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ENGINEERING DEPARTMENT

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BLOOD Pb RESPONSE TO AIR Pb

As you requested, I have analyzed data in the literature on the relationship between air Pb and blood Pb. I have concluded that:

(i) The Azar et al. data indicate that the slope of the log blood Pb - log air Pb relationship is small. For example, a 100% increase in air Pb results in a 11.2% increase in blood Pb.

(ii) The data by Azar et al. show that blood Pb will increase approximately 1 μgm/100 ml when air Pb increases 1 $\mu gm/m^3$. It should be noted that the blood Pb - air Pb response curve is a log-log relationship and is not linear.

(iii) Points (i) and (ii) are based on the data reported by Azar et al. It is shown that other data in the literature are consistent with those reported by Azar et al.

A discussion of the analysis is attached. Please contact me if you have any questions.

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ANALYSIS ON THE RELATIONSHIP BETWEEN AIR Pb AND BLOOD Pb

1. Introduction

The following analysis of the relationship between air Pb and blood Pb concentrations is based on data reported in the papers listed in the References at the end of this report.

2. The Slope of the Blood Pb - Air Pb Curve is Small

The Azar(1) paper develops a log-log relation between air Pb and Blood Pb of the form

$$\log \text{blood Pb} = 1.2257 + 0.153 \log \text{air Pb}$$

$$\text{or} \quad \text{blood Pb} = 16.82\ (\text{air Pb})^{0.153} \qquad (1)$$

Assuming the log-log model is correct, the percent increase in blood Pb which results when air Pb is increased from x_1 to x_2 is given by

$$\text{Blood Pb Increase (\%)} = 100((x_2/x_1)^{0.153}-1) \qquad (2)$$

This relationship shows the small dependence of blood Pb on air Pb. For example, a 100% increase in air Pb (ie the air Pb doubles) results in only an 11.2% increase in blood Pb.

$$\text{Blood Pb Increase (\%)} = 100((2/1)^{0.153}-1) = 11.2\%$$

Table 1 summarizes increase in blood Pb as a function of air Pb. From equation (2) we see that the % increase in blood Pb is dependent on the slope of the log-log equation (ie, b = 0.153). Results using the slope of the Goldsmith and Hexter line (3) (ie, b = 0.243) are also included in Table 1 for comparative purposes. It should be noted that the Goldsmith-Hexter slope lies outside the 95% confidence limits of the Azar et al. slope (0.153 ± 0.079). Even with the larger Goldsmith and Hexter slope the % increase in blood Pb is considerably smaller than the corresponding increase in air Pb.

3. Change in Blood Pb (μgm/100 ml) Resulting from a 1 μgm/m³ Increase in air Pb is approximately 1 μgm/100 ml

The log-log model reported by Azar et al (reference 1, equation 1) can be used to compute the expected change in blood Pb resulting from a 1 μgm/m³ increase in air Pb. The change in blood Pb is given by

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$$\Delta \text{ Blood Pb } (\mu gm/100 \text{ ml}) = \text{Current Blood Pb } \left(\left(\frac{\text{current air} + 1}{\text{current air Pb}}\right)^{b} - 1\right)$$

where b is the slope of the log-log equation. The blood Pb - air Pb response is shown in Table 2 for both the Azar et al slope (b=0.153) and the Goldsmith and Hexter slope (b=0.243). An examination of Table 2 indicates that, in general, a 1 $\mu gm/m^3$ increase in air Pb results in a blood Pb increase of 1 μgm/100 ml.

4. The Azar et al Blood Pb - Air Pb Relationship Is the Best Available Model and Is Consistent with Results from Other Studies

The preceeding information is based on the Azar et al blood Pb - air Pb model. This model was developed from the most comprehensive study conducted to date. The air Pb exposure for 150 subjects was determined 24 hours/day for periods of 2-4 weeks. Blood samples were obtained twice/week from each subject.

The slope of the log-log relationship reported by Azar et al, Goldsmith and Hexter, and calculated from the Albany Study are

Study	Slope (b)	95% Conf. Limits
Azar, et al	0.153	±.079
Goldsmith and Hexter	0.243	
Albany Study	0.243	

Given two blood Pb values and the corresponding air Pb values, the slope of the log-log model is

$$\text{Slope (b)} = \frac{\log (\text{Blood Pb}_2/\text{Blood Pb}_1)}{\log (\text{Air Pb}_2/\text{Air Pb}_1)}$$

where air Pb_1 < air Pb_2. For example, the slope developed from the Albany Study is

$$\text{Slope} = \frac{\log (35/26)}{\log (10.9/3.2)} = 0.243$$

Log Blood Pb - log air Pb slopes developed from data reported in references 2, 4, 5, and 6 are summarized in Table 3 and shown graphically in Figure 1. The results in Table 3 were developed using assumed ambient air Pb concentrations of 1.2 $\mu gm/m^3$ for Kehoe's subjects and 2.0 $\mu gm/m^3$ for the Williams, King and Walford and Cole to Lynam data sets. With the exception of the latter two studies the estimated slopes are in general agreement with the Azar et al slope.

Table 1

Percent Increase in Blood Pb as a Function
of Percent Increase in Air Pb

Air Pb Ratio (x_2/x_1)	Air Pb % Increase	% Increase in Blood Pb Slope = 0.153*	Slope = 0.243**
1.10	10	1.5	2.3
1.25	25	3.5	5.6
1.50	50	6.4	10.4
2	100	11.2	18.3
3	200	18.3	30.6
4	300	23.6	40.1
5	400	27.9	47.9
10	900	42.2	75.0

* Azar et al (1)
** Goldsmith and Hexter (3)

Table 2

Blood Pb Response ($\Delta\mu gm/100\ ml$) to a
1 $\mu gm/m^3$ Increase in Air Pb

Data Source	Current Level		ΔBlood Pb ($\mu gm/100\ ml$) 1 $\mu gm/m^3$ Air Pb Increase	
	Air Pb	Blood Pb	Slope=0.153*	Slope=0.243**
Starke, FL*	0.64	16.4	2.5	4.2
Barksdale, WI*	1.01	13.8	1.5	2.5
Philadelphia Cab*	2.62	22.4	1.1	1.8
Los Angeles Office Wkrs.*	3.06	19.9	0.9	1.4
Los Angeles Cab*	6.10	24.6	0.6	0.9
Albany Study	3.2	26	1.1	1.8
Albany Study	10.9	35	0.5	0.8

* Azar et al (1)
** Goldsmith and Hexter (3)

Table 3

Log Blood Pb - Log Air Pb Slope Estimated From Data in the Literature

Data	Exposure µgm/m³	Exposure Time(HR/WK)	Pb-in-Air Ambient**	Pb-in-Air Combined	Blood Pb Unexposed	Blood Pb Exposed	Slope (b)*
Kehoe (1960) Subject FC	75	37.5	1.2	17.67	25	42	.193
Kehoe (1966) Average of Subjects JS&LD	150	10.5	1.2	10.5	23.4	27.2	.069
		21	1.2	19.8	23.4	38.7	.179
		31.5	1.2	29.1	23.4	40.3	.170
		42	1.2	38.4	23.4	44.1	.183
Kehoe (1966) Average of Subjects NK&SS	10	10.5	1.2	1.75	19.5	20.3	.107
		21	1.2	2.30	19.5	21.0	.114
		31.5	1.2	2.85	19.5	21.5	.113
		42	1.2	3.40	19.5	22.4	.133
		52.5	1.2	3.95	19.5	24.7	.198
		63	1.2	4.50	19.5	27.0	.246
		73.5	1.2	5.05	19.5	26.2	.206
Williams, King and Walford							
Machine Pasters	218	40	2.0	53.4	28+	74	.296
Hand Pasters	150	40	2.0	37.2	28+	63	.277
Forming Dept.	134	40	2.0	33.4	28+	63	.288
Cole and Lynam							
Convicts	10.9	161	2.0	10.5	22	35	.280

*Slope - log (Blood Pb Ratio)/log (air Pb Ratio)
**Estimated ambient exposure
\+ Average of Plastic Depts A & B

REFERENCES

1. Azar, A., Snee, R. D. and Habibi, K. (1972). Relationship of Community Levels of Air Lead and Indices of Lead Absorption. Proceedings of the International Symposium Environmental Health Aspects of Lead. Amsterdam, October 2-6, 1972, pp. 581-594.

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3. Goldsmith, J. R. and Hexter, A. (1967). Respiratory Exposure to Lead: Epidemiological and Experimental Dose-Response Relationships. Science, 158, 132-134.

4. Kehoe, R. A. (1960). The metabolism of lead in man in health and disease. The Harken Lectures, 38-53.

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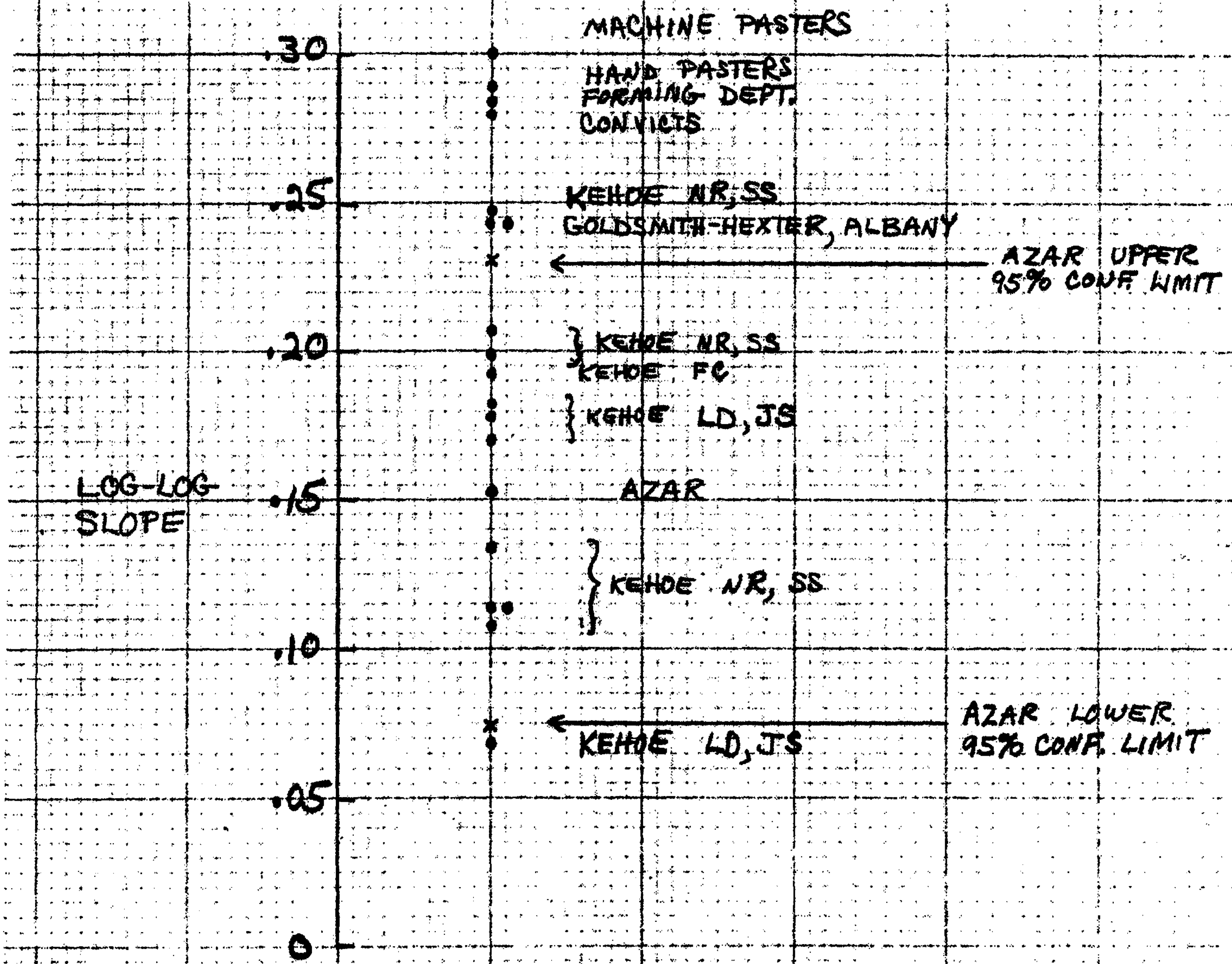
6. Williams, N. K., King, E., and Walford, J. (1969). An Investigation of Lead Absorption in an Electric Accumulator Factory with the Use of Personal Samplers. Brit J Ind Med 26, 202-216.

FIGURE 1



MACHINE PASTERS
HAND PASTERS
FORMING DEPT.
CONVICTS
KEHOE NR, SS
GOLDSMITH-HEXTER, ALBANY
AZAR UPPER 95% CONF. LIMIT
KEHOE NR, SS
KEHOE FC
KEHOE LD, JS
AZAR
KEHOE NR, SS
AZAR LOWER 95% CONF. LIMIT
KEHOE LD, JS
LOG-LOG SLOPE
.30
.25
.20
.15
.10
.05
0

Data Set	X_o Air Pb	y_o Blood Pb	Δ Blood Pb / Δ 1 μg/m³ AIR Pb AZAR	G&H
Starke, Fla	.64	16.4	2.5	4.2
Barksdale, Wisc.	1.01	13.8	1.5	2.5
Phila. Cab	2.62	22.4	1.1	1.8
LA. Office	3.06	19.9	0.9	1.4
L.A. Cab	6.10	24.6	0.6	0.9
albany	3.2	26	1.1	1.8
albany	10.9	35	0.5	0.8

Model $y = ax^b$ line thru x_o, y_o with slope b is $\log y = \log y_o + b(\log x - \log x_o)$

or $y = y_o\left(\frac{x}{x_o}\right)^b$

$$\frac{\Delta y}{\Delta X = 1} = y_o\left(\frac{x_o+1}{x_o}\right)^b - y_o\left(\frac{x_o}{x_o}\right)^b$$

$$= y_o\left[\left(\frac{x_o+1}{x_o}\right)^b - 1\right]$$

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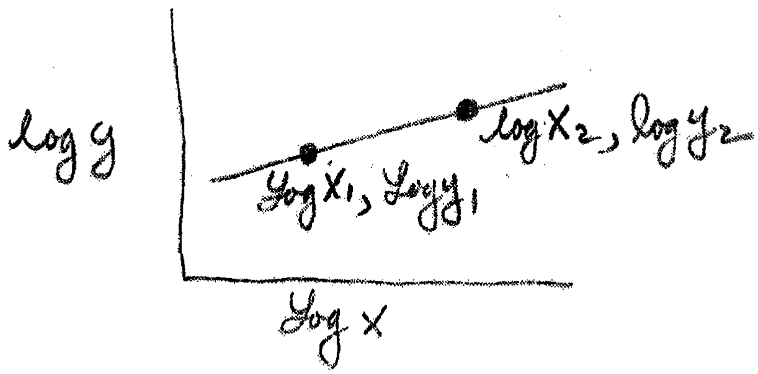
Azar, Snee, Habibi Relationship

$$\log \text{Blood Pb} = 1.2257 + .153 \log \text{Air Pb}$$

If $y = ax^b$ then $\%\ \text{Increase} = 1 - \left(\frac{x_2}{x_1}\right)^b$



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$$\frac{y_2}{y_1} = \left(\frac{x_2}{x_1}\right)^b$$

X Ratio $\left(\frac{x_2}{x_1}\right)$	DUPONT % Increase	b=.243 % Goldsmith & Hexter
1	0	0
2 = DOUBLE	11.2	18.3
3 = TRIPLE	18.3	30.6
4	23.6	40.1
5	27.9	47.9
10	42.2	75.0

$$\underline{\log \text{Blood Pb} = a + b \log \text{air Pb}}$$

Study	b
Azar etal	.153 ± .079 < .232 / .074
Goldsmith & Hexter	.243
Albany Study	.243

$$b = \frac{\log (35/26)}{\log (10.9/3.2)} = .243$$

KEHOE FC

$$\text{Blood Pb} = A(\text{air Pb})^B$$

$$\log \text{blood Pb} = 1.2257 + .153 \log \text{Air Pb}$$

Air Pb	Blood Pb	$\dfrac{\Delta \text{ Blood Pb}}{\Delta \text{ Air Pb} = 1 \mu gm/m^3}$
1	16.8	1.9
5	21.5	0.6
10	23.9	0.4

$$\%\ \text{Increase} = \left[\left(\frac{X_0+1}{X_0}\right)^b - 1\right] * 100$$

	b	
X_0	.153	.243
1	11.2	18.3
5	2.8	4.5
10	1.5	2.3

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