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Seventh International PCB Workshop: Chemical Mixtures in a Complex World

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The 7th International PCB Workshop was held in Arcachon, France in June 2012. France was a major producer of polychlorinated biphenyls (PCBs, about 10% of the world production in the 1970's) and remains a country with significant PCB exposure in the general population. Therefore the question of risk assessment and management is a subject of major interest for national health authorities, as evident in recent efforts in PCB risk assessment involving large scale monitoring programs in environmental compartments (aquatic and terrestrial), in foods (TDS) and humans (general population and fish consumers). Therefore the meeting began with an overview of French PCB history as an introduction to the topic.

Opening seminar: 25 years of PCB risk assessment in France

The scientific story began in the early 1970's when the first analysis for PCBs was carried out by R. Mestres in Montpellier. His analytical technique was then employed by J.L. Monod in Marseille on environmental samples taken on an international oceanographic cruise (of particular interest was the contamination of penguins in Kerguelen Islands). In 1972 the French Ministry of Environment was established and in that same year initiated a research network, entitled “contamination of the food chain” with emphasis on heavy metals, organochlorine pesticides and PCBs. The official position was that PCBs have only low toxicity to man which was supported by several decades of experience in industry. In 1974 a first crisis occurred related to contamination of soft cheese and this event showed the differing views and priorities between the scientific and the regulatory agencies in France. In 1975 the use of PCBs was limited to closed and controlled equipment. A number of analyses in environmental compartments began, especially in the aquatic ecosystem, both marine and freshwater. At the end of the seventies a national monitoring network, RNO, was established and analysis for PCBs was included in the coastal pollution survey. Since 1987 federal regulation ended the industrial uses of PCBs in new equipment. In 1988 a high level of contamination was found in Rhône river fish and the Public Health Council (CSHPF) was requested to establish limits. A first TDI (total daily intake limit) of 5 μg/kg/day and a tolerance level in fish of 2 ppm were established. However, due to a dioxin problem at the end of the eighties, the emphasis shifted towards dioxin like (DL) PCBs. In 1998 a TEF (Toxicity Equivalency Factor) was set for the DL-PCBs, the TDI and the tolerance limits were established for dioxins + DL-PCBs, and the monitoring programs were focused on DL-compounds. During the next decade some changes in Toxic Equivalence (TEQ) levels occurred because of modifications in TEF values. In 2002 a common EU TDI was established and the limits in foods were edited in 2006 to reflect these changes. However, in 2003 the French national food safety agency, AFSSA, proposed an approach for PCB risk evaluation and management based on indicator PCBs (PCB-i) and then determined 6 NDL-PCBs (non-dioxin-like PCBs) as indicators. A TDI of 10 ng/kg/d was determined in 2003 and maximum limits in foods were established in 2006. Very recently (April 2012) the EU adopted maximum levels in foods based on the 6 NDL-PCBs. Related to the Human Monitoring programs, the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) set biological reference values based on blood levels (700 ng/g lipid for women under 45 years and 1800 ng/g lipid for the general adult population). Finally, in 2008 a National Action Plan on PCB was initiated in order to improve the different environmental, sanitary and technical problems of PCB contamination. It is now clear that the main challenge is the risk evaluation for complex mixtures. A need is to develop a concept for establishing toxicological reference values that combines the different approaches of (1) individual TDIs for each congener, (2) toxicity of mixtures “like” occurring profiles, (3) bioassays testing, and others. The work on PCB risk assessment and management is far from over.

Session 1: Origin, analysis, levels in environmental compartments

The first session of the 7th PCB Workshop, entitled “Origin, analysis, levels in environment compartments” was chaired by K. Hornbuckle and B. Lebizec. The topic of this session was the identification and quantification of current sources of PCBs, levels in the atmosphere, soil and water, and transfer in the food web. Contaminated food consumption has historically been the major contributor to PCB body burden. Recently the atmospheric source of PCB exposure was pointed out and characterized, especially in urban environments. Temporal and spatial trends of PCB concentrations in vapor phase at five United States Integrated Atmospheric Deposition Network (IADN) sites located in the Great Lakes basin suggest a strong urban atmospheric source of these pollutants. Additional field studies of airborne PCB congeners in urban and rural environments have found evidence for localized sources: emissions from contaminated sediments; the presence of PCBs in current commercial house paint; and emission of PCBs from contaminated indoor air ventilation. PCB concentrations generally showed a slow rate of decline corresponding to environmental half lives of 17 years. OH-PCBs, the primary metabolites produced by different organisms (bacteria, plants and animals), have been detected in the environment and are considered as a new class of environmental contaminants. Overall there is strong evidence that air is an important route of exposure, but many questions remain. Among these are the challenges of quantifying this route of human exposure and in assessing the risk of airborne PCB exposure to human health.

Session 2: Mechanism of Action and Metabolite Interactions

The second session, chaired by M. Duffel and J.-P. Cravedi, recognized that many important recent discoveries have shed new light on the toxicology of PCBs, and that PCB congeners with fewer chlorines are generally more susceptible to biotransformation. Possible metabolites include arene oxides, phenols, dihydrodiols, catechols, hydroquinones, quinones, conjugates ranging from glucuronides, sulfates, and methoxycatechols to glutathione adducts, mercapturic acids, and other metabolic products derived from glutathione conjugates. These reactions are often highly dependent upon the structure of the PCB congener. Knowledge of the specific toxicities of the metabolites is important in understanding health effects. For example, genotoxic and carcinogenic effects including point mutations and pre-neoplastic foci in the rat have recently been identified for lower chlorinated PCB congeners and related oxygenated metabolites. New findings showing the ability of PCBs to shorten the length of telomeres and to reduce the activity of telomerase point towards a yet unexplored possible pathway to organ damage. The observation that hydroxylated PCBs (OH-PCBs) are able to interact as substrates and inhibitors with family 2 sulfotransferases, enzymes important in metabolism of alcohol-containing steroids and bile acids as well as many xenobiotic alcohols, points towards a new pathway of endocrine disruption. OH-PCBs and PCB-sulfates, can also bind with high affinity to the thyroid hormone transport protein transthyretin (TTR). Examination of brominated aromatic hydrocarbons, particularly polybrominated diphenyl ethers (PBDEs), show similar biotransformation pathways as PCBs which may result in toxic effects already described for PCBs e.g.: DNA damage and endocrine disrupting activities through binding to transthyretin and estrogen receptors and inhibition of estradiol sulfotransferase. Moreover, not only tetrabromobisphenol A, but unexpectedly also its sulfated metabolite were noted as agonists of the PPAR gamma receptor. It was also observed that the nutritional context including dietary lipids and plant derived polyphenols can change the biological effects of PCBs. These concepts were examined in detail in studies on caveolae, lipid invaginations in the plasma membrane, and their role in endothelial changes caused by exposure to co-planar PCBs. Thus the toxicological effects of PCBs and related compounds are not only caused by parent compounds, their metabolites, and the combined effects of these compounds, but also influenced by other environmental factors, together forming the real chemical mixture present at the molecular level in the cells and organs. For such reasons the Seventh PCB Workshop was then entitled “Chemical Mixtures in a Complex World”.

Session 3: Health Effects/Critical Limits

The third session, entitled Health effects/critical limits was chaired by J.-F. Narbonne and I. Pessah. Researchers and experts have endeavored to identify and quantify the risk associated with these chemical mixtures. More than 25 years in fundamental and applied research on PCB mixtures will provide a perfect example in the progress in risk-based methodologies for assessing health impairments from chemical mixtures. At the beginning of the story, risk assessment was based on classical NOEL/LOEL observed in experimental animals treated with commercial mixtures i.e. Aroclors, Phenoclor, Kaneclor… where the mixtures were considered equivalent to a single compound. Later the risk evaluation was based on relative potency factors with response addition of specific congeners representing similar mode of action. The principle mode of toxic action of dioxin-like PCBs is the activation of aryl hydrocarbon receptor (AhR). During recent years, significant progress has been made in the analysis of the toxic impact of AhR ligands, including identification of novel genes and mechanisms related to developmental toxicity and tumor promotion/progression, and consequently in 2005 a revision was made to TEF values for some PCB congeners. This approach evolved to include multiple receptor targets that contribute to PCB toxicity in different organ systems (e.g., hepatic *vs.* brain *vs.* endocrine) and are quantified using multiple distinct end points. The relative effective potency (REP) potencies of ultrapure NDL-PCB congeners were estimated by means of *in vitro* bioassays covering major known endocrine-disrupting effects, inhibition of gap junction intercellular communication and neurotoxic mechanisms. This set of REPs was then used for assessment of contribution of individual PCB congeners to overall toxic potencies of complex PCB mixtures found in general human populations. The most abundant PCBs 138, 153, 170, 180, and also PCB 118, contributed most significantly to calculated anti-androgenic or gap junction intercellular communication - inhibitory potencies of mixtures. It was also observed *in vitro* that PCB 153 can modulate further cell functions associated with altered intracellular signaling and disrupted tissue homeostasis, including suppression of membrane proteins caveolin-1, E-cadherin, beta-catenin and plakoglobin, modulation of lipid signaling molecules and increased redox signaling. Moreover some less abundant congeners, such as PCB 95, 101 and 136 may contribute to neurotoxicity of PCB mixtures, and these congeners have been recently shown to predominate in schools with legacy sources. The specific studies on neurotoxicity of NDL-PCBs indicated that hexa- and heptachlorobiphenyls were also able to alter basal and depolarization-evoked $[Ca^{2+}]_i$, but that tri-, tetra-, and pentachlorinated (e.g., PCB 95) NDL-PCBs were the most potent. Hydroxylated PCBs produced more complex effects on depolarization-evoked calcium signals and resemble responses to those reported for hydroxylated polybrominated diphenyl ethers (OH-PBDEs) and tetrabromobisphenol-A. On the other hand, NDL-PCBs are also capable of reducing neurotransmission by inhibiting VGCCs and $\alpha_4\beta_2$ nACh-receptors as well as by activation and potentiation of $GABA_A$ receptors. These new modes of action can contribute to the NDL-PCB-induced neurobehavioral and neurodevelopmental effects observed *in vivo*. Moreover, sexually dimorphic effects of PCBs on neurodegeneration process were suspected. Results on markers of neurological disorders (myelin basic protein, density of dopamine transporters, Bax and Bcl-2 for apoptosis) suggest that reproductively senescent women may be at greater risk for contaminant-induced reductions in basal ganglia DA function, including PD, than comparably exposed men.

Finally NDL-PCBs alter cellular signaling and contribute to developmental neurotoxicity. PCBs alter activity dependent dendritic growth and complexity both *in vitro* and *in vivo* implicating a ryanodine receptor dependent mechanism for PCB developmental neurotoxicity that alters the CaM kinase II – CREB-Wnt2 signaling pathway. Mice expressing mutations in ryanodine receptor type 1 show significantly increased susceptibility of primary myotubes (embryonic muscle cells) to Ca^{2+} dysregulation and contractility to very low-level PCB exposures. Both *in vitro* and *in vivo* investigations on the neurotoxic effects of low doses of NDL PCB mixtures, with a particular focus on early stages of development, indicated that one of the primary targets promoting dysregulation appears to involve ryanodine receptor mediated impairment in Ca^{2+} dynamics. Finally providing mechanistic information on PCB congeners will be useful to setting biological limits for critical health effects for general and at risk (susceptible) populations.

Session 4: Human Exposure and Human Biomonitoring

The fourth session, chaired by N. Fréry and J-C Leblanc, presented a summary of monitoring programs on dioxins and PCBs. **Dietary exposure assessments** were carried out with food monitoring programs in 26 European countries between 1995 and 2010. Consumption data of 53,728 individuals covering 17 European countries and 7 age groups extracted from the EFSA Comprehensive European Food Consumption Database were considered. The current exposure level to dioxins and DL-PCBs in the European population was estimated to be on average between 0.57 and 2.54 pg TEQ_{WHO05}/kg b.w. per day and the current exposure level to NDL-PCBs was estimated to be on average between 4.3 and 25.7 ng/kg b.w. per day. The most exposed population groups (when expressing the intake on a body weight basis) are **toddlers and other children** (<10 years old). The percentage of individuals exposed above the TDI was estimated to be between 1.0 and 52.9% depending on the country and age group. Fish and other seafood, meat and milk products appeared to be the highest contributing food groups; their relative importance depending on the country and age group. A general decrease in the exposure levels to dioxins and DL-PCBs of 16.6% to 79.3% was observed between 2002–2004 and 2008–2010. The decrease seems to be less for the NDL-PCBs, which needs further investigation.

The AESOP Study is examining congener-specific exposures to PCBs among an urban cohort of children and their mothers in East Chicago, Indiana, an area contaminated with industrial pollutants, including PCBs. These exposures are being compared to a rural cohort without recognized industrial sources of PCBs (Columbus Junction, Iowa). The combination of multiyear annual blood samples and concurrent air samples at subjects' homes and schools, both indoors and outdoors, along with detailed questionnaire data, provide a unique study from which to determine the contribution of inhalation exposure to the body burden of PCBs. Dredging of the Indiana Harbor and Ship Canal began in late 2012 and will place 3.5 million cubic meters of PCB-laden sediment in a disposal facility within the East Chicago community. The AESOP study shows that indoor levels of PCBs contribute more to the body burden than outdoor levels in both communities. Blood samples collected in the first two years demonstrate congener profiles indicative of exposure to the more-volatile lower molecular weight congeners than most prior studies. Mothers exhibit higher levels of serum PCBs than their children with a profile skewed toward more chlorinated congeners. This suggests that inhalation exposures represent an important PCB exposure pathway and are especially important for children. So, if the focus has been on food exposure, it seems relevant today to study airborne exposure to PCBs, an important source largely ignored until now.

Since 1987, levels of PCBs and PCDD/Fs in **human milk** were determined in WHO-coordinated exposure studies as suitable indicators for the bioaccumulation of POPs and for evaluation of the effectiveness (Art.16) of the Stockholm Convention by UNEP. Samples from more than 60 countries were submitted for the jointly organized WHO/UNEP studies. A decrease observed in food is in accordance with the one observed in human milk. Samples collected between 2001 and 2011 show a wide difference of **dioxin and PCB levels among countries** (range of individual pools: 2–50 pg WHO-PCDD/F(1998)-TEQ/g fat; 1–30 pg WHO-PCB(1998)-TEQ/g fat; 4–1000 ng/g fat for NDL-PCBs), with the highest levels

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observed in Europe (Czech Republic) for NDL-PCBs. Low or middle levels of PCDD/Fs and PCBs are mostly observed in Australia and Pacific Islands (such as in Fiji), Asia (except for India with high levels of dioxins) and in Caribbean, Central and South American countries. In Africa, the contamination with dioxins is characterized by two extremes: i) Some countries are in the group with the lowest dioxin levels in breast milk and ii) some cases show highest levels. The highest levels might have two reasons: i) in one country, dioxin emissions and production of food are quite close together in a densely populated country and ii) in two other countries, related to contaminated clay ingestion (geophagy; dioxin-contaminated clays assumed to be formed by geological processes over time). It seems relevant to study PCB levels in new countries being parties to the Stockholm Convention. With regard to the situation in European countries being in the middle and upper third with regard to PCDD/F and in particular PCBs, follow-up is recommended.

In France, a national human biomonitoring (HBM) survey on serum NDL-PCB biomarkers in adults (18–74 yrs) was recently performed by InVS. Besides from the general population, blood PCBs levels were also obtained from specific populations, like those living around incinerators or having regular freshwater fish consumption habits from rivers still environmentally contaminated. Mean levels for total PCBs were 479 ng/g of lipids in general population and 353 ng/g of lipids in women of childbearing age. With regard to PCBs the predominance of mid-chlorinated congeners was observed due to the presence of PCBs with high Kow such as PCB 153, 138, and 180. The decrease at international level was also seen at national level, in particularly in France where serum NDL-PCB levels were divided by three in 20 years (1986–2006/07) and breast milk dioxin levels were decreased by 40% in 10 years (1998–2007). The French NDL-PCB levels remain relatively higher than those of other countries, except Czech Republic or Slovakia. The French results underline the importance of individual characteristics on PCB levels, such as age and recent loss of weight. When the NDL-PCB levels were studied in general or specific populations, such as in people living in the vicinity of incinerators or in anglers, no big difference was observed among populations, except for anglers who are high consumers of fish which accumulate PCBs.

In Lebanon, a protocol for HBM survey on PCBs in milk and blood was recently presented from the University Saint Joseph (Beirut) for discussion and coordination with international programs.

Session 5: Special problems of PCBs in African countries; A shift of sources of PCBs?

A fifth session on PCBs in Africa, chaired by R. Gioia and A. Sasco, presented indications of a continuing shift in primary emission sources of PCBs to the countries of the South, including Africa. This is supported by air, milk and fish concentrations data of PCBs in Africa which clearly show an increase of PCBs during the last 5–10 years, suggesting potential health risks especially for the newborns. There is a growing of potential PCB sources in Africa, including transformers, continuing import of e-waste from countries of the North, shipwreck and biomass burning. The potential for detrimental effects on environmental and human health due to long range transport of PCBs by air, water and waste or by any other means should be of equal concern when managing POP-like chemicals. Further efforts are needed to mitigate export of obsolete products and waste from the countries of the North to the countries of the South as well as sound waste management and solution for elimination and remediation of PCBs from the environment.

It may be pointed out that national monitoring programs were initiated in African countries. In Tunisia PCBs were measured in surface sediments of Bizerte lagoon collected from 18 sampling sites, chosen on the basis of their environmental features and probable pollution sources. PCB 18, 138 and 153 were the prominent congeners accounting for 61 to 95% of the total PCBs. The highest levels of PCBs were found near the commercial harbor of Bizerte. Compared with other countries in the world, the concentrations of PCBs in the surface sediment of the Bizerte lagoon is low to moderate.

A HBM survey was performed in northern Tunisia from around Bizerte on 113 serum samples collected between 2011 and 2012. The mean of the sum PCBs concentrations was 136 ng g^{-1} lipid. The PCB profile consisted of persistent congeners, such as PCB138, PCB-153 and PCB-180 which contributed for approximately 83% to the total PCBs. PCBs levels were significantly higher in males than in females. Given the existence of a positive correlation between fish consumption and Tunisian body burdens, PCBs levels were determined in two fish species among its edible marine species (mullet and sea bass) collected from Bizerte Lagoon and the Mediterranean Sea. Concentrations of PCBs detected in mullet were 2.5 higher than in Sea bass. Fish sampled in the Mediterranean ocean were generally comparable to those found in studies from other Mediterranean regions. PCB levels in fish sampled in Bizerte Lagoon were 2.5 higher than those collected in Mediterranean Sea.

Results of the first study performed in the Niger River aimed to evaluate the level of PCB contamination of three fish species collected during the spring 2011. The total concentration of PCBs was the highest in *Tilapia nilotica*, followed in descending order by *Clarias anguillaris* and *Lates niloticus*. Among the 7 PCB congeners determined, PCBs 153 and 180, were the main compounds in the three species.

Session 6: Risk issues

The last formal session of the Workshop, chaired by D. Osterberg and P.-M. Badot, dealt with the challenging issue of risk and public policy. The first aspect in Risk issues deals with technical aspects. PCBs were used in a wide variety of applications, some of which dissipative, some others comprising closed systems. As a first management step, an inventory of such equipment was prepared, e.g. of PCB contaminated transformers. Generally speaking, the use of chlorinated solvents is declining, and applications are in closed systems. When cleaning transformers some fugitive losses may occur, of both PCBs and (especially) the cleaning solvent. At present, the inventory of PCB transformers in Western Europe is basically on its way to depletion. This is not the case in less industrialized nations, e.g. a single steel company in Iran still has an inventory of ca. 200 PCB-containing transformers. Poor countries specializing in dismantling ships in the process import lots of problems, such as asbestos and PCBs. Based on the teachings of Western Europe, some managerial problems were analyzed, including plant licensing, the organization and issuance of transport and cleansing operations, internal and external controls, environmental and occupational health issues. Installing cleansing plant may involve enormous amounts of red tape and public opposition. Geniece Lehmann of the US EPA discussed non-Aroclor origins of PCBs. Contamination from electronic fluorescent ballasts and building materials have been identified in public school classrooms in the US. She discussed a lack of standards to evaluate airborne PCB levels and the difficulty in deciding what levels of contamination might pose a risk.

Another paper discussed PCB elimination. In Japan, a government corporation (JESCO) is using new chemical techniques to destroy PCBs in modern beautiful buildings designed to blend in with modern Japan and avoid the NIMBY (not in my backyard) problem. Since 1954, approximately 58,000 tons of PCBs were manufactured in Japan. 5,500 t of liquid PCB was completely destroyed by thermal decomposition with risk communication in 1980’s. The Special Measures Law Concerning the Promotion of Proper Treatment of PCB waste was enacted in Japan in 2001. PCB facilities in Japan use only chemical decomposition methods, such as “hydrothermal oxidation decomposition method”, “dechlorination method”. JESCO will establish five regional plants nationwide. Each facility is assigned by the government to treat PCB wastes of each region in Japan. The Ministry of Environment established “PCB Waste Collection and Transport Guideline” in 2004 and revised 2006. The Guideline specifies technical requirements to adhere to standards for transportation of PCB wastes, based on the Waste Management Law. While worker protection within the company seemed of a high standard, the transportation company bringing PCB contaminated materials to the plants did not have similar worker protection. The two standards of worker protection provide opportunities to monitor worker exposure. The organization PCBs Elimination Network (PEN) with its 700 members has made great improvement over the last four years in the knowledge of PCB elimination science.

Another paper in the session related to risk evaluation in occupational exposure conditions. Recent worker blood data gathered at the US National Institute of Occupational Safety and Health, demonstrated the decrease over time in PCB levels in the same workers in a US electrical capacitor factory. However, evidence has been accumulating that PCBs and their metabolites exert neurological or behavioral affects at low doses and therefore needs for PCB risk assessment and management through elucidating the state of environmental levels and human exposures to PCBs have grown ever larger. In Japan, OH-PCB levels were analyzed in urine samples of workers who worked in a PCB storage room. This technique was efficient for management of safety and health of workers in PCB treatment and transportation in comparison with conventional monitoring method of blood sampling.

Finally, Beatrice Sécrétan of the International Agency for Research on Cancer (IARC) described the IARC monograph process and the deadlines for researchers to become part of the new PCB panel being formed for early 2013 deliberations. Several participants at this conference were invited to Lyon to participate.

Conclusions

As anticipated by the organizing and scientific committees, the Arcachon PCB Workshop provided an opportunity for researchers of varied backgrounds and expertise to integrate their knowledge and experience, and to apply these to questions of the detection, movement, metabolism, toxicity, remediation and risk assessment for this class of industrial chemicals and environmental pollutants. It is apparent that considerable scientific support has been made available to elucidate mechanisms of action of specific congeners and metabolites. The special issue of ESPR is dedicated to very last advances in these fields. For additional information about the Seventh PCB Workshop speakers and titles, please see http://www.colloques-adera.fr/7th-PCB-Workshop/.

GLOSSARY OF TERMS

AFSSA /ANSES	National Food Safety Agency (Agence française de sécurité sanitaire de l'Alimentation puis Agence Nationale de Securite sanitaire de l'alimentation de l'environnement et du travail)
CSHPF	National Council of Hygiene (Conseil Superieur d'Hygiene Publique de France)
DL-PCBs	Dioxin – like PCBs
EFSA	European Food Safety Authority
HBM	Human biomonitoring
IADN	Integrated Atmospheric Deposition Network
IARC	International Agency for Research on Cancer
InVS	French Institute for Public Health (Institut national de Veille Sanitaire)
NDL – PCBs	Non-dioxin – like PCBs
OH-PCBs	Hydroxylated PCBs
PBDEs	Polybrominated diphenyl ethers
PCBs	Polychlorinated biphenyls
PEN	PCBs Elimination Network
RNO	National network for chemical monitoring along the French coasts (Réseau National d'Observation)
TDI	Total daily intake limit
TDS	Total diet study, methodology for food exposure evaluation
TEF	Toxicity Equivalency Factor
TEQ	Toxic Equivalence
TTR	Transthyretin

Biographies

Professor Jean-François Narbonne is Emeritus Professor in Toxicology in the Department Sciences and Technology at the University of Bordeaux. He earned a PhD degree in Toxicology in 1979 at the University of Bordeaux 1 where he remained as the director of the Food Toxicology Laboratory (1981–1997) and then the head of the Toxicology unit in the Laboratory of Environmental Chemistry and Toxicology (1997–2012). His research interests are focused on the molecular mechanisms of toxicity and the development of biomarkers in humans (food toxicology) and in sentinel species (fish, molluscs, worms) towards PAHs, PCBs, dioxins and pesticide exposures. He has been involved in several EU projects (GICBEM, BIOMAR, BEEP) dealing with the health status of coastal zones. Prof. Narbonne is an expert member of national agencies and panels dealing with human and environmental toxicology (French Agency for Human Safety, CSHPF; French Agency for Safety, Environment and Security, ANSES). Prof. Narbonne has published over 200 scientific papers and presented over 200 oral communications in international scientific meetings. He is also the author of several books and reports dealing with exposure and toxicology of dioxins, PCBs, PAHs and heavy metals.

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before receiving an Alexander von Humboldt Research Fellowship and travelling to Germany to study with Prof. Franz Oesch at the University of Mainz. There he took a post-fellowship position as a Project Leader in SFB 302 “Early Stages in Carcinogenesis.” Dr. Robertson joined the University of Kentucky’s Graduate Center for Toxicology in 1986. He Past President of the Ohio Valley regional chapter of the Society of Toxicology and Past President of the UK Chapter of Sigma Xi, The Scientific Research Society. Dr. Robertson, who joined the University of Iowa in 2003, is a receipient of the John Doull Lifetime Achievement Award from the Central States Chapter of the Society of Toxicology.