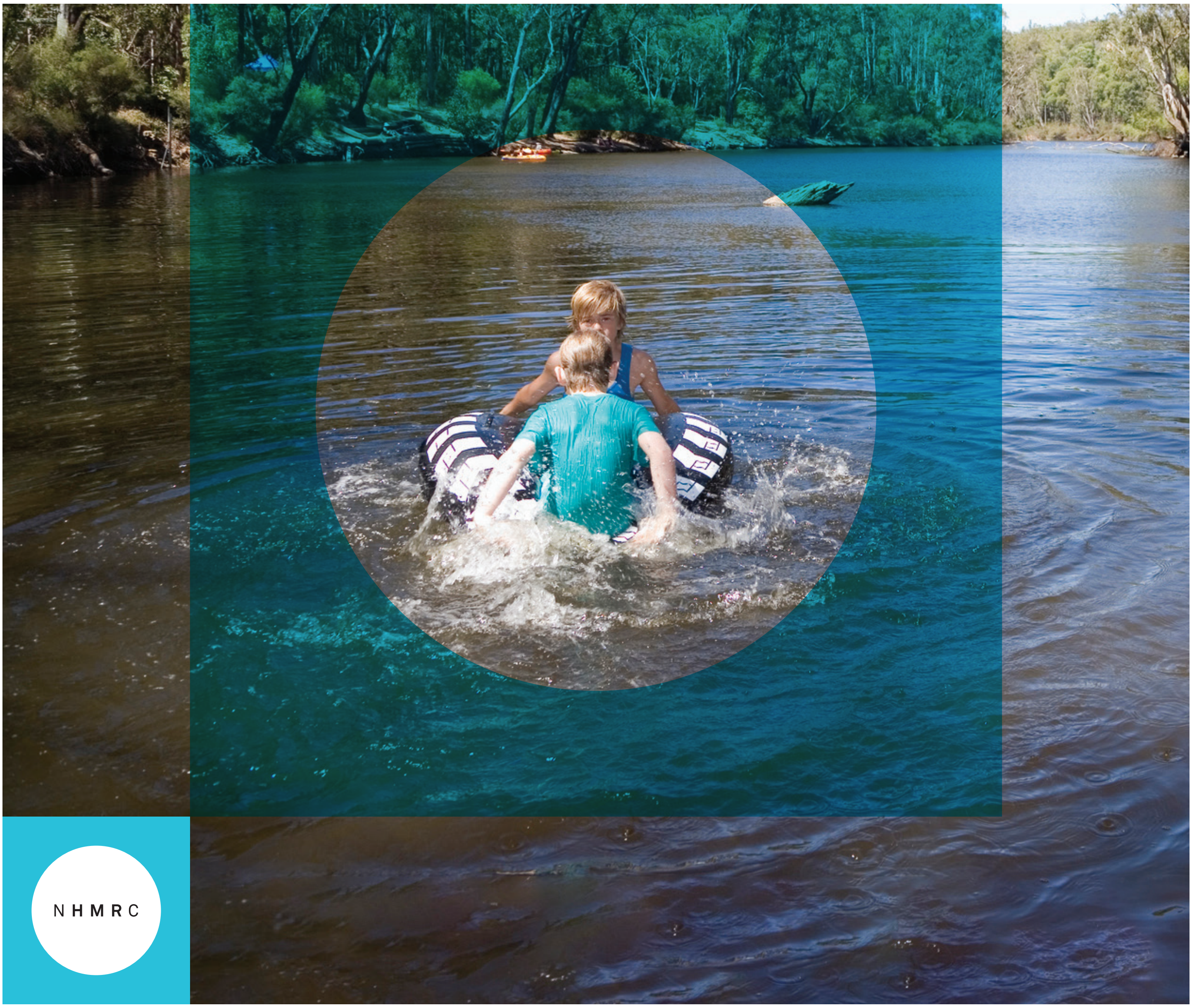
Australian Government
National Health and Medical Research Council

BUILDING A HEALTHY AUSTRALIA

Guidance on Per and Polyfluoroalkyl substances (PFAS) in Recreational Water



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Guideline

Based on health considerations, the summed concentration of perfluorooctane sulfonate (PFOS, CASRN 1763-23-1) and perfluorohexane sulfonate (PFHxS, CASRN 355-46-4) in recreational water resources should not exceed 2 µg/L.

Based on health considerations, the concentration of perfluorooctanoic acid (PFOA, CASRN 335-67-1) in recreational water resources should not exceed 10 µg/L.

The frequency of outdoor recreational activities can vary between regions, and adjusting the frequency of these events can be used to produce location-specific guideline values in consultation with the relevant health regulator.

General discussion

Per- and poly-fluoroalkyl substances (PFAS) are manufactured chemicals, not found naturally in the environment. The PFAS group includes perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS). PFAS are persistent in the environment and have demonstrated potential for bioaccumulation and biomagnification in humans.

Sources of contamination for PFAS

PFAS have been used in a wide range of consumer products, including surface treatments such as non-stick cookware, solution treatment for carpet and treatment of apparel for stain resistance and water repellence. They have also been widely incorporated in aqueous film forming foam used to extinguish fires, and PFAS have been found to have contaminated sites where there has been historic use of PFAS-containing firefighting foams. Over time, these chemicals have been transported through subsurface environments to contaminate surface and ground water, and have migrated into adjoining land areas.

Level detected in Australian water

While some water near contaminated sites has been monitored for PFAS, this has not been done routinely for Australian recreational water.

Whilst published data on recreational water samples are scarce, a few studies have published data for river and estuarine systems. For example, Gallen et al. (2014) collected water samples along the Brisbane River to provide an estimate of the release of PFAS from flooded urban areas. PFOA mean concentration was 0.0001- 0.006 µg/L and PFOS mean concentration was 0.0002 - 0.02 µg/L.

These were the most frequently detected and abundant PFAS. A study of PFAS (Thompson et al., 2011) in environmental samples taken from Homebush Bay in the upper reaches of Sydney Harbour and Parramatta River Estuary, both urban/industrial areas, detected concentrations of PFOA 0.004-0.006 µg/L and PFOS 0.007-0.2 µg/L respectively.

Route of exposure for PFAS

Exposure is a key factor in determining the risk of toxic effects from chemicals on humans in recreational waters and this varies with different recreational activities. The frequency, extent and likelihood of exposure are crucial aspects of assessing risks to human health from a contaminant. Important exposure routes relevant to recreational water use are outlined in Table 1.

Humans can also be exposed to PFAS present in food, consumer products, dust and drinking water (Health Canada, 2016a; Health Canada, 2016b). The major exposure sources of perfluorinated compounds are expected to be food and consumer products (Tittlemier et al., 2007). However the proportion of exposure from drinking water can increase in individuals living in areas with contaminated drinking water (Health Canada, 2016a; Health Canada, 2016b).

Exposure to PFOS and PFOA from both inhalation and dermal routes during showering and bathing has previously been assessed as negligible (Health Canada, 2016a; Health Canada, 2016b). This is due to their high molecular weight and low volatility (Krishnan and Carrier, 2008). Moreover, dermal permeability (skin absorption) figures estimated in *in vitro* studies predict that, under typical conditions, skin is resistant to PFOS and PFOA transport (Fasano et al., 2005; Franko et al., 2012).

Table 1 Routes of exposure to PFAS in recreational water

Potential Route of exposure	Comments	Expected significance for PFAS
Ingestion	Ingestion is likely during immersion or partial immersion activities. Very young children are likely to ingest proportionally greater amounts of water than adults when bathing, swimming or playing in the water. However, data on the quantities of water ingested during recreational water activities are difficult to obtain.	Exposure to PFAS via ingestion routes during bathing, swimming or playing in water is expected to occur.
Direct surface contact (dermal)	The most frequent routes are absorption through skin, eyes and mucous membranes. Wetsuits, when used for long periods in the water, trap water against the skin and create a microenvironment that enhances absorption of some chemicals through the skin.	Exposure to PFAS via dermal routes during recreational water use, e.g. swimming is considered to be negligible.
Inhalation	Inhalation of volatile chemicals may occur. Inhalation of non-volatile chemicals may be important in circumstances where there is a significant amount of spray, such as in water skiing.	Exposure to PFAS via inhalation routes during water activities is considered to be negligible.

Table adapted by the Water Quality Advisory Committee (2018) from NHMRC *Guidelines for Managing Risk in Recreational Water* (2008) and Health Canada (2016) publications.

Health considerations for PFAS

Food Standards Australia New Zealand (FSANZ) conducted a review of the available literature for the purposes of determining Australian Tolerable Daily Intakes (TDIs) for PFOS, PFOA and PFHxS.

The following summarises FSANZ's findings:

- It is not possible to identify any causal associations between PFOS, PFOA and PFHxS and human health effects from epidemiological studies due to limitations in study design and inconsistency in study results (FSANZ, 2017).
- While there is evidence of associations with increased serum cholesterol and decreased body weights at birth, it is not possible to determine whether PFOS or PFOA cause the changes, or whether other factors are involved. As these are observational studies, FSANZ considers that the meaning and clinical significance of the associations for PFOS and PFOA for decreased birth weight and increased cholesterol in humans are uncertain and should be interpreted with caution (FSANZ, 2017).

- There are studies showing both negative and positive associations between increasing PFOS and PFOA concentrations and compromised antibody production in humans. However, to date there is no convincing evidence for increased incidence of infective disease associated with PFOS or PFOA effects on human immune function (FSANZ, 2017).
- Epidemiological studies have not provided convincing evidence of a correlation between PFOS and PFHxS and any cancer type in human beings. Although associations between PFOA and some human cancers have been suggested from some epidemiological studies, results have often been contradictory, and a causal relationship cannot be established with reasonable confidence (FSANZ, 2017).
- The International Agency for Research on Cancer Monograph (IARC) found there is limited evidence of carcinogenicity in humans for PFOA and classified it as possibly carcinogenic to humans (*Group 2B*) (IARC, 2017).

FSANZ concluded that available human epidemiology data are not suitable to support the derivation of TDI for PFOS or PFOA, which is consistent with the findings of other regulatory agencies. Therefore, FSANZ has recommended TDIs based on extensive toxicological databases in laboratory animals (FSANZ, 2017).

General Guidance on Conducting a Quantitative Risk Assessment

If it is suspected that contamination has occurred and there is significant exposure of recreational water users, chemical analysis will be required to support a quantitative risk assessment. Care should be taken in designing the sampling program to account for spatial and temporal concentration variations.

2008 methodology

Guidance on conducting a quantitative risk assessment in *Chapter 9: Chemical Hazards* of the *Guidelines for Managing Risk in Recreational Water* suggests considering the expected exposure in terms of dose and frequency and points to the *Australian Drinking Water Guidelines* (ADWG) as a reference for exposure through ingestion. The calculation is based on the suggestion from Mance et al. (1984) that recreational water makes a minor contribution to intake, equivalent to 10% of drinking water consumption. Given most authorities (including the World Health Organization) assume consumption of 2 L of drinking water per day, ingestion of 0.2 L per day from recreational contact with water is assumed (WHO, 2003). This value assumes a daily lifetime exposure and hence is conservative. Based on this assumption, a recreational water guideline value can be calculated by multiplying the ADWG guideline value by 10. This methodology has been used to calculate all the Health Based Guideline Values (HBGV) for all chemicals in the 2008 *Guidelines for Managing Risk in Recreational Water.*

While the Mance et al. (1984) methodology has been widely used, it has a number of limitations:

- The method makes no allowance for other exposure routes, such as inhalation and dermal absorption, which may be significant for some chemicals. In the case of PFAS these exposure routes are considered to be negligible.
- The method does not apply explicit assumptions for rates of accidental water ingestion during recreational water use.
- The method does not provide explicit assumptions regarding patterns of recreational water use. Therefore, it is not possible for communities to assess whether the assumptions apply to realistic patterns of recreational activity at specific sites, which may vary according to location, availability of alternative recreational facilities, and cultural practices.

Revised methodology

The National Health and Medical Research Council's Water Quality Advisory Committee (WQAC) recommended an alternative methodology to calculate the recreational water guideline value. Instead of basing it on an ingestion rate of 0.2 litres of water per day as per the ADWG formula, a calculated ingestion volume per water-based recreational event is used in combination with an assumed number of water-based recreational events per year (event frequency). Numerous conservative assumptions are applied such that this approach is designed to protect the majority of the population. NHMRC acknowledge that there is currently limited data available, particularly data that can be assumed to appropriately relate to recreational use of water bodies in Australia. These include locally relevant 'event frequency' data and representative rates of accidental ingestion during these events. The NHMRC Recreational Water Quality Advisory Committee will review this methodology as part of updating the Guidelines for Managing Risk in Recreational Water.

Estimation of Annual Accidental Ingestion (AAI) volume

The established TDIs for PFAS chemicals have been determined based on long-term exposure end-points, rather than acute toxicity endpoints. Therefore, it is appropriate that recreational water quality guidelines be similarly established based on patterns of use that reflect long-term accumulated exposure, rather than short-term variations. Since recreational water use may be highly seasonal, exposure assumptions are based on annual total exposure scenarios. An annual accidental ingestion (AAI) volume can be estimated as follows:

AAI (Litres/year) = Ingestion volume per event (Litres/event) x Event frequency (events/year)

The following conservative default assumptions have been made, with the cohort of frequent users of recreational water in mind (i.e. 95 percentile):

- **Ingestion volume per event = 0.2 Litres/event**.

  Although the recreational water guidelines do not apply to swimming pools, much of the available data relate to swimming pools. These data have been used to guide assumptions of volumes of recreational water ingested from natural sources.

  This is the upper 95% confidence level reported for children swimming in swimming pools and freshwater environments (Schets et al. 2011). It was also the upper 95% confidence level for men in swimming pools. It is slightly higher (hence more protective of health) than volumes reported for women in swimming pools, men and women in freshwater, and each of men, women and children in marine water (Schets et al. 2011). This figure is also cautious compared to other recent studies, primarily focused on swimming pool exposure (Dufour et al., 2006). Furthermore, it is conservative of exposure estimates for occupational and sports divers in fresh, marine, urban canal and circulation pool environments (Schijven and Husman, 2006).

- **Event frequency = 150 events/year.**

  This figure is provided as the 'upper estimate' in Table 6.2.15 of the Australian Exposure Factor Guide (EnHealth, 2012). However, it provides greater health protection than the few (international) data that could be identified for fresh and marine surface waters (Schets et al., 2011). It is also cautious compared to other sources regarding swimming pool use frequency (Chowdhury, 2015; Schets et al., 2011).

Applying the above assumptions provides an annual accidental ingestion (AAI) volume of 30 Litres/year:

30 (Litres/year) = 0.2 Litres/event x 150 Events/year

Recreational Water Health Based Guideline Values for PFAS

Perfluorooctane sulfonate (PFOS) and perfluorohexane sulfonate (PFHxS)

FSANZ (2017) found there was insufficient toxicological and epidemiological evidence to justify establishing a TDI for perfluorohexane sulfonate (PFHxS) and recommended that the TDI for perfluorooctane sulfonate (PFOS) apply to the sum of PFHxS and PFOS to be protective of human health. Based on human health considerations, the TDI for PFOS and PFHxS combined is 0.02 micrograms per kilogram (μg/kg) of body weight per day (FSANZ, 2017). Using this guidance the recreational water HBGV is calculated in Box 1. The methodology is based on Chapter 6 of the ADWG, where 70 kg is taken as the average weight of an adult. An AAI of 30 Litres/year is assumed, as described above. Since recreational water exposure is anticipated to make only a minor contribution to overall exposure to PFOS and PFHxS, it is appropriate that only a minor portion of the TDI is allocated to this source. This is achieved by the inclusion of a proportionality factor of 0.1 in the HBGV calculation (this is based on an internationally recognised reference value of water contributing 10% of intake, a minor contribution to the overall exposure, and is consistent with that used in the ADWG and by the World Health Organization). A separate HBGV has not been calculated for children because the TDI (developed by FSANZ) does not specifically apply to children as it is based on decreased parental and offspring body weight in a multi-generational reproductive toxicity study in rats. This also means that the resulting HBGV will be protective of vulnerable groups including pregnant women. The assumption used in developing the HBGV for adults results in a value that will protect the majority of the population including children who, as a cohort, are likely to be regular users of recreational water. The guideline value was rounded to a single significant figure, as recommended in section 6.3.3 (Guidance on rounding) of the ADWG.

Box 1: Calculation of recreational water Health Based Guideline Value (HBGV) for PFOS and PFHxS

The recreational water guideline value of 2 μg/L for total PFOS and PFHxS is determined as follows:

$$2\ \mu g/L = \frac{0.02\ \mu g/kg\ \text{body weight/day} \times 365\ \text{days/year} \times 70\ kg \times 0.1}{30\ L/\text{year}}$$

Perfluorooctanoic acid (PFOA)

Based on human health considerations, the TDI for PFOA is 0.16 μg/kg of body weight per day (FSANZ, 2017). Using this guidance the recreational guideline value is calculated in Box 2. The methodology is based on Chapter 6 of the ADWG, where 70 kg is taken as the average weight of an adult. An AAI of 30 Litres/year is assumed, as described above. Since recreational water exposure is anticipated to make only a minor contribution to overall exposure to PFOA, it is appropriate that only a minor portion of the TDI is allocated to this source. This is achieved by the inclusion of a proportionality factor of 0.1 in the HBGV calculation based on an internationally recognised reference value of 10% of exposure to the chemical coming from drinking water. This is consistent with that used in the ADWG. The standard rounding convention detailed in ADWG (section 6.3.3, Guidance on rounding) has been applied to the resulting HBGV, resulting in the HBGV being rounded to 10 μg/L for PFOA.

Box 2: Calculation of recreational water HBGV for PFOA

The recreational water guideline value of 10 µg/L for PFOA is determined as follows:

$$10\ \mu g/L = \frac{0.16\ \mu g/kg\ \text{body weight/day} \times 365\ \text{days/year} \times 70\ kg \times 0.1}{30\ L/\text{year}}$$

Scenario-specific recalculation of HBGV

There is no ‘typical’ exposure to PFAS. NHMRC has developed default values that will protect the majority of the population, including children. As such, the HBGVs presented in this fact sheet were derived from a calculated annual accidental ingestion (AAI) of 30 Litres/year. This AAI was derived from an assumed Event Frequency of 150 events/year. This was selected as a health protective value, intended to be broadly applicable to a wide range of recreational scenarios.

Across Australia, however, people’s use of recreational water is not the same, given Australia’s climate and geography. Some recreational water resources may be used less frequently than assumed in this guideline, and (in rare cases) some may be used more frequently. In such cases relevant bodies such as a local Council may want to reassess the AAI, based on a more locally-appropriate event frequency and in consultation with the state or territory health regulator. When doing so, the relevant body needs to provide a clear evidence base to the regulator for the alternative event frequency before recalculating the AAI. This justification may be based on observational data or other considerations, including seasonal patterns of recreational water use. A revised AAI may then be used by the Council or relevant body to undertake scenario-specific recalculation of the HBGVs. These scenario-specific recalculated HBGVs may then be used to assess recreational water quality risks associated with PFAS in such specific scenarios.

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