

HUMAN CONTACT WITH RECREATIONAL OR DRINKING WATER – WHAT DO WE KNOW?

P. Cressey and B. Horn

Risk and Response Group, ESR, Christchurch, New Zealand

ABSTRACT

In order to assess human health risks associated with chemical or microbiological hazards in recreational or drinking water, we need to have information on the frequency and magnitude of human contact with these water types, as well as information on the water types themselves. Human physiological and behavioural aspects that help to define exposure to hazards are referred to as exposure factors. While understanding exposures is essential when assessing risks, it must be remembered that managing risks needs to protect the whole population not just the 'average' consumer.

This paper reports on selected water-related exposure factors for New Zealanders, derived through a Ministry of Health-funded project to develop exposure factors for assessing the risk from hazardous substances and products. In particular, information will be provided on how much drinking-water New Zealanders ingest and what specific beverage classes contribute most to drinking-water ingestion, based on detailed dietary recall information from national nutrition surveys. In the home, residual microbiological risks may be influenced by thermal treatment of water (boiling) and the changing patterns of hot and cold water ingestion with age will be discussed. While children predominantly ingest non-thermally treated water, about 50% of water ingested by adults has been boiled.

Information will also be presented on recreational water activities New Zealanders engage in and the estimated amounts of water ingested through some of these activities. These activities include primary contact recreation activities (swimming, surfing) and secondary contact activities (boating, fishing).

KEYWORDS

Exposure factors, drinking-water, recreational water contact.

1 INTRODUCTION

Risk assessment may be used to assess the potential impact of chemical or microbiological hazards in recreational or drinking water on human health. Risk assessment is viewed as a four-step process, including hazard identification, dose-response characterisation, exposure assessment, including consideration of vulnerable population groups, and risk characterisation. Exposure assessment is a key component of risk assessment and is often the only situation-specific component of the risk assessment. Exposure assessment includes factors that characterise the rate of contact with a particular matrix and the concentration or loading of a substance of interest in that matrix. Human physiological and behavioural aspects that help to define contact rates are referred to as exposure factors.

The current paper presents a synthesis of some available New Zealand and other information for selected water-related exposure factors. This should not be viewed as implying any need for changes in current risk management policies and practices. Risk management requires measures to protect the whole population, including vulnerable populations, not just the 'average' consumer.

For assessment of risks associated with substances in drinking-water or recreational water it is desirable to have a consistent set of exposure factors, so that risk assessment for different substances are as comparable as possible. This has resulted in the development of ‘exposure factor handbooks’, most notably those developed by the United States Environmental Protection Agency (USEPA, 2011), but also handbooks developed for Australia (EnHealth, 2012) and Europe (ECETOC, 2001).

Exposure factors would ideally be related specifically to the population for which risk is being assessed, but in many cases such information is not available and it is necessary to apply the best available information. This paper summarises water-specific exposure factors developed or adopted by ESR for use in risk assessments carried out for the Ministry of Health. It is intended that this paper will provide insights into some water-associated behaviours of New Zealanders and provide associated exposure factor information.

2 DRINKING-WATER INGESTION

Drinking-water ingestion is a key pathway of exposure to environmental chemicals and microbiological agents. Contamination of water may occur at the water supply source (groundwater, surface water or rainwater); during treatment (such as, disinfection by-products formed during chlorination); or post-treatment (such as leaching of lead or other materials from plumbing systems). People may be exposed to contaminants in drinking-water when consuming water directly as a beverage or indirectly from foods and beverages made with water. While a further small quantity of drinking-water may be ingested in the form of aerosols during activities such as showering, this has not been included in the current analysis. While ingestion of aerosols may be important in consideration of some specific hazards, such as legionellosis, for most hazards drinking-water ingestion will be the major and most important exposure route for water-borne hazards. While water treatment will generally result in safe drinking water, microbiological risks may occasionally arise, particularly in situations in which source water of questionable quality is untreated. For such situations, microbiological risks will vary depending on whether water has been thermally treated (boiled), as in consumption of hot beverages. In these situations, interest is mainly on the proportion of water ingested without thermal treatment (cold water).

No systematic collection of water ingestion data for New Zealanders has been made. However, the periodic national nutrition surveys include a 24-hour dietary recall (24HDR) component (Russell et al., 1999, MoH, 2003, University of Otago and Ministry of Health, 2011). The 24HDR includes a complete listing of all food and beverages consumed within the previous 24-hour period, including estimates of the amount of each food consumed. Data were examined from the most recent children’s (5–14 years) survey (MoH, 2003) and adult (15+ years) surveys (University of Otago and Ministry of Health, 2011). Water ingestion was taken to be the sum of:

- Water, ingested as a beverage, but not including bottled water
- Tea, brewed
- Coffee, instant or brewed
- Chocolate, malted or other drinks prepared by addition of water
- Fruit juices or drinks prepared from concentrate, cordial or powder by addition of water
- Ice

The 24HDR records identify added water as a separate item for many of these beverages. However, where this information is not provided, the assumptions used by Hopkins and Ellis (1980) were adopted. Specifically, milk added to hot beverages was assumed to account for 20% of the volume of the drink, while fruit juices or drinks prepared from concentrate or cordial were assumed to be 75% water. Where records identified that beverages were made up exclusively with milk, these records were excluded from the analysis of drinking-water ingestion.

Estimates of drinking-water ingestion by New Zealanders are summarised in Table 1.

Table 1. Tap water ingestion by New Zealanders^a

Age Group ^b	Mean ^c		95 th Percentile	
	mL/day ^d	mL/kg/day ^d	mL/day ^d	mL/kg/day ^d
5 to <6 years	411	19.3	1081	45.9
6 to <11 years	468	15.4	1072	36.1
11 to <15 years	530	10.2	1336	26.5
All children	487	13.7	1200	35.4
15 to <18 years	1078	16.1	2724	39.1
18 to <21 years	1028	14.8	2737	39.9
≥21 years	1478	19.4	3204	40.7
>65 years	1304	18.0	2494	35.1
All adults	1434	19.0	3090	40.3

^a Tap water was taken to be the sum of non-bottled water drunk as a beverage, ice and the water component of beverages prepared by addition of water (tea, coffee, other chocolate or malt-based drinks, drinks prepared from cordial, concentrate or powder)

^b Age groupings are designated to align as closely as possible with the age grouping used by USEPA, within the constraints of the data set

^c Means are weighted using survey weights

^d Original results were in grams, but have been converted to millilitres by assuming the density of water is exactly 1 g/mL

The data in Table 1 suggest a substantial discontinuity between children and adults with respect to water ingestion. Investigation of the data suggests that this is due to differences in tap water ingestion, rather than the emergence of tea drinking in older age groups or replacement of tap water with bottled water. Bottled water consumption is not common in New Zealand, with only 3% of adults and 1.5% of children reporting consumption in the nutrition survey cohorts (unpublished data). Whether this is a true difference, due to the difference in timeframes for the two surveys or an artefact of the survey methodologies is unclear.

It should further be noted that, as these results are only based on a single day of dietary recall the 95th percentiles are likely to be higher than the habitual, long-term 95th percentile level of ingestion.

In comparison, the study of Watson and MacDonald (2014) recorded information on tap water consumption for a cohort ($n = 369$) of pregnant women (median age 32 years). The median consumption of tap water was in the range 750-1000 g/day. For women aged 20-40 years in the national nutrition survey the median ingestion of tap water was 1000 g/day.

Estimated volumes of tap water ingestion for New Zealand are intermediate between estimates for Australians (higher) and estimates from the USA (lower).

2.1 COLD DRINKING-WATER INGESTION

For exposure assessment of chemicals in drinking-water the treatment of the water in the home is generally not considered. However, for microbiological assessments, particularly in situations in which source water of questionable quality is untreated, water that has been thermally treated (eg. boiled) will carry a much lower microbiological risk than cold water. Data from the nutrition surveys were reanalysed to only include servings of water likely to have been consumed cold and excluding water consumed as a component of hot beverages (tea, coffee, etc.). That is, water ingested as a beverage, water used to reconstitute powdered or concentrated fruit-type drinks and water used to make ice. Table 2 presents the results of this analysis. Total tap water consumption figures from Table 1 are also reproduced here for comparison.

Table 2. Total and cold tap water ingestion by New Zealanders

Age Group ^a	Tap water consumption, mean ^b (95 th percentile)			
	Total		Cold	
	mL/day ^c	mL/kg/day ^c	mL/day ^c	mL/kg/day ^c
5 to <6 years	411 (1081)	19.3 (45.9)	367 (1000)	17.1 (40.0)
6 to <11 years	468 (1072)	15.4 (36.1)	419 (1000)	13.8 (33.0)
11 to <15 years	530 (1336)	10.2 (26.5)	448 (1250)	8.6 (23.5)
All children	487 (1200)	13.7 (35.4)	425 (1050)	12.1 (31.9)
15 to <18 years	1078 (2724)	16.1 (39.1)	951 (2500)	14.1 (36.7)
18 to <21 years	1028 (2737)	14.8 (39.9)	834 (2410)	12.0 (36.6)
≥21 years	1478 (3204)	19.4 (40.7)	749 (2250)	9.6 (28.4)
>65 years	1304 (2494)	18.0 (35.1)	456 (1500)	6.2 (21.8)
All adults	1434 (3090)	19.0 (40.3)	765 (2265)	10.0 (30.3)

^a Age groupings are designated to align as closely as possible with the age grouping used by USEPA, within the constraints of the data set

^b Means are weighted using survey weights

^c Original results were in grams, but have been converted to millilitres by assuming the density of water is exactly 1 g/mL

While approximately 90% of water consumed by young children is consumed cold, for adults this percentage falls to 51%, as hot drinks are more frequently consumed. The proportion of water consumed cold is even lower for older New Zealanders (>65 years), with only 35% of water consumed cold. These proportions are comparable to those for the Australian population, with 51% of ‘total water’ consumed by adult Australians being cold, while 37% of water consumed by older Australians was consumed cold (EnHealth, 2012).

3 RECREATIONAL WATER CONTACT

Participation in recreational water activities is a potential route of exposure for adults or children to substances that may be present in the water or in the sand, mud or silt under or surrounding the body of water.

Recreational water contact in New Zealand is classified into two levels of exposure:

Primary contact is when users are in direct contact with water, and can fully immerse their body and swallow water. This includes activities such as surfing, water skiing, diving, swimming, or white water sports.¹ Potential exposure mechanisms for primary contact activities include swallowing water, aerosol inhalation or dermal contact to all the body surface.

Secondary contact recreation is where there is direct contact with water, but swallowing water is unlikely. It includes activities such as wading, boating and fishing. Potential exposure mechanisms for secondary contact include; aerosol inhalation, the transfer of water onto the hands which may then be transferred to the mouth and dermal contact of water with a proportion of the body surface.

Recreational water activities are common in New Zealand where most of the population is in easy travelling distance of swimming pools, fresh or marine water sites. The top activities identified in the Active New Zealand Survey Series (Sport New Zealand, 2015, Sport New Zealand, 2012) are given in **Error! Reference source not found.3**.

¹ <http://mfe.govt.nz/more/environmental-reporting/fresh-water/suitability-swimming-indicator/suitability-swimming>

Table 3. New Zealanders participation in water-based activities

Activity	Percentage of survey participants who participated in an activity in the last year		
	Adults 16+ (2013/14)	Youth 5-18 year old (2011)	
		Boys	Girls
Swimming	30.2	79.8	84.7
Fishing	19.5	48.8	33.9
Canoe/Kayaking	8.1	40.6	38.6
Surfing	4.3 ^a	17.8	14.0
Body boarding		26.7	24.6
Scuba diving	3.4	<1.0	<1.0
Aquarobics	2.8	None	<1.0
Water skiing	2.4	<1.0	<1.0
Sailing/Yachting	2.1	11.6	8.7
Rowing	<1.0	14.3	12.4
Water Polo	<1.0	11.4	11.2

Source: (Sport New Zealand, 2015, Sport New Zealand, 2012)

^a The youth survey identified surfing and body boarding as separate activities, while the adult survey classified them as a single activity.

Swimming is the predominant water-contact activity for both children and adults in New Zealand.

3.1 FREQUENCY OF RECREATIONAL WATER CONTACT

The frequency of exposure events can be used to determine average or typical exposure, for chronic (chemical) hazards or the total number of acute exposure events, which is of interest in microbiological risk assessment.

3.1.1 ACTIVE NEW ZEALAND DATA

A total of 6000 adults aged 16 years and over took part in the 2013/14 survey on their participation in sport and active recreational activities (Sport New Zealand, 2015) and 4443 took part in a survey in 2006/7.

These surveys collected data on which months of the year people participated in each activity, frequency of participation and location setting of the activity.

From the 2006/7 survey, in any one month 16.4% (95% CI 14.7–19.0) of New Zealand adults participated in swimming and 7.5% (95% CI 6.2–8.7) participated in fishing at least once. These estimates used data weighted by age. Among adults, 36.8% of swimming events were in surface waters (eg, rivers, sea), with the remainder being at sports facilities or at home.

A similar survey for children was conducted in Term 3 of 2011, which surveyed 17,000 children aged five to 18 years from 500 schools across New Zealand (Sport New Zealand, 2012). The frequency question used three groupings: never, a few times or regularly (defined as at least once a week), to define how often people participated in the given activity in the year of the study. The percentage of children in each of these frequency groups for a range of water activities is given in Table 4.

Table 4. Frequency of recreational water contact by New Zealand children

	Body boarding	Canoeing/ kayaking	Fishing	Flippa ball, water polo	Rowing	Sailing	Surfing	Swimming
Girls (mostly 5-6 year olds)								
Not done this year (%)	78.2	NT	68.5	97.5	NT	97.1	NT	4.7
Few times this year (%)	20.7	NT	29.7	2.2	NT	2.6	NT	49.2
One or more times a week (%)	1.1	NT	1.8	0.3	NT	0.3	NT	46.0
Boys (mostly 5-6 year olds)								
Not done this year (%)	76.1	NT	52.5	94.2	NT	94.7	NT	5.4
Few times this year (%)	23.2	NT	44.8	5.1	NT	5.3	NT	46.4
One or more times a week (%)	0.7	NT	2.7	0.7	NT	0.0	NT	48.2
Girls (mostly 7-10 year olds)								
Not done this year (%)	72.6	NT	56.9	78.3	NT	84.3	NT	8.2
Few times this year (%)	23.2	NT	37.3	17.3	NT	14.1	NT	47.0
One or more times a week (%)	4.2	NT	5.8	4.4	NT	1.6	NT	44.8
Boys (mostly 7-10 year olds)								
Not done this year (%)	67.5	NT	42.7	79.1	NT	82.4	NT	11.4
Few times this year (%)	27.6	NT	43.4	16.0	NT	14.7	NT	54.2
One or more times a week (%)	4.8	NT	13.9	4.9	NT	2.9	NT	34.5
Girls (mostly 11-14 year olds)								
Not done this year (%)	71.1	56.0	60.7	86.4	86.8	91.9	85.3	12.4
Few times this year (%)	27.4	42.0	37.2	10.3	11.7	7.5	12.7	62.8
One or more times a week (%)	1.5	2.1	2.1	3.3	1.5	0.7	2.1	24.8
Boys (mostly 11-14 year olds)								
Not done this year (%)	64.6	50.1	41.6	85.1	82.6	84.1	79.5	14.8
Few times this year (%)	32.9	47.4	50.3	11.5	15.8	13.5	17.2	63.4
One or more times a week (%)	2.5	2.5	8.0	3.4	1.6	2.4	3.3	21.8

Source: Sport New Zealand (2012)

NT: Not given in overview document.

3.1.2 YEAR 11 RECREATIONAL WATER ACTIVITIES

A survey of Year 11 students (aged 15–18 year old) was conducted in 41 schools across New Zealand during June and July 2003. The purpose of the survey was to assess the nature and extent of their participation in recreational water activities and their associated water safety knowledge and behaviour (Moran, 2008, Moran, 2009).

A total of 2202 students took part in the survey. The percentage of students participating in swimming activities at different frequencies per year at different locations is given in **Error! Reference source not found.**⁵, along with the frequency of students participating in non-swimming water activities.

The information in Table 5 confirms that children are most likely to swim in public pools, followed by swimming at patrolled surf beaches and un-patrolled beaches. Those with access to a home pool will tend to be frequent swimmers. Swimming in rivers and creeks is the least likely of the surveyed locations. Paddling and surfing are the most common non-swimming water recreation activities, with surfing having a higher proportion of frequent participants.

Table 5. Location and frequency of New Zealand Year 11 swimming activities in the previous year

Percentage of students for each location/activity	Never	Not often (1-9 times)	Quite often (10-19 times)	Very often (20+ times)
Swimming				
Home, private pool	47.9	26.6	10.6	14.9
Public pool	11.4	44.5	22.7	21.5
Patrolled surf beach	23.8	40.8	20.1	15.3
Un-patrolled surf beach	32.2	38.9	15.5	13.4
Flat-water beach	35.5	42.1	12.8	9.6
Lake, pond	36.3	40.3	13.9	9.5
River, creek	52.9	32.0	8.4	6.8
Non-swimming activities				
Paddling	33.5	39.1	17.7	9.7
Surfing	34.7	30.9	18.0	16.4
Small craft boating	40.6	37.9	11.4	10.1
Boat based fishing	43.4	30.0	15.7	10.9
Land based fishing	46.0	33.0	13.9	7.1
Underwater act	54.5	28.3	10.9	6.2
Large boat/yachting	53.4	29.6	8.4	8.6
River activities such as tubing and rafting	65.1	26.2	5.9	2.7
Other water sports such as water skiing	65.4	18.5	8.1	8.0
Netting/shell fishing	75.6	16.7	5.0	2.6

3.1.3 FRESHWATER FISHING LICENCES

While no specific data were found for fishing frequency in New Zealand. In the 2013/2014 fishing season, 78,440 (whole season equivalent) fresh water fishing licences were purchased.² Given that 19.5% of New Zealand adults surveyed (Table 3) reported fishing in the last year, this suggests that the majority of recreational fishing in New Zealand occurs in the ocean.

3.2 WATER INGESTION DURING RECREATIONAL WATER ACTIVITIES

Given the frequency of swimming in New Zealand and the fact that this is a primary water contact activity, it is important to have an understanding of the amount of water likely to be ingested during swimming. No New Zealand-specific information is available and there is a need to rely on the best available international data.

² http://www.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Fresh%20water/recreation-freshwater-environment.aspx Accessed 28 January 2016.

Studies aiming to define the amount of water swallowed during recreational water activities have used two approaches; self-reported survey estimates and the use of swimming pool chemicals detected in the urine of swimmers.

Cyanuric acid is sometimes used in outdoor pools to stabilise chlorine, which otherwise degrades due to exposure to UV radiation. Cyanuric acid passes through the body unchanged and is excreted in the urine. Collection and testing of urine samples post-swimming, combined with knowledge of the concentration of cyanuric acid in the swimming pool, allows the volume of water swallowed to be estimated.

Table 6 summarises information on water ingested during swimming. It should be noted that further details of the study of Evans et al. (2006) were kindly provided by the principal study investigator (Alfred Dufour, USEPA, personal communication).

Table 6: Estimated volume of water (mL) swallowed during swimming activities

Age-gender group	Estimated volume of water swallowed during swimming activities, mean (mL) (95% CI)		
	Swimming Pool	Fresh water	Seawater
Dutch swimming survey (Schets et al., 2011)^a			
Child (<15 years)	51 (0.62–200)	37 (0.14–170)	31 (0.08–140)
Female (≥ 15 years)	23 (0.03–110)	18 (0.02–86)	18 (0.02–90)
Male (≥ 15 years)	34 (0.02–170)	27 (0.02–140)	27 (0.02–140)
USEPA – Open air swimming pools (Evans et al., 2006)^b			
6-<16 years, all	47 (P95 141)		
16+ years, all	24 (P95 84)		
16+ years, males	30 (P95 115)		
16+ years, females	19 (P95 57)		
Arizona open air swimming (Suppes et al., 2014)^b			
All Swimmers	13.7 (range 0.0–105.5)		
Children (<18 years)	25.7 (range 0.9–105.5)		
Adults (18+ years)	3.5 (range 0.0–50.9)		
Lap Swimmers ^a	1.6 (range 0.0–9.2)		
Leisure Swimmers ^b	17.8 (range 0.0–105.5)		

95% CI: 95th percentile confidence interval P95: 95th percentile

^a Water ingestion estimated by self-reported volumes

^b Water ingestion estimated from cyanuric acid in urine samples

While there is generally reasonable agreement between the Dutch and USEPA studies summarised in Table 6, the Arizona open-air swimming study reported substantially lower quantities of water ingestion. However, the Arizona study was relatively small (35 subjects). An Australian exposure factors handbook proposed mean water ingestion figures for swimmers of 50 mL/hour (children) and 25 mL/hour (adults), based on the studies of Schets et al. (2011) and Evans et al. (2006).

4 CONCLUSIONS

New Zealand-specific information on drinking-water ingestion is available from the 24HDR component of the national nutrition surveys. While summary statistics of these data are within the range of other international estimates, there appears to be a major discontinuity between estimates from children's and adult nutrition surveys. The proportion of water that is ingested cold decreases with age. For children, the majority of water is ingested cold, while for older adults only about one-third of water is ingested in a cold state.

Swimming is the main contact water recreational activity for adult and younger New Zealanders. The main locations for swimming are public swimming pools and beaches. While no New Zealand specific information is available for water ingestion during swimming, international studies are available. The larger of these studies, from two different countries, show sufficient similarity in results to suggest that these estimates are adequate surrogates for use in the New Zealand context.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Ministry of Health for funding the work described in this paper and a wider body of work on exposure factors. Particular thanks go to Natalia Foronda and Sally Gilbert of the Ministry of Health and Jeff Fowles of Tox-Logic for their critical input.

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