Spring 2005

HEALTH EFFECTS REVIEW

Perflourinated Compounds (PFCs)

Introduction

Perfluorinated compounds (PFCs) are persistent and bioaccumulative chemicals with a broad range of industrial and consumer applications. They have been used as surfactants and surface protectors in the manufacture of plastic, electronics, textile, and construction material for over fifty years. Common products that contain PFCs include floor polishes, shampoos, carpets, upholstery, and fire-fighting foams [1]. These compounds have the unique chemical property of repelling both water and oil, making them ideal for use in Teflon and Scotchguard materials. PFCs can be released into the environment via product manufacturing, use, and disposal. Many of the degradation products of PFCs have been found in the environment throughout the world, but perfluorooctane sulfonate (PFOS; C8F17SO3-) and perfluorooctanoate (PFOA; C7F15COO-) are two of the most widely detected. Because of the strong carbon-fluorine (C-F) bond associated with PFCs, PFOS and PFOA are environmentally persistent and have been detected in human blood samples throughout the world [2-6]. Concentrations of PFOA and PFOS measured as part of a biomonitoring program had a mean of approximately 4-5 and 30-40 ppb, respectively [4]. This report summarizes studies of human exposure levels and their potential health effects related to PFOS and PFOA.

Routes of Exposure

PFCs were first discovered in humans over thirty years ago, but it was only over the past few years that analytical capabilities allowed the detection of low levels in human and wildlife samples. Since then, PFOS and, to a lesser degree, PFOA, have been identified in samples throughout the world. Because of PFCs seemingly ubiquitous nature, 3M Company, one of the largest manufacturers of PFOS and PFOA, phased out production of the chemicals in 2002.

Routes of human exposure and the relative importance of different exposure routes remains unknown [3]. PFOS, PFOA, and other PFCs are global contaminants have been found in wildlife in locations like Great Lakes, Hong Kong, and the Canadian arctic [7-9]. This suggests that some PFC precursors are capable of long distance transport. PFOS is a metabolite of perfluorooctanesulfonyl fluoride (POSF; C8F17SO2F), a volatile liquid used to make polymers [10]. Although PFOS and PFOA have very low volatility, both can bioaccumulate. PFOS has been found in animal species including bald eagles, fish, polar bears, and seals [11]. Based on their chemistry, their estimated bioconcentration factors are less than the lipophilic organochlorines such as PCBs [7]. PFOS and PFOA, among other PFCs, are persistent organic pollutants (POPs).

PFCs have been detected in water sources throughout the world. After an accidental release of fire-fighting foam, PFOA was reported in the surface water of a Canadian tributary at levels reaching 11.3 ug/L. Drinking water samples taken near a 3M production plant in West Virginia had levels of PFOA below 3 ug/L. This is much lower then the interim risk screening of 150ug/L established by the West Virginia Department of Environmental Protection. PFCs have also been detected in air samples. Airborne levels of certain PFCs were detected at levels ranging from 10 to 100 pg/m3 in Ontario Canada [10].

Occupational exposure to PFCs has been identified for employees of 3M manufacturing facilities [12]. Workers at various 3M manufacturing plants had measured levels of PFOA ranging from 0.1 to 81.3 ppm. People who were occupationally exposed had levels approximately an order of magnitude greater than the general population.

Epidemiological studies have been conducted on the 3M occupational cohort [12]. Positive significant associations were observed between PFOA and cholesterol, triglyceride, and thiiodothyronine. Negative correlations were shown for HDL and cholecystokinin-33. Mortality studies have also suggested an association between PFOA exposure and prostate cancer, but in this recent study, this SMR was not statistically significant.

Human Exposure Levels

Organofluorine compounds were first found in human blood in the 1960s. Similar to PBDEs, the current interest derives largely from the discovery of the ubiquitous presence of PFCs in human and animal tissues. In humans, the two compounds that appear to be present in the largest amounts are PFOS and PFOA. Both chemicals have a lipophilic end (a chain of carbons with fluorines attached) and a hydrophilic end. Both chemicals are very persistent in people, with half-lives estimated to be on the order of 5-10 years, but with large variation.

The main routes of human exposure are not understood. Among other possibilities, residual unreacted starting material could be present in consumer products. A recent small study of human blood samples from around the world found the highest levels of PFOS in the USA and Poland, intermediate levels in Korea, Belgium, Malaysia, Brazil, Italy, Columbia and the lowest in India [6]. Levels have been best studied in the USA: In 645 adult blood donors from six cities, PFOS was log normally distributed with a geometric mean of about 35 ppb. PFOA was the next most common identified PFC with a geometric mean of about 5 ppb. There was little difference with age (donors were 20-69), an unexpected finding for compounds with long half-lives [4].

A Japanese study of 15 mother-infant pairs found PFOS present in cord blood at about one third the levels of maternal blood [2]. PFOA was detected in only a few samples of maternal blood and no cord blood. Although additional work is needed on PFOA, it is known that PFOS can cross the placenta.

Toxicology

Although the toxicity of PFCs has been explored by industry and government agencies using animal data, results are difficult to interpret for humans because of the very high doses that are often administered in these studies. Interpretations are further complicated by differences in results among animal species. In general, studies show that large doses of PFOS administered to pregnant rats and mice resulted in high mortality of the dams. The lethal dose necessary to kill fifty percent of the study animals was estimated at 10 mg/kg for mice and 3 mg/kg for rats [10]. Survival at lower doses did not differ from controls, although postnatal body weight gains were reduced in the exposed group.

Neonatal mortality resulting from PFOS administration to pregnant rats suggests that the critical window of exposure may be during late gestation or perinatal period [10]. The exact mechanism for the PFOS-induced neonatal mortality remains unclear. Considering the critical exposure window is late in the gestational development, one current hypothesis is that PFOS targets organ systems like the lungs, which develop late in gestation.

There also concerns about potential neuroendocrine effects associated with PFOS exposure, in addition to possible developmental, reproductive, and systemic effects. PFOS has been shown to bioaccumulate in the brains and livers of rats, impact estrous cyclicity, and decrease serum leptin concentrations [13]. Although concentrations administered to the rats were higher than the levels reported in the environment, the results may have important health relevance for the work-exposed population.

For PFOA, some of the toxicological endpoints of interest in animal studies include post-natal development, liver-to-brain-weight ratio, bodyweight change, and the development of Leydig cell tumors [3]. Although the most recent human epidemiological studies did not find a statistically significant positive association between PFOA and cancer mortality risk, cancer bioassays in rats produced significant increases in pancreatic acinar cell carcinoma as well as increased Leydig cell tumors.

Conclusion

Organochlorine compounds such as PCBs, dioxin and DDT have long been of great environmental concern. Scientific work on brominated fire retardants has exploded in the six years since the discovery of exponentially increasing levels of polybrominated diphenyl ethers (PBDEs) in breast milk. It is perhaps not surprising that another major class of halogenated organic compounds, the perfluorinated compounds (PFCs), has also attracted recent attention. Perfluorinated compounds are widely used in industry and consumer products such as polymers, surfactants, and other uses. They can be found in Teflon and the original formulation of Scotchguard. Although numerous animal toxicity studies exist, the results are difficult to interpret for the general human population. Also, very little is known about the probable exposure routes. Because of the ubiquitous nature of PFCs in the environment, continued research into the possible health effects is certainly warranted.

References Cited:

1. Olsen G, Church T, Larson E et al. 2004. Serum concentrations of perfluooctanesulfonate and other fluorochemicals in an elderly population from Seattle, Washington. Chemosphere 54:1599-1611.

2. Inoue K, Okada F, Ito R et al. 2004. Perfluorooctane sulfonate (PFOS) and related perfluorinated compounds in human maternal and cord blood samples: Assessment of PFOS exposure in a susceptible population during pregnancy. Environmental Health Perspectives 112:1204-1207.

3. Butenhoff J, Gaylor D, Moore J et al. 2004. Characterization of risk for general population exposure to perfluoroctanoate. Regulatory Toxicology and Pharmacology 39:363-380.

4. Olsen G, Church T, Miller J et al. 2003. Perfluorooctanesulfonate and other fluorochemicals in the serum of American Red Cross adult blood donors. Environmental Health Perspectives 111:1892-1901.

5. Kubwabo C, Vais N, Benoit F. 2004. A pilot study on the determination of perfluorooctanesulfonate and other perfluorinated compounds in blood of Canadians. Journal of Environmental Monitoring 6:540-545.

6. Kannan K, Corsolini S, Falandysz J et al. 2004. Perfluorooctanesulfonate and related fluorochemicals in human blood from several countries. Environmental Science and Technology 38:4489-4495.

7. Boulanger B, Vargo J, Schnoor J et al. 2004. Detection of perfluorooctane surfactants in Great Lakes water. Environmental Science and Technology 38:4064-4070.

8. So M, Taniyasu S, Yamashita N et al. 2004. Perfluorinated compounds in coastal waters of Hong Kong, South China, and Korea. Environmental Science and Technology 38:4056-4063.

9. Martin J, Smithwick M, Braune B et al. 2004. Identification of long-chain perfluorinated acids in biota from the Canadian Arctic. Environmental Science and Technology 38:373-380.

10. Lau C, Butenhoff J, Rogers J. 2004. The developmental toxicity of perfluoroalkyl acids and their derivatives. Toxicology and Applied Pharmacology 198:231-241.

11. Giesy J, Kanna K. 2001. Global distribution of perfluorooctane sulfonate in wildlife. Environmental Science and Technology 35:1339-1342.

12. Kudo N, Kawashima Y. 2003. Toxicity and toxicokinetics of perflurooctanoic acid in humans and animals. Journal of Toxicological Sciences 28:49-57.

13. Austin M, Kasturi B, Barber M. 2003. Neuroendocrine effects of perfluorooctane sulfonate in rats. Environmental Health Perspectives 111:1485-1489.

Prepared by the Department of Environmental Health, Boston Univeristy School of Public Health under the direction of the International Joint Commission's Health Professionals Task Force. The Health Effects Review is a quarterly publication that summarizes the latest scientific literature on human health effects and environmental pollutants. This does not represent the official position of the International Joint Commission.

Review Coordinator: Verónica Maria Vieira, M.S.
Senior Science Advisor: Dr. David M. Ozonoff

For further information please contact Jim Houston, Secretary, Health Professionals Task Force
E-mail: houstonj@ottawa.ijc.org