

# MIND, DISRUPTED

How toxic chemicals change how we think and who we are



## Perfluorinated Chemicals (PFCs)

### What Are Perfluorinated Chemicals (PFCs)?

**P**erfluorinated chemicals (PFCs) are a group of synthetic chemicals that have been used in a variety of consumer and industrial applications for over 50 years.<sup>1</sup> They are characterized by long, fully fluorinated carbon chains with different functional head groups.<sup>2</sup>

PFCs are used in products to resist grease, oil, stains, and water, and are also used in fire-fighting foam.<sup>3</sup> PFC coated products may include non-stick cookware, Teflon®, GORE-TEX®, water-proof clothing, fast food wrappers, pizza boxes, popcorn bags, stain-resistant carpet, paint, and windshield washer fluid.<sup>4</sup>

Perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) are the most researched of the PFC substances, but recent studies have identified at least 13 other related chemicals that are largely unresearched. The carbon-fluorine bond of these chemicals is incredibly strong, which makes it resist breakdown and causes PFCs to build up in the food web.<sup>5</sup> Once PFCs are released into the environment, they remain indefinitely and do not break down. PFCs “are stable to acids, bases, oxidants, and reductants and are generally not believed to undergo metabolic or other degradation in the environment.”<sup>7</sup>

According to the US EPA, PFCs have become concentrated in humans and other animals due their presence in the environment as well as exposures from food and consumer products. PFCs bioaccumulate and are subject to long-range atmospheric transport.<sup>6</sup> While certain PFCs, including PFOS and PFOA, have been or are in the process of being voluntarily phased out by industry, they may still be present in older products. Also, other PFCs are still being widely used.

### How Are We Exposed to PFCs?

The major sources of PFC exposure in humans are not very well understood, and are still being investigated. Dietary intake is thought to be a major source. This can result from eating animals exposed to PFCs through water, soil and dust that are contaminated by PFC production and the degradation of consumer products containing PFCs.<sup>7</sup> It is estimated that 2-12 tons of PFCs per year are transported to the Arctic through oceanic and atmospheric currents, which contributes to human and animal

exposure.<sup>7</sup> PFCs bioaccumulate in the bodies of animals, and humans are exposed to PFCs by consuming animal products. A recent study in Spain found PFCs in a wide variety of food sources. Fish and dairy products represented the most significant source of exposure.<sup>8</sup> In another study from Canada, beef was found to be the most significant dietary source of PFOS.<sup>9</sup> Dietary intake of PFCs may also result from eating foods packaged in materials with grease and water-resistant coatings that may contain PFCs, such as fast food.<sup>10</sup> When the food comes into contact with the packaging, it may become contaminated with PFCs.

People may also be exposed to PFCs from sources in the indoor environment—from PFC-coated products such as stain-resistant carpeting and textiles and nonstick cookware—and from breathing in and ingesting air and dust that contain PFCs.<sup>11</sup> PFCs have been found in residential and workplace dust. The results of a recent study measuring PFC levels in the dust of residences, offices and day care centers suggested that ingestion of indoor dust is a significant source of PFC exposure, especially for toddlers.<sup>12</sup> Young children and toddlers may ingest significant quantities of dust due to hand-to-mouth behavior and their tendency to play on the floor.<sup>13</sup>

### PFCs in Our Bodies

PFOA binds to serum albumin (a plasma protein) and can be circulated throughout the bloodstream.<sup>14</sup> PFOA has a long half-life in the body, which means that it can remain in the body for a long time after exposure. In a study of retirees from PFC manufacturing facilities, the average half-life in blood was 3.8 years for PFOA and 5.4 years for PFOS.<sup>15</sup>

In a study that analyzed blood samples from 473 people from nine countries, PFOS was the most frequently detected PFC.<sup>16</sup> “Concentrations of PFOS were the highest in the samples collected from the United States and Poland (>30 ng/mL); moderate in Korea, Belgium, Malaysia, Brazil, Italy, and Colombia (3 to 29 ng/mL); and lowest in India (<3 ng/mL).”<sup>16</sup> Researchers found no age or gender differences in PFOA or PFOS in this study.

Four PFC compounds (PFOS, PFOA, PFHxS, and PFNA) were found in more than 98% of the serum samples of 2,094 participants in the 2003–2004 National Health and Nutrition Examination

Survey (NHANES), an ongoing study of the general U.S. population.<sup>17</sup> Concentrations in the general population are typically in the low parts per billion (ng/mL) range. When compared to PFC levels in 1999–2000 NHANES participants, levels of PFOS, PFOA and PFHxS were significantly reduced, whereas PFNA levels were 100% higher. “The apparent reductions in concentrations of PFOS, PFOA, and PFHxS most likely are related to [voluntary] discontinuation of manufacturing processes for these chemicals in 2002.”<sup>17</sup>

Studies have found PFCs in breast milk. A 2004 study of 45 breast milk samples from participants in Massachusetts found PFOS and PFOA in 100% and 98% of the samples, respectively.<sup>18</sup> Higher levels of PFOA were found in the breast milk of first-time mothers.

### What does Exposure to PFCs Mean for Our Health?

The presence of environmental chemicals in the human body does not necessarily imply that they are causing adverse health effects; however, environmental chemical exposures can and do affect human health. It is important to note that both the dosage and the timing of exposure have significant effect on any potential health outcome.

The following information is intended to inform the reader about the current state of knowledge on the health effects of perfluorinated chemicals, including both human and animals studies.

Research has linked PFCs to a range of health effects. A majority of research on PFCs has been conducted on animals. These studies should be viewed with some caution, as there are major differences in how PFCs behave in the bodies of some animals compared to humans, and in expression of proteins and other biological factors that lead to certain health outcomes.<sup>19</sup> Specifically, rodents may be more susceptible to the effects of PFCs. Also, animals are often exposed higher levels of the chemical than humans. Still, animal toxicological studies have been found to be valuable in predicting human health impacts.<sup>20</sup> The number of human studies on the possible health effects of PFCs is increasing.

#### Liver Toxicity

Researchers have linked ingestion of PFCs to liver enlargement in non-human primates given high doses of PFOS.<sup>21</sup> PFC ingestion has also been associated with liver cancer in animal studies.<sup>22</sup>

#### Developmental Toxicity

In an animal study, high neonatal mortality rates were correlated with high levels of PFCs in the serum and liver.<sup>23</sup> Rat pups exposed to PFOS *in utero* had decreased body weight, developmental delays and decreased levels of thyroid hormones which are essential for normal growth and development.<sup>23,24</sup> PFOA and PFOS exposure *in utero* has also been linked to small reductions in birth weight in newborn humans at typical exposure levels for the U.S. population.<sup>25,26</sup>

Exposure of neonatal mice to PFOA and PFOS is linked to irreversible changes in the brain.<sup>27</sup> Adult mice that were exposed to PFOA and PFOS displayed decreased spontaneous behavior,

increased hyperactivity, and lack of habituation to a new environment.<sup>27</sup>

Although rat pups exposed to PFOA *in utero* were more likely to be smaller when they were born, they gained weight at a faster rate. As researchers stated, “recent results suggest that obesity and a number of organ specific abnormalities can be observed in these animals by 18 months of age.”<sup>28</sup>

Furthermore, a recent animal study found that PFOA exposure was associated with abnormalities in mammary gland development.<sup>29</sup> Researchers concluded that these abnormalities may play a role in the abnormal growth of young PFOA-exposed mice.<sup>29</sup>

#### Thyroid Hormone Disruption

PFDA and PFOS have been shown to reduce levels of circulating thyroid hormones in animals.<sup>30,31</sup> A study of factory workers exposed to PFCs showed the most highly exposed male workers had higher triiodothyronine (T3) levels. These workers had serum PFC concentrations in the parts per million range.<sup>32</sup>

#### Estrogenic Effects

Male rats exposed to PFOA for 14 days experienced a decrease in testicular testosterone and an increase in serum estradiol.<sup>33</sup> However, exposure of Cynomolgus monkeys to ammonium perfluorooctanoate did not result in a decrease in testosterone or an increase in estradiol. Monkeys in the study all had serum PFOA concentrations above 10 ppm ( $\mu\text{g}/\text{mL}$ ).<sup>34</sup> PFC exposure has also been associated with abnormal enlargement of Leydig cells (cells in the testes that secrete testosterone) and Leydig cell adenomas (benign tumors).<sup>35</sup> This raises concern because abnormal enlargement of Leydig cells is common in infertile men.<sup>36</sup>

#### Infertility

A recent UCLA study found that women with higher serum levels of PFOA and PFOS have increased risk of infertility. Women who required greater than 12 months to achieve pregnancy had median PFOS concentrations of  $38.3 \pm 13.0$  (ng/ml plasma), while women who achieved pregnancy in less than one month had median concentrations of  $35.5 \pm 12.8$  (ng/ml plasma). A similar trend was seen for PFOA concentrations, with concentrations of  $6.3 \pm 2.7$  (ng/ml plasma) and  $5.6 \pm 2.6$  (ng/ml plasma) respectively. Women in the higher PFC category were also more likely to have irregular menstrual cycles.<sup>37</sup>

In men, high combined levels of PFCs may also affect semen quality. In a recent Danish study, young men with high combined levels of PFOS and PFOA had less than half the number of normal sperm than men with low levels of PFOA and PFOS.<sup>38</sup> The concentrations of PFCs in the study participants were similar to concentrations seen in the U.S. population.<sup>38</sup> Men with lower sperm quality have a harder time conceiving children.<sup>39</sup>

#### Cancer

Workers in a PFOS manufacturing facility experienced increased rates of bladder cancer, though findings are limited by small

## Reducing Your Exposure

You can prevent or minimize exposure to PFCs in the following ways:

- Minimize packaged food and greasy fast foods in your diet. These can be held in containers that are coated with PFCs to keep grease from soaking through the packaging, including french fry boxes, pizza boxes and microwave popcorn bags.<sup>52</sup>
- When purchasing furniture or carpet, decline optional treatments for stain and dirt resistance, and find products that have not been pre-treated with chemicals by questioning the retailers.<sup>52</sup> Most of these chemical treatments contain PFCs that might contaminate your home and family.
- Avoid buying clothing that bears a Teflon label or other indication that it has been coated for water, stain, or dirt repellency.<sup>52</sup> Many of these coatings are PFCs.
- Phase out the use of Teflon and other non-stick cookware and other equipment that is heated in your home. When heated to high temperatures, Teflon and products with other non-stick PFC coatings may emit fumes that can be harmful.<sup>52</sup>
- Avoid buying cosmetics and other personal care products with the phrase “fluoro” or “perfluoro” on the ingredient list.<sup>52</sup> Products that may contain PFCs include lotions, pressed powders, nail polish, and shaving cream.

numbers. The most highly exposed workers had serum PFOS concentrations between 1-2 ppm ( $\mu\text{g}/\text{mL}$ ).<sup>40</sup> In another study of workers exposed to PFOA, risk of prostate cancer was associated with length of employment (length of exposure). Serum PFC concentrations were not measured in this study.<sup>41</sup>

### Immune System Effects

After mice were exposed to PFOA in one study, they had reduced production of lymphocytes (immune system cells) by both the spleen and the thymus.<sup>42,43</sup> PFOA has also been shown to suppress the humoral immune response (immunity that is mediated by antibodies secreted by B cells) in both *in vivo* and *ex vivo* systems.<sup>44</sup> This may decrease the body’s ability to respond to bacterial invasion and infection.

Exposure to PFOA may also enhance the immune response to environmental allergens, which increases the severity of allergies.<sup>45</sup>

### Cholesterol

A handful of studies have shown an association between concentrations of certain PFCs in blood and increased cholesterol, and specifically low density lipoproteins, in humans. While

these studies are not able to show a cause-and-effect relationship, they have found a similar pattern in the general U.S. population,<sup>46</sup> in community residents who were exposed to higher levels of PFOA through drinking water,<sup>47</sup> and in workers in manufacturing facilities that use PFCs.<sup>48</sup>

### Regulations for PFCs

PFOS has been classified as very persistent, very bioaccumulative and toxic by the European Commission’s Scientific Committee on Health and Environmental Risks (SCHER).<sup>49</sup> In May 2009, PFOS and PFOSF were added to the international Stockholm Convention on Persistent Organic Pollutants (POPs), a global, legally binding treaty, albeit with exemptions for certain uses. The European Union has restricted the use of PFOS and is considering the risks of PFOA exposure.<sup>49</sup>

In Canada, PFOS was added to the list of toxic substances under the Canadian Environmental Protection Act, prohibiting the use, sale and manufacture of PFOS and items containing PFOS.<sup>50</sup>

New York has proposed a statewide purchasing policy that would restrict the purchase of products containing toxic substance, including perfluorinated compounds.<sup>51</sup>

## Endnotes

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