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Perfluoroalkyl acids (PFAAs) in indoor and outdoor dusts around a mega fluorochemical industrial park in China: Implications for human exposure

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ABSTRACT

The manufacture of fluorochemicals can lead to high levels of perfluoroalkyl acids (PFAAs) contaminating the surrounding environment and consequently elevated exposure to the local residents. In this study, measurements of PFAAs associated with indoor and outdoor dusts around a mega fluorochemical industrial park (FIP) were made. Perfluorooctanoic acid (PFOA) and short-chain perfluoroalkyl carboxylic acids (C4–C7 PFCAs) were the predominant forms in all samples. The signature of the PFAAs in dusts in the local area matched that found within the FIP complex. The contamination plume in the local area could be linked to the prevailing wind direction starting from the FIP. The dust concentrations decreased exponentially with distance from the FIP (noticeably in the first 5 km). PFAAs contamination could be detected at the furthest location, 20 km away from the FIP. The concentrations of PFAAs were higher in indoor dust (73–13,500 ng/g, median: 979 ng/g) than those in outdoor dust (5–9495 ng/g, median: 62 ng/g) at every location. The highest estimated daily intake of PFOA via dust ingestion (26.0 ng/kg·bw/day) was for toddlers (2–5 years) living 2 km away from the FIP, which is posing human health risk, though exposure remains within the provisional tolerable daily intake values.

1. Introduction

Perfluoroalkyl acids (PFAAs), including perfluorocarboxylates (PFCAs) and perfluorosulfonates (PFSAs), are synthesized chemicals which have high surface activity, thermal and acid resistance, and repellency of water and oil (Giesy and Kannan, 2002). These properties have led to their use in various commercial products and industrial processes, such as textile, food containers, upholstery, fire-fighting foams, metal plating and fluoropolymer manufacturing (OECD, 2002; Buck et al., 2011; Wang et al., 2014b). Their presence in so many products and non-biodegradability has led to their wide distribution in the environment. With a potential for bioaccumulation and potential adverse effects in biota and humans, they have attracted increasing scientific attention and enhanced awareness among regulators (Lindstrom et al., 2011). In 2009, perfluorooctane sulfonic acid (PFOS), its salts, and perfluorooctane sulfonyl fluoride (POSF) were listed as persistent organic pollutants (POPs) by the Stockholm Convention (UNEP, 2009). Perfluorooctanoic acid (PFOA), another highly investigated PFAA, is due to be phased out in the USA following agreements with industry in that country by 2015 (USEPA, 2006). There has been a trend for the manufacture of PFAAs and fluoro-polymers/-telomers to shift from North America and Europe to emerging economies, especially China (Wang et al., 2014a; Wang et al., 2016).

In humans, statistical associations between PFOS or PFOA levels and reduced birth weight (Stein et al., 2009), cholesterol (Nelson et al., 2010), uric acid (Steenland et al., 2010), sperm quality (Joensen et al., 2009), kidney and testicular cancer (Barry et al., 2013), and ulcerative colitis (Steenland et al., 2013) have been reported. The main routes for human exposure to PFAAs include ingestion of dust, food and drinking water consumption, and inhalation of PFAAs-contaminated air (Fromme et al., 2009; D'Hollander et al., 2010). A number of studies have reported that household dust contains PFAAs (Björklund et al., 2009; Goosey and Harrad, 2011; Fraser et al., 2013). Indoor dust is mixture of settled particles, human skin and fabric micro fibers, whereas outdoor dust is mostly made of microorganisms, spores, traffic-related emissions and soil-derived particles. Humans can mitigate their exposure to contaminants in food or beverages by choosing different products, but this choice does not exist when the contaminant is present in their physical environment where they work, live and play. Given the association of PFAAs with dust, it is likely that young children who are often in close contact with floors and dusty surfaces and have a greater propensity to put their hands and objects in their mouths will be particularly exposed.

Our previous studies have found an important point source of PFAAs, a mega fluorochemical industrial park (FIP), in the Xiaoqing River basin

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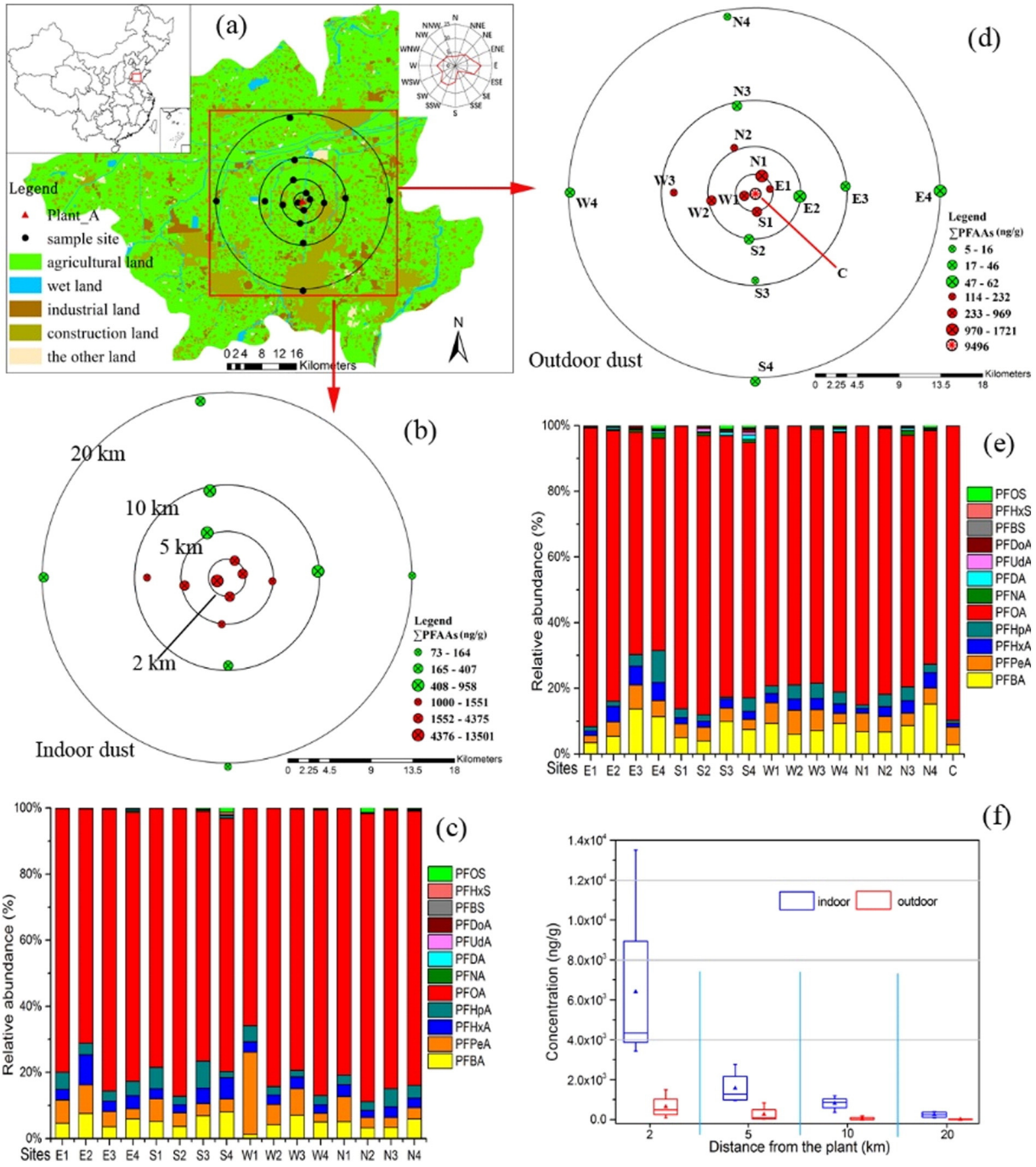

Fig. 1. (a) Map of the study area and sampling sites; (b) Spatial distribution of PFAAs in indoor dusts; (c) Relative abundance of individual PFAA in indoor dusts; (d) Spatial distribution of PFAAs in outdoor dusts; (e) Relative abundance of individual PFAA in outdoor dusts; (f) Comparison of PFAAs concentration in indoor dust and outdoor dust. The lower and upper ends of the box are the 25th and 75th percentiles of the data. The horizontal solid line within the box is the median value and the symbol ▲ represents the arithmetic mean value.

in northern China (Wang et al., 2014a). PFAAs levels up to 1.06 mg/L, with a mass load of 174 kg/d, were identified at downstream of the FIP (Wang et al., 2016). The FIP is one of the largest production facilities of the fluorochemical industry in Asia. It was founded in 1987 and began to produce polytetrafluoroethylene (PTFE) in 2001, with a production capacity of 49,000 tons in 2013. This FIP also produces other fluoropolymers (FP) that involve PFOA as a processing aid (Wang et al., 2014a; Wang et al., 2016). While PFOA is largely released via the production and use of Ammonium Perfluorooctanoate (APFO) (Wang et al., 2014b), the C4–C7 PFCAs mainly come from impurities of PFCAs in FP/fluoroelastomer (FE) products or degradation of FP precursors (Shi et al., 2015).

This study provides a detailed and systematic investigation on the concentration and distribution of PFAAs in indoor and outdoor dust samples from households around the FIP. The objective was to determine the influence of PFAAs emitted from the FIP and estimate the daily intake of dominant PFAAs present in dust. Such information is necessary for effective management of PFAAs production from the FIP and for human health risk assessment.

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