Human exposure to PFCs by drinking water

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Abstract

The aim of this study was to investigate the presence and potential health risks of perfluorinated compounds (PFCs) in drinking water. An extended literature review was initially conducted to collect monitoring data of PFCs in drinking water, worldwide. In order to assess the potential risk for human health associated with the presence of PFCs in drinking water, risk assessment was based on Risk Quotient (RQ) methodology, while RQs were calculated for different life stages, applying different scenarios based on the Acceptable Daily Intake (ADI) values published in the literature. According to the results, there is a considerable number of published articles in scientific journals (31) concerning the presence of PFCs in drinking water. Their mean concentration levels ranged from less than 1 ng L^{-1} up to less than 200 ng L^{-1}. Amongst all target compounds, perfluorooctanesulfonic acid (PFOS) seemed to pose a probable risk to human health, especially to infants and young children, indicating the need for further research.

Keywords: perfluorinated compounds, drinking water, human health risk assessment.

1. Introduction

PFCs are a class of emerging persistent organic pollutants (POPs) that consist of a fully fluorinated hydrophobic alkyl chain attached to a hydrophilic end group. For over 50 years, PFCs have been widely used in several industrial and household applications due to their unique physicochemical properties such as thermal stability and oxidative resistance (Vecitis et al., 2009). PFCs are persistent, bio-accumulative and potentially hazardous to humans and wildlife (Ahrens et al., 2011). Regarding their toxicity in humans, research has associated PFCs with adverse effects on growth, birth weight, fertility disorders, early menopause in women, carcinogenesis and thyroid malfunction (Rahman et al., 2014).

Human risk assessment (HRA) methodology has been recently applied during the last years to estimate the possible threat posed by micropollutants found in drinking water to human health (Etchepare and van der Hoek, 2015; Yang et al., 2017). Beside the frequent detection of PFCs in drinking water and the aforementioned chemical and toxicological properties of these compounds, to the best of our knowledge HRA methodology has not been previously applied to estimate the human health risk from the consumption of drinking water containing PFCs.

Based on the above, the main objectives of the current study were to collect data for the occurrence of PFCs in drinking water worldwide and to apply the HRA methodology to estimate human health risk from the consumption of drinking water containing PFCs.

2. Materials and Methods

2.1. Monitoring data collection

An extended literature review was initially conducted between October 2017 and April 2018, to collect monitoring data of perfluorinated compounds (PFCs) in drinking water, worldwide. Data from 31 articles, dated from 2002 to 2018, was retrieved using the PubMed, Scopus, Web of Science and Science Direct databases, while the following keywords “perfluorinated compounds OR PFCs OR PFOS OR PFOA” AND “drinking water OR tap water OR bottled water” were used.

2.2. Human health risk assessment

In order to assess the potential risk for human health associated with the presence of PFCs in drinking water, the RQ methodology was applied for age-specific groups, while RQ calculations were based on the measured concentration (MC) of the target compounds in drinking water and the Drinking Water Equivalent Level (DWEL), according to Eqs. (1) and (2):

$$\text{DWEL} = \frac{\text{RSC x ADI x BW}}{\text{DWI x AB x FOE}} \qquad (1)$$

$$\text{RQ} = \frac{\text{MC}}{\text{DWEL}} \qquad (2)$$

Where ADI (μg kg^{-1} day^{-1}) is the Acceptable Daily Intake, BW (kg) represents the 50^{th} percentile body weight, RSC is the Relative Source Contribution factor which determines the percentage of the exposure due to drinking water (100% or 20%), DWI (L day^{-1}) is the 95^{th} percentile Drinking Water Intake, AB defines the gastrointestinal absorption rate presuming to be equal to 1 and FOE is the Frequency of Exposure (350 days/365 days = 0.96) (Etchepare & van der der Hoek, 2015; EPA, 2016; Yang et al., 2017; Riva et al., 2018).The RQ values were initially calculated for the worst case scenario, based on the maximum concentrations of the target compounds, applying Eqs. (1) and (2). If the RQ value is less than 0.2, the risk posed by the micropollutant is negligible, whereas when values are equal to or higher than 1 adverse effects on human health are probable. For compounds with $0.2 \leq RQ < 1$ further research is required (Etchepare & van der der Hoek, 2015; Yang et al., 2017). For those PFCs that RQ values were higher than or equal to 0.2, another scenario was applied for the average measured concentrations, in order to investigate the possible threat for human health under more realistic conditions.

3. Results and Discussion

3.1. PFCs occurrence in drinking water

PFCs concentrations are reported in 31 relevant studies from 2002 to 2016. The majority of drinking water samples were from Europe (22 papers), Asia and Australia (14 papers), North America (6 papers), Africa (5 papers) and South America (3 papers). Concentrations of PFOS and PFOA were highest in North America and lowest in Asia. In contrast to Europe, Asia and North America, samples from Australia, Africa and South America were very few to compare means and concentration ranges for all PFCs. For PFCs other than PFOS and PFOA, the most commonly reported were PFHpA, PFNA, PFHxS, PFHxA, PFDA, PFBS, PFPeA, PFBA, PDUnDA and PFDoDA.

3.2. Human health risk due to PFCs

Human health risk assessment revealed that in all worst case scenarios, the specific PFCs, apart from PFOS, posed no serious risks to human health. On the other hand, PFOS presented $RQ_{max} > 0.2$ in all established scenarios, while in one applied scenario where RSC = 20%, RQ_{max} values were higher than 1, for all studied age groups. In this specific scenario, for infants and children up to 6 years old, RQ_{max} was higher than 2, reaching the value 5.6 for infants up to 3 months.

For PFOS, which seemed to pose a possible threat to human health via the worst case scenarios, additional calculations of the RQ values were conducted using the mean measured concentrations (MC_{mean}), in order to apply a more realistic risk assessment. RQ_{mean} values were lower than 0.2 in all scenarios, apart from one, where they remained higher than 0.2 for infants and children up to 6 years old, indicating that PFOS should be included in future monitoring programs, as it is shown to present probable concern to human health.

4. Conclusions

PFCs have been detected in drinking water worldwide. The majority of the examined PFCs seemed to present no serious threat to humans in all established scenarios. On the contrary, the results of the present study revealed that PFOS constitutes a probable risk for human health, pointing out that future national monitoring programs should include the specific emerging contaminant and limits in drinking water should be set out by authorities.

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