SERUM PCDD, PCDF AND PCB LEVELS IN FIREFIGHTERS OF SHELEKHOV COHORT 17 YEARS AFTER THE FIRE AT "IRKUTSKCABLE" FACTORY

Chernyak YI[1], Shelepchikov AA[2], Brodsky ES[2], Feshin DB[2], Kolesnikov SI[1], Merinova AP[1], Grassman JA[3]

[1]Institute of Occupational Health and Human Ecology, East-Siberian Scientific Center of Human Ecology, Siberian Branch of the Russian Academy of Medical Sciences, P.O. Box 1170, Angarsk, 665827, Russia; [2]Severtsov Institute of Ecology and Evolution of Russian Academy of Sciences, 33, Leninskiy prosp., Moscow, 119071, Russia; [3]Brooklyn College-CUNY, 2900 Bedford Avenue, Brooklyn, NY 11210-2889, USA

Abstract
This paper reports serum PCDD/PCDF and PCB levels among the "Irkutskcable" factory firefighters 17 years after the catastrophic fire incident. In this random sampling of 20 firefighters from the cohort of 165, none had TEQ exceeding 100 pg/g of lipids. When compared to men who are currently working as firefighters, serum dioxin concentrations in the firefighters who participated in the 1992 event shows "smoothing" and significant differences in overall congener profiles were not found. However, groups exhibited some differences in the concentrations of certain combustion markers such as 1,2,3,4,6,7,8-HpCDF. The groups did not exhibit differences in PCB levels and their profiles. Future studies will compare the firefighter's serum PCDD/PCDF and PCB concentrations to similar males who have not worked as firefighters in order to assess the relative contribution of environmental and occupational sources.

Introduction
In 1992, a major fire broke out at the "Irkutskcable" factory in the city of Shelekhov, Russia. Dioxin-contaminated soot was formed during the combustion of approximately 1000 tons of plastic which included quantities of polyvinylchloride[1]. Firefighters avoided using respirators because of the high concentrations of organic compounds and concerns about the possibility of explosion. Previous measurements of the lipid adjusted levels of dioxins in the firefighter's serum showed that they are the mostly highly exposed cohort in Russia[2]. The average lipid-adjusted dioxin concentration in their serum was 169 pg/g (range: 50-477 pg/g, n=15; total WHO-TEQ), whereas firefighters who were comparable in age and professional experience but did not participate in the fire had mean lipid-adjusted levels of dioxins 105 pg/g (range: 27-205 pg/g)[3]. As a comparison, dioxin levels in the blood of American veterans participating in the Vietnam conflict ranged from 13 to 209 pg/g of lipids[4], while the upper 95th percentile levels of dioxins in similarly aged US citizens is 17 pg/g lipid[5]. Many of the firefighters subsequently developed a complex of neurological syndromes characteristic of toxic encephalopathy accompanied by a distinct array of psychological abnormalities and sensory neuropathies accompanied by autonomic disorders of limbs. Their high proportion of disabilities distinguishes this cohort from other firefighters in the region. Dioxins were not the only source of intoxication, but were part of a multicomponent mixture that had the potential to interact with the exposure of other compounds. Here we report the current level of PCDD/PCDFs and PCBs in "shelekhov firefighters" blood serum 17 years after the fire.

Materials and Methods
Selection of the serum donors: In November 2008, serum samples were obtained from 20 firefighters for dioxin analysis. Thirteen of the selected firefighters participated in the suppression of the 1992 "Irkutskcable" fire. As previously described, the men were among 165 firefighters who were recruited from local professional organizations and illness registries after excluding those with a history of hepatic disorders[3]. The collaborating institutions strictly complied with the requirements for the protection of human subjects. Written informed consent was obtained from all participants. The firefighters were divided into four groups: Group 1 (not presented in this examination) consists of subjects who were first hospitalized in 1992-1993 with acute intoxication and subsequent diagnosis of Firefighter Syndrome Complex. Group 2 is made up of firefighters who had neurological syndromes related to the fire and registered one to two years later with Firefighter Syndrome Complex. Group 3 includes Shelekhov firefighters that may or may not have been acutely intoxicated but did not develop Firefighter Syndrome Complex. Group 4 consists of firefighters who did not participate in extinguishing the Shelekhov fire. An oral questionnaire was used to obtain demographic, familial, occupational, and personal

information regarding diet. Eligible candidates for dioxin analyses were over 35 years old, had weights between the 10th and 90th percentile for the cohort. From the list of eligible candidates, firefighters were selected at random for this study.

Table 1. Firefighter lipid-adjusted serum PCDD/PCDF/PCBs

	WHO-TEF	*Group 2 (n=8)*		*Group 3 (n=5)*		*Group 4 (n=7)*	
		Mean	***Min-max***	**Mean** [1]	***Min-max***	**Mean**	***Min-max***
Age, years		**45**	***39-49***	**42**	***33-48***	**40**	***35-51***
pg/g lipid							
WHO-TEQ$_{PCDD/PCDF}$		**14,2**	***7,7-23,3***	**12,6**	***8,2-20,1***	**13,8**	***6,4-27,2***
WHO-TEQ$_{PCB}$		**21,9**	***15,8-34,2***	**25,6**	***13-49,3***	**26,0**	***9,4-53,3***
WHO-TEQ$_{PCDD/PCDF + PCB}$		**36,1**	***23,5-52,7***	**38,2**	***23,3-62,3***	**39,8**	***15,8-80,6***
2,3,7,8-TCDD	1	2,7	*<1,2-8,1*	3,6	*1,9-8,2*	3,2	<0,7-8,4
1,2,3,7,8-PeCDD	1	1,1	*<1-4*	0,7	*<1,3-3,3*	0,2	<1-1,5
1,2,3,4,7,8-HxCDD	0,1	1,2	*<0,9-2,2*	1,3	*<1,1-2,3*	1,7	0,8-2,8
1,2,3,6,7,8-HxCDD	0,1	4,2	*2,3-8,3*	4,0	*3,3-4,4*	4,0	2,2-5,7
1,2,3,7,8,9-HxCDD	0,1	1,4	*<1,5-3,2*	0,6	*<1,1-1,8*	1,9	0,9-3
1,2,3,4,6,7,8-HpCDD	0,01	4,2	*<5,7-13,1*	4,2	*<6,7-12*	1,3	<6,4-8,8
OCDD	0,0001	56,5	*<20-158*	68,7	*<30-201*	105	<19-206
2,3,7,8-TCDF	0,1	1,6	*<0,9-2,9*	2,7	*1,1-4*	2,1	<1-4,2
1,2,3,7,8-PeCDF	0,05	0,4	*<0,7-1,5*	0,3	*0-1,3*	0,6	<0,5-2,5
2,3,4,7,8-PeCDF	0,5	16,0	*10-26,9*	12,3	*8,8-18,6*	15,4	6,7-26,4
1,2,3,4,7,8-HxCDF	0,1	7,2	*3,8-13,5*	4,9	*2,9-7*	6,8	3,7-11,4
1,2,3,6,7,8-HxCDF	0,1	5,8	*3,5-11,6*	4,4	*3,1-6,3*	6,6	3,2-9,8
1,2,3,7,8,9-HxCDF	0,1	1,7	*<1,8-2,8*	1,9	*1,3-2,9*	1,7	<2,3-3,3
2,3,4,6,7,8-HxCDF	0,1	0,3	*<1,6-2,1*	1,3	*0-2,8*	1,1	0,9-2,1
1,2,3,4,6,7,8-HpCDF	0,01	4,2	*1,8-8,5*	5,1	*3-7,6*	9,3	2,4-18,4
1,2,3,4,7,8,9-HpCDF	0,01	<2		<2		<2	
OCDF	0,0001	<8		<8		<8	
PCB-77	0,0001	<40		<40		<40	
PCB-81	0,0001	<15		<15		<15	
PCB-126	0,01	56	*28,5-118*	70	*34,7-108*	81	*22,4-202*
PCB-169	0,001	79	*51-141*	67	*36,6-132*	74	*23,5-141*
ng/g lipid							
PCB-105	0,0001	6,7	*3,8-12,3*	8,4	*4,4-66,3*	10,6	*6,5-17,6*
PCB-114	0,0005	2,5	*1,7-4,2*	2,2	*1,3-9*	2,8	*1,3-5,1*
PCB-118	0,0001	29,0	*17,2-50,5*	32,6	*18,2-178*	38,5	*16,4-66,6*
PCB-123	0,0001	0,2	*0,1-0,5*	0,3	*0,1-2,7*	0,5	*0,1-1*
PCB-156	0,0005	16,1	*10,7-25,2*	11,2	*8,6-17,9*	15,2	*5,1-38,8*
PCB-157	0,0005	5,0	*3,3-8,2*	3,7	*2,8-6,3*	4,8	*1,6-11,8*
PCB-167	0,00001	3,1	*1,9-4,8*	2,9	*2-5*	3,5	*1-8,2*
PCB-189	0,0001	1,0	*0,6-1,5*	0,6	*0,4-1,3*	0,8	*0,2-2*
Total Sum PCBs[2]		261	*195-414*	251	*161-757*	298	*115-597*

[1] Means for group 3 exclude a sample that was contaminated. [2] For the 12 non-dioxin-like PCBs.

Serum dioxin quantitation: Twenty analyses were performed at the A.N. Severtsov Institute of Ecology and Evolution (Moscow) using blood samples obtained in November 2008. Seven polychlorinated dibenzo-*p*-dioxin (PCDD), 10 polychlorinated dibenzofuran (PCDF), 12 polychlorinated biphenyl (PCB), and 12 non-dioxin-like PCB congeners were analyzed in each of the samples. After overnight fasts, blood samples were collected in 15 ml red top Vacutainer tubes that were ¾ filled. 40-50 ml of blood was taken from each firefighter and the serum was extracted in the same tubes using a standardized procedure. The serum was transferred to glass vials with

teflon lined screw caps, frozen, and delivered to the lab for analyses. PCDD/PCDFs and PCBs were analyzed using $^{13}C_{12}$ standards (Wellington Lab EPA-23ISS, 23RS, 23SS, WP-LCS, MBP-MPX) and HRMS technique (Finnigan MAT95XP) on SGE BPX-5 0.22x0.25x30 column for PCDD/PCDFs and c-PCBs; and SGE HT-8 0.25x0.25x30 column for non-dioxin-like PCBs (28, 52, 66, 74, 99, 101, 110, 128, 138, 153, 180 and 209). Toxic equivalents (WHO-TEQ) for PCDD/PCDFs and PCBs were calculated with equivalency factors (1998 TEFs) recommended by the World Health Organization for human[6]. Congeners levels below the detection limit were analyzed as "0" values.

Results and Discussion

Table 1 shows that the average total TEQ in serum for the groups ranged from 36,1 to 39,8 pg/g lipid. Average serum PCDD/PCDF concentrations did not differ by group. More than 10 years have passed since the participants from group 2 have worked as firefighters. Only one member of group 3 currently works as a firefighter; the others either do not work or have changed their jobs. Therefore, over the past 17 years, the dioxin levels in blood of the firefighters who were potentially highly exposed in the 1992 "Irkutskcable" fire appear to have decreased to the levels typical for currently working firefighters having constant potential source of additional exposure.

Analysis of the pattern of congeners in individuals can be used to identify sources of exposure provided that their mechanisms of formation and potential for bioaccumulation are taken into account. Combustion and other high temperature processes may result in the formation of complex mixture of PCDD/PCDF congeners. PCDD/PCDF retention varies according to the level of chlorination with congeners having 2,3,7,8-chlorination being readily accumulated. Bioaccumulation of the more highly chlorinated congeners declines as chlorination increases. Differences in congener retention and the resultant congener profiles can, in some cases, be associated with chronic occupational exposures or specific events. Measurement of serum 1,2,3,4,6,7,8-HpCDF, which can be readily formed during combustion, reflects only recent exposure since it has low bioaccumulation potential. High levels of this congener were measured in blood serum lipids of firefighters shortly after the tragedy on September 11 at World Trade Center in New York[7]. The concentrations of 1,2,3,4,6,7,8-HpCDF in the serum of "shelekhov" firefighters (groups 2 and 3) are either similar or lower than the levels measured in group 4 firefighters (fig. 1A). This observation suggests that the formerly high concentrations of this congener acquired through employment as a firefighter has declined to levels produced by dietary and environmental exposures.

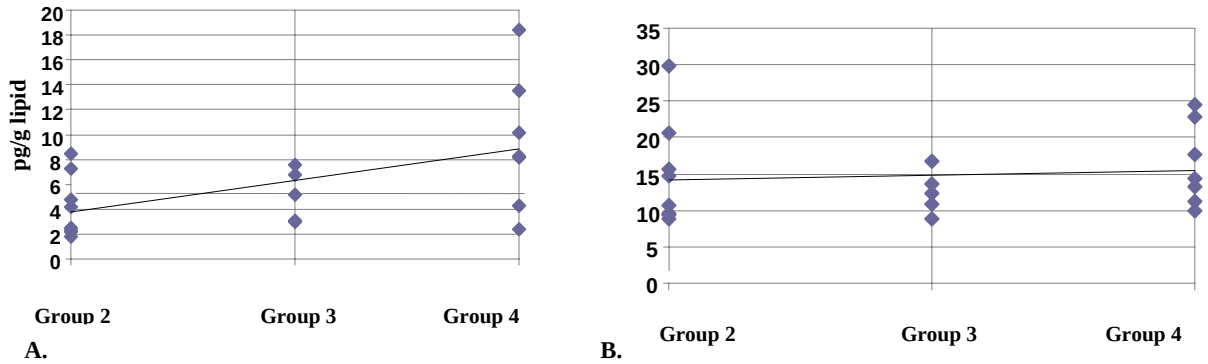
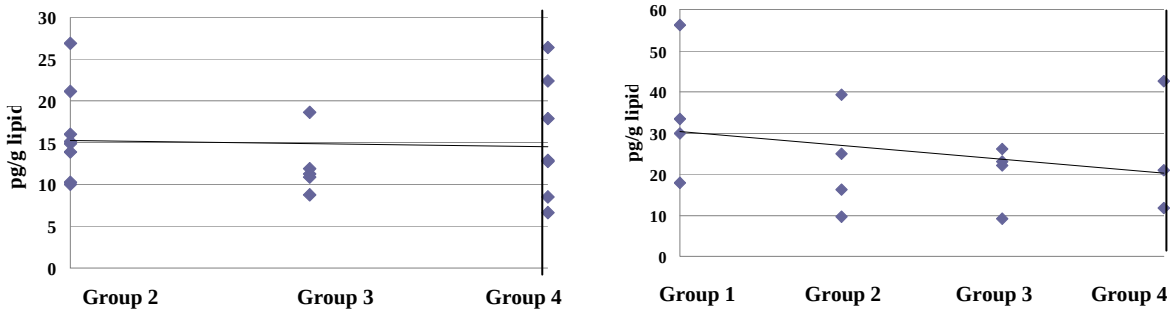


Figure 1 Lipid-adjusted serum levels in firefighters. (**A**) 1,2,3,4,6,7,8-HpCDF (**B**) Sum-HxCDFs.

Another indicator of combustion are the 2,3,7,8-substituted HxCDFs which have significant bioaccumulative ability in comparison with the HpCDF. Although HxCDFs concentrations did not differ between groups (fig. 1B), two individuals in group 2 have higher levels of HxCDFs. Since their total serum PCDD/PCDFs also exceeds the values detected in other group 2 firefighters, the levels of these congeners may be due to exposure sustained during the fire suppression at the cable factory. 2,3,4,7,8-PeCDF is a highly hazardous congener due to its' toxicity, ability to bioaccumulate, and significant concentrations in combustion products. In addition, food TEQs are usually dominated by 2,3,4,7,8-PeCDF so variations in diet may explain high levels of this congener. However, the average concentration of this congener is higher in group 2 than in group 3 (fig. 2A). Working firefighters (group 4) have wider range of this index. Comparison with Figure 2B suggests that the 2,3,4,7,8-

PeCDF have declined in the past 5 years[3]. Note that in comparison with the previous examination, levels of control group remained almost the same, while levels of "shelekhov" firefighters decreased. This is consistent with the current understanding of the half-life of elimination for 2,3,4,7,8-PeCDF[8].



A. **B.**

Figure 2. Lipid-adjusted serum levels of 2,3,4,7,8-PeCDF in firefighters (**A**) in 2008 and (**B**) 2004 (the highest value for each group has been excluded).

PCBs contributed more than 50% of the total TEQ in all samples (table 1), a level which is consistent with the high levels of environmental pollution in the region[9]. Significant differences between specific congeners as well as total content of PCB were not detected between the groups. Even though PCB may be formed during combustion, there is no mechanism for its incorporation into the serum. The profile of basic congeners in combustion products is close to that found commercial technical mixtures except for a greater proportion of coplanar congeners (77, 81, 126, 169). However, these congeners are not good indicators of combustion because they bioaccumulate and may be transformed in living organisms[10].

Acknowledgments

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