# PERFluorinated Organics in Our Diet

## Reporting

### Project Information

**PERFOOD**
Grant agreement ID: 227525

**Project website**

**Status**
Closed project

**Start date**
1 August 2009

**End date**
30 November 2012

**Funded under**
FP7-KBBE

**Overall budget**
€ 4,011,390

**EU contribution**
€ 2,999,432

**Coordinated by**
UNIVERSITEIT VAN AMSTERDAM

**Netherlands**

### This project is featured in...

**RESEARCH*EU MAGAZINE**

The big clean-up: how to tackle toxic substances

NO. 25, SEPTEMBER 2013
Final Report Summary - PERFOOD (PERFluorinated Organics in Our Diet)

Executive summary:

The PERFOOD project assessed the origin of perfluorinated alkylated substances (PFAS) in our diet and the diet's contribution to the total human exposure to PFAS. PERFOOD's main achievements can be summarized as follows:

The reliability of measurements of perfluorinated alkyl acids (PFAA: carboxylates, sulfonates and phosphonates) at very low levels (pg/g) in food items has been improved enormously.

The very low method detection limits (MDL) achieved by the high quality analytical method development within the project allowed for many detects in food items that hitherto could not be reported because of much higher MDLs.

Determination of precursors of PFAA has been made possible. Candidate reference materials have been prepared that will serve the analytical community in Europe and the rest of the world. The food surveys conducted in the project identified food types with major relevance and employed strict and harmonized sampling protocols. In this manner a large data set was created allowing geographical comparisons to be made, as well as comparison between raw food, composite food, processed food and duplicate meals.

The project's sampling program was not designed to find a distribution of concentrations of PFAS within each single food item. Food processing such as home cooking or preparation in cantinas does not add significantly to the levels of PFAS already present in food items. Vegetables take up PFAS from (pore) water; in particular leafy vegetables will contribute to human dietary exposure. Short-chained (C4-6) PFAAs are of particular importance, since they get transferred best to the vegetative (edible) parts of plants.

In cattle, PFAA were shown to have transfer factors (from feed and water to meat and milk) similar to those of hydrophobic compounds. In farmed fish concentrations of PFAS are lower than in feral fish because the levels of PFAS in feed given to farmed fish are very low. The results of the project's surveys show that the current data on PFAS available in the EFSA database may overestimate human dietary exposure, mostly because these are older data from older equipment, where often relatively high MLDs were applicable. Baby food and milk products do not provide additional high exposure to PFAS.

Two types of food contact materials were found to possess a high potential for transfer of PFAS and or PFAS precursors (notably fluorotelomer alcohols) to food, viz. baking paper and butter wraps. In general, PFAS containing paper-based packaging of food poses a potential for migration of PFAS into the wrapped or packaged food. Migration pathways include direct migration of PFCAs as well as migration of precursors. There are signs that the use of F-containing linings in paper have decreased substantially recently. PTFE coated pans generate PFCAs at temperature above 200 °C. However, the relevance of migration of PFCAs from pans to baked food is minor.
All exposure estimates calculated from the project's survey results for both adults and children show margins of safety well above 1, i.e. exposure is at a level much below existing TDIs, except the estimates made for hot spots. In this risk characterization, a TDI for PFHxS was assumed equal to that of PFOS, and a TDI for C6-C11 PFCAs was assumed to be similar to that of PFOA. For PFBS and for PFBA no TDIs are available or can be assumed at the moment, and hence no risk characterization given for these two compounds.

Current levels of PFOA in human blood can be described quite well by toxicokinetic modelling using current dietary exposure data. For PFOS, however, the dietary exposure is less well explaining the human blood levels; this finding can be partly explained by the relatively long half-life of PFOS, but may point at an additional source of exposure.

Dietary intake patterns of PFAS differ from region to region. In addition, different exposure media are responsible for differences in exposure between the several PFAS compounds. For example, drinking water and water used for preparation (of e.g. beverages) and cooking is a more important source of intake of short chain PFAS, whereas fish is the main source of intake of longer chain PFAS.

In some countries / regions dust can be as important a source of human exposure as the diet. So far the data available on levels of PFAS in dust are highly variable, however, which may be due to true variability or analytical problems.

Project context and objectives:

Description of project context and objectives and summary of results

Food intake is assumed to be the major source of PFAS exposure for humans [1, 2]. The European Food Safety Authority (EFSA) has set a tolerable daily intake of 150 ng PFOS/kg body weight and 1500 ng PFOA/kg body weight in 2008 [3]. In 2012 EFSA performed a dietary intake estimation based on 54,195 analytical results obtained for 7,560 food samples reported by European Union (EU) Member States [4]. The conclusion was that the high frequency of non-quantifiable results (The aims of the PERFOOD project are to assess the origin of Perfluorinated alkylated substances (PFAS) in our diet and the diet's contribution to the total human exposure to PFAS. To that end the project developed robust and reliable analytical tools for the determination of PFAS, and used these to:

(i) qualify and quantify PFAS in our diet;
(ii) understand how PFAS are transferred from the environment into dietary items, and
(iii) quantify the possible contribution of food / beverage contact materials and food and water processing to the overall PFAS levels in our diet.

The newly gained knowledge enabled us to evaluate the possible routes, including their relative importance, of human exposure to PFAS via our diet, to assess the role of the technosphere in the contamination of our food, and to identify ways to reduce the PFC contamination of dietary articles.
Several different analytical method protocols based on LC-MS/MS methodology, were developed in the course of the project in order to provide significant analytical performance improvements (e.g. detection limits, matrix effects reduction) that allows analysts to determine PFAS in food items at the pg/g level. In addition, LC- and GC-high resolution MS methods were tested for the determination of PFAS and several types of precursors (e.g. FTOHs, PAPs) and applied successfully to food samples.

The consortium has initiated the production of two certified reference materials (CRM), viz. a fish homogenate and a drinking water material that contain certified levels of certain PFAS. The certification process is under way and will be terminated in 2013. The CRMs will be available commercially from the IRMM in Geel, Belgium.

A standardised selection of food items, sampling procedures and analytical methods was identified in order to assess the occurrence of the common set of PFAS in the European diet through European wide surveys. These surveys have identified major sources of PFC exposure via food in a uniform manner, enabling the comparability of data through Europe. The prioritisation of type and number of food items collected in the survey was based on an extensive evaluation of national consumption data from eight different European countries. The survey design was such that four distinct regions in Europe (Norway, Czech Republic, Belgium and Italy) with different dietary habits representing the northern, eastern, central and southern parts of Europe, respectively, have been identified, together with 14 food categories. The first survey focused on single (non composite food) samples with specific items selected for each food category. The second focused on a comparison of market basket and cauldron studies with data on individual food items, and also assessed levels of PFAS in certain hot spot areas in Europe. The results of the surveys show that some food categories, viz. seafood, fish, bovine liver, pork and bovine meat and hen eggs appear to be more highly contaminated with PFAS than other items. Most elevated levels so far were found in food items from Belgium, indicating the influence of industrial production sites of PFAS. Different PFCA patterns can be found in the four sampling locations, with Norway showing a higher abundance of long-chained PFCAs in the food categories analysed.

Raw food items contain higher concentrations of PFAS than the processed or cooked food products in most cases. In general, the levels in raw food, unprepared composites samples, warm meal cauldrons, and composite food prepared with non-stick cookware are not a matter of concern. Elevated PFAS levels could be found in almost all selected hotspots.

For tracking of the origins of PFAS in dietary items several laboratory and field experiments were conducted in the project. A conventional dairy farm with a herd of milk cows served to perform a mass balance study of PFAS using bulk flow data of water, feed, milk, etc., needed for mass balance calculation. Relatively low biotransfer factors of PFCAs and PFOS were observed in meat and milk from dairy cows. However, the increased enrichment of PFOS and long-chain PFCAs in liver indicates that consumption of offal food from dairy cows will result in a higher human exposure.

In controlled greenhouse experiments, vegetables were grown and exposed to different solutions of PFAS. Results from these experiments show that PFAAs are taken up by plants and that relatively high concentrations occur in the roots of the plants especially of long-chained PFAAs. Short chain PFAS are translocated to leaves. Uptake factors derived from the field cultivation experiments with spiked soils
showed lower accumulation factors than from the greenhouse experiments, but a similar accumulation pattern among the PFAS analogues: concentrations of short chain PFAS were highest in the vegetative parts of all plants.

Carry-over rates of PFAS from feed to fillet in farmed fish have been estimated in the range of 0.06 to 0.6 %. The regular consumption of farmed fish would lower the PFOS intake about 10 times with respect to wild fish consumption.

Groundwater bodies may become contaminated by PFAS from different sources. Groundwater bodies originating from either river water or rainwater show distinctly different patterns of relative abundances of PFAS. Field measurements revealed that landfills can be an important source of PFAS to the groundwater. The presence of PFAS in drinking water depends on the technologies used in different treatment plants. Drinking water prepared by treatment which does not include GAC filtration or reverse osmosis will generally contain higher PFAS levels, in particular when surface waters, bank infiltrated waters or phreatic groundwater is used as source water. Other processes used in producing drinking water, e.g. coagulation, rapid sand filtration, dune passage, aeration, rapid sand filtration, ozonation, pellet softening, and slow sand filtration are not effectively removing PFAS from contaminated source waters.

Several food contact materials (FCM) such as baking papers, sandwich papers and butter wraps have been found to be a potential source of migration of organic fluorine compounds into food. In the project screening methods were developed and these methods detected PAPs and S-PAPs as well as PTFE in these FCM. FTOH were detected in almost every F positive FCM, maximum PFCA levels were in the upper ppb range; however, they were not detectable in a series of FCM.

The PFAAs intake estimates made by the PERFOOD project are background exposures in the selected Belgian, Italian, Czech, and Norwegian regions. In the general population, the resulting margin of safety (MOS) for PFOS (TDI = 150 ng/kg bw per day), as the most sensitive contaminant, amounted to greater than 300 and greater than 100 in adults and children, respectively, for mean consumption; in children as high consumers (95P), the lowest MOS was 72. For PFOA, the estimated intake was far below the TDI of 1500 ng/kg (BW) per day in all regions considered. Regional-based intake patterns can be recognized, on the basis of both the different food consumption habits, and of a different occurrence in selected food items. Potential high overexposure with respect to the PFOS TDI has been predicted in some of the hot spot areas considered, where the local food of animal origin represents the main source of exposure. Considering the different bioaccumulation features of PFOS and PFOA, the intake estimates from toxicokinetics modelling appear in good agreement with that from the systematic PERFOOD assessment. In the estimates, the uncertainties related to the potential contribution from dust and food-packaging materials appear negligible. The design of the food surveys within PERFOOD did not allow for a complete representativity of the food sampling.

The presence of potentially hidden small but diffuse hot spots area can result in exposures above the TDIs. The results of the PERFOOD assessments, including the sensitivity analysis performed, allow one to identify threshold values for the contamination of most consumed food items, water included, that can be translated into geo-referenced risk management options.

Potential impact, dissemination activities and exploitation of results

PERFOOD has contributed with a number of routinely applicable and highly sensitive chemical methods for analysis of PFASs in food and drinking water. These methods allow for the first time for reliable quantification of a suite of PFASs in different food items, which is a prerequisite for exposure estimation. PERFOOD has contributed to the overall awareness of the difficulties with the determination of PFAS concentrations in food and beverages. The lack of reliable data thus far has been preventing an accurate risk determination regarding PFAS exposure via food, which is assumed to be the main exposure pathway to humans. The latest interlaboratory study could demonstrate an improvement of the quality of the data reported between the participants. In addition, certified reference materials to validate analytical methods have been lacking for PFASs in food and beverages. Hence, the PERFOOD consortium decided to produce two materials, one fish and one water material, which will be available for purchase in 2013. These achievements PERFOOD will contribute to more reliable data reported to be used in future risk assessments and source apportionments for PFASs, finally allowing for sound and science-based decision making.

The results of the PERFOOD surveys on PFAS levels in a wide range of food collected in a harmonized way in four key regions of Europe will have implications on a broad range of societal areas, including, food processing industry, food sellers, national and international food safety authorities, food consumers, overall population, schools, cantinas, and individuals. The results will enable the EU to review human exposure estimates that may possibly lead to new recommendations for PFAS data. Last but not least the scientific community will benefit from the new knowledge and new methodologies that have resulted from the PERFOOD surveys.

PERFOOD has identified pathways of PFAS contamination in food and beverages and their sources. Transfer of PFAS from source water to beverages, from feed to meat, dairy products and farmed fish, from soils to vegetables has been demonstrated to occur and to depend on the levels of PFAS in source materials. Reduction of the presence of PFAS in source materials would be an effective way of reducing concentrations of PFAS in food items. In addition, potential specific measures have been identified in PERFOOD to further reduce levels, such as materials that can remove PFAS from the drinking water production cycle and/or the conditions of their operation (e.g. active carbon beds for removal of PFAS from water), or the use of alternative sources for preparation of beverages.

The results of PERFOOD demonstrate that food contact materials with a fluorine based coating have the potential to increase levels of PFAS in dietary items during food packaging and/or food preparation. The
PERFOOD outcomes have been considered in the recent EFSA opinion on perfluoroalkylated substances in food. The increase of PFAS levels due to food contact materials has been shown for a wide temperature range between 5 °C and 220 °C. The general impact of these findings is therefore the identification of food contact materials as a major contributor to food levels, especially with respect to food items, which contain only trace levels in their raw state.

Paper based food contact materials, which are used in packaging of moist and fatty food items like butter or cheese, and paper based processing aids like baking papers were investigated. In both types of application coatings on the basis of fluorinated polymers were found to be present. Such coatings may undergo hydrolysis followed by a release of fluorotelomer alcohols (FTOH). Furthermore, PFAA were detected in such paper products. Within the framework of the PERFOOD project data were produced that clearly indicated the release of PFAS (FTOHs) from perfluoroalkylphosphates (PAPs) during baking procedures.

The German Bundesamt für Risikobewertung (BfR) in Berlin publishes recommendations for Food contact materials. Recommendation XXXVI/2 applies to paper and paperboard that comes into contact with or affects foodstuffs during baking. According to that recommendation paper and paperboard must withstand a temperature of at least 220 °C for the intended period of heating without decomposing. In reaction to the above mentioned findings the BfR changed their recommendation with respect to PAPs in 2011. Thus, the use of PAPs is no further recommended in paper and board products intended to come in contact with food during baking. The recommendation XXXVI/2 is not legally binding, but the listing of a chemical in this document labels it as safe in the said application. Therefore, there is no direct legal impact; however, the removal of PAPs from the list may have an impact on the frequency of application of PAPs in baking procedures.

PERFOOD also investigated the interaction of PTFE based food contact materials with food items. In this type of application PFOA was formerly used as emulsifier, but PFOA was gradually replaced by polyfluorinated compounds with ether moieties which prevent a degradation into perfluorinated carboxylates with chain lengths higher than C3 (e.g. ADONA). However, findings of PERFOOD indicated unequivocally the release of perfluorinated carboxylates from the PTFE coated pans in overheating experiments. In these experiments empty pans were put on the cooking stove for 30 minutes. The pans reached temperatures between 260 and 350 °C and emitted up to 4000 ng of PFCA (sum of PFCA congeners from PFBA to PFDoA). Whereas this study shows only a potential for an impact on PFAA levels in food, further cooking experiments with PTFE coated baking aids and pans highlighted an increase of PFAS levels in prepared foods. The mechanism of the production of PFCA in such application is still under investigation; however, PERFOOD results have put the safety of PTFE cookware on the scientific agenda again. In relation to TDIs of 150 and 1500 ng/kg b.w. and day for PFOS and PFOA, there is no risk resulting from the application of PTFE cookware. However, the experimental results may explain slightly increased levels in food items which contain only very small amount of PFAA in their raw state.

Perfluororinated alkylated substances are ubiquitously distributed. Therefore, in the PERFOOD project, the study of the occurrence of PFAS has been focused, especially on pathways that end up in human exposure. As a prerequisite to develop risk management considerations, a risk assessment has been performed which was focused primarily on the general populations, but as a second step scenarios have been evaluated to identify possible particular situations leading to health risks requiring subsequent risk
management. This includes an evaluation of the toxicological properties characterizing the hazards and the resp. dose (NOAEL) of the substances and a comparison with exposure doses.

At the moment, there is only limited toxicological information. The European Food Safety Agency has established a TDI level of 150 ng/kg for PFOS and 1500 ng/kg for PFOA, the two most prominent representatives of the PFAS. Conflicting results have been reported regarding to PFOA and PFOS blood concentrations and a variety of biochemical markers like triglycerides and cholesterol. Correlations of endocrine effects and PFOA / PFOS exposures have been reported but these data did not find way into risk assessment.

Despite the wide range of the dietary exposure estimates resulting from PERFOOD, the calculated exposures do not show exceeding of the TDIs, with the exception of hotspot areas. Therefore, some particular risk management measures are needed that may focus on hot spots.

At the moment, the exposure assessment taking into consideration general tendencies in concentrations and consumption does not indicate any health risk in humans. EFSA estimated blood concentrations of about 12 ng/ml to be corresponding to an external dose of 4 ng/kg per day. Consequently, the dose of 0.4 ng/kg per day estimated in the PERFOOD assessment would correspond to concentrations of about 1 ng/ml, which are slightly below the critical concentrations reported in epidemiologic studies, but certainly warrant to be given more attention. The findings should be also considered in the current process of evaluation of PFAS in the REACH regulation. Environmental concentrations of PFAS should be reduced as soon as possible. The toxicological profiles of other PFAS should be established on the basis of epidemiologic data.

During the PERFOOD project, several dissemination activities took place. Two International workshops were organised:

Anthropogenic Perfluorinated Compounds, 15-17 June 2011, Amsterdam, the Netherlands
Per- and polyfluorinated substances, 7-9 November 2012 in Idstein, Germany.

Besides publications in peer reviewed journals and congress presentations, also communication to the general public took place, like:

- press release, (e.g. Persisting perfluorinated compounds, Pim de Voogt, ResearchMedia Bristol)
- TV coverage / report, (e.g. Clip on migration of PFAA into Butter and Emission of PFAA from PTFE coated pans. Martin Schlummer, Solis TV for West Deutscher Rundfunk WDR)
- radio coverage (e.g. Pollutants in Food; interview Dorte Herzke, Tromso¸, Norway)
- brochures / posters / flyers (e.g. workshops)
- Coverage in specialist press
- coverage in general (non-specialist) press (e.g. Miljoand gifter i dricksvatten - ett dolt problem for manga kommuner? Urs Berger, Stockholm Sweden)
- coverage in national press (e.g. Mademballage af papir og pap er fyldt med miljo,gift, Pim de Voogt, Danish Press articles Ingenia,ren)
- websites for the general public (e.g. three PERFOOD newsletters were made and published on the...
PERFOOD website)
- events targeting general public (e.g. events targeting food safety officers (e.g. Italian veterinary services) about the implementation of PFAS residues monitoring plans, within scheduled training and teaching activities. Events targeting university students at national / European level about the intake assessment of PFAS residues, within scheduled training and teaching activities, Gianfranco Brambilla, Italy)
- invited lectures and key notes (e.g. Emerging water contaminant, Pim de Voogt, Nicoya, Costa Rica)

An overview of the PERFOOD dissemination activities is shown below.

Use and dissemination of foreground

Dissemination

The consortium has defined clear deliverables and their level of dissemination. The internal rules of exploiting findings, concepts and technologies are put down in the consortium agreement. The chances of any discovery or development to be patentable were discussed and decided on the basis of the consortium agreement and in the plenary meetings. The non public partners took the lead in recognising commercial dissemination plans and articulating them for the whole consortium. For other protocols, tools, or models developed during the PERFOOD project, which in the end may appear to have no direct market potential, the concepts and the deliverables are communicated to potential end users and will become public domain. Dissemination activities on the scientific level involve the production of scientific peer-reviewed manuscripts, conference presentations, book chapters, and PhD dissertations, which were of critical necessity for all research and higher education partners. This was basically the responsibility of each partner or ideally partner group. Plans for scientific manuscripts were circulated among the consortium and confidentiality items defined in a premature state so as not to conflict with potential commercial exploitation later on. More popular presentation of the PERFOOD project work occurred through press releases, radio and TV interviews, popular articles, and public seminars or on the Internet. Important dissemination activities in the later phase of PERFOOD are taken form of dissemination workshops for stakeholders. The target audience of the workshop was governmental or private food analysis laboratories, food processing and packaging industries, consultants, governmental agencies and NGOs. Tutors and lecturers in the workshop were the partners of the consortium.

PERFOOD organised knowledge transfer / training workshops back-to-back with its progress meetings and stakeholder meetings (see WP8). The workshops principally target consortium partners, but were also open to students and employees of the host institute, thus providing professional training / education of future work potential. The objective of the stakeholder and training workshops was to promote practical applications of novel strategies and approaches in the analysis of PFCs in food and water, and transfer existing and emerging knowledge to the scientific community and potential (end-)users, such as technical consultants, regulators, policy makers, problem owners, and the public.

The PERFOOD project has initiated a worldwide inter-laboratory study to assess the variability of different analytical techniques dedicated to food samples. The study is also open for laboratories outside the consortium in order to assess the world-wide quality of PFC data produced. The project also provided certified reference materials that will enhance the data quality and comparability of the food and nutrition
analysis community. The website of the project consortium will post method protocols developed during the several work packages (WPs, notably WP1 and 2) thus providing up to date methodologies for the global food and nutrition analysis community.

The consortium has sought active participation of food processing and food packaging industries by offering an associated membership opportunity to such stakeholders. Membership benefits are defined with the stakeholders on the basis of win/win partnership and included mutual exchange of information, materials (samples, standards), and knowledge.

Links with other projects

The activities conducted within the PERFOOD project obviously bear relevance to ongoing activities within the European Union (EU) Framework Programs as well as with several ongoing national and international activities. PERFOOD has sought active participation in ongoing projects and invite other projects to dissemination activities of PERFOOD. PERFOOD has established active links with the following EU projects or activities:

CONFFIDENCE is a project recently approved in the Seventh Framework Programme (FP7) Theme Food, Agriculture and Fisheries. The project is about detection methods in food: contaminants in food and feed: inexpensive detection for control of exposure, coordinated by RIKILT in the Netherlands (contact Dr Jacob de Jong). Partner UvA will establish contacts with this project.

Partner FI-IME has been involved in the recently finished German national study on Untersuchungen zum bergangaus PFT-belasteten Boden in Pflanzen. Partner FI will also contact a recent project on PFOS transfer from feed to cow started by the German state ministry of Nordrhein-Westfalen.

PERFOOD has actively participated in activities of European networks of excellence, such as SAFEFOODERA, and the Network of reference laboratories for monitoring emerging environmental pollutants (NORMAN, see http://www.norman-network.net for details). Partners VU and KWR are actively involved in NORMAN and will act as a link to this network. Data from PERFOOD surveys will be input in the NORMAN network database.

Partner NILU and UvA participate in a cooperation between China and Norway (PFC-CHINO) in which data on occurrence of PFAS in environmental and dietary samples are being collected and analysed. The PERFOOD project has been formally invited to participate in this project. Data on PFAS in food generated by PERFOOD have been formatted in a way compatible with existing EFSA database requirement. The results of surveys 1 and 2 have been submitted to the EFSA database on PFAS in dietary items. All partners have actively linked with other ongoing national and international (e.g. OECD) activities related to PFAS in food and drinking water.

Project website: http://www.perfood.eu/
Related documents

140180071-8_en.zip

Last update: 29 April 2013
Record number: 55843