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H ISTORY AND CURRENT STATUS OF FAST AND SENSITIVE ANALYTICAL METHODS FOR MEASURING COMPOUNDS OF ENVIRONMENTAL CONCERN AT THE CENTERS FOR DISEASE CONTROL AND PREVENTION

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Introduction

Since we began measuring 2,3,7,8-tetrachlorodibenzo-*p*-dioxin[1, 2], the number of chemicals that have been found in environmental samples has continued to increase over the years. The approach we have taken to increase the number of analytes that we are able to measure in people has been to develop separate sample cleanup procedures for each class of chemicals[3-11]. The various sample extracts are then quantified on separate high-resolution mass spectrometers (HRMS). This approach requires a separate sample from each person for each class of chemicals and also a HRMS for each separate analysis. Because of the growing need for methods that can quantify more analytes from a single human sample, we began a research program in the early 1990's to develop new techniques such as fast gas chromatography and comprehensive two-dimensional gas chromatography[12-20]. In addition, we began testing high-resolution and time-of-flight mass spectrometry (TOFMS) for their suitability as detectors for these techniques[16, 19, 20].

Results and Discussion

Fast GC with HRMS and TOFMS detectors.

Fast GC coupled with HRMS selected ion monitoring (SIM) was able to quantify PCDDs, PCDFs, and cPCBs in less than 10 minutes, whereas previously the method required one hour[15]. In fact, the PCDDs, PCDFs, and cPCBs could be quantified in about 300 seconds, but several of the hexa-chlorinated dioxins and furans coelluted under these conditions[16]. Fast GC/HRMS analysis of persistent and non-persistent pesticides could be accomplished in under 400 seconds[17]. Using a TOFMS detector coupled with fast GC allowed the analysis of 38 PCB congeners found in human samples in 300 seconds[19]. This technique was further expanded to allow the simultaneous analysis of 38 PCBs and 13 persistent pesticides (PPs) in 300 seconds[20]. We also were able to quantify the PCBs and PPs in a shorter time period by using two GC columns connected to the same injector and both exit ends of the columns into the HRMS ion source. The extract injection then split between the two columns (a short 0.1 mm I.D. and a longer 0.25 mm I.D. column) [21]. We analyzed the PPs and last two eluting PCBs (206/209) from peaks eluting from the short, narrow bore column and analyzed the rest of the 36 PCBs from peaks eluting from the longer 0.25 mm I.D. column. This same injector/dual column technique allowed a faster analysis for the 51 compounds[21]. We also developed a faster single column analysis for the 51 PCBs and PPs[22].

Comprehensive Two-Dimensional GC (GCxGC) With HRMS and TOFMS Detectors.

In 1991, I was presenting a talk in the same session with Dr. John Phillips from Southern Illinois University. John had recently developed a new concept for GC analysis that the called Comprehensive Two-Dimensional GC[23]. This chance encounter would spark an almost decade

long collaboration with John, until his untimely death in 2000. When we began applying this new technique to persistent organic pollutants (POPs) the GCxGC technique utilized a modulation system than involved painting a portion of a capillary column with copper paint. A two-stage modulator was used by alternately heating the stages of the modulator using an applied electrical current[24].

This system was developed over the next several years and applied to the quantitative measurement of non-persistent pesticides by GCxGC with FID detection[13,14]. In addition, this GCxGC modulation system was used to quantify PCDDs, PCDFs, and cPCBs by coupling with a HRMS[15,16]. We obtained the highest sensitivity yet reported for 2,3,7,8-TCDD of S/N=14 for 350 attograms injected on-column[15]. The other PCDDs, PCDFs, and cPCBs could also be quantified and GCxGC/HRMS contour plot is shown in Figure 1.

We subsequently began working with a series of commercial (Zoex Corp.) thermal modulators based on a vertically mounted rotating heating element installed inside the GC oven[16,18,25]. More recently, we have been using the next generation of modulation devices installed as part of the commercially available GCxGC-TOFMS Pegasus 4D system (Leco Corp., St. Joesph, MI). This modulator is a "Quad Jet" system (dual-stage) based on the use of a dual cryogenic liquid nitrogen cold jet and a dual hot jet installed on an Agilent 6890 GC unit. We have used this GCxGC-TOFMS system to quantify up to 58 compounds in a single MS run[26,27]. A portion of the two-dimensional plane showing the 38 PCBs is given in Figure 2.

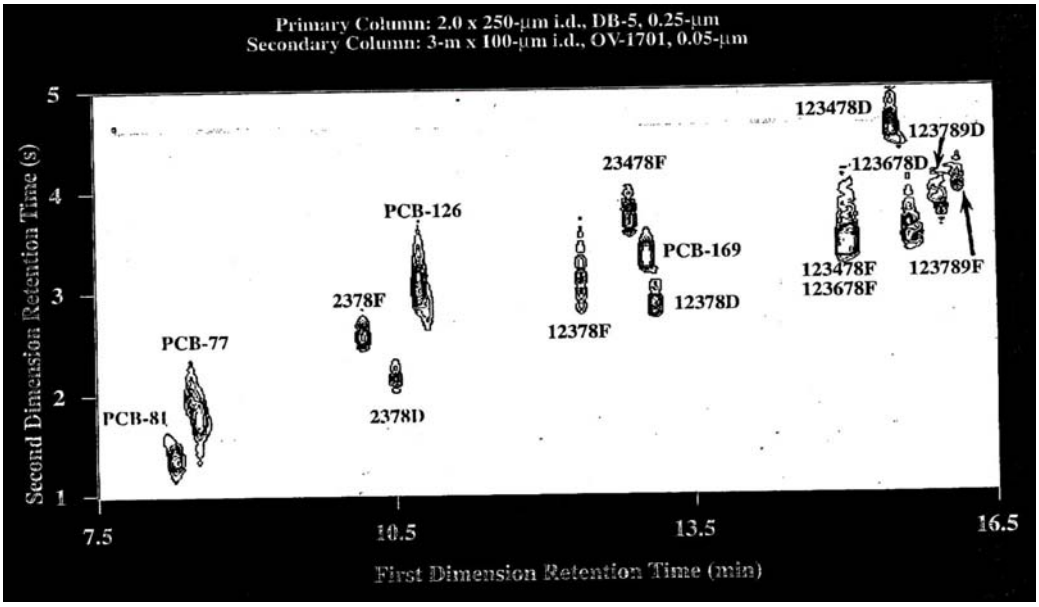

Figure 1. Comprehensive GCxGC/HRMS contour plot of 2,3,7,8-chlorinated dibenzodioxins, dibenzofurans, and coplanar PCBs (rotated heater modulator).

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38 Human Prominent PCBs

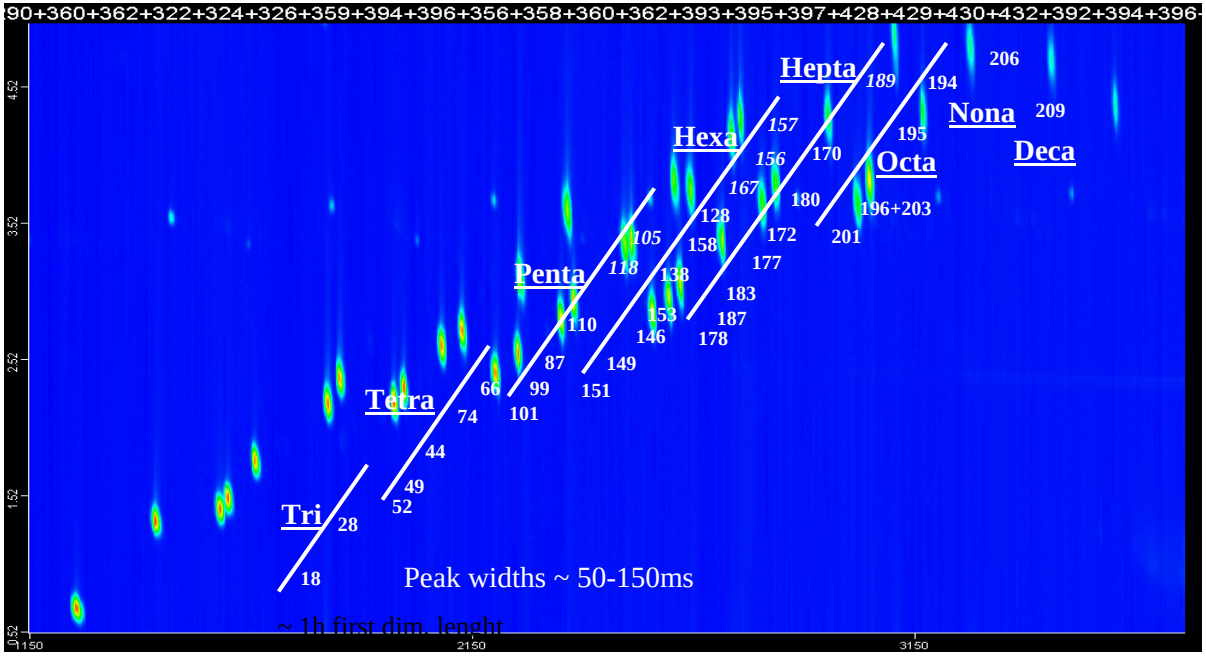

Figure 2. Comprehensive GCxGC-TOFMS contour plot of 38 PCB congeners (Quad Jet modulator).

We have recently developed a Universal Human Exposure Assessment Method that currently allows the extraction and cleanup of a single serum sample for 180 chemicals[28]. We are evaluating the suitability of the GCxGC-TOFMS system to quantify as many as possible of these chemicals in a single MS run.

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