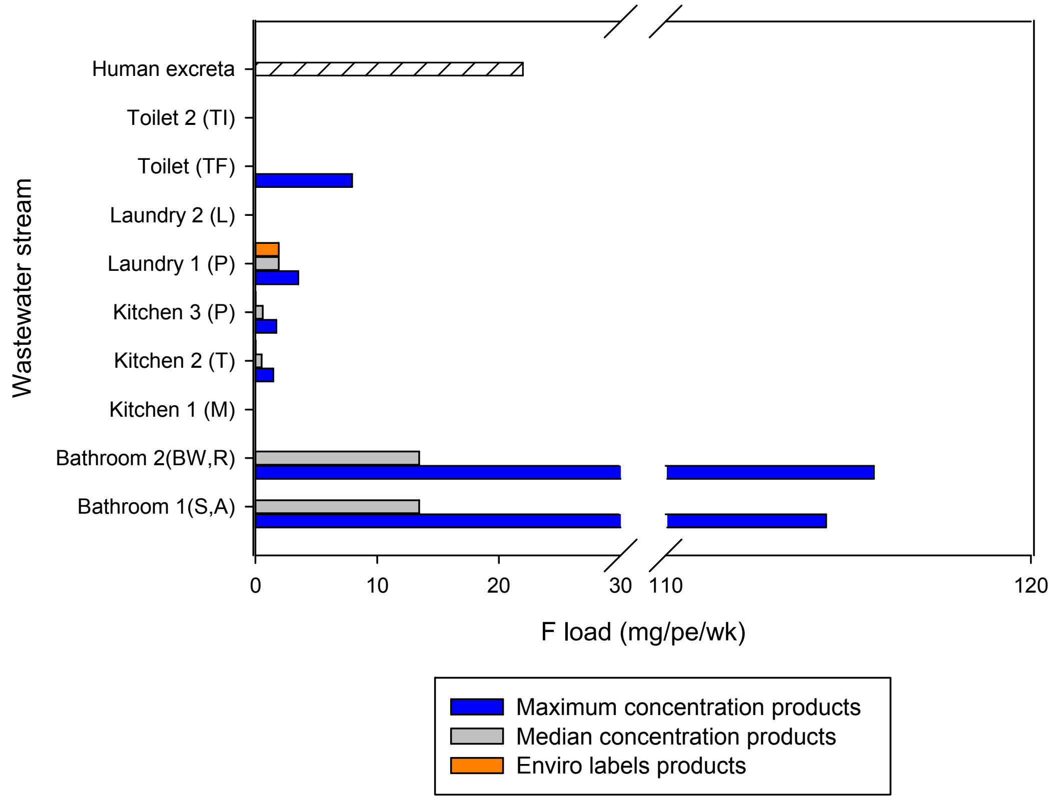

Figure 16: Fluoride load from use of environmental label, median and maximum fluoride concentration products in household streams.

5.2.6. Molybdenum

Figure 17 shows the mass loads derived from the use of household products with maximum and median molybdenum concentrations, and from use of a combination of "enviro" and low Mo content products in a household.

The maximum molybdenum (Mo) loads derived from household product use were less than 0.33mg/pe/wk for individual household wastewater streams shown in Figure 17.

Median loads were less than 0.14 mg/pe/wk for each of the streams. Majority of the loads decreased by less than 5μg/pe/wk with the adoption of "environment" label and low Mo products. But loads for laundry 1 and toilet 2 increased to 0.26 mg/pe/wk and 0.13 mg/pe/wk, respectively.

When the loads for the household combined streams were evaluated, the maximum load for the household was equivalent to 97% of the human load (0.61 mg/pe/wk). Adoption of median and enviro label products produced the equivalent of 26% and 44% of the anthropogenic load respectively.

In summary, Mo loads from household products in individual streams were less than loads from anthropogenic waste. The largest loads from product use came from the laundry when powder concentrate was used (0.33 mg/pe/wk) and from the toilet (0.21 mg/pe/wk).

Product selection did not affect the ranking of individual sources within a household, but it could reduce the overall household load from product use by as much of 71%. Results also show that environmental label products may not cause significant load reduction for an individual wastewater stream compared to the median loads as both produced similar loads. The only exception was Laundry 1, where the load from "enviro label" products was larger than the median load, in which case the loads were respectively 0.26 and 0.14 mg/pe/wk (Figure 17).

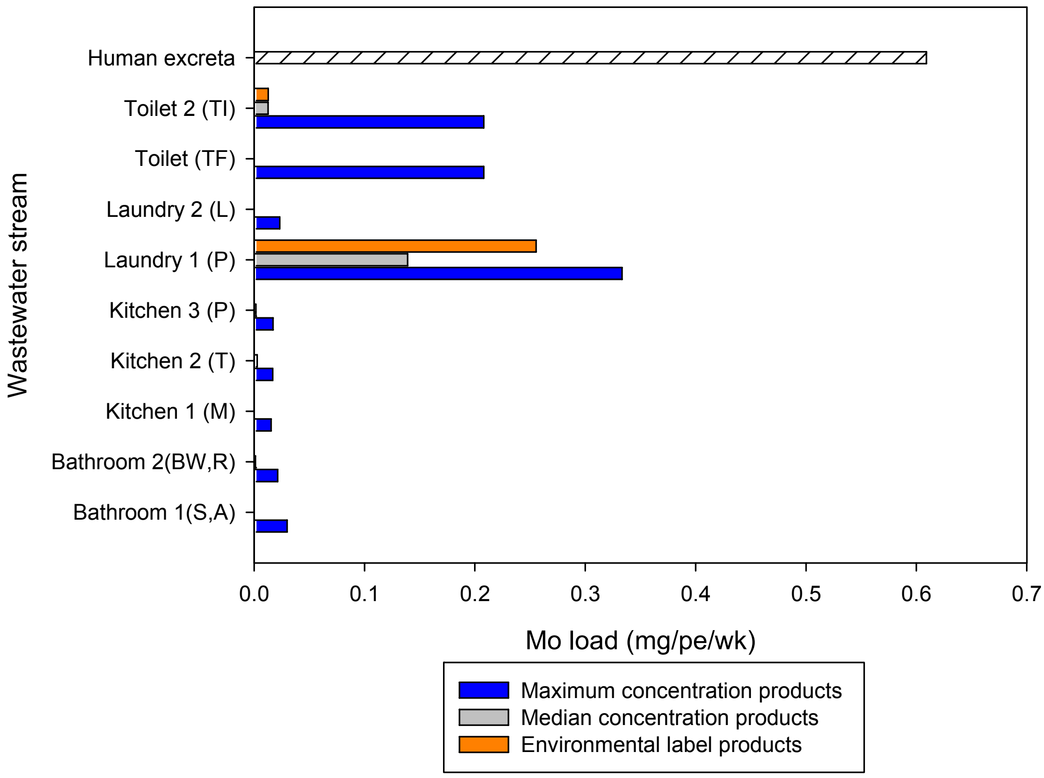

Figure 17: Molybdenum load from use of environmental label, median and maximum molybdenum products in household streams.

5.2.7. Selenium

Selenium loads from product use in individual wastewater streams ranged from nil to 0.185 mg/pe/wk and are shown in Figure 18.

The bathroom and the laundry generated the largest loads from household products at 0.185 mg/pe/wk and 0.154 mg/pe/wk for bathroom 1 and laundry 2 respectively. Loads from the toilet and the kitchen were negligible.

Each individual wastewater source produced the equivalent to less than 1/3 of the anthropogenic load of 0.595 mg/pe/wk. However, all household products combined generated a maximum load of 0.339 mg/pe/wk, equivalent to 57% of the anthropogenic load.

Product selection affected the load values. Median loads were lower than the maximum loads. For instance, as shown in Figure 18, bathroom 1 had maximum and median loads of 0.185 mg/pe/wk and 0.024 mg/pe/wk, respectively. Using products of median concentration the household load from product use was reduced from 47% to 4% of the anthropogenic load.

On the other hand, the adoption of environmental label products had a lesser impact in reducing the loads from the median values. The reduction differed for each stream as shown in Figure 18. For bathroom 1 the median and enviro loads were the same, 0.024 mg/pe/wk, whilst for kitchen 2 and 3 the Se load decreased from 0.5 mg/pe/wk and 0.6 mg/pe/wk to nil, and for Laundry 1 the enviro load increased to 0.009 mg/pe/wk.

In summary, the anthropogenic load was considered a more important source of Se compared to the household products evaluated. Yet, product selection can contribute to a significant load reduction, as products loads can be equivalent to up to 57% of the anthropogenic load.

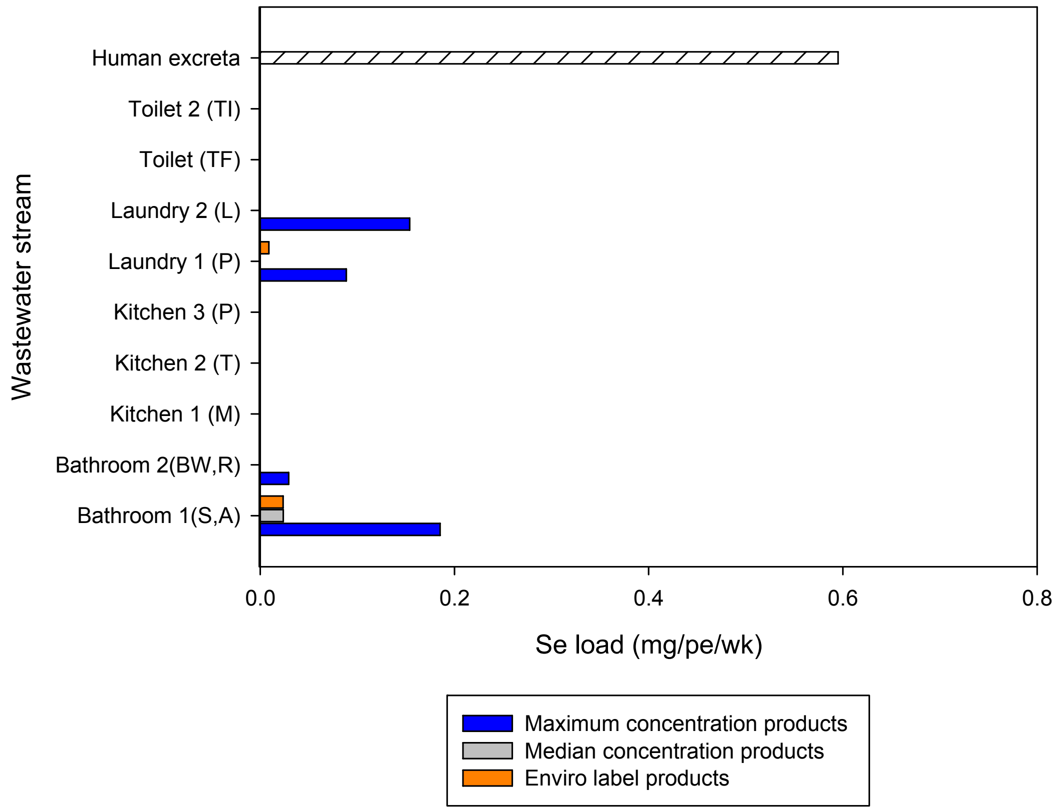

Figure 18: Selenium load from use of environmental label, median and maximum selenium concentration products in household streams.

5.2.8. Nitrogen

The anthropogenic load is the major source of nitrogen in wastewater, being responsible for at least 75% of all the nitrogen (Metcalf and Eddy 2003, Larsen and Gujer 1996).

As seen in Figure 19, nitrogen (TKN) was discharged in every stream. However, loads generated by product use were small compared to the anthropogenic load.

The maximum load from product use for the combined household streams was equivalent to only 7% of the anthropogenic load. When products of median and enviro label concentrations were adopted the load was further reduced to 0.85% and 1.8% of the anthropogenic load.

When considering TKN from products only, the laundry and the bathroom produced the two highest nitrogen loads, with maxima of 4.4 g/pe/wk and 1 g/pe/wk respectively

Products used in the toilet (toilet paper and fresheners) had the lowest load contribution.

Adoption of environmental label products does not necessarily result in the reduction of the nitrogen load in wastewater when compared to products with median concentrations for laundry streams.

In summary, products have a very limited impact on nitrogen in wastewater; the load generated was less than 7% of the TKN load from human excreta. Hence, product selection whilst reducing loads has little effect on the overall nitrogen load of the household. Adoption of environment label and low TKN content products had no significant reduction in loads. Instead TKN in some streams increased.

Traditionally nitrogen has not been a parameter of concern in household products for environmental purposes.

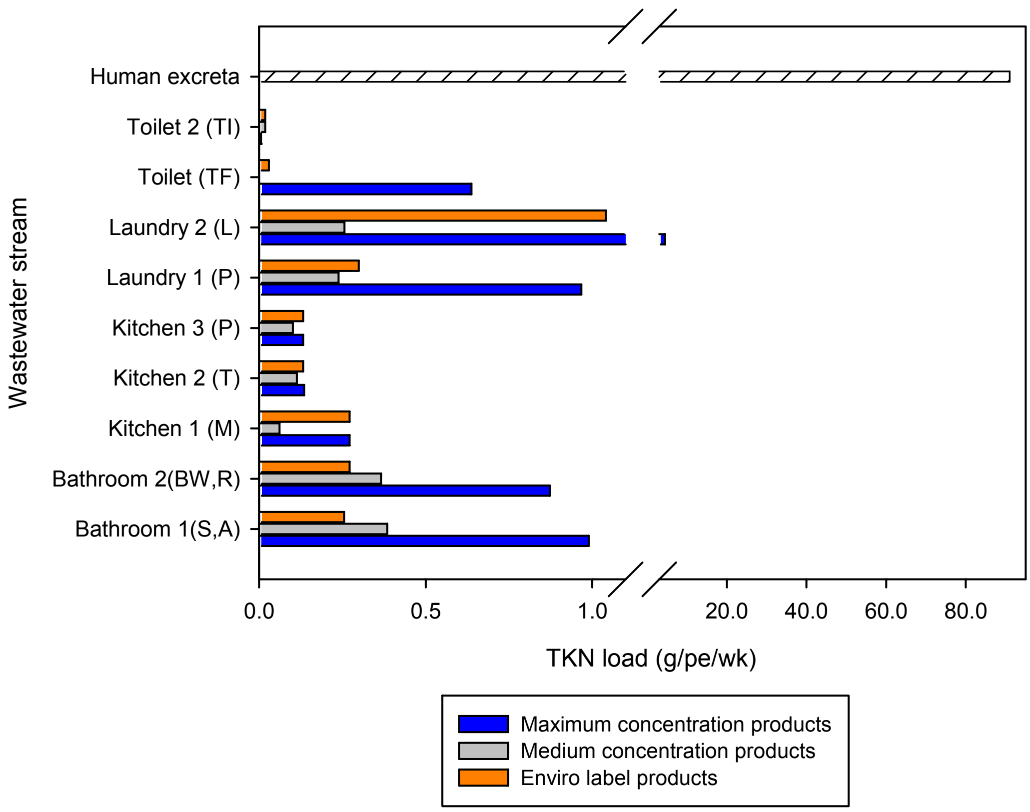

Figure 19: Nitrogen load from use of environmental label, median and maximum nitrogen concentrations products in household streams.

5.2.9. Phosphorus

The loads of phosphorus (TP) generated in the various sources within a household are shown in Figure 20.

Product selection could either halve or increase by two thirds the load of P into the sewer.

The average anthropogenic load of phosphorus adopted was 22.4 g/pe/wk, but values ranging from 0.7 to 31.5 g/pe/wk have also been reported in the literature (Metcalf and Eddy 2003). Loads from household product use were 40.4 g/pe/wk, 9.8 g/pe/wk and 0.1 g/pe/wk for maximum, median and environment label concentrations.

Analysis of individual streams identified the laundry as the major non-anthropogenic source of phosphorus among the household streams (Figure 20). However, loads varied with the brand and type of products adopted in each stream as evidenced for the laundry, the kitchen and the toilet in Figure 20 for the median, maximum and environmental product concentrations.

The ranking of household sources based on load also changed when maximum or median product concentrations were evaluated as previously shown in Table 16:

- Maximum concentrations: Laundry>Bathroom>Kitchen>Toilet
- Median concentrations: Laundry>Kitchen> Bathroom>Toilet

In summary, household products can be a significant contributor to the TP load in wastewater. The contribution can range from less than 0.5% to more than 180% of the anthropogenic load depending on the type, brands and combination of household products adopted. Environmental label and low P products were effective in reducing the load of P to 0.5% of the anthropogenic load.

The laundry was the major non-anthropogenic source of phosphorus in a household, followed by either the kitchen or the bathroom depending on the products adopted.

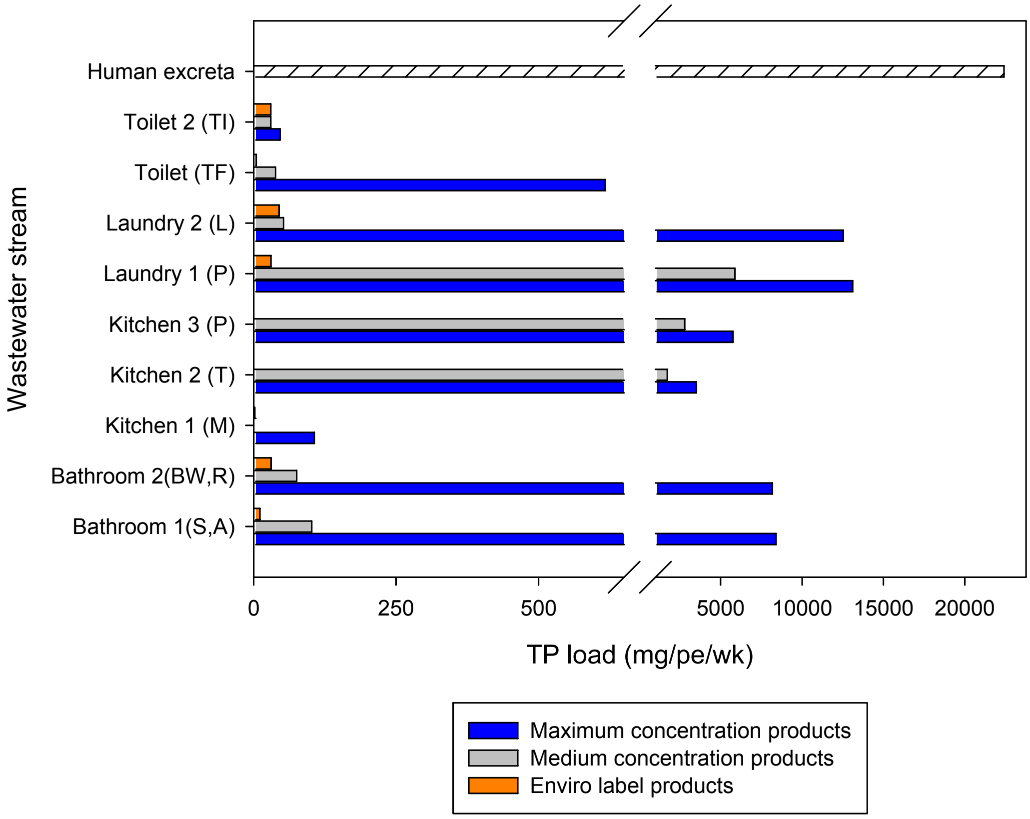

Figure 20: Phosphorus load from use of environmental label, median and maximum phosphorus loads products in household streams.

6. IMPACT ON WASTEWATER LOADS

The contribution of household products to the overall load discharged by a household into sewer is determined by a range of factors:

(a) The type of element considered:

(b) The type of products adopted (e.g. powder or liquid detergents) ,

(c) The brands of products adopted.

(d) Household habits.

Figure 21 to Figure 23 illustrate the contribution from each household outlet to the total household load with product selection (scenarios WW1, WW2 and WW3). In the figures, the toilet stream includes loads from both products and human excreta. The load from human excreta is assumed to be the same in all three scenarios. The other household streams represent the load from product use only. The load from tap water was not included in any of the scenarios.

The detailed descriptions for scenarios WW1, WW2 and WW3 were given previously in section 5.1. The wastewater streams for the household are also shown as mass loads in Appendix 2.

WW1 used the products with the maximum concentration of each element in each product category adopted; it included the use of laundry powder and dishwashing liquid (no dishwasher).

WW2 also adopted products with maximum concentration, but the type of products adopted differed. It included for instance laundry liquid and dishwasher powder.

Finally, WW3 assumed the use of environmental label products or products with the least element concentration when no enviro label product was available.

The overall mass load for each scenario is not shown as this was covered in section (5); instead this section aims to look at the relative importance of the sources for each scenario.

The importance of each household source was dependent on the elements and the scenario adopted.

In all three scenarios, loads from the kitchen had a lesser impact on the overall load to sewer compared to the other streams (toilet, bathroom and laundry) and the toilet was the major source of nitrogen and phosphorus in the household.

The laundry and the bathroom were also important sources for most contaminants as seen in Figure 21 and Figure 22.

WW1 represents the most common scenario expected in households, under that scenario the greywater from the bath and the laundry can contribute up to 80% of the load of Cr, Cl and F, up to 64% and 61% of Sb and Co, respectively. Whilst, the toilet was the major source of Mo and Se.

In WW2, the change in product type, such as from powder to liquid detergent, resulted in a lesser contribution from the laundry and the bath to the overall Cl and Mo household loads.

Under scenario WW3, in Figure 23, the adoption of products of low elemental content, significantly reduced the contribution of greywater to the overall loads in wastewater, making the toilet the major source of all elements in the household.

In summary, this illustrates how the contribution of the different household sources can change with product selection and how this can also impact the effectiveness of adopting at source control measures such as greywater diversion, when managing the overall wastewater discharge to sewer.

Kitchen and toilet wastewater are typically discharged to sewer whilst laundry and bathroom wastewater can be diverted to garden.

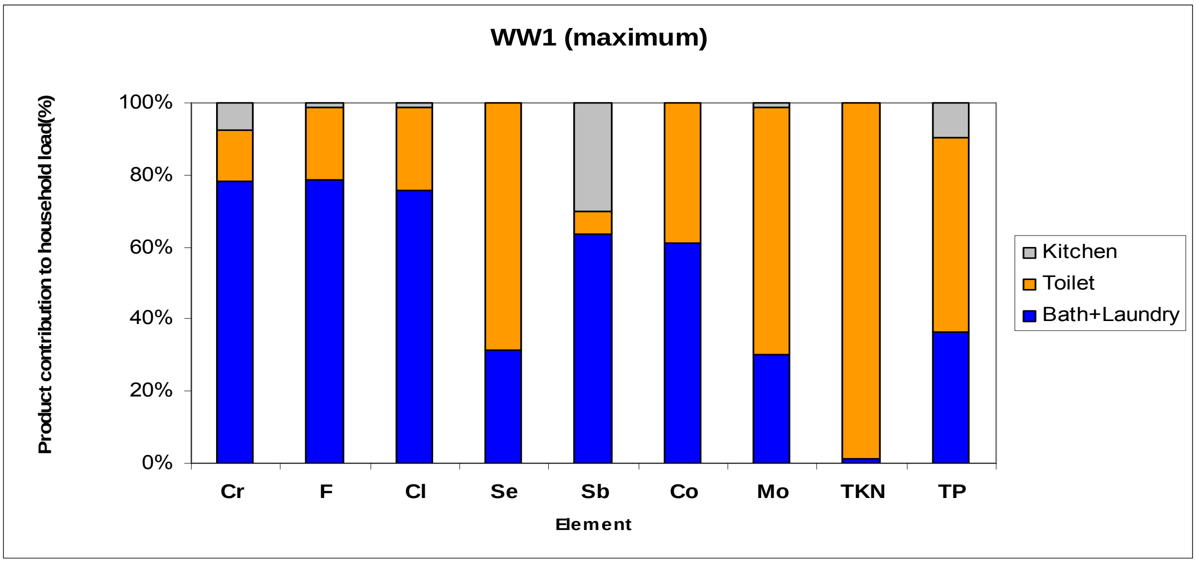

Figure 21: Relative contribution to elemental loads for scenario WW1. The toilet load includes human excreta. Laundry powder detergent and manual dishwashing are used.

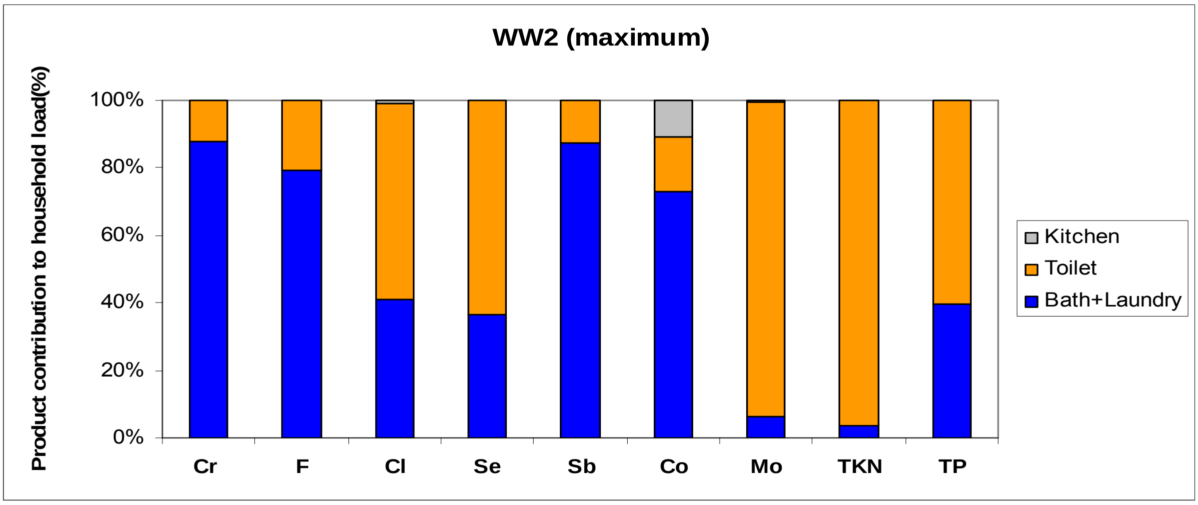

Figure 22: Relative contribution to elemental loads for scenario WW2. The toilet load includes human excreta. Liquid laundry detergent and dishwasher powder are used.

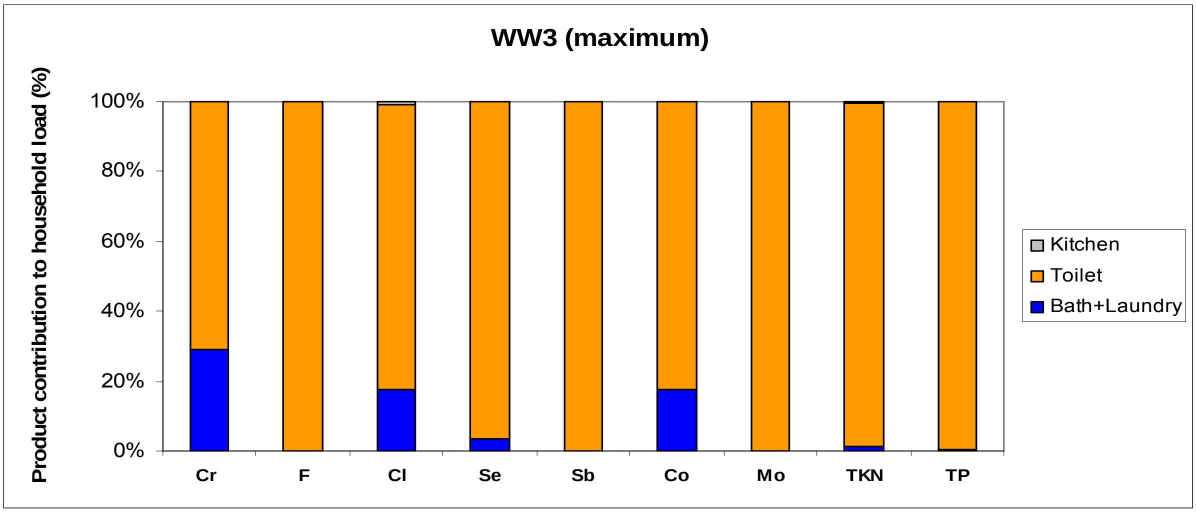

Figure 23: Relative contribution to elemental loads when green products are used. The toilet load includes human excreta.

7. CONCLUSIONS AND RECOMMENDATIONS

A range of 156 household products commonly used in the bathroom, laundry, kitchen and toilet were analysed to determine:

(a) Their content of antimony, cobalt, chromium, chloride, fluoride, molybdenum, selenium, nitrogen (as total Kjeldahl nitrogen) and phosphorus (as total phosphorus), and

(b) The loads and distribution of such elements within household wastewater streams.

The data gathered in this report was used to simulate the effect of a range of strategies on the quality of wastewater. The data generated could be used to evaluate a larger range of scenarios for future research.

Frequency of detection

Phosphorus, nitrogen, chloride and chromium were the most common elements among household products. They were detected in 97%, 84%, 80% and 64% of the products analysed. Phosphorus, nitrogen and chromium were detected in all cleaning and personal care product categories. Chloride, detected in most products, was below detection in toilet paper.

Molybdenum, fluoride, cobalt and selenium were detected in less than 30% of the products:

Antimony was detected in less than 10% of household products.

Phosphorus, nitrogen, chloride, fluoride and selenium are part of compounds used in the formulation of a range of household products. Fluoride is added to toothpaste and to some mouthwash formulations for caries prevention, whilst selenium is incorporated into the formulation of some medicated shampoos, e.g. as selenium sulphide, to combat dandruff. Interestingly, traces of fluoride were also detected in some brands of hair colouring, dishwashing and laundry detergents although it was not listed as an ingredient.

The other elements, antimony, chromium, cobalt and molybdenum, were generally detected in parts per million concentrations, and often only in selected products within a category. This suggests that they are more likely contaminants derived from raw materials, manufacturing process or packaging used for the products.

Elemental Loads in households

The contribution of household products to the elemental load in a household was evaluated assuming a one-person household and an average frequency of product use. The loads were compared to the load derived from human excreta.

Household products contributed to the overall element load to sewer. However, the size of the contribution depends on the element in question, the product categories and brands adopted by the household.

- Nitrogen: products have a minimal impact on the load of nitrogen. Loads were estimated to correspond to only 0.9% to 7% of the anthropogenic load. The bathroom and the laundry were the major sources for product loads.
- Phosphorus: products can be a significant load contributor, but the contribution varies significantly with brands. The contribution could be equivalent to 0.5% to 180% of the anthropogenic load. The laundry, the kitchen and the bathroom were the top 3 major sources when products are concerned.
- Selenium: products' load could be equivalent to up to 57% of the anthropogenic load. Contaminants originated mainly from the bathroom and the laundry.

- Molybdenum: selected products can be a significant load contributor. The contribution from selected products could be equivalent to up to 97% of the anthropogenic load, but median product concentrations generated a contribution of 26% only. Contaminants originated mainly from the laundry and the toilet.
- Fluoride: products can be a significant load contributor. The potential contribution ranged from the equivalent to less than 9% up to 586% of the anthropogenic load depending on the type and brands of products used in a household. Median product concentrations generated a contribution of 73%.The bathroom was the major point of origin.
- Chromium: products are a significant load contributor. The potential contribution ranged from 146% to 362% of the anthropogenic load for most products. However, loads were dependent on the type and brands of products used and one particular brand of toilet freshener with an extremely high Cr content generated loads 275 times larger than the anthropogenic load. Most commonly, sources were distributed across the household.
- Chloride: products are a significant load contributor. The potential contribution ranged from less than 34% up to 459% of the anthropogenic load depending on the type and brands of products adopted in a household. Median product concentrations generated a contribution of 35%. The major source was determined by the brands adopted and could be either the bathroom, the laundry or the toilet.
- Cobalt: products can be a significant load contributor, but their Co content varied markedly across products and brands within a same product type. The potential household product contribution ranged from less than 25% to up to thirteen times the anthropogenic load depending on the type and brands of products adopted. The major source was determined by the brands adopted.
- Antimony: the product contribution can vary markedly, ranging from nil to 950% of the anthropogenic load. The median was 9%. Major product sources were either the laundry or the kitchen.

Overall, the loads from household products are determined by the type and brand of products used, the dose and frequency of use in the household. Analysis of the products has shown that the elemental concentration among products varies widely between product categories and within brands.

There are specific brands that have markedly higher element concentrations than the majority of products within a category. This was observed in the comparison of the loads derived from the maximum, median and enviro label concentrations for each product category. The adoption of median concentration and enviro label/low concentration products resulted in a marked load reduction compared to the maximum concentrations.

However, the adoption of enviro label products and the associated load reduction was in some cases not much lower than what was already achieved by the median load. This was the case for antimony (because of concentrations at the detection limit), molybdenum, and nitrogen. However, for chromium, cobalt, chloride, fluoride, selenium and phosphorus the adoption of environmental label and selected products of low elemental concentrations will cause a reduction of contaminant loads.

Not all enviro label products had lower elemental concentrations than other products, with the exception of phosphorus. As a result the resulting loads may not necessarily be lower than other products, particularly for individual streams. This can have a bearing on the quality of greywater streams diverted to garden for instance.

Implications to contaminant management

Product selection has potential to reduce the loads of contaminants entering wastewater in residential areas. This is a useful strategy for some contaminants, such as phosphorus, chloride and selenium, but less effective for others such as nitrogen, molybdenum and cobalt due to either the low contribution of products to the overall household load compared to other inputs as in the case of nitrogen or the overall small load in wastewater as for antimony, molybdenum and cobalt.

Elements which are part of the formulation of a product, such as phosphorus, nitrogen, chloride, fluoride and selenium, can generally have their entry into the product traced and quantified. However, for other contaminants, present in trace amounts and not part of the formulation identifying the source of contamination would require further investigation of manufacture processes and raw materials.

Product selection would also be useful to householders trying to reduce the loads of contaminants diverted either to sewer or into the garden, as in the case of greywater.

However, access to information and knowledge about product formulation to householders is limited. Often the householder is neither concerned nor aware of the ingredients in products adopted in the household, and relies on advice from the manufacturer of from other sources.

Labels typically used in products such as “biodegradable”, “low P” or “environmentally friendly” generally refer to a single environmental aspect, most often P content in regards to surface water discharge or persistence in aquatic environments. Such labels do not provide sufficient relevant information to reflect the current patterns of water treatment and reuse, e.g. water treatment and recycling, nor the associated environmental impacts, for instance on soil and plant health in case of land application.

8. REFERENCES

Alaejos, MS and Romero, CD (1993) Urinary selenium concentrations, Clinical Chemistry 39(10), 2040-2052.

Altmann, PL and Dittmer, DS (1972-1974) Biology Data book, Second Edition, Federation of American Societies for Experimental Biology, 1489.

Anderson, R.A (1997) Chromium as an essential nutrient for humans, Regulatory Toxicology and Pharmacology, 26(1), 35-41.

Asano, T (2007) Water Reuse, McGraw-Hill.

Ashley, P.M, Craw, D., Graham, B.P., Chappell, D.A.(2003) Environmental mobility of antimony around mesothermal stibnite deposits, New South Wales, Australia and southern New Zealand, Journal of Geochemical Exploration, 77, 1-14.

ANZECC and ARMCANZ (2001) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Chapter 4, Primary Industries, Australian and New Zealand Environment and Conservation Council and Agriculture Resource Management Council of Australia and New Zealand.

ANZECC and ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 3, Primary Industries –Rationale and Background information, Australian and New Zealand Environment and Conservation Council and Agriculture Resource Management Council of Australia and New Zealand.

Encyclopedia Britannica (2009) “Chemical industry” Encyclopedia Britannica Online.Web 24 Nov. 2009, http://www.search.eb.com/eb/article-82227, last accessed 15/10/2009.

Bügel, S, Larsen, EH, Sloth, JJ, Flytlie, K, Overvad, K, Steenberg, LC and Moesgaard, S. (2008) Absorption, excretion, and retention os selenium from a high selenium yeast in men with a high intake of selenium, Food Nutrition Research, 52 10.3402/fnr.v52i0.1642., http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=2596749&blobtype=pdf, last accessed 02/10/2009.

Christova- Boal, D, Eden, RE, McFarlane, S (1996) An investigation into greywater reuse for residential properties, Desalination, 106, 391-397.

Connor, M.A. and Wilkie, P.J. (1995) Domestic contributions to levels of key organics and inorganic pollutants in Melbourne sewage, University of Melbourne, June 1995

Cook, S, Tjandraatmadja, G, Marleni, N (2010) Impact of source management strategies on quality and loads in residential wastewater: scenario analysis, Water for a Healthy Country National Research flagship, CSIRO.

Crockett, J. (2003), Feasibility study for a dry composting toilet and urine separation demonstration project, http://www.ghd.com.au/aptrixpublishing.nsf/AttachmentsByTitle/PP+CompostingToiletStudy+PDF/$FILE/e4215.pdf

CWW (2006) Personal communication, City West Water.

CWW (2009) Drinking Water quality Report 2009, City West Water.

Davies, T. D, Pickard, J. and Hall, K. J. (2005) Acute molybdenum toxicity to rainbow trout and other fish, J. Environ. Eng. Sci, 4: 481–485

Diaper, C, Tjandraatmadja, G, Pollard, C, Tusseau, A.C, Price, G, Burch, L, Gozukara, Y, Sheedy, C and Moglia, M (2008), Sources of critical contaminants in domestic wastewater: Contaminant loads from household appliances, Water for a Healthy Country report series, CSIRO Publishing.

Eriksson E., Auffarth K., Henze M. and Ledin A. (2002) Characteristics of grey wastewater, Urban Water, 4, 85-104

Francesconi, KA and Pannier, F (2004) Selenium metabolites in urine: a critical overview of past work and current status, Clinical Chemistry, 50(12), 2240-2253.

Friedler, E. (2004) Quality of individual domestic greywater streams and its implication for on-site treatment and reuse possibilities, Experimental Technology, 25, 997-1008.

Foy, CD, Chaney, R.L. and White, M.C. (1978), The physiology of metal toxicity in plants. Annu. Rev. Plant Physiol, 29, 511–566.

Fox, D, Molloy, R, Rixon, A., Tjandraatmadja, G and Carey, J (2006) Review and statistical assessment of Trade Waste Data in Victoria, Report to the Department of Sustainability and Environment, University of Melbourne.

Gebel, T., Claussen, K. and Dunkelberg, H.(1998) Human biomonitoring of antimony, International Archives of Occupational and Environmental Health. 71(3), 221-224.

Gray S.R. and Becker N.S.C Becker (2002) Contaminant flows in urban residential water systems. Urban Water, 4, 331-346

Grevatt, PC (1998) Toxicological review of hexavalent Chromium, August 1998, USEPA, http://www.epa.gov/iris/toxreviews/0144-tr.pdf, last accessed 02/10/2009.

Gropper, SS, Smith, JL and Groff, JL (2008) Advanced nutrition and human metabolism, 5th Edition, Wadsworth CENGAGE Learning.

Hargelius *et al*., (1995) Hushållsspillvatten Framtagende av nya schablonvården för BDT-vatten. In Vad innehåller avlopp från hushåll?. Stockolm: Swedish EPA

Hart, B.T (1974) A compilation of Australian water quality criteria", Australian Water Resources Council Technical Paper number 7.

Heitland, P and Köster, H.D. (2005) Biomonitoring of 30 trace elements in urine of children and adults by ICP-MS, Clinica Chimica Acta, 365, 310-318

Henze, , M, Harremoës, P, Jansen,J.laC., Arvin, E. (2002) Wastewater treatment –Biological and chemical processes, Springer-Verlag, 97.

Hypes, W.D (1974) Characterisation of typical household water greater. On J.H.T. Winnerberger (ed.) Manual of Greywater Treatment Practice, 79-88.

Health Canada (1997) Water quality and health - Antimony, May 1997, http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/antimony-antimoine/index-eng.php, last accessed 02 October 2009.

Hypes W.D. (1974) Characterisation of typical household greywater. In J.H.T. Winneberger (Ed) Manual of greywater treatment practice, 79-88

Icon (2001) Pollutants in Urban Waste and Sewage Sludge – Final Report, IC Consultants Ltd.

Kim, J.H, Gibb, H.J, and Howe, P.D. (2006) Cobalt and inorganic cobalt compounds, Concise International Chemical Assessment Document 69, World Health Organisation, http://www.who.int/ipcs/publications/cicad/cicad69%20.pdf, last accessed 02 October 2009.

Larsen, T.A. and Gujer, W. (1996) Separate management of anthropogenic nutrient solutions (human urine), Wat.Sci.Tech, 34(3-4), 87-94.

LeBlanc, A, Dumas, P. and Lefebvre, L.(1999), Trace element content of commercial shampoos, The Science of the Total Environment, 229, 121-124.

Lemly, A.D. (2002) Symptoms and implications of selenium toxicity in fish: the Belews Lake case example, Aquatic Toxicology, 57, 39-49.

Maher, WA.*(* 2009), Antimony in the environment – the new global puzzle, Environ. Chem*, 6*, 93–94.

McLaughlin, MJ, Tiller, KG, Naidu, R and Stevens, DP (1996) Review: the behaviour and environmental impact of contaminants in fertilizers, Australian Journal of Soil Research, 34, 1-54.

McLaughlin, MJ,, Tiller, KG, and Smart, MK (1997) Speciation of cadmium in soil solution of saline/sodic soils and relationship with cadmium concentrations in potato tubers. *Australian Journal of Soil Research,* 35, 1–17

Metcalf and Eddy (2003) Wastewater Engineering, Treatment and reuse, Ed G. Tchobanoglous, F.L.Burton and H.D. Stensel, Mc-Graw-Hill, 4th Edition.

Michalke, K.,Schmidt, A.,Huber, B.,Meyer, J.,Sulkowski, M.,Hirner, A. V.,Boertz, J.,Mosel, F.,Dammann, P., Hilken, G., Hedrich, H. J., Dorsch, M., Rettenmeier, A. W., Hensel, R. (2008) Role of intestinal microbiota in transformation of bismuth and other metals and metalloids into volatile methyl and hydride derivatives in humans and mice, Applied and Environmental Microbiology, 74(10),3069-3075.

NHMRCC and NRMMC (2008) Australian Drinking Water guidelines, Chapter 6, National Health and Medical Research Council and Natural Resource Management Ministerial Council, http://www.nhmrc.gov.au/publications/synopses/_files/adwg_11_06.pdf, last accessed 02 October 2009.

NRMMC/EPHC/AHMC (2006) Australian Guidelines for Water Recycling:Managing Health and Environmental Risks (Phase 1), National Water Quality Management Strategy, Natural Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers' Conference, November 2006, 149, http://www.ephc.gov.au/sites/default/files/WQ_AGWR_GL__Managing_Health_Environmental_Risks_Phase1_Final_200611.pdf, last assessed 26 October 2009.

O'Connor *et al* (2001) A modified risk assessment to establish molybdenum standards for land application of biosolids, Journal of Environmental Quality, 30, 1490-1507.

Palmquist, H. and Hanæus, J (2005) Hazardous substances in separately collected grey- and blackwater from ordinary Swedish households, Science of the Total Environment, 348,1-3, 151-163.

Patriarca, M., Menditto, A.,Rossi, B.,Lyon, T. D. B. and Fell, G. S. (1999) Environmental exposure to metals of newborns, infants and young children, IXth Italian-Hungarian Conference in Spectrochemistry - Analytical Techniques in Environmental Chemistry, Siena, Italy, 351-361.

Rose, JB, Sun, G, Gerba, CP, Sinclair, NA (1991) Microbial quality and persistence of enteric pathogens in graywater from various household sources, Water Research, 25(1), 37-42.

Rule, K.L., Comber, S.D.W., Ross, D.,Thornton, A., Makropoulos, C.K. and Rautiu, R., (2006) Diffuse sources of heavy metals entering an urban wastewater catchment, Chemosphere, 63, 64-72.

SEWL (2009) South East Water 2008/09 Drinking Water quality report, South East Water Limited.

Shareef, A, Kookana, R, Kumar,A and Tjandraatmadja, G (2008)Sources of Emerging Organic Contaminants in Domestic Wastewater, Water for a Healthy Country National Research flagship, CSIRO Publishing.

Shotyk, W., Krachler, M., Chen, B., (2006) Contamination of Canadian and European bottled waters with antimony from PET containers. J. Environmental Monitoring, 8 (2), 288–292.

Sörme L. and Lagerkvist R. (2002) Sources of heavy metals in urban wastewater in Stockholm. The Science of the Total Environment, 298, 131-145

Stephenson,T (1987) Sources of Heavy Metals, Chapter 1, in Heavy metals in wastewater and sludge treatment proceses, Ed. J.N. Lester, 47-64.

Terry, M, Zayed, A.M., de Souza, M.P., Tarun, A.S (2000) Selenium in higher plants, annual Review of Plant Molecular Biology, 51, 401-432.

Tjandraatmadja, G and Diaper, C (2007) Sources of critical contaminants in domestic wastewater: a literature review, Water for a Healthy Country National Research flagship, CSIRO Publishing.

Tjandraatmadja, G, Diaper, C, Gozukara,Y, Burch, L,Sheedy,C and Price, G (2008) Sources of priority contaminants in domestic wastewater:contaminant loads from household products, Water for a Healthy Country National Research flagship, CSIRO Publishing.

Tjandraatmadja, G, Pollard, C, Gozukara,Y and Sheedy,C (2009a) Characterisation of priority contaminants in residential wastewater, Water for a Healthy Country National Research flagship, CSIRO Publishing.

Tjandraatmadja, G, Pollard, C, Gozukara,Y and Sheedy,C (2009b) Investigation of seasonality effects on domestic wastewater quality, Water for a Healthy Country National Research flagship, CSIRO Publishing.

Tschan, M, Robinson, B.H and Schulin, R (2009) Antimony in the soil-plant system – a review, Environmental Science, 6, 106-115.

Tunaley J. (2004) An assessment of a domestic sand filter for greywater treatment. Bachelor or Applied Science, Environmental Science (Hons) Thesis, School of Applied Sciences, RMIT University.

USEPA (2009), Antimony compounds, US Environmental Protection Agency, http://www.epa.gov/ttn/atw/hlthef/antimony.html, last accessed 15/10/2009.

Van Cauwenbergh , R. Hendrix, P, Robberecht, H, Deelstra, H (1997) Daily dietary molybdenum intake in Belgium using duplicate portion sampling, S. Lebensm Unster Forsch A, 205, 1-4.

Vinneras, B. (2001) Report 244 - Licentiate thesis: Faecal separation and urine diversion for nutrient management of household biodegradable waste and wastewater, Swedish University of Agricultural Science, Uppsala.

Westerhoff, P, Prapaipong, P, Shock, E and Hillaireau, A (2008) Antimony leaching from polyethylene terephthalate (PET) plastic used for bottled drinking water, Water Research, 42, 551-556.

WHO (2000) Fluorides, Chapter 6.5, World Health Organisation Regional Office, http://www.euro.who.int/document/aiq/6_5fluorides.pdf, last accessed 12 October 2009.

WHO (2006) Cobalt and inorganic cobalt compounds-concise international assessment document, no.69, World Health Organisation.

Yadav, AK, Kaushik, CP, Haritash,AK,Singh, B, Raghuvanshi, S.P, Kansal,A (2007) Determiantion and probable ingestion of fluoride through tea, toothpaste, tobacco and pan masala, Journal of Hazardous Materials, 142 (1-2), 77-80.

YVW (2009) Drinking Water Quality Annual Report 2008/09, Yarra Valley Water.

APPENDIX 1 – ELEMENTS IN PRODUCTS

Table 17: Frequency of element detection in household products analysed

Product category	*Number of products tested*	*Frequency of detection (%)*								
		Cl	*Cr*	*Co*	*F*	*Mo*	*Se*	*Sb*	*TKN*	*TP*
Cleaning	22	82	55	9.1	9.1	33	18	4.6	91	100
Shower	32	100	59	59	0	25	19	3.1	94	97
Hair dye	6	100	50	0	83	0	0	0	100	100
Oral care	14	86	86	0	79	14	36	7.1	64	100
Deodorant	9	89	33	0	0	44	33	0	44	89
Sunscreen and lotions	16	38	63	6.3	0	13	0	6.3	81	88
Dishwashing	16	81	67	18.8	47	38	0	13	94	100
Laundry	33	88	79	9.1	30	33	30	24	79	100
Toilet paper	8	0	50	38	0	63	0	13	100	100
Total	156	80	64	20	23	29	18	9.6	84	97

Table 18: Elements in cleaning products

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Surface cleaning	CGE1*	Cream Cleanser	<34	0.57	0.03	<0.14	0.196	<0.01	<0.15	0.080	0.10
	CGE2	Multi-purpose	<37	5.58	0.01	<0.04	<0.04	<0.04	<0.04	3.12	0.08
	CGE3	Multi-purpose	<36	<0.12	<0.1	<0.005	0.01	0.12	<0.005	0.43	0.004
	CGE4*	Disinfectant	<10	39.30	<2	<0.3	0.069	<0.01	<0.02	0.25	0.03
	CGE5	Disinfectant	<117	42.90	<0.01	<0.01	<0.12	<0.12	<0.12	0.27	0.04
	CGE6p	Disinfectant	<76	1.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.40	0.01
	CGE7	Disinfectant	<11	1.69	<0.01	<0.01	<0.001	<0.127	<0.03	0.69	1.14
Toilet cleaning	CTO1	Toilet Cleaner	<22	0.07	<2	<0.3	<0.001	<0.06	<0.03	0.17	0.02
	CTO2*	Toilet Cleaner	<22	0.30	<2	<0.3	0.03	<0.07	<0.01	0.13	0.001
	CTO3g	Toilet cleaner	<1	5.58	<2	<0.3	1.50	<0.005	0.05	3.03	0.06
	CTO4p	Toilet Cleaner	<154	<0.52	<2	<0.3	0.06	<0.02	4	0.10	0.009
Floor and Surface cleaning	CFL1*	Floor cleaner	5.5	1.53	<0.006	<0.06	0.01	<0.06	<0.06	<0.04	6.49
	CFL3	Floor Cleaner	<12	0.73	0.016	<0.05	0.050	<0.005	<0.02	0.10	0.0004
	CFL4g	Floor and Surface	<13	3.15	<2	<0.3	0.017	<3	<0.02	1.97	0.006

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	CFL5	Floor cleaner	<35	1.62	0.014	0.07	0.069	<0.07	<0.07	nd	0.01
Toilet freshener	CTF1*	Toilet freshener	38.6	<0.35	<2	<0.3	0.99	<0.02	1	0.001	0.29
	CTF2	Toilet freshener	<51	6.79	<2	<0.3	0.26	<0.02	<0.03	0.32	0.19
	CTF3p	Toilet freshener	<41	5.84	<0.025mg/L	<0.002mg/L	0.33	<0.02	0.09mg/L	3.07	3.00
In cistern freshener	CTC1	In cistern toilet freshener	<1,721	166.0	<2	<0.3	0.37	<0.02	0.07	11.20	2.90
	CTC2	In cistern toilet freshener	<37	<0.37	<2	<0.3	174	<0.04	0.06	1.06	2.57
	CTC3	In cistern toilet freshener	<32	79.40	<2	<0.3	0.48	<0.02	0.15	35.80	2.00
	CTC4p	In cistern toilet freshener	<4	5.51	<2	<0.3	0.30	3.9	1	268.84	3.08

Note: * market leader, p – private label, g –environmental friendly label, nd – not determined

Table 19: Elements in laundry products

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP(g/kg)
Fabric softener	LFS1*	Fabric softener	<8	0.21	<0.006	<0.06	<0.06	<0.01	<0.06	2.35	0.04
	LFS2	Fabric softener	<0.9	<0.21	<0.9	<0.9	0.32	<0.88	<0.03	1.15	0.17
	LFS3	Fabric softener	<10	0.13	<2.0	<0.3	<0.01	<0.006	<0.001	0.93	0.04
	LFS4p	Fabric softener	<5	0.13	<0.1mg/L	<0.005mg/L	0.01	0.09	<0.03	0.47	0.01
	LFS5	Fabric softener	<0.3	<0.0001	<0.005	<0.05	3.5	<0.005	0.047	1.03	0.19
	LFS6g	Fabric softener	<61	<0.21	<0.004	<0.04	<0.04	<0.01	<0.04	1.30	0.02
	LFS7	Fabric softener	<1.5	5.73	<0.004	<0.04	0.03	<0.01	<0.04	0.87	0.02
Laundry powder	LPC1	Top loader concentrate	15	0.07	<1.0	0.2	1.1	<0.005	0.54	0.002	2.10
	LPC2	Top loader concentrate	10	2.69	0.37	0.13	0.4	<0.005	<0.03	<0.007	27.60
	LPC3*	Top loader concentrate	0.5	0.82	<1.0	<0.1	0.21	<0.005	<0.03	0.07	13.05
	LPC4	Top loader concentrate	8	1.31	<1.0	<0.3	1.1	<0.005	0.58	0.04	42.31
	LPC5	Top loader concentrate	10	1.12	<1.0	<0.1	0.61	<0.005	1	<0.002	24.46
	LPC6p	Top loader concentrate	<87	13.73	0.08	<0.06	0.18	<0.01	<0.06	<0.03	0.96
	LPC7	Top & Front loader concentrate	10	2.00	<1.0	0.2	0.87	<0.005	0.6	0.26	38.05

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP(g/kg)
	LPC8g	Top & Front loader concentrate.	8	1.31	0.037	<0.09	0.28	<0.01	1.065	0.03	0.11
	LPC9	Front concentrate	<96	6.34	0.046	0.186	1.2	<0.005	1.2	1.83	43.97
	LPC10	Front concentrate	14	2.82	<0.09	0.12	0.57	<0.005	0.94	<0.006	34.50
	LPC11	Front concentrate	<7	97.03	<1.0	≤0.1	0.78	<0.005	1.35	0.03	54.47
	LPC12	Front concentrate	<90	1.50	<1.0	<0.1	0.13	<0.01	<0.2	<0.15	12.02
	LPC13	Top loader powder	<133	224.61	0.056	0.465	0.28	<0.01	<0.47	0.27	5.76
Laundry liquid	LL1*	Laundry liquid	<9	0.06	0.57	<0.3	<0.3	<0.005	<0.03	0.09	0.13
	LL2	Laundry Liquid	<10	0.47	<1.0	<0.3	0.55	0.103	<0.03	0.02	15.30
	LL3	Laundry Liquid	<9	0.36	<0.025mg/L	<0.002mg/L	<0.001	<0.005	0.047	1.67	0.16
	LL4	Laundry liquid	<0.3	3.87	0.057	0.410	0.25	<0.01	<0.04	<0.02	42.53
	LL5	Laundry Liquid	<0.3	<0.003	0.007	<0.034	0.03	<0.01	<0.03	0.31	0.005
	LL6	Laundry Liquid	<0.3	7.05	0.08	0.04	0.04	<0.01	<0.04	0.01	39.54
	LL7	Laundry Liquid	<55	5.47	<0.9	<0.3	3.5	<0.89	<0.03	0.02	46.24
	LL8	Laundry Liquid	<106	2.13	<0.13	<0.134	0.13	<0.01	<0.134	<0.04	22.72
	LL11g	Laundry Liquid	<0.3	0.67	<2.0	<0.3	0.09	<0.01	<0.002	2.78	0.15

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP(g/kg)
	LL12p	Laundry Liquid	<0.3	3.28	<2.0	<0.3	<0.007	1.8	<0.001	14.57	0.01
	LW1	Wool wash	<9	1.24	<1.0	<0.3	<0.001	<0.005	<0.03	2.35	0.02
Soaker	LSK1*	Soaker	1.1	2.00	0.046	<0.08	0.02	<0.01	<0.08	4.26	1.11
	LSK2	Soaker	1	2.27	<1.0	<0.2	0.23	<0.005	0.06	0.27	18.16

Note: * market leader, p – private label, g –environmental friendly label, nd – not determined

Table 20: Elements in toilet paper

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Toilet paper	TOI1*	Toilet paper	<13	<0.13	<2.0	<0.4	0.76	<0.005	0.046	0.25	0.019
	TOI2	Toilet paper	<23	<0.24	<1.0	<0.3	<0.001	<0.005	<0.03	0.43	0.013
	TOI3	Toilet paper	<13	<0.13	<3.0	<0.5	0.73	<0.005	<0.03	0.61	0.005
	TOI4	Toilet paper	<12	<0.12	<4.0	<0.6	0.18	0.060	<0.03	0.16	0.006
	TOI5p	Toilet paper	<13	<0.13	<5.0	<0.7	1.8	<0.005	0.035	0.20	0.031
	TOI6g	Toilet paper recycled	<12	<0.11	<6.0	<0.8	1.03	0.242	0.036	0.38	0.017
	TOI7g	Toilet paper recycled	<11	<0.14	<7.0	<0.9	0.8	<0.005	0.29	0.34	0.001
	TOI8	Toilet paper	<14	<0.14	<0.08	0.016	0.824	0.085	0.018	0.56	0.011

Note: * market leader, p – private label, g –environmental friendly label, nd – not determined

Table 21: Elements in sunscreen and other skincare

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Personal care	FCL1	Face Cleanser	<0.3	3.85	<0.18	<0.18	0.70	<0.2	<0.18	1.84	0.12
	FCL2	Face cleanser	<0.3	<0.001	<0.1	<0.1	0.47	<0.1	<0.1	<0.0002	<0.0005
Sunscreen	SUN1*	Sunscreen 30+	<19.8	1.35	<2.0	<0.3	0.11	<0.02	0.13	0.61	0.002
	SUN2	Sunscreen 30+	<4.6	0.41	<2.0	<0.3	0.02	<0.01	<0.02	0.02	0.001
	SUN3	Sunscreen 30+	<10	Nd	<0.37	<0.37	<0.37	<0.37	<0.37	1.01	0.90
	SUN4	Sunscreen 30+	<9.8	0.54	<2.0	<0.3	0.06	0.204	0.028	<0.00003	<0.0001
	SUN5	Sunscreen 30+	<3.4	<0.03	<2.0	<0.3	0.006	<0.02	<0.04	0.19	0.02
	SUN6	Sunscreen 30+	<3.6	8.16	<2.0	<0.3	0.03	<0.01	<0.02	0.21	0.002
	SUN7p	Sunscreen 30+	<2.5	<0.03	<2.0	<0.3	0.08	<0.005	<0.02	0.91	<0.0001
Face cream	CRF1	Face cream	<0.3	<0.001	<2.0	<0.3	0.003	<0.03	<0.05	0.39	0.05
	CRF2	Face cream	<0.3	0.007	<1.0	<0.3	0.002	<0.02	<0.06	3.74	0.07
	CRF3p	Face cream	<4	<0.04	<2.0	<0.3	<2.00	<0.9	<0.02	<0.0001	0.0002
	CRF4	Face cream	<7.1	0.77	<0.4	0.05	0.35	<0.39	<0.4	2.40	0.38
Body and Hand lotion	CRB1*	Hand and body	<3	<0.03	<0.37	<0.37	<0.37	<0.37	<0.37	0.08	0.02

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	CRB2	Hand and body	<0.3	<0.001	<0.39	<0.39	<0.40	<0.39	<0.39	0.98	0.07
	CRB3	Hand and body	<0.3	<0.001	<0.3	<0.3	<0.30	<0.3	<0.3	<0.01	0.007
	CRB4	Hand and body	<1.5	<0.015	<1	<0.3	<0.001	<0.005	<0.03	0.12	0.07
	CRB5p	Hand and body	<3.2	<0.032	<0.4	<0.40	<0.40	<0.4	<0.4	0.22	0.08

Note: * market leader, p – private label, g –environmental friendly label, nd – not determined

Table 22: Elements in deodorants

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Deodorant	DEO1A*	Aerosol	<2.5	126.22	<1.3	<1.3	<2.6	<3.00	<1.3	<0.003	0.08
	DEO2A	Aerosol	<1.0	58.02	0.124	<0.62	<0.62	<0.6	<0.6	0.09	0.18
	DEO5Ap	Aerosol	<8.5	210.40	0.62	<3.09	<3.09	<3.0	<3.09	0.08	0.59
	DEO10A	Aerosol	<7.2	84.14	<0.31	<0.31	1.88	<0.4	0.62	<0.53	1.10
	DEO11A	Aerosol	<1.8	0.09	0.45	<0.3	3.9	<0.6	<0.3	<0.33	<0.13
	DER1	Roll-on	<4.1	52.12	<0.4	<0.4	<0.4	<0.4	1.18	3.72	0.003
	DER2	Roll-on	<8.9	27.34	<2.0	<0.3	1.00	<0.04	0.51	<0.39	0.35
	DER3	Roll-on	<941	<0.0002	<0.32	<0.03	<0.03	<0.3	1.62	3.77	0.35
	DER4	Roll-on	<2.9	48.2	<2.0	<0.3	0.79	<0.01	<0.02	<0.54	0.96

Note: * market leader, p – private label, g –environmental friendly label, nd – not determined

Table 23: Elements in oral care products

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Mouthwash	MW1*	Mouth wash	<0.98	0.02	<0.02	<0.02	0.7	<0.02	<0.02	<0.02	0.006
	MW2	Mouth wash	15.1	0.08	0.11	<0.04	0.13	<0.04	<0.04	0.03	0.00
	MW3	Mouth wash	<0.4	0.04	0.01	<0.03	<0.03	<0.03	<0.03	<0.01	0.04
	MW4p	Mouth wash	0.8	0.19	<2	<0.3	0.04	<0.02	<0.03	<0.01	0.05
	MW5	Mouth wash	287	0.08	<2	<0.3	0.01	<0.01	<0.02	0.05	0.08
Toothpaste	TP1*	Toothpaste	1,098	0.005	0.09	0.15	0.30	<0.15	<0.15	<0.09	0.20
	TP2	Toothpaste	315.8	1.34	<0.4	<0.4	0.8	<0.41	<0.4	0.36	10.34
	TP3	Toothpaste	919	0.10	<0.46	<0.46	0.9	<0.46	<0.46	0.25	0.66
	TP4	Toothpaste	0.3	0.70	0.09	<0.4	<0.45	<0.4	<0.4	0.78	33.22
	TP5	Toothpaste	438.9	1.30	<0.4	<0.4	1.21	<0.4	<0.4	0.78	39.20
	TP6	Toothpaste	167.7	0.11	0.05	<0.08	0.30	<0.07	0.08	<0.07	0.66
	TP7	Toothpaste	887.8	<0.40	<0.45	<0.45	0.47	<0.4	<0.45	1.59	13.28
	TP8p	Toothpaste	202.4	<0.28	<2	<0.3	0.95	<0.01	0.12	0.16	0.51
	TP9g	Herbal Toothpaste	<4.5	0.18	<0.45	<0.45	0.47	<18.8	<0.45	0.63	0.11

Note: * market leader, p – private label, g –environmental friendly label, nd – not determined

Table 24: Elements in shower and bathroom products

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Shampoo	SHW1	Hair remover	<2.5	8.92	<0.37	<0.37	<0.07	<0.4	<0.37	38.24	<0.0001
	SHA1*	Shampoo	<2.6	1.83	<1	<0.1	0.88	0.26	0.058	7.45	0.01
	SHA2	Shampoo	<0.3	1.94	<1	<0.1	0.99	0.29	<0.02	8.12	0.81
	SHA3	Shampoo	<0.3	9.87	0.022	<0.07	0.15	0.076	<0.2	1.54	0.10
	SHA4	Shampoo	<0.3	11.53	<1	<0.1	1.4	43	0.095	4.61	0.14
	SHA5	Shampoo	<1.7	5.10	<0.07	<0.07	0.07	<0.07	<0.07	3.61	0.15
	SHA6	Shampoo	<1.6	4.76	<0.16	<0.16	0.47	<0.2	<0.16	1.68	0.46
	SHA7	Anti-dandruff Shampoo	<1.5	3.66	<2	<0.3	0.18	0.43	0.4	1.53	1.73
	SHA8	Anti-dandruff Shampoo	<14	6.11	2.35	<0.48	<0.05	0.04	<0.03	1.03	1.27
	SHA9p	Shampoo	<21	7.10	<0.025	<0.002	<0.001	<0.005	0.049	4.85	0.001
	SHA10g	Shampoo	<17	5.43	<0.025	<0.002	1.3	0.43	0.02	3.85	0.20
	SHA11	Anti-dandruff Shampoo	<1.5	7.13	4.6	<2.3	<2.3	<2.3	<2.3	9.04	0.10
Conditioner	SCD1*	Conditioner	<0.3	0.40	<1	<0.1	<0.001	<0.005	0.049	1.33	0.006
	SCD2	Conditioner	<13	0.51	<1	<0.3	0.88	0.28	<0.03	0.33	0.02

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	SCD3	Conditioner	<20	1.77	<1	0.05	1.3	0.39	<0.03	0.46	1.93
Soap bar	SOB1	Soap bar	<66	187.06	<0.9	<0.9	<0.9	<0.9	<0.9	0.06	0.37
	SOB2*	Soap bar	<5.4	18.6	<1.76	<1.76	<1.76	<1.76	<1.76	<0.0001	0.79
	SOB3	Soap bar	<0.3	1.63	0.280	<0.93	<0.93	<0.9	<0.93	<0.0001	0.38
	SOB4	Soap bar	<4	115.4	0.39	<1.95	<1.9	<1.9	<1.95	0.03	2.52
	SOB5g	Soap bar	<6	92.59	0.280	<0.124	<1.24	<1.2	<1.24	0.10	0.0003
	SOB6p	Soap bar	<6	121.49	0.327	<1.95	<1.95	<1.95	<1.95	0.05	1.02
Hand wash	SOC1	Hand wash	<2	8.56	<0.025mg/L	<0.002mg/L	1	0.33	<0.03	1.85	0.06
	SOC2*	Hand wash	<2.2	2.71	<2	<0.3	1.2	<0.08	<0.08	3.14	75.03
	SOC3	Hand wash	<0.3	4.82	<1	<0.3	1.2	0.39	<0.03	0.66	0.004
	SOC4p	Hand wash	<2.5	21.85	<2	<0.3	<0.02	2.5	<0.02	1.72	0.10
	SOC5	Handwash	<3	8.79	<0.025mg/L	<0.002mg/L	1	0.32	0.02	1.83	0.03
Body wash gel	SOG1	Body wash	<1.5	0.03	<2	<0.3	0.011	4.9	<0.04	1.70	0.01
	SOG2	Body wash	<1.5	0.02	<2	<0.3	<0.02	4.5	<0.03	2.01	0.0001

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	SOG3	Body wash	<13	13.75	<1	<0.3	1.2	0.35	0.02	2.37	0.04
	SOG4g	Body wash	<2.2	29.08	<2	<0.3	0.02	2.2	<0.01	3.41	0.002
Personal care	FCL1	Face Cleanser	<0.3	3.85	<0.18	<0.18	0.7	<0.2	<0.18	1.84	0.12
	FCL2	Face cleanser	<0.3	<0.001	<0.1	<0.1	0.47	<0.1	<0.1	<0.0002	<0.0005
Shaving products	SHV1p	Shave Foam	<1.8	4.43	<2	<0.3	<0.01	<0.005	<0.001	2.16	0.02
	SHV2*	Shave foam	<0.3	0.19	<2	<0.3	<0.01	<0.005	<0.001	4.19	0.02
	SHV3p	Shave foam	<7.6	1.38	<1.2	<1.2	<1.2	<1.2	<1.2	1.99	0.01
	SHV4	Shave stick	<74.9	16.48	<15	<15	<15	<15	<15	0.45	0.08
	SHV5	Shave foam	<3.4	16.84	<3	<3	<3	<3	<3	0.09	<0.02
Hair colour	HAI5	Hair dye	16	2.70	<0.19	<0.19	0.19	<0.19	<0.19	10.03	1.02
	HAI6	Hair dye	13.2	1.29	<0.22	<0.22	0.22	<0.22	<0.22	7.00	0.78
	HAI7	Hair dye	26.5	1.38	<0.14	<0.14	0.14	<0.14	<0.14	11.48	0.09
	HAI8	Hair dye	2.5	0.10	<2.2	<2.2	<2.2	<2.2	<5.1	7.56	0.04
	HAI9	Hair dye	2.7	3.56	<6.6	<6.6	<6.6	<6.6	<6.6	10.77	0.20

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	HAI10	Hair dye	<3.2	0.10	<4.1	<4.1	<4	<4.1	<4.1	1.38	0.05

Note: * market leader, p – private label, g –environmental friendly label, nd – not determined

Table 25: Elements in dishwashing products

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Manual Dishwashing	DWL1*	Liquid Detergent	<23	10.79	<1	<0.002mg/L	0.185	0.05	<0.002	0.27	0.002
	DWL2	Liquid Detergent	<85	10.15	<1	<0.1	0.16	7.6	<0.2	0.42	0.01
	DWL3	Liquid Detergent	<23	0.08	<1	<0.1	<0.001	<0.005	0.083	2.74	0.01
	DWL4	Liquid Detergent	<19	6.23	<1	<0.1	<0.001	<0.005	<0.03	0.84	0.01
	DWL5g	Liquid Detergent	<20	6.06	<1	<0.1	<0.001	<0.005	<0.03	3.70	0.02
	DWL6p	Liquid Detergent	<1.75	<0.02	<2	<0.3	0.02	1.4	0.21	0.84	1.45
Dishwasher	DWT1*	Auto tablet	41.0	<0.05	<0.94	<0.94	0.377	<0.94	<0.94	3.77	0.0005
	DWT2p	Auto tablet	28.4	3.89	<2	<0.3	0.059	<0.02	<0.03	1.90	21.80
	DWT7	Auto tablet	<31	1.54	<2	<0.3	1.06	<0.53	0.16	3.09	95.71

Function	Product ID	Description	Concentration in product (mg/kg or as stated)								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	DWT3p	Auto tablet	0.7	1.21	<1	<0.1	1	<0.005	0.47	3.22	97.70
	DWT4	Auto powder	5.6	2.67	<2	<0.3	<4.6	<4.6	0.16	0.95	53.39
	DWT5	Auto powder	16	2.03	0.85	0.82	0.55	<0.01	<0.03	0.93	49.31
	DWT6g	Auto powder	0.5	0.18	<2	<0.3	0.11	<0.01	<0.002	3.69	0.01
	DWT8p	Auto powder	17.12	46.64	<1	0.1	0.9	<0.1	0.2	0.03	8.34
Rinse aid	DWA1	Rinse aid	<0.3	0.07	<2	<0.3	<0.03	<0.01	<0.02	<0.02	0.08

Note: * market leader, p – private label, g –environmental friendly label, nd – not determined

Table 26: Summary of element concentration in products

Function	Summary statistics	Units	Element								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Surface cleaning	Mean	mg/kg	<117	13.01	0.006	<0.3	0.039	0.017	<0.15	0.75	0.20
	SD	mg/kg	0	19.31	0.011	0	0.074	0.045	0	1.06	0.41
	Median	mg/kg	<35.5	1.69	<2	<0.1	<0.04	<0.04	<0.03	0.40	0.04
	Number of brands		7	7	7	7	7	7	7	7	7
Toilet cleaning	Mean	mg/kg	<154	1.49	<2	<0.3	0.398	<0.07	1.01	0.86	0.02
	SD	mg/kg	0	2.73	0	0	0.735	0	1.99	1.45	0.03
	Median	mg/kg	<22	0.18	<2	<0.3	0.045	<0.04	0.03	0.15	0.01
	Number of brands		4	4	4	4	4	4	4	4	4
Floor and surface cleaning	Mean	mg/kg	1.4	1.42	0.58	0.58	0.704	0.571	0.86	0.61	0.94
	SD	mg/kg	2.4	1.21	1.51	1.51	1.48	1.512	1.57	0.87	2.45
	Median	mg/kg	<13	1.53	<0.01	<0.06	0.05	<0.06	<0.06	0.13	0.01
	Number of brands		4	4	4	4	4	4	4	3	4
Toilet fresheners	Mean	mg/kg	5.5	37.65	<2	<0.3	25.3	0.557	0.34	45.76	2.01
	SD	mg/kg	14.6	63.31	0	0	65.6	1.474	0.45	99.20	1.26

Function	Summary statistics	Units	Element								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	Median	mg/kg	<39	5.84	<2	<0.3	0.37	<0.2	0.09	3.07	2.57
	Number of brands		7	7	7	7	7	7	7	7	7
Fabric softeners	Mean	mg/kg	<61	0.89	<2	<0.9	0.55	0.01	0.01	1.16	0.07
	SD	mg/kg	0	2.14	0	0	1.31	0.03	0.02	0.59	0.08
	Median	mg/kg	<5	0.13	<0.006	<0.05	0.01	<0.01	<0.04	1.03	0.04
	Number of brands		7	7	7	7	7	7	7	7	7
Laundry liquid	Mean	mg/kg	<19	2.34	0.071	0.05	0.46	0.19	0.0047	1.95	16.68
	SD	mg/kg	0	2.50	0.178	0.13	1.08	0.57	0.015	4.53	19.66
	Median	mg/kg	<5	1.40	<0.35	<0.30	0.06	<0.01	<0.030	0.06	7.73
	Number of brands		10	10	10	10	10	10	10	10	10
Laundry powder	Mean	mg/kg	5.8	27.34	0.05	0.10	0.60	0	0.56	0.20	23.03
	SD	mg/kg	5.9	64.81	0.10	0.14	0.38	0	0.52	0.50	18.59
	Median	mg/kg	8	2.00	0	0	0.57	0	0.58	0.03	0.03
	Number of brands		13	13	13	13	13	13	13	13	13

Function	Summary statistics	Units	Element								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Soaker	Mean	mg/kg	1.05	2.13	0.023	<0.14	0.13	<0.01	0.03	2.27	9.63
	SD	mg/kg	0.1	0.19	0.032	0	0.15	0	0.04	2.82	12.06
	Median	mg/kg	1.05	2.13	0.023	<0.14	0.13	<0.008	0.03	2.27	9.63
	Number of brands		2	2	2	2	2	2	2	2	2
Toilet paper	Mean	mg/kg	<23	<0.24	<7	0.002	0.77	0.05	0.053	0.37	0.01
	SD	mg/kg	0	0	0	0.006	0.54	0.085	0.097	0.16	0.001
	Median	mg/kg	<13	<0.13	<4	<0.6	0.78	<0.01	0.03	0.36	0.01
	Number of brands		8	8	8	8	8	8	8	8	8
Sunscreen	Mean	mg/kg	<7.7	1.74	<1.8	<0.3	0.04	0.029	0.023	0.42	0.13
	SD	mg/kg	0	3.18	0	0	0.04	0.077	0.049	0.419	0.337
	Median	mg/kg	<4.6	0.48	<2	<0.3	0.03	<0.02	<0.03	0.21	0.002
	Number of brands		7	6	7	7	7	7	7	7	7
Face cream	Mean	mg/kg	<7.7	0.19	<1.8	0.013	0.089	0.03	<0.13	1.63	0.13
	SD	mg/kg	0	0.383	0	0.025	0.174	0	0	1.756	0.171

Function	Summary statistics	Units	Element								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	Median	mg/kg	<4.6	0.004	<2	<0.3	0.003	<0.02	<0.06	1.40	0.06
	Number of brands		4	4	4	4	4	4	4	4	4
Hand & body lotion	Mean	mg/kg	<1.7	<0.03	<1	≤0.4	≤0.4	≤0.4	≤0.4	0.28	0.05
	SD	mg/kg	0	0	0	0	0	0	0	0.399	0.034
	Median	mg/kg	<1.5	<0.015	<0.4	<0.4	<0.4	<0.4	<0.4	0.12	0.068
	Number of brands		5	5	5	5	5	5	5	5	5
Deodorant	Mean	mg/kg	<941	67.39	0.13	<0.7	0.84	<3	0.44	0.85	0.40
	SD	mg/kg	0	66.67	0.24	0	1.32	0	0.61	1.64	0.407
	Median	mg/kg	<4.1	52.12	<0.3	<0.3	<1	<0.4	<0.6	<0.39	0.35
	Number of brands		9	9	9	9	9	9	9	9	9
Toothpaste	Mean	mg/kg	448	0.42	0.02	0.02	1	<19	0.02	0.51	10.91
	SD	mg/kg	417.7	0.556	0.04	0.05	0.39	0	0.04	0.508	15.22
	Median	mg/kg	316	0.11	<0.4	<0.4	<0.5	<0.4	<0.4	0.36	0.66
	Number of brands		9	9	9	9	9	9	9	9	9

Function	Summary statistics	Units	Element								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Mouthwash	Mean	mg/kg	60.6	0.08	0.023	<0.04	0.177	<0.7	<0.04	0.02	0.04
	SD	mg/kg	126.7	0.065	0.047	0	0.296	0	0	0.022	0.032
	Median	mg/kg	0.8	0.08	<0.1	<0.04	0.044	<0.03	<0.03	<0.01	0.04
	Number of brands		5	5	5	5	5	5	5	5	5
Shampoo	Mean	mg/kg	<21	5.86	0.63	<0.5	0.49	4.05	0.06	4.30	0.45
	SD	mg/kg	0	2.999	1.49	0	0.55	12.92	0.12	2.8 5	0.576
	Median	mg/kg	<2	5.43	<1	<0.1	0.18	0.076	<0.06	3.85	0.15
	Number of brands		11	11	11	11	11	11	11	11	11
Conditioner	Mean	mg/kg	<20	0.90	<1	0.02	0.73	0.22	0.02	0.70	0.65
	SD	mg/kg	0	0.762	0	0.03	0.66	0.20	0.03	0.54	1.11
	Median	mg/kg	<13	0.51	<1	<0.1	0.88	0.28	<0.03	0.46	0.02
	Number of brands		3	3	3	3	3	3	3	3	3
Soap bar	Mean	mg/kg	<66	89.48	0.21	<2	<2	<2	<2	0.041	0.85
	SD	mg/kg	0	69.23	0.17	0	0	0	0	0.038	0.895

Function	Summary statistics	Units	Element								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	Median	mg/kg	<15	104.01	0.28	<1.4	<1.5	<1.5	<1.1	0.041	0.58
	Number of brands		6	6	6	6	6	6	6	6	6
Hand wash	Mean	mg/kg	<3	9.35	<2	<0.3	0.88	0.71	0.004	1.84	15.05
	SD	mg/kg	0	7.45	0	0	0.50	1.01	0.009	0.88	33.53
	Median	mg/kg	<2.2	8.56	<2	<0.3	1	0.33	<0.03	1.83	0.06
	Number of brands		5	5	5	5	5	5	5	5	5
Body wash	Mean	mg/kg	<13	10.72	<2	0.3	0.31	2.99	0.005	2.37	0.01
	SD	mg/kg	0	13.85	0	0	0.59	2.12	0.01	0.75	0.02
	Median	mg/kg	<2	6.89	<2	<0.3	0.02	3.35	0	2.19	0.006
	Number of brands		4	4	4	4	4	4	4	4	4
Shaving	Mean	mg/kg	<75	7.86	<5	<1.2	<15	<15	<15	1.78	0.03
	SD	mg/kg	0	8.18	0	0	0	0	0	1.63	0.03
	Median	mg/kg	<8	4.43	<2	<0.3	<1.2	<1.2	<1.2	1.99	0.02
	Number of brands		5	5	5	5	5	5	5	5	5

Function	Summary statistics	Units	Element								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
Hair colour	Mean	mg/kg	10.1	1.52	<7	<7	0.09	<7	<7	8.04	0.37
	SD	mg/kg	10.3	1.39	0	0	0.10	0	0	3.71	0.43
	Median	mg/kg	7.95	1.33	<1.2	<1.2	0.07	<1.2	<2.2	8.79	0.15
	Number of brands		6	6	6	6	6	6	6	6	6
Liquid dishwashing detergent	Mean	mg/kg	<85	5.55	<2	<0.3	0.06	1.51	0.05	1.47	0.25
	SD	mg/kg	0	4.69	0	0	0.09	3.04	0.09	1.41	0.59
	Median	mg/kg	<22	6.14	<1	<0.3	0.01	0.025	<0.04	0.84	0.01
	Number of brands		6	6	6	6	6	6	6	6	6
Dishwasher tablet	Mean	mg/kg	13.7	7.27	0.11	0.12	0.51	0	0.12	2.20	40.78
	SD	mg/kg	15.0	15.96	0.30	0.29	0.44	0	0.16	1.44	40.05
	Median	mg/kg	10.8	1.79	<1.5	<0.3	0.46	<0.1	0.08	2.49	35.56
	Number of brands		8	8	8	8	8	8	8	8	8
Dishwasher powder	Mean	mg/kg	9.8	12.88	0.2	0.2	0.39	<1.2	0.09	1.40	27.76
	SD	mg/kg	8.1	22.53	0.4	0.4	0.41	0.0	0.11	1.58	27.50

Function	Summary statistics	Units	Element								
			F	Cl (g/kg)	Se	Sb	Cr	Co	Mo	TKN (g/kg)	TP (g/kg)
	Median	mg/kg	10.8	2.35	0.0	0.1	0.33	<0.1	0.08	0.94	28.83
	Number of brands		4	4	4	4	4	4	4	4	4

APPENDIX 2 – PRODUCT CONTRIBUTION TO ELEMENTAL LOADS FROM A SINGLE PERSON HOUSEHOLD

The elemental mass loads shown in this section were estimated from the typical product consumption for a single person household in Melbourne, as specified in section 3.2.6.

Table 27: Major antimony loads from household products

Product type	*Maximum Sb weekly load (mg/pe/week)*
Toilet paper	0.0001
Floor cleaner	0.001
Facial lotion	0.002
Conditioner	0.003
Toothpaste	0.006
Dishwashing powder	0.088
Laundry liquid	0.111
Laundry powder	0.176

Table 28: Major chloride loads from household products

Product type	*Maximum Cl weekly load (mg/pe/week)*
Cream cleanser	6
Depilatory	27
Mouthwash	45
Floor cleaner	47
Hair colouring	53
Facial lotion	54
Toothpaste	56
Multi-purpose	56
Roll-on deodorant	73
Facial Cleanser	81
Toilet cleaner	84
Conditioner	94
Dishwashing tablet	140
Aerosol deodorant	294
Shampoo	307
Shaving foam	354
Disinfectant	429
Sunscreen	571
Laundry soaker	611
Dishwashing liquid	793

Product type	Maximum Cl weekly load (mg/pe/week)
Dishwashing powder	1,678
Toilet freshener	1,396
Body wash	1,083
Fabric softener	1,290
Hand wash	1,835
Laundry liquid	1,904
Soap	15,713
In-cistern	34,162
Laundry powder	84,901

Table 29: Major cobalt loads from household products

Product type	Maximum Co weekly load (mg/pe/week)
Multi-purpose	0.001
Toilet paper	0.002
Sunscreen	0.014
Facial Cleanser	0.015
Fabric softener	0.020
Shampoo	0.037
Body wash	0.045
Conditioner	0.069
Hand wash	0.10
Laundry liquid	0.49
Dishwashing liquid	0.56
In-cistern	0.80

Table 30: Major chromium loads from household products

Product type	Maximum weekly Cr load (mg/pe/week)
Multi-purpose	0.0001
Floor cleaner	0.0008
Toilet cleaner	0.012
Disinfectant	0.001
Roll-on deodorant	0.001
Hair colouring	0.003
Aerosol deodorant	0.005
Sunscreen	0.008
Toilet paper	0.009
Shampoo	0.037

Product type	***Maximum weekly Cr load (mg/pe/week)***
Toilet cleaner	0.012
Facial Cleanser	0.045
Dishwashing liquid	0.014
Cream cleanser	0.015
Facial lotion	0.025
Body lotion	0.026
Body wash	0.045
Laundry soaker	0.062
Hand wash	0.051
Toothpaste	0.051
Conditioner	0.069
Dishwashing tablet	0.038
Mouthwash	0.167
Dishwashing powder	0.194
Toilet freshener	0.204
Laundry powder	0.288
Fabric softener	0.788
Laundry liquid	0.945
In-cistern	35.8

Table 31: Major fluoride loads from household products

Product type	***Maximum weekly F load (mg/pe/week)***
Floor cleaner	0.08
Laundry soaker	0.3
Hair colouring	0.4
Dishwashing tablet	1.5
Dishwashing powder	1.7
Laundry powder	3.5
Toilet freshener	7.9
Toothpaste	46.1
Mouthwash	68.3

Table 32: Major molybdenum loads from household products

Product type	***Maximum Mo weekly load (mg/pe/week)***
Aerosol deodorant	0.001
Hand wash	0.002
Toilet paper	0.002
Roll-on deodorant	0.002
Conditioner	0.003
Toothpaste	0.005
Body wash	0.007
Sunscreen	0.009
Shampoo	0.011
Toilet cleaner	0.060
Fabric softener	0.011
Laundry liquid	0.013
Dishwashing liquid	0.015
Laundry soaker	0.016
Dishwashing tablet	0.017
Dishwashing powder	0.017
Toilet freshener	0.206
In-cistern	0.206
Laundry powder	0.323

Table 33: Major selenium loads from household products

Product type	***Maximum Se weekly load (mg/pe/week)***
Multi-purpose	0.0001
Aerosol deodorant	0.0009
Laundry soaker	0.0124
Cream cleanser	0.0003
Floor cleaner	0.0002
Toothpaste	0.0037
Mouthwash	0.0256
Soap	0.0328
Laundry powder	0.0887
Shampoo	0.122 (anti-dandruff)
Laundry liquid	0.1539

Table 34: Major total Kjeldahl nitrogen loads from household products

Product type	*Maximum TKN weekly load (mg/pe/week)*
Aerosol deodorant	0.1
Cream cleanser	0.8
Toilet paper	5.1
Roll-on deodorant	5.3
Disinfectant	6.9
Soap	8.3
Mouthwash	11.1
Hair colouring	15.3
Floor cleaner	29.5
Multi-purpose	31.2
Facial Cleanser	38.6
Toilet cleaner	45.5
Toothpaste	66.9
Body lotion	68.6
Sunscreen	70.4
Conditioner	70.6
Shaving foam	88
Depilatory	115
Body wash	127
Facial lotion	131
Dishwashing powder	133
Dishwashing tablet	136
Shampoo	216
Dishwashing liquid	212
Hand wash	264
Laundry powder	438
Fabric softener	529
Toilet freshener	633
Laundry soaker	1,150
Laundry liquid	3,933
In-cistern	4,033

Table 35: Major phosphorus loads from household products

Product type	***Maximum TP weekly load (mg/pe/week)***
Depilatory & Facial Cleanser	0
Shaving foam	0.1
Toilet paper	0.3
Toilet cleaner	0.5
Multi-purpose	0.8
Cream cleanser	1
Deodorant	1.3-1.5
Body wash	1.5
Facial lotion	13
Disinfectant	13.2
Hair colouring	15.3
Mouthwash	18.3
Fabric softener	42.5
Shampoo	45.8
In-cistern	46.3
Toilet freshener	59.9
Sunscreen	62.6
Conditioner	102
Dishwashing liquid	107
Floor cleaner	111
Soap	212
Toothpaste	1,647
Dishwashing tablet	3,515
Laundry soaker	4,903
Dishwashing powder	5,763
Hand wash	6,302
Laundry liquid	12,485
Laundry powder	13,072

APPENDIX 3 – COMPARISON OF HOUSEHOLD LOAD SCENARIOS

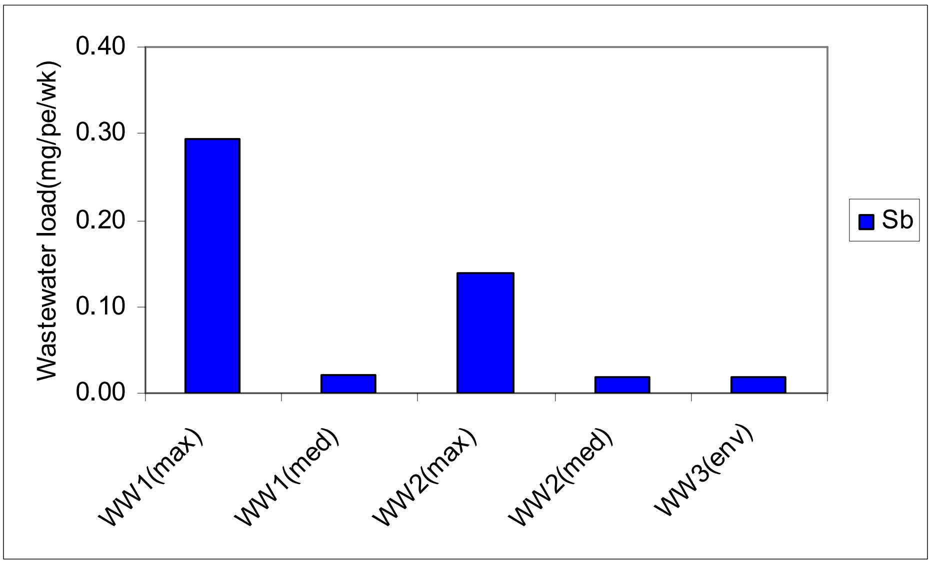

Figure 24: Antimony loads generated by household product use in a 1 person household.

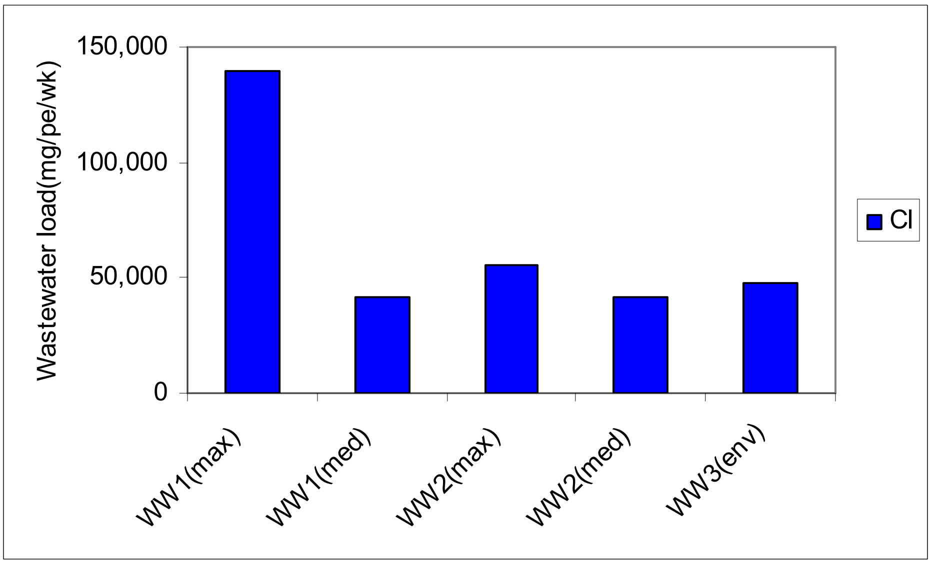

Figure 25: Chloride loads generated by household product use in a 1 person household.

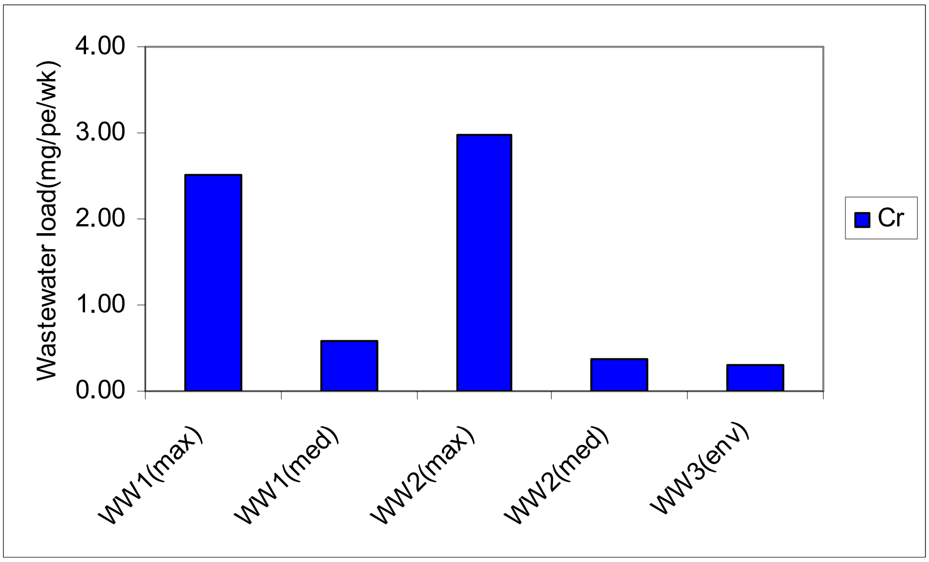

Figure 26: Chromium loads generated by household product use in a 1person household.

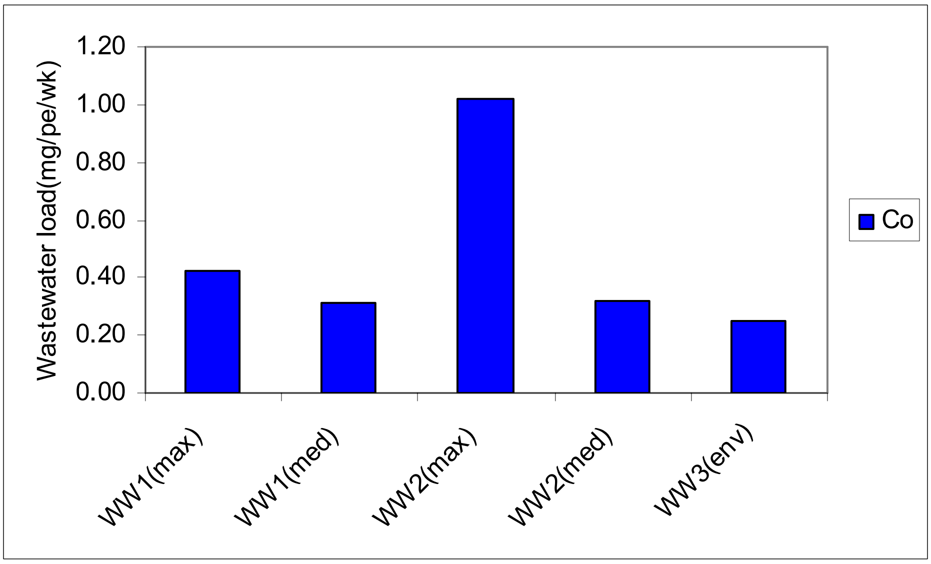

Figure 27: Cobalt loads generated by household product use in a 1 person household.

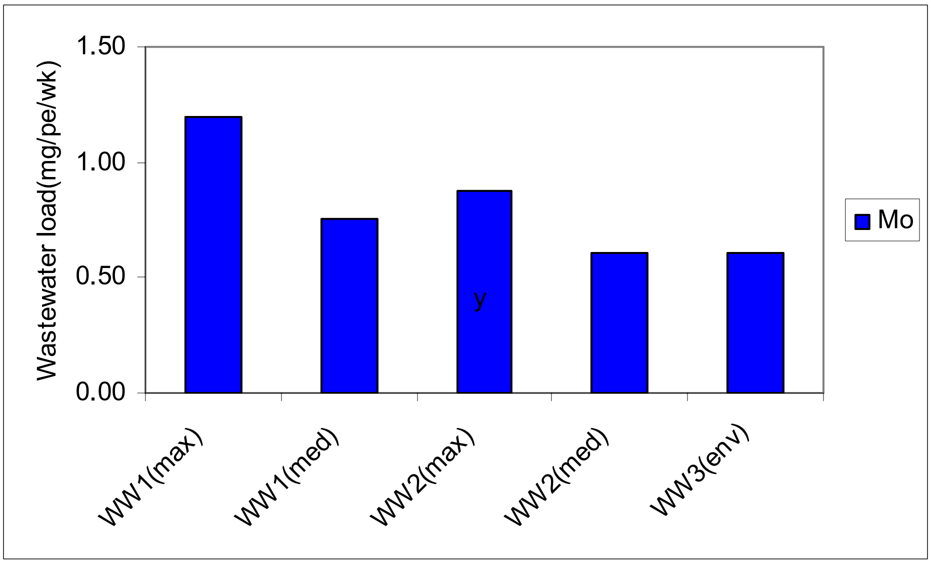

Figure 28: Molybdenum loads generated by household product use in a 1 person household.

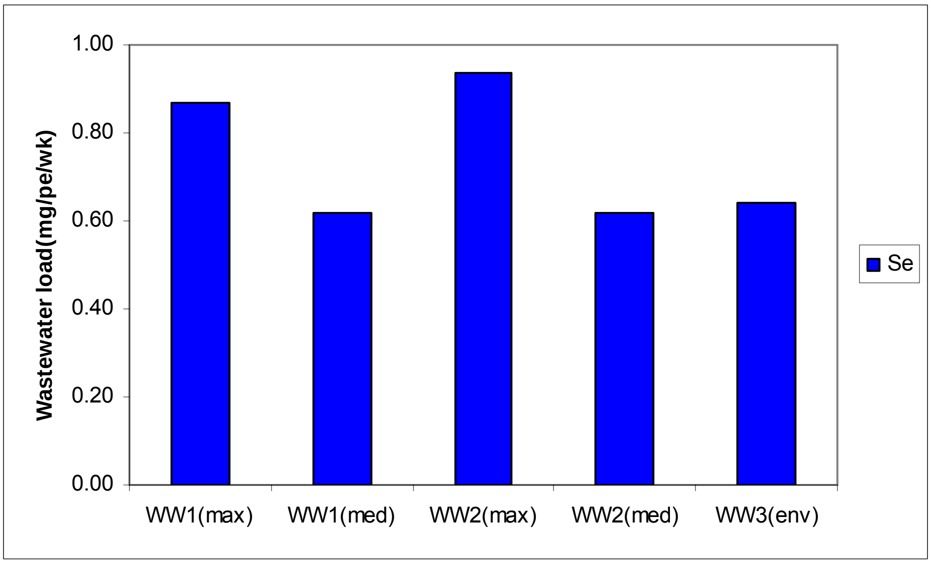

Figure 29: Selenium loads generated by household product use in a 1 person household.

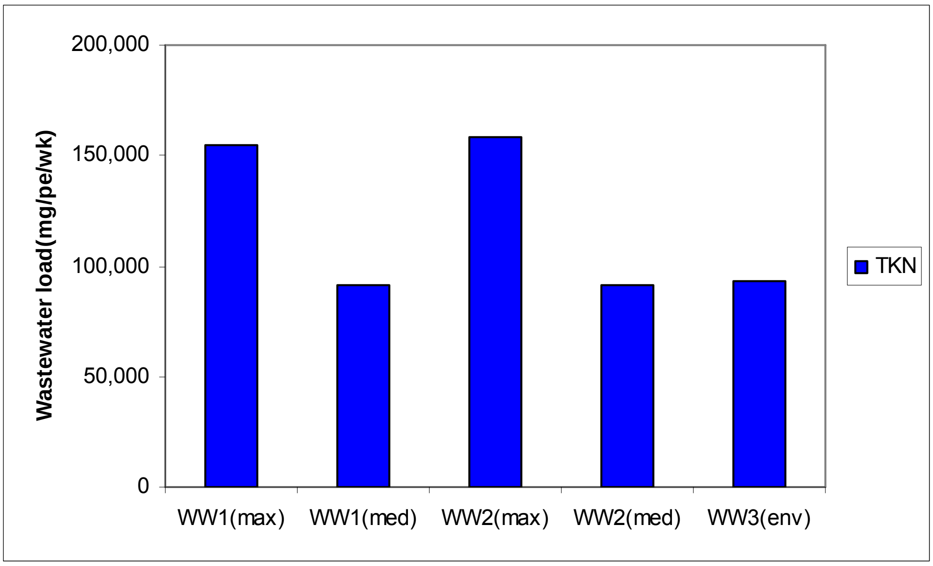

Figure 30: Total Kjeldahl nitrogen loads generated by household product use in 1 person household.

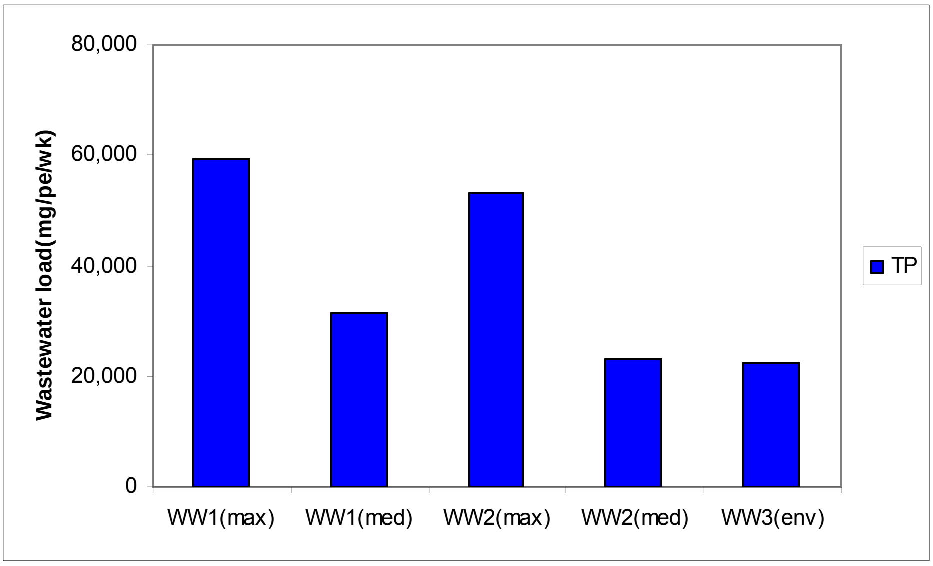

Figure 31: Total phosphorus loads generated by household product use in a 1 person household.

Contact Us

Phone: 1300 363 400
+61 3 9545 2176

Email: enquiries@csiro.au

Web: www.csiro.au