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Study on polychlorobiphenyl serum levels in French consumers of freshwater fish

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HIGHLIGHTS

- French consumption of freshwater fish was relatively infrequent.
- People most at risk, eating PCB-BP$^+$ fish, represented 13% of the study population.
- Serum PCB level predictors in French angler population were investigated.
- Main predictors of serum PCB level: age and consumption of PCB-BP+ freshwater fish
- Recommendations for safe consumption of freshwater fish were proposed.

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ABSTRACT

Introduction: Polychlorobiphenyls (PCBs) are persistent pollutants that are widespread in the environment and in foodstuffs, particularly in freshwater fish, which frequently exceed the maximum levels set by European regulations.
Objectives: First, we describe the consumption of freshwater fish and serum PCB levels in French anglers, a population expected to have the highest level of dietary PCB exposure. Second, we investigated whether there is a statistical relationship between serum PCB levels and the angler consumption of freshwater fish with high PCB bioaccumulation potential (PCB-BP$^+$ freshwater fish) in order to make recommendations with regard to safe consumption of freshwater fish.
Methods: We conducted a survey of anglers from six sites with contrasting PCB contamination levels. The survey included a food consumption frequency questionnaire and blood samples were taken to assess serum PCB levels. We used a regression model to determine the main factors contributing to serum PCB levels.
Results: Consumption of PCB-BP$^+$ freshwater fish was relatively infrequent. Serum PCB levels of the study population and of women of childbearing age were in the same range as those observed in the French population and in neighbouring European countries, but higher than in the North American population.
The two factors with the highest positive association with serum PCB levels were age ($R^2 = 61\%$) and the consumption of PCB-BP$^+$ freshwater fish ($R^2 = 2\%$). Using the regression model, we calculated, for several scenarios depending on the age and gender of the population, the maximum annual frequencies for PCB-BP$^+$ freshwater fish consumption that do not exceed the critical body burden threshold.
Conclusion: Following the results of this study, the French agency for food, environmental and occupational health and safety (ANSES) issued an opinion and recommended some specific maximum freshwater fish consumption frequencies to protect the French general population.

Abbreviations: AFSSA, French agency for food safety; AIC, Akaike information criterion; ANSES, French Agency for Food, Environmental and Occupational Health & Safety; BMI, Body mass index; DHA, Docosahexaenoic acid; DL-PCBs, Dioxin-like PCBs; EPA, Eicosapentaenoic acid; FNPF, *Fédération Nationale de la pêche en France*; GL, Great Lakes; ICAR-PCB, Name of the study on polychlorobiphenyl serum levels in French consumers of freshwater fish; INCA2, Name of the French Individual and National Food Consumption Survey; InVS, French Institute for Public Health Surveillance; LOQ, Limit of quantification; NDL-PCBs, Non-dioxin-like PCBs; PCBs, Polychlorobiphenyls; PCB-BP$^+$ freshwater fish, Freshwater fish species with high bioaccumulation potential; PCB-BP$^-$ freshwater fish, Freshwater fish species with low bioaccumulation potential; PCDD/Fs, Dioxins and furans; R^2, Coefficient of determination; US, United States of America.

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1. Introduction

Polychlorobiphenyls (PCBs) are persistent contaminants that bioaccumulate in the environment. PCBs, associated with a wide range of health effects, banned in France in 1987. Due to past uses, these lipophilic substances are still widespread in the environment and in foodstuffs. In the general population, diet represents 90% of PCB exposure, with fish being a major source of PCB exposure (Arnich et al., 2009). In December 2006, the European Commission set maximum levels for certain contaminants in foodstuffs, in particular for dioxins (PCDD/Fs) and dioxin-like PCBs (DL-PCBs) in marketed fish (Regulation (EC) no., 1881/2006). The primary aim of these regulatory limits is to eliminate the most contaminated fish from the market. This regulation was updated in December 2011 and non-dioxin-like PCBs (NDL-PCBs) were also included (Commission Regulation (EU) No, 1259/2011 of 2 December 2011). In France, freshwater fish exceeding these maximum regulatory levels have been found in several rivers. Surveillance plans have distinguished two types of freshwater fish: freshwater fish species with high bioaccumulation potential (PCB-BP$^+$ freshwater fish) (i.e., eel (*Anguilla anguilla*), barbel (*Barbus barbus*), bream (*Abramis brama*), carp (*Cyprinus carpio*), wels catfish (*Silurus glanis*) and roach (*Rutilus rutilus*) (AFSSA, 2009b) as opposed to other freshwater fish species that are less likely to accumulate PCBs (PCB-BP$^-$ freshwater fish) (bleak (*Alburnus alburnus*), gudgeon (*Gobio gobio*), pike (*Esox lucius*), largemouth black bass (*Micropterus salmoides*), crucian carp (*Carassius carassius*), chub (*Leuciscus cephalus*), common nase (*Chondrostoma nasus*), European perch (*Perca fluviatilis*), black bullhead (*Ameiurus melas*), pike-perch (*Sander lucioperca*), tench (*Tinca tinca*), rainbow trout (*Oncorhynchus mykiss*), dace (*Leuciscus leuciscus*) and minnow (*Phoxinus phoxinus*)). Furthermore, consumption of freshwater fish may increase blood PCB levels. For example, American studies in the Great Lakes area (GL), particularly affected by PCB pollution, have highlighted higher blood PCB levels in freshwater fish consumers (Turyk et al., 2006).

In 2008, the French Ministry of Health requested that the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) and the French Institute for Public Health Surveillance (InVS) set up a national study (ICAR-PCB study) to investigate whether there is a statistical relationship between serum Polychlorobiphenyl levels and the consumption of PCB-BP$^+$ freshwater.

Regarding the benefits and risks of fish consumption, the French Food Safety Agency issued an opinion (AFSSA, 2010b) and recommended that, as part of a balanced diet, the general population should consume two servings of fish per week, one of which should be high in EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), and from different species and sources (wild, farmed, fishing location, etc.). However, the recommendations regarding the consumption of freshwater fish were not as specific as those of marine fish. AFSSA recommended that women of childbearing age, pregnant and breastfeeding women, children under the age of 3, young girls and adolescent girls avoid, as a precautionary measure, the consumption of so-called PCB-bioaccumulating freshwater fish, particularly eel, barbel, bream, carp and wels catfish.

Freshwater fish, except certain species such as trout, are not as frequently sold on the commercial market as marine fish. It has been suggested that the most-exposed population is anglers who consume fish caught in contaminated areas. The ICAR-PCB study therefore focused on anglers and members of their households.

In this article, we first describe the selection of participants, their demographic characteristics, their consumption of freshwater fish and their serum PCB levels. Second we present a regression model to establish a statistical association between the consumption of PCB-BP$^+$ freshwater fish and serum PCB levels, and then, based on this relationship, we third suggest maximum consumption frequencies for these fish, i.e., frequencies at which there is no long-term risk of exceeding the critical body burden threshold, as derived from epidemiological studies (AFSSA, 2010a).

2. Materials and methods

2.1. Study participants

The ICAR-PCB study was carried out between April 2009 and May 2010. The target population was anglers and their families, a large population in France with roughly 1.5 million members of the French Angler Association (FNPF, *Fédération Nationale de la Pêche en France*) (FNPF, 2009). A national database did not exist at the beginning of the study, so we chose to recruit the individuals on six sites having a sharp contrast in river PCB contamination levels (sediment and fish media) and a specific database of individuals was created for the study, collecting information from these six sites only. We selected six sites representing 23 river sections (Fig. 1) and a total of 900 km of river. We assumed to include, based on sediment contamination, two rivers with high levels of PCBs (Seine and Somme Rivers), two rivers with medium levels (Rhone and the Rhine-Moselle river system) and two rivers with low levels (Loire and Garonne Rivers) (Fig. 4 in supplementary material). The data on fish PCB contamination collected during the same period of this study confirmed this preliminary classification and thereby helped define areas of similar contamination level, as described in statistical method part (Anses, 2012, 2013a,b,c,d,e).

Not all freshwater fish species have the same ability to bioaccumulate PCBs. PCB bioaccumulation depends on the species life history and/or diet, and, in particular, whether they feed on sediments and individual age. We assumed that the consumption of PCB-BP$^+$ species was an important contributor to human dietary PCB exposure in the study population. For this reason, consumers and non-consumers of these fish made up the study sample. Given the small number of consumers identified in our survey, we considered as a consumer a person eating PCB-BP$^+$ freshwater fish more than twice per year.

The final survey database was constituted by 21,180 households composed of individuals being between 18 and 75 years old, living in one of the six study sites (current residence) and holding a fishing license. A complex sampling design, which has been described elsewhere (Anses/InVS, 2011), was used to obtain a representative sample of anglers on the study sites. In few words, the study population was selected through a two-stage sampling design: the angler households and members from these households. The data were also weighted for unequal sampling probabilities as over-representation of the 18-to-44 year-old age class in non-consumer angler households, and for differential non-response. Finally, response rate was 44%, which is satisfactory for this kind of study. The participants were 606 anglers or members of their families, representing 21,180 angler households. The step-by-step selection of participants was detailed in supplementary material (Figs. 5 and 6).

2.2. Data collection

Anglers were interviewed by phone and asked to describe their consumption of PCB-BP$^+$ freshwater fish. They also described the consumption of these fish for all members of the household (between 18 and 75 years old). This step identified the households of interest and eligible individuals. Sampled people (consumers and non-consumers) were then interviewed in their home to obtain data on their anthropometric and demographic characteristics such as age, gender, body mass index (BMI), socio-economic status, among others. They also detailed their consumption of specific freshwater fish (PCB-BP$^+$ freshwater fish; PCB-BP$^-$ freshwater fish) and their consumption of specific seafood (sea bass, cod, sea bream, mackerel, whiting, sardine, salmon, tuna, anchovy, herring, pilchard, crab, velvet swimming crab and scallop). Lastly, anglers or household members reported their general dietary habits, covering the potential predictors of serum PCB levels, presented below. Data were collected with a food frequency questionnaire of 90 food items based on the questionnaire used in the FLVS study (Lafay et al., 1997). These 90 items included potential predictors