PAH AND THE WTC RESPONSE

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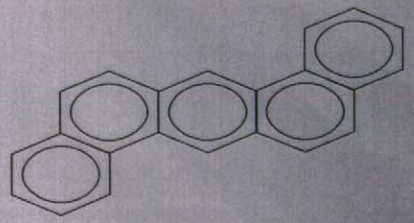
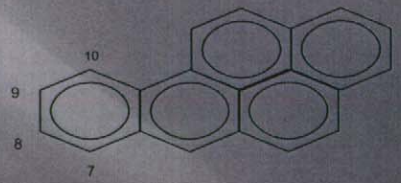
Polycyclic aromatic Hydrocarbons (PAH)

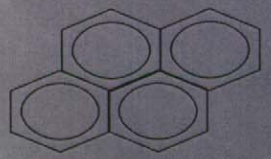
- Benzene rings fused during burning with insufficient oxygen
- Well absorbed from lungs and skin



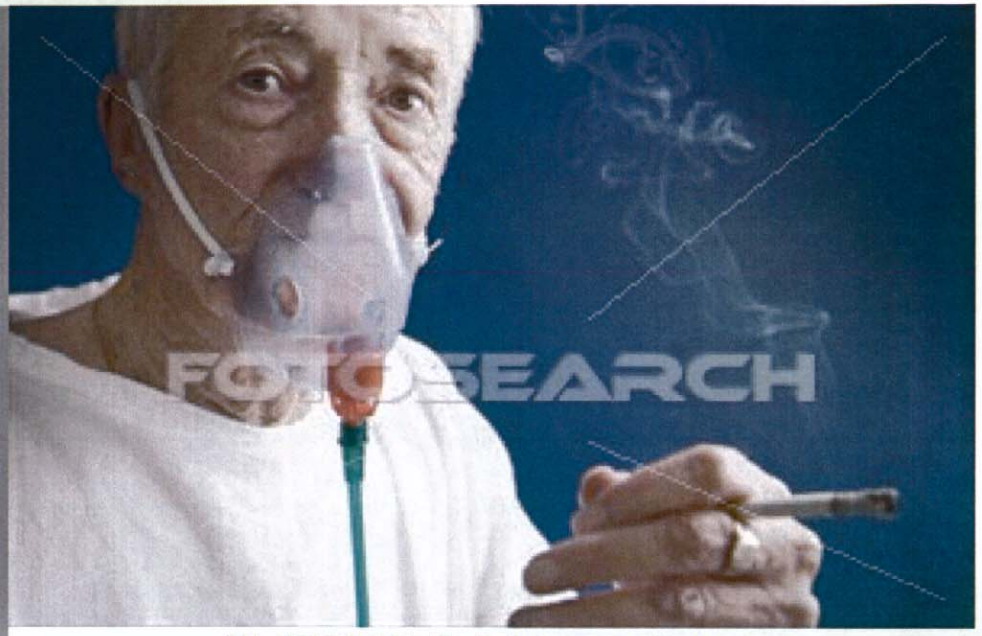
dibenz(a,h)anthracene



benzo(a)pyrene



pyrene



42-17323271 fotosearch.com

PAH exposure associated with lung cancer

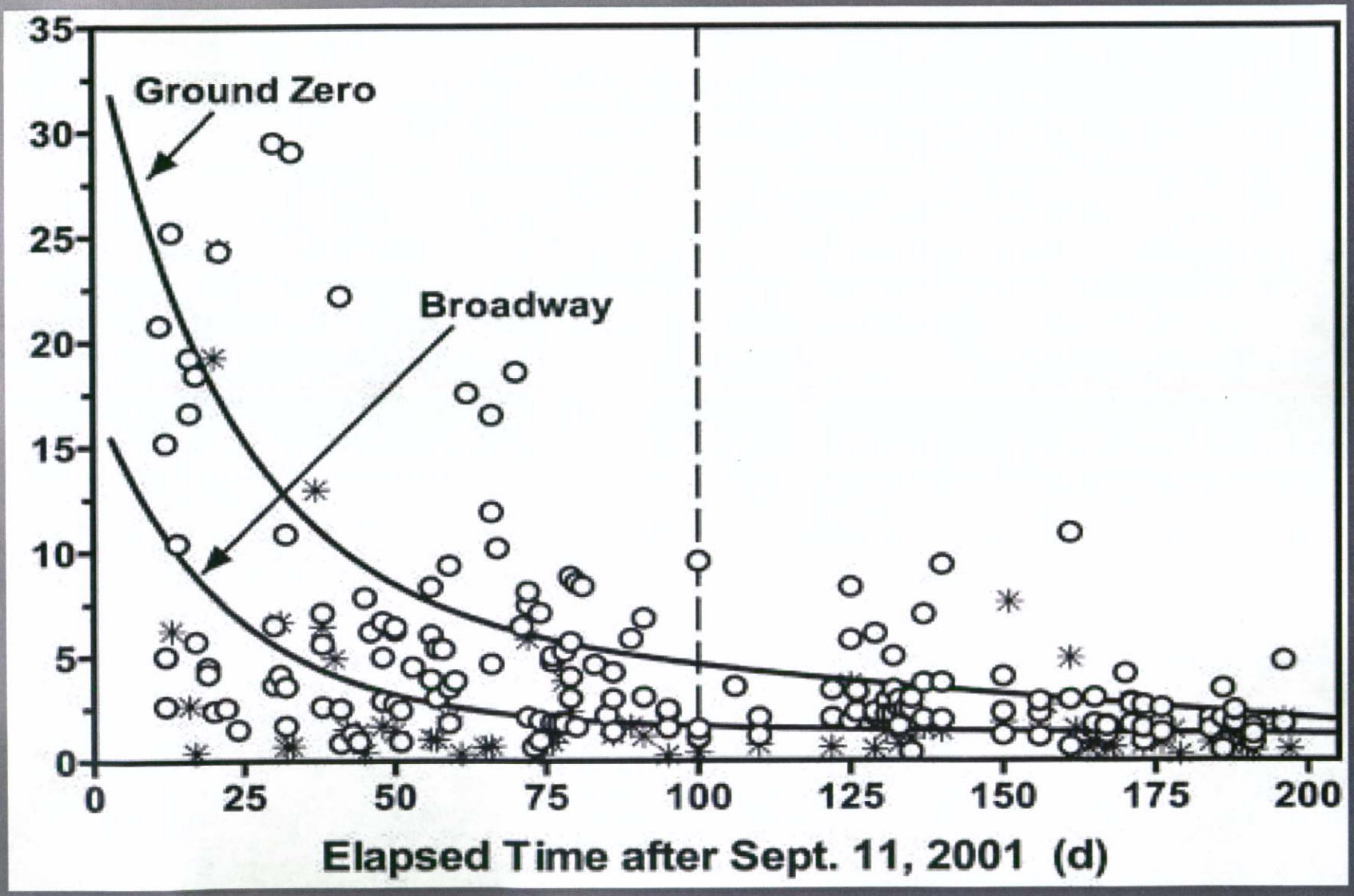
- Smokers
- Coke Oven Workers
- Aluminum Smelter Workers
- Chimney sweeps

- PAH are absorbed by the body and metabolized to compounds that can bind to DNA and then cause mutations that can initiate carcinogenesis.
- It IS biologically plausible that PAH can cause cancer….IF….there is sufficient exposure.

PAH Exposures at WTC

- Sources: ~90,000 l of jet fuel, 500,000 l transformer oil, 380,000l of diesel and heating oil and approximately the same amount of gasoline burned plus any and all burning items
- Area samples collected at the fence line beginning 9/16-23/01; no personal samples. (Pleil et al, 2004)
- Biomarker samples collected once on October 1, 2001 (Edelman,2003)
- Window film samples Oct. 27 and 29, 2001 (Butt et al., 2004)

Pleil et al., 2004 data



Accurate exposure estimates?

- All air measurements and estimates based on area samples collected at the fence line; area samples typically underestimate worker exposure. Difference can be 3-40 fold…or more; or less
- Included only PAH in the particulate phase; Burstyn et al.(2002) estimated that 10X more PAH was found in the vapor phase in asphalt workers…..but Quinlan et al (1995) saw about equal amts. for coal liquefaction workers

Unmeasured effects

- What is the impact of being in a plume?
- What was the effect of exercise/exertion?
- Data were collected to determine ground level environmental exposure; no attempt to capture peaks; or to assess exposed worker exposure; Authors state that exposure to workers at the site could be "much higher"

Butt et al., 2004 data

- Windows in buildings at var. distances sampled:
- Within 1 km (0.6 mi) average was 77,100 ng/m^2
- Downwind sites had averaged 130,000 ng/m^2
- Upwind sites averaged 18,500 ng/m^2
- Upwind sites >2km averaged 6000 ng/m^2
- Can't be used for exposure estimates but indicate differences of proximity and in the plume

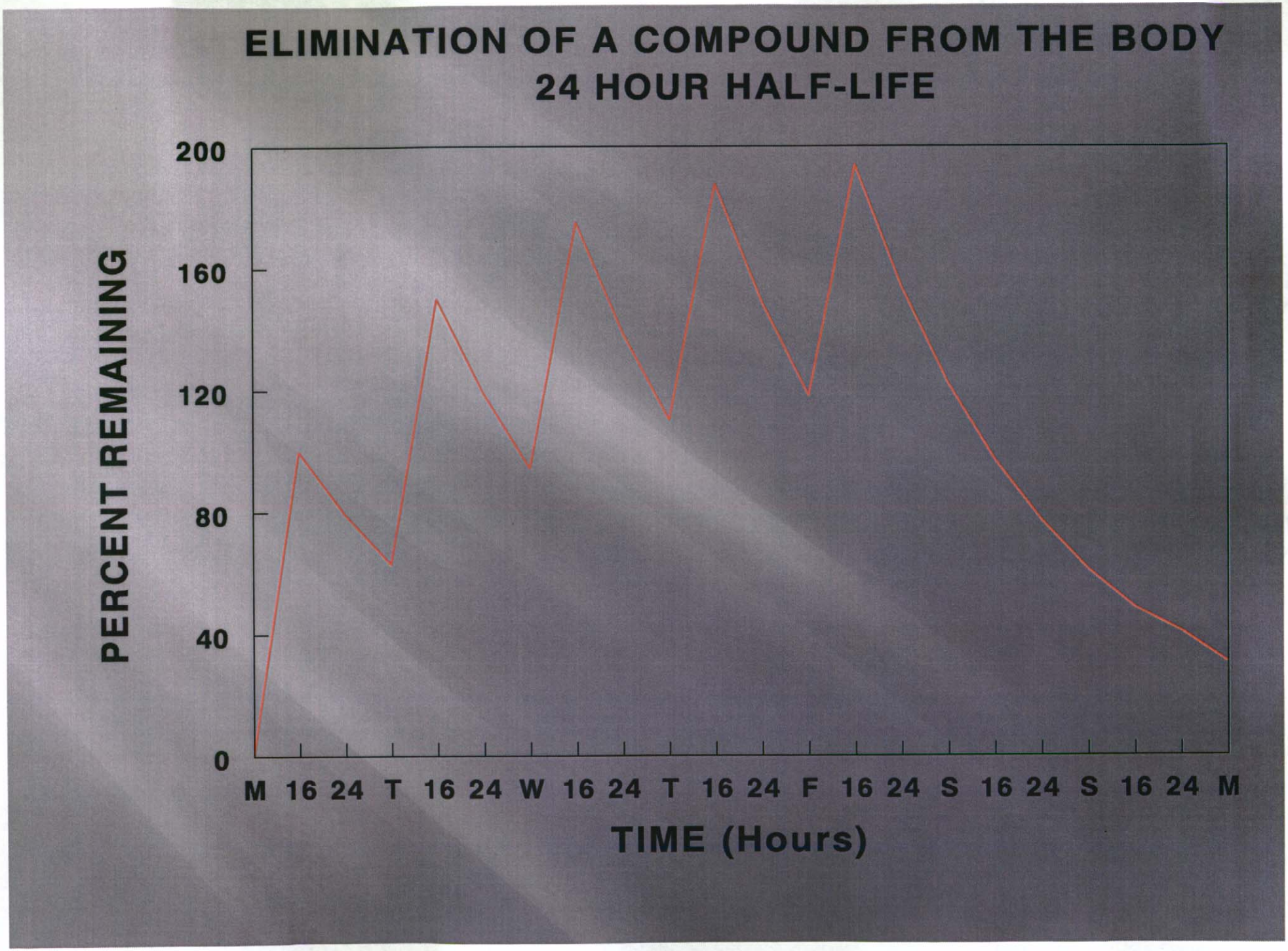
Individual Variation In Absorption Of Airborne Contaminants Can Be Assessed

Pulmonary Absorption Rate Varies with the Ventilation Rate

Physical Workload (W)	Alveolar Ventilation (L Air/Min)	Heart Rate (L/Min)	Increase Ventilation (vs. Light)
0 (Rest)	5.0	6.0	1.0
50 (Light Work)	16.0	9.0	1.0
100 (Moderate)	27.0	13.0	1.7
150 (Heavy)	38.0	19.0	2.4

Biomonitoring PAH exposure 1HP

- Pyrene is an important component of PAH
- There IS a Biological Exposure Index for 1HP, the major metabolite of pyrene. ACGIH BEI
- Biomonitoring can account for differences in absorption, distribution, metabolism and elimination if it is done correctly.
- Can take into account both skin and inhalation exposures
- Exposures can be reconstructed
- But it is easily mis-used


ELIMINATION OF A COMPOUND FROM THE BODY
24 HOUR HALF-LIFE
PERCENT REMAINING
200
160
120
80
40
0
M 16 24 T 16 24 W 16 24 T 16 24 F 16 24 S 16 24 S 16 24 M
TIME (Hours)

1-HP data (ug/l): Edelman et al, 2004

All Exposed	0.092
Controls	0.062
Day 1 + FF@collapse	0.110
Day 1+2 NC	0.113
Spec Ops Command	0.159
ACGIH BEI	1.000*

- *end of shift, end of workweek sample specified

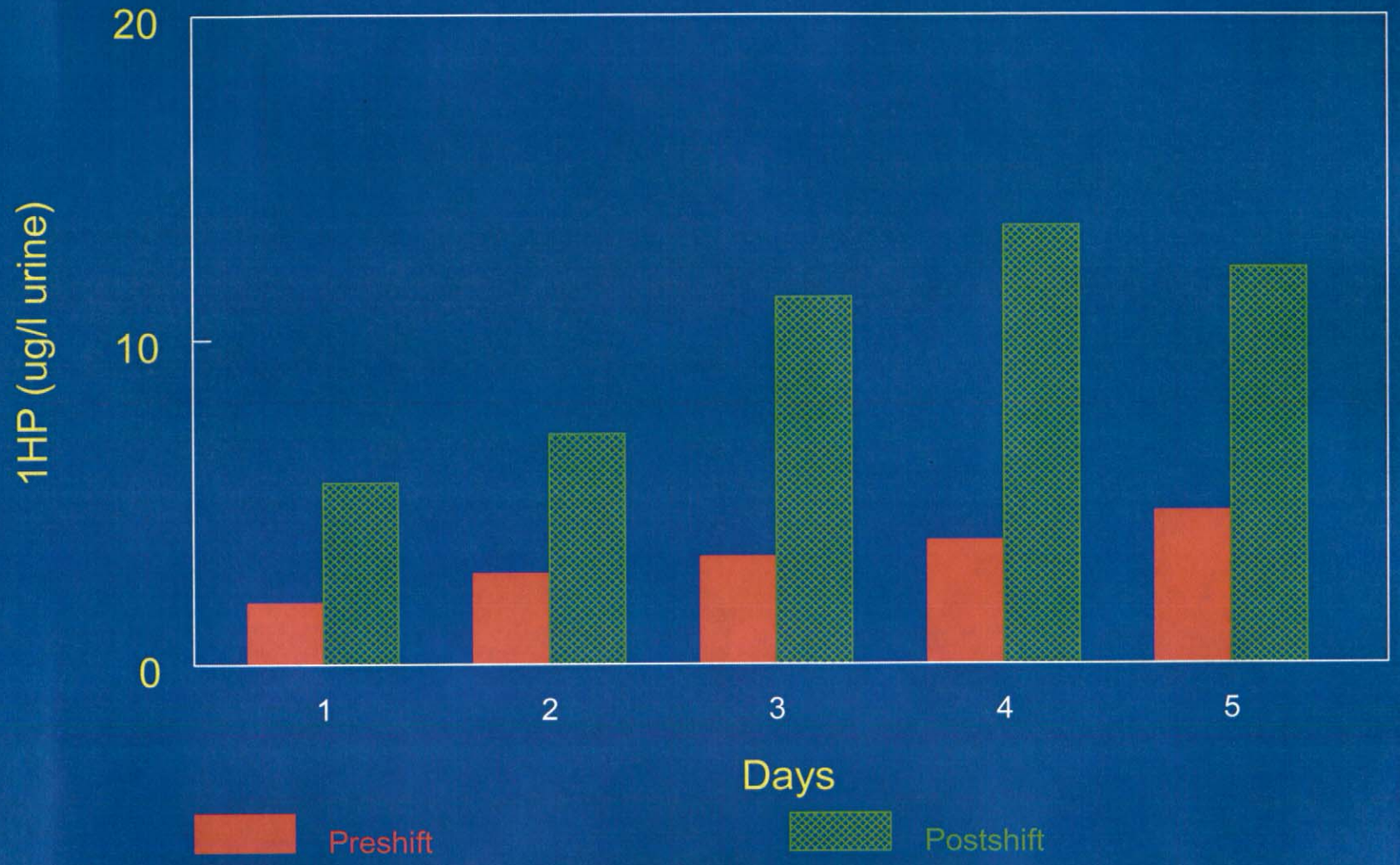
Are Edelman's data accurate exposure estimates?

- Samples were collected 22-24 days after peak exposures; the half-lives of 1HP are 5.5h, 23h and 23 days.
- No variances reported (the outliers are what count in IH) 4% were said to be in the upper 5% of CDC's NHANES values….how many controls were in the upper 5%?
- May have sampled at lowest point prior to an exposure; Sampling time relative to last exposure not given.

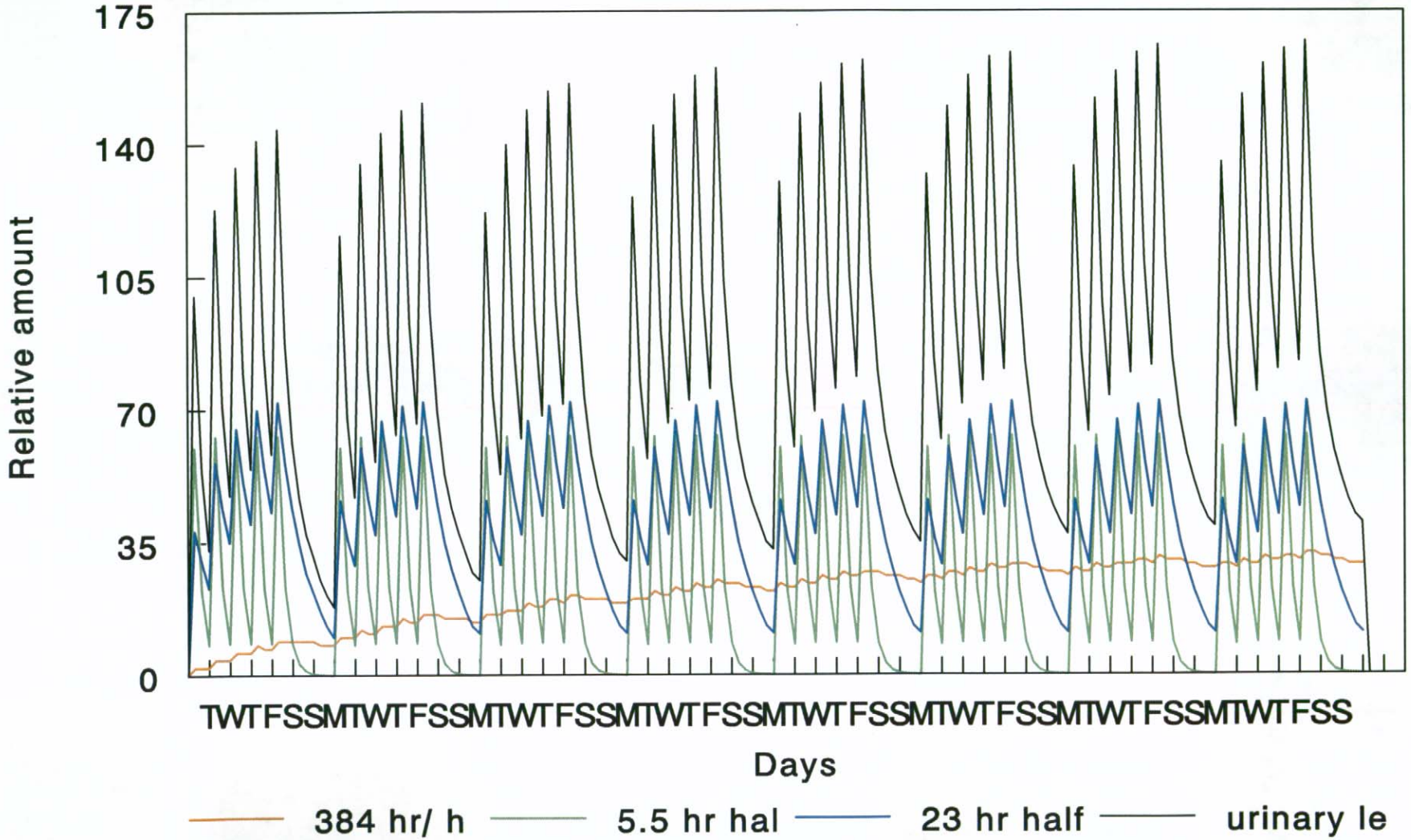
Edelman data:II

- Sampling time relative to last exposure not given
- Firefighters seem to have lower 1HP levels than many workers to begin with.
- Absorption from lung complete? What about large particle masses? PAH on particles might not be rapidly absorbed (Gerde, et al data, below)

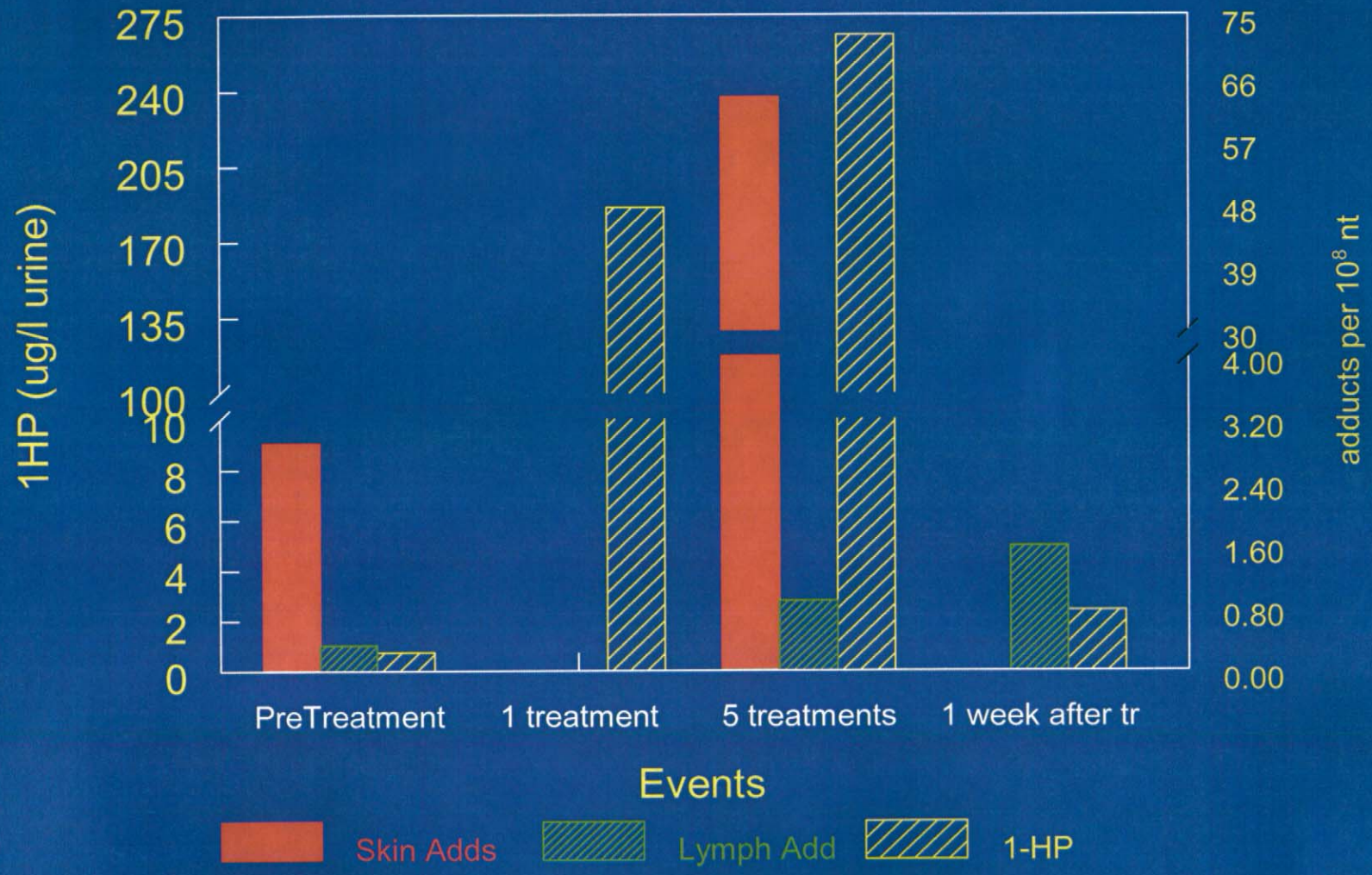
Pre- and Post- 1HP Levels in Aluminum Plant Reduction Workers



VanSchooten et al, 1995, Cancer Epi. Biomarkers and Prev., 4,69-77


175
140
105
70
35
0
Relative amount
TWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSS
Days
384 hr/ h
5.5 hr hal
23 hr half
urinary le

Timecourse of DNA adducts and 1HP levels in Psoriasis Patients treated with coal tar



Godschalk et al. (1998) Cancer Epi. Biomarkers Prev., **7**, 767-73.

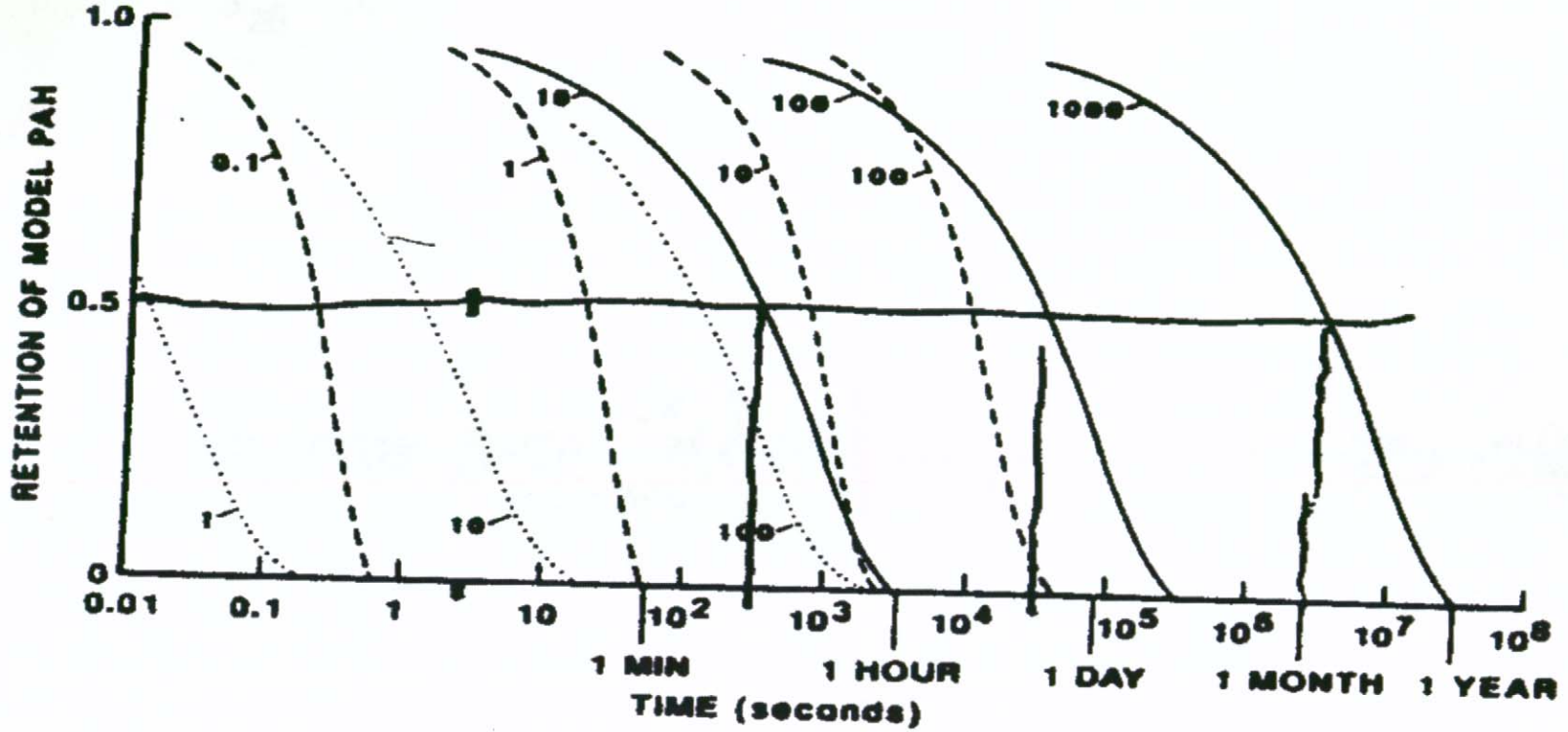


FIG. 3. The simulated release rates of a PAH from model aggregates of various sizes: Dashed lines show ie release from pure crystal aggregates (Model A). Solid lines show the release from inert dust aggregates ntaining PAH crystals (Model B), and dotted lines show the release from dust aggregates with a PAH sorbing from their surfaces (Model C). The numbers at the curves show the initial diameter of the aggregate μm. The larger the particle aggregate the slower the release of their associated PAHs. Because the release PAHs from different size aggregates spans such a large interval in time, it is likely that, at low-dose halation exposures, carrier particles will influence the local dosimetry of PAHs only shortly after deposition, hereas at high-dose instillation exposures, retention of particles should be more important.

TABLE 2-3. Percent retention of inhaled aerosol particles in various regions of the respiratory tract.

The figures in the columns are percent retention; the column headings are particle sizes in μm. A 4 sec respiratory cycle is assumed. (From Hatch and Gross,[11] Table 3-4.)

	Percent retention									
	450 cm^3 Tidal air					1500 cm^3 Tidal air				
	20	6	2	0.6	0.2	20	6	2	0.6	0.2
Mouth	15	0	0	0	0	18	1	0	0	0
Pharynx	8	0	0	0	0	10	1	0	0	0
Trachea	10	1	0	0	0	19	3	0	0	0
Pulmonary bronchi	12	2	0	0	0	20	5	1	0	0
Secondary bronchi	19	4	1	0	0	21	12	2	0	0
Tertiary bronchi	17	9	2	0	0	9	20	5	0	0
Quarternary bronchi	6	7	2	1	1	1	10	3	1	1
Terminal bronchioles	6	19	6	4	6	1	9	3	2	4
Respiratory bronchioles	0	11	5	3	4	0	3	2	2	4
Alveolar ducts	0	25	25	8	11	0	13	26	10	13
Alveolar sacs	0	5	0	0	0	0	18	17	6	7
Totals	93	83	41	16	22	99	95	59	21	29

PAH Adsorb on particles

- Soot and concrete particles attract PAH differently ; but both do
- Particles my accumulate in lung and slow absorption into the body
- Particles may be coughed up, expectorated or swallowed, but this seems a detoxification pathway

Other interacting exposures

- Metabolic enhancers
  - PCBs and TCDD
  - Highest ambient level of TCDD ever measured anywhere in the world after 9/11
- Silica: PAH enhance the carcinogenicity of silica exposures….Additive plus!
- Asbestos: PAH enhance the carcinogenicity of asbestos exposures; Multiplicative!

Conclusions

- Exposure of workers to PAH within the Ground Zero site was almost certainly higher and maybe substantially so, than what is indicated by the major exposure studies.
- A fuller report of the biological monitoring data is needed to predict what the exposures may have been during the early periods after 9/11 and who may have had highest exposures.
- If the effective half life is ~24 hours, 1HP levels on 9/12 could have been well above the BEI level assuming NO Exposure since 9/11/01…..


THANKS

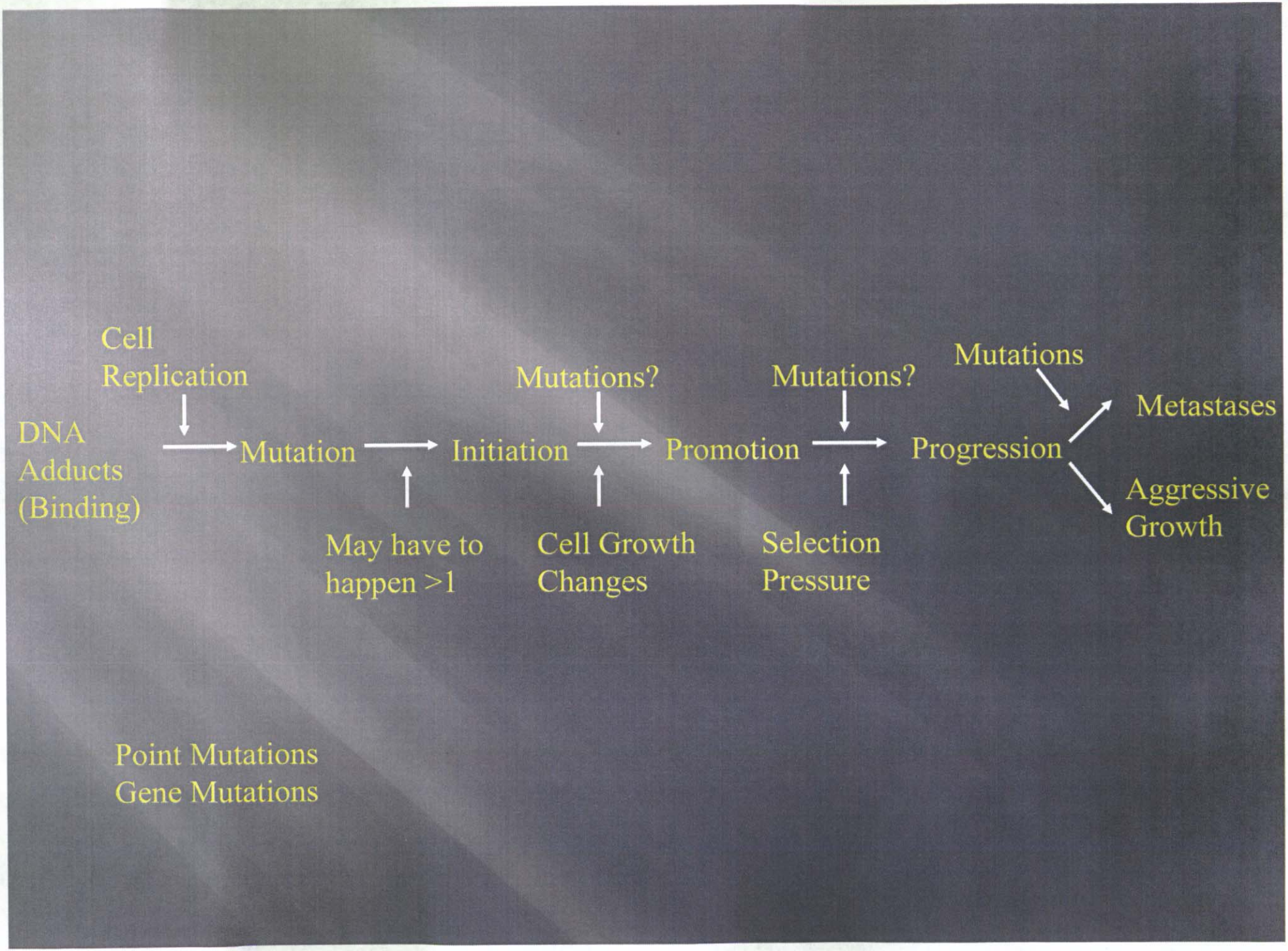

Cell
Replication
DNA
Adducts
(Binding)
Mutation
Initiation
Promotion
Progression
Mutations?
Mutations?
Mutations
Metastases
Aggressive
Growth
May have to
happen >1
Cell Growth
Changes
Selection
Pressure
Point Mutations
Gene Mutations

Table 1. Adjusted geometric mean chemical concentrations and ANCOVA results.

				Arrival time			Unit assignment		
Chemical	Units	Exposed, all except controls (n = 318)	Control (n = 47)	Day 1 present at collapse (n = 148)	Days 1–2 present after collapse (n = 142)	p-Value, present at collapse vs. 1–2 days	Special Operations Command (n = 95)	Other firefighters (n = 195)	p-Value, special vs. other
1-Hydroxypyrene	ng/L urine	93.2*	62.5	110*	113*	NS	159*	77.9	< 0.01
1-Hydroxyphenanthrene	ng/L urine	186	158	197	206	NS	248*	164	< 0.01
2-Hydroxyphenanthrene	ng/L urine	164	119	163	191*	NS	211*	147	< 0.01
3-Hydroxyphenanthrene	ng/L urine	162	127	168	185*	NS	214*	145	< 0.01
1,2,3,4,6,7,8-HCDBD	pg/g lipid	27.8*	19.2	30.1*	26.4*	NS	30.6*	25.9*	NS
1,4-Dichlorobenzene	µg/L blood	0.235	0.165	0.274	0.289	NS	0.343*	0.231	< 0.01
meta/*para*-Xylenes	µg/L blood	0.066*	0.051	0.066	0.071	NS	0.081*	0.057	< 0.01
Methyl *tert* butyl ether	µg/L blood	0.124	0.101	0.129	0.138	NS	0.166*	0.107	< 0.01
Lead	µg/dL blood	2.76*	1.93	3.08*	2.98*	NS	3.77*	2.43*	< 0.01
	µg/L urine	1.17	1.01	1.44*	1.19	NS	1.77*	0.96	< 0.01
Antimony	µg/L urine	0.203*	0.165	0.271*	0.238*	< 0.01	0.381*	0.169	< 0.01
Cadmium	µg/L urine	0.324	0.377	0.355	0.299	< 0.01	0.351	0.303*	< 0.01
Uranium	µg/L urine	0.00611*	0.00752	0.00643	0.00576*	NS	0.00610*	0.00607*	NS

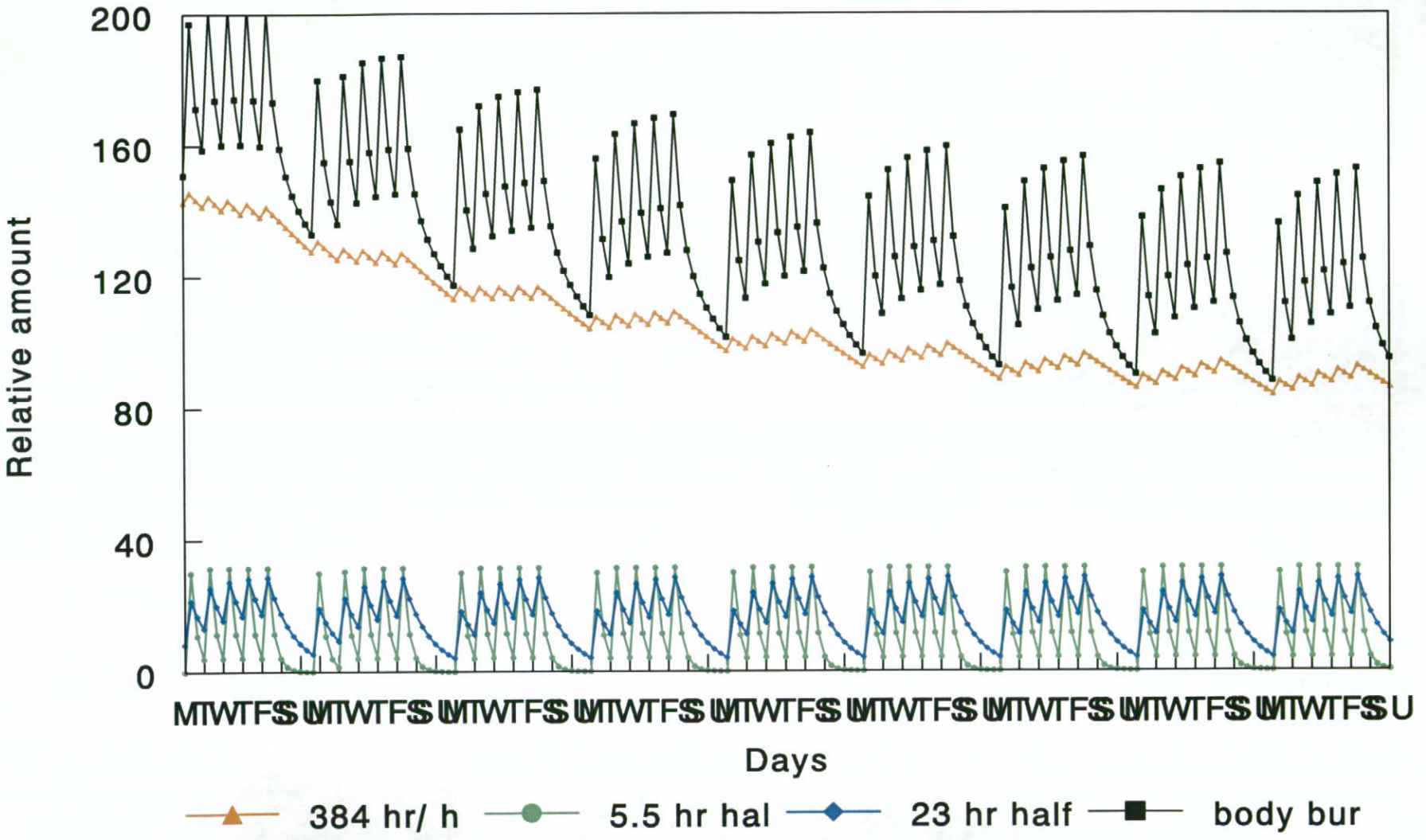
Abbreviations: HCDBD, heptachlorodibenzodioxin; NS, not significant. To be listed in this table, a chemical had to show a difference between any two of the groups by Kruskal-Wallis testing ($p < 0.05$). All chemicals listed in the table were significant by ANCOVA at $p < 0.01$, except 1-hydroxyphenanthrene ($p = 0.0246$) and uranium ($p = 0.0273$), for differences between any two of the six exposure groups adjusted for covariates of age, race, creatinine, and log cotinine.

*Significantly different from controls, $p < 0.01$.

Influence of selected variables on 1-HP post shift samples in 2 groups of needle coke plant workers with chronic exposure to PAH

Workers	Variable	P-value	R^2 value
Maintenance			
	Pre-shift level	0.0003	0.521
	Dermal Exp.	0.028	
	Air Levels	0.581	
Operations			
	Pre-shift Levels	0.0008	0.424
	Dermal	0.318	
	Air Levels	0.067	

Boogaard and van Sittert (1995) Sci. Tot. Environ. 163, 203-9


200
160
120
80
40
0
Relative amount
MTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSU
Days
384 hr/ h
5.5 hr hal
23 hr half
body bur

PAH and other exposures interact

- Asbestos and smoking: Multiplicative effect?
- Silica and smoking: Additive effect
- Arsenic and smoking: Multiplicative