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THE BINGHAMTON STATE OFFICE BUILDING PCB, DIOXIN AND DIBENZOFURAN ELECTRICAL TRANSFORMER INCIDENT: 1981-1986.

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ABSTRACT

The Binghamton State Office Building (BSOB) polychlorinated biphenyl (PCB) and chlorinated benzene containing electrical transformer arcing and fire incident of February 5, 1981, was the first recognized incident of its kind. A surge of excess electricity led to an electrical panel malfunction at 5:30 AM. For about 30 minutes intense heat was generated as electrical arcing occured. Dense smoke containing polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) as well as biphenylenes billowed up through air shafts and contaminated all areas of the building later tested for these chemicals. This incident was the first outside a laboratory setting to demonstrate the conversion of PCBs, in the presence of oxygen and heat, to PCDFs, and of the chlorinated benzenes to PCDDs. It demonstrated a hitherto unsuspected potential health hazard of PCB and chlorinated benzene containing electrical transformers, and by implication, capacitors, when not properly separated from areas of buildings used by workers and public. The building has been shut since then and an estimated $40,000,000 may be spent on direct cleanup and rehabilitative costs prior to reopening of the building, if it is to be reopened. Elevated levels of serum PCBs were detected in workers, eg., firefighters initially involved in the fire, which stabilized at lower levels later in the year. Elevated penta- and hexa- chlorinated furan isomers corresponding to isomers found in the soot (and identical to some Yusho isomers) were found in some cleanup workers. Electron microscopy of percutaneous liver biopsies of three patients chemically exposed from the incident showed lesions similar to those seen in guinea pigs fed the soot, which was biologically quite active. This incident, and others occurring afterward, has led the US Environmental Protection Agency to ban PCB containing transformers from similar buildings.

INTRODUCTION

On February 5, 1981 an electrical malfunction in a modern, 18 story office building led to overheating of a transformer in the BSOB, Binghamton, New York, about 180 miles northwest of New York City. Between 180 and 200 US gallons of transformer fluid leaked from the overheated transformer in a basement of the building. This fluid originally was constituted as a 65% Arochlor 1254 and a 35% tri- and tetra- chlorinated benzene containing mixture. Due to an unusual arrangement of air shafts, ducting and air handling systems the entire building was contaminated, including hidden spaces under floors, spaces above false ceilings, and inside air ducts (1,2). Initial sampling showed the soot to be 5% PCB in content. In addition, 2,168,000 parts per billion (ppb) of PCDFs, 20,000 ppb of PCDDs as well as 50,000 ppb of chlorinated biphenylenes were also found in soot samples.

Since that time the building has been subject to a variety of cleanup efforts. During the first few weeks after the accident, several hundred workers were exposed to the chemicals by virtue of being involved as office workers, cleanup workers, electricians, police, firefighters, security workers and, initially, firefighters and police. Lawsuits were filed, or the intent to sue was initiated, in some instances possibly to not lose the right to eventual lawsuit, should injury from chemicals develop at a later date. Under present New York law, a lawsuit must be filed within three years after the incident-not the injury or illness-or the statute of limitations precludes initiation of lawsuits. The New York State legislature is considering changing this law which predates an understanding of the latency period involved in some chemical injuries, especially in the case of carcinogens or reproductive toxins, such as those involved in this incident.

As a result of the Binghamton incident, and others which followed, the United States Environmental Protection Agency (US EPA) has ruled that PCB containing transformers must be phased out in several years in many public buildings. Their action was based partially on economic considerations, as well as on health considerations.

The BSOB was constructed less than twenty years ago at a cost of 17 million dollars. Its total cleanup costs are estimated to be 40 million dollars, including replacement of furnishings. Certain hidden spaces will be cleaned and others will not. Estimated time of opening is in 1987, 6 years after the incident.

RESULTS

Toxicological findings (3-5) include the following: The BSOB soot does not inactivate the chemicals as determined by guinea pig bioassays. For example, the rate of cancers is increased in animals fed the BSOB soot as compared to control animals. Electron microscopic findings in liver cells were similar to those previously described in animals or persons exposed to PCBs, PCDFs or 2,3,7,8 TCDD. The toxicity of this mixture appears to be to a large extent due to the level of 2,3,7,8 substituted penta- and hexa- chlorinated dibenzofurans. The BSOB soot but not fireplace soot or charcoal used as controls lead to malformations in chick embryos as well as decreased viability.

Human findings from Binghamton exposed patients include the following (6-10): Elevated serum PCB levels which returned to normal levels within one to two years in some patients including firefighters involved with the fire, with a match of the PCB isomers found in soot and adipose tissues, in some cases. Elevated PCDF levels in some exposed patients as compared with Binghamton controls were found, as were elevations of specific isomers of PCDFs in fat tissue which corresponded to isomers identified in the BSOB soot. Some of the penta- and hexa-chlorinated PCDFs were the same as found in Yusho patients in Japan. Control BSOB adipose tissue samples revealed, for the first time, the high level of PCDDs and PCDFs in the general US population, around 1,000 to 1,200 ppt on a wet weight basis. These were 2,3,4,7,8, PCDF, 1,2,3,4,7,8 PCDF and 1,2,3,6,7,8 PCDF. Transient serum liver enzyme elevations were found in some patients as were elevations of triglycerides and cholesterol levels in serum taken shortly after the exposure. These usually returned to normal levels within one year after the incident. Three patients suffered from prolonged elevations of liver enzymes for which no cause other than the chemical exposure could be found. These three patients exhibited similar ultrastructural alterations to those seen in animals dosed with PCBs, 2,3,7,8 TCDD, the BSOB soot, or in humans exposed to chlordecone (Kepone) (11) or the Yusho rice oil incident (12) Lipid droplets were found in the hepatic parenchymal cell cytoplasm, as was a slight increase in smooth endoplasmic reticulum. Glycogen was plentiful. Mitochondria were pleomorphic or deformed and giant mitochondria were present. Some cristae lined up parallel rather than perpendicular to the long axis of mitochondria and crystalline structures were found in other mitochondria. Large, dense, electron intramitochondrial granules were seen in many mitochondria. In addition, several cases of skin cancer, including one malignant melanoma, were found in exposed workers. Several suicides were reported in the original group of approximately 500 potentially exposed persons, in or near the building in February 1981.

Risk assessment calculations for reentry into the building, and "acceptable daily intakes" (ADIs) of PCDDs and PCDFs were calculated, possibly for the first time for a building, as part of the BSOB's reentry criteria. The calculations were derived from rat one nanogram per kg per day no effect levels (NOELs) for 2,3,7,8 TCDD. Rats, being intermediate in sensitivity, were chosen rather than the more sensitive guinea pigs, and a safety factor of 500 fold was applied. An assumption was made that other sources of intake such as food or air need not be factored into this equation; rather, that only BSOB air levels and soot levels of PCDDs and PCDFs (but not PCBs to date) need to be considered. Conversion to "2,3,7,8 TCDD equivalents" for other PCDD and PCDF isomers was employed and a review of the sparse scientific literature was used for conversion factors. Recently, work by Nagayama and associates suggests that conversion factors based on enzyme induction studies in animals may underestimate toxicity to humans (13). At any rate a 2 picogram/Kg/day is considered an ADI for 2,3,7,8 TCDD equivalents, calculated by the New York method or 10 pg 2378 TCDD equivalents/M^3 of air and 25 ng/M^2 surface for office worker reentry. The New York approach is considerably less conservative than the California method, which assigns an equal potency to all tetra- to hepta 2,3,7,8 chlorine substituted dioxins and dibenzofurans rather than weighting downwards the higher chlorinated PCDDs and PCDFs.

This difference is apparent in Table I, modified from New York State BSOB records. It can be seen that using the California method of calculation we have 40 pg/M^3 of "2,3,7,8 TCDD equivalents" in the air, well above the allowed 10 pg amount for reentry, but using the New York State Health Department method of calculating dioxin equivalents we find a 7.5 pg/M^3 air level, within the level for reentry for workers without protective gear. Despite an apparent similarity in the "dioxin equivalents", 10 pg/M^3, used by the New York and California Health Departments, the method of calculation is very different. A further difficulty can be appreciated in Tables II and III. In Table II two highly qualified chemical laboratories analyzed the same sample or a split sample and come up with as much as 17:1 fold differences (2,000 vs 120) or 1:5 fold differences (5,900 vs 29,500) in furan levels, in some instances. In Table III two highly qualified laboratories varied from each other by a factor of from 1.3 to 6.3 fold. Thus, if one cannot be certain of the exact amounts of specific isomers of dioxins or furans present, there is a further major difficulty in calculating safety for reentry. Few laboratories are able to perform analyses for mixtures containing many isomers because of technical difficulties including chemical cleanup problems, separation difficulties, lack of available chemical standards, and the many chemical interferences possible. In addition the proper GC/MS equipment is needed. Cost is high and turnaround time quite slow at present. Laboratory charges vary from $500 to $2,000 per analysis depending on the number of samples, their difficulty and the analyses desired; average turnaround time is measured in months.

Contamination levels of the building after several years of cleaning, usually by repeated washing with steam or water and detergent rather than by removing and replacing walls, floors, and lighting fixtures, can be seen in Tables IV and V. What is noteworthy here is the uneven results from this method of cleaning, even after four years and 30 million dollars of cleanup effort. W1, W2, etc., refer to locations and, usually, a floor number.

CONCLUSIONS AND DISCUSSION

The BSOB contamination of an office building was the first of its kind to be identified. It has provided a rich learning experience with respect to medical, legal, insurance, cost, chemical, toxicological and cleanup (vs. dismantling) issues. The unexpected health hazards related to PCB transformers were first documented here, by human and animal data, from the chemically contaminated soot and air. The costs associated with such defective design and/or maintenance problems as found in the BSOB were also first documented here. Weaknesses in the New York State legal system with respect to a three year statute of limitations after an incident, rather than after onset of illness, presenting problems for potential plaintiff and defendant alike with respect to chemicals which may cause illness after a latent period, are well documented here. Potentially affected workers must file law suits in that period of time, during which no illness may exist, or forever lose the right to sue later, possibly after the development of cancer or an adverse reproductive outcome occurs, which may or may not be linked to the chemicals of exposure.

The use of fat biopsies for determining whether there is or is not an increased body burden of PCDDs or PCDFs after such incidents was first documented here, as was the use of liver biopsy ultrastructural analysis as a sensitive although not specific marker of exposure to dioxins and related compounds. The usefullness of serial serum PCB measurements in documenting ingestion of PCBs after such acute exposures was documented in Binghamton, as it was previously in the Yusho PCB/PCDF incident. The high level of PCDDs and PCDFs in the general population was unexpected.

Difficulties in cleanup techniques and the difficulties in chemical analysis of the isomers involved has been documented by this incident, as have the difficulties of risk assessment and determination of reentry criteria.

The extent of the health hazard posed to persons working in PCB, PCDF and PCDD contaminated buildings is not yet clear. It is only by following exposed workers over time, accurately estimating their exposure, and using a suitable control group that this question will be answered. Special health problems may be posed to the fetus or a nursing newborn if the mother works in such a building. These chemicals are transferred through the placenta and also in breast milk. The infant may have a more sensitive immune system than an adult, and the effect of a given level of these chemicals may be greater because of the infant's small size and the long period of time which the chemicals will remain in the body (of a fetus or newborn) as compared to an adult. The intake of PCBs, PCDDs and PCDFs from other sources, such as food, also must be considered. It is possible, based on current knowledge, that current risk assessments either overestimate or underestimate potential human health hazards. What is clear is that it is possible to take steps to minimize human exposure to these toxic compounds.

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TABLE I

BINGHAMTON STATE OFFICE BUILDING 1984
CALCULATIONS OF AVERAGE "2,3,7,8-TCDD EQUIVALENTS"
DUE TO VARIOUS DIBENZOFURANS, DIBENZODIOXINS AND BIPHENYLENES FOR
6TH AND 14TH FLOOR AIR SAMPLES (MODIFIED FROM NEW YORK RECORDS)

BEST ESTIMATE OF AVERAGE CONCENTRATION	X	RELATIVE ACTIVITY OF COMPOUND CLASS VS. DIBENZODIOXINS	X	RELATIVE ACTIVITY DUE TO CHLORINE SUBSTITUTION	=	NEW YORK CALCULATION "2,3,7,8-TCDD EQUIVALENTS"	CALIFORNIA CALCULATION "2,3,7,8-TCDD EQUIVALENTS"
2,3,7-8 TCDF 8 pg/M^3	X	1/3	X	1	=	2.7 pg/M^3	8 pg/M^3
PENTA CDFs: 12378 +12348 +23478 14 pg/M^3	X	1/3	X	1	=	4.7 pg/M^3	14 pg/M^3
HEXA CDFS: 9 pg/M^3	X	1/3	X	1/30	=	0.1 pg/M^3	18 pg/M^3
					TOTAL	7.5 pg/M^3	40 pg/M^3

TABLE II

COMPARISON OF BATTELLE VS. NEW YORK STATE DEPARTMENT OF HEALTH (NYSDOH)

Sample	2,3,7,8-TCDF	TOTAL TCDF	TOTAL PENTA CDF	TOTAL HEXA CDF
BSOB WIPE, STAIR TREAD PCDD W-13 (NYSDOH 43968) FLOOR 16-17	5,900	45,000	99,000	41,000
BSOB WIPE, STAIR TREAD PCDD W-14 (BATTELLE) FLOOR 16-17	29,500	145,000	117,000	60,700
BSOB WIPE, VINYL WALL W-7 (NYSDOH 43969)	1,100	13,000	8,500	2,000
BSOB WIPE VINYL WALL PCDD W-6 (BATTELLE)	1,320	4,980	820	120

TABLE III

BINGHAMTON STATE OFFICE BUILDING
TEST PLAN: MEASUREMENTS OF RESIDUAL CONTAMINANTS REPORT
SEPTEMBER 5, 1984

POLYCHLORINATED DIBENZOFURAN ANALYSIS LABORATORY COMPARISON
(SINGLE EXTRACT)

CHLORINE NUMBER (ISOMER)	STALLING 1981 (µg/g)	RAPPE 1981 (µg/g)	FACTOR
2,3,7,8-TCDF	3.7	12	3.2
TETRA	5.4	28	5.1
PENTA	107	670	6.3
HEXA	512	965	1.9
HEPTA	102	460	4.5
OCTA	30	40	1.3

TABLE IV

BINGHAMTON STATE OFFICE BUILDING
JANUARY 25, 1985 NEW YORK STATE REPORT

RESULTS OF PCB-1254 SURFACE WIPES COLLECTED IN THE BSOB, SEPTEMBER 1984

TYPE OF SURFACE	FLOOR	LOCATION	CONCENTRATION (µg/M^2)	AVERAGE (µg/M^2)	AVERAGE s.d.
FLOORS (MASTIC)	3	LOBBY CORE	10		
	6	LOBBY CORE	45	55.00	65.2
	13	LOBBY CORE	15		
	17	LOBBY CORE	150		
	5	WEST/OUTER	10		
	10	WEST/OUTER	11	19.25	11.2
	15	WEST/OUTER	34		
	18	WEST/OUTER	22		
STAIRWELL TREADS	7-8	EAST	13	66.5	76.6
	17-18	EAST	120		
PAINTED LIGHT FIXTURES (UPPER)	4	WEST/OUTER	100		
	8	WEST/OUTER	10	31.75	45.5
	10	WEST/OUTER	8		
	16	WEST/OUTER	9		
	3	NEAR CORE	26		
	6	NEAR CORE	21	19.75	6.8
	12	NEAR CORE	10		
	17	NEAR CORE	22		
CONCRETE-MEN'S RESTROOM CHASE	2		7	24.5	24.7
	18		42		

TABLE V

BINGHAMTON STATE OFFICE BUILDING
JANUARY 25, 1985 NEW YORK STATE REPORT
(1984) DATA)

QUANTITY OF PCDF, PG/M^2 (LIMIT OF DETECTION)

SAMPLE	2,3,7,8-Tetra	Tetra	Penta	Hexa	Hepta	Octa
PCDD W1	520	1200	(37)	(80)	(503)	(1340)
PCDD W2	250	345	90	18	(554)	861
PCDD W3	1720	2980	(10)	170	(119)	(650)
PCDD W4	2940	6160	1970	620	(226)	(1185)
PCDD W5	1450	3690	310	(13)	(205)	(463)
PCDD W6	1320	4980	820	120	(58)	(285)
PCDD W8	16200	55500	10400	1040	(211)[1]	46109[1]
PCDD W9	7390	36400	240	5580	(3244)	(5015)
PCDD W10	(20)	(20)	56	20	(347)	(979)
PCDD W11	87	153	48	(8)	(274)	(495)
PCDD W12	16500	125000	136000	128000	60300	26800
PCDD W14	29500	145000	117000	60700	55800	37200
PCDD W15	8590	51100	46000	26000	22600	14200
PCDD W16	61000	331000	341000	222000	186000	100000
PCDD W17	287	639	240	40	(268)	(601)
PCDD W18	88	213	130	(6)	(233)	(777)
PCDD W19	4400	14800	9130	870	3200	2360
PCDD W20	27300	75900	40500	9890	28300	7480
PCDD W21ns[2]	3760	3760	(4)	(7)	(31)	(114)
PCDD W21fb	(24)	(24)	(10)	(9)	(75)	(375)
Lab Blank	(26)	(26)	(23)	(103)	(74)	(280)
Lab Blank	(4)	(4)	(4)	(5)	(24)	(87)
Lab Blank	(2)	(2)	(7)	(4)	(11)	(29)

1 Calculated using TCDD-$^{13}C_{12}$ due to Interferences at M/Z 472
2 Spiked with 5 NG of 2,3,7,8-TCDF