



Intra Company

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September 27, 1970

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Subject: Asbestos in Brake Lining Wear Debris

It is estimated that an average of about 100g of eryectile asbestos per car per year are consumed as a result of brake lining wear. This estimate is based on lining volume worn from various types of brakes using proving ground lining life experience, and assumes typical lining asbestos content and 10,000 miles of use per year. The average is weighted according to the 1968 Ford Motor Company passenger car product mix. (A previous estimate of 307g was based on unrealistically high wear volumes and rates.) For a U.S. population of 90 million cars, about 10,000 tons per year of brake lining asbestos would thus be worn away, with more of the wear being concentrated in regions of high car population density. Approximately 1 million tons of asbestos per year are consumed in the U.S. for all applications¹. According to Selikoff², the health hazard from asbestos which could be emitted to the atmosphere through brake lining wear is small compared to the hazard from asbestos dispersed in the air from other sources, such as insulation used in the building trades. Professor Selikoff is an accomplished worker in the field of asbestos disease epidemiology³⁻⁵.

Electron microscope studies by Lynch⁶ indicate that less than 1% of the brake lining wear debris generated during normal braking is fibrous asbestos — the remainder of the asbestos initially present (about 50% of the lining) is decomposed into non-fibrous dust particles. Gatrell and Schreiber¹⁰ found asbestos decomposition products in wear debris by infrared analysis, although their work did not preclude the survival of some fibers. X-ray diffraction analyses of drum dust in our own laboratory have not indicated the presence of undecomposed asbestos. If, based on the work by Lynch, it is assumed that as much as 1% of the inorganic portion of the wear products ends up as undecomposed asbestos fibers, then about 1.4g of fiber per car per year would be emitted (139 ton/year in the U.S.).

See attached Reference list.

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Asbestos has been implicated as a carcinogen³⁻⁸. It is suggested that this carcinogenic effect is associated with the fibrous nature of asbestos. I know of no studies on the physiological effects of asbestos decomposition products. However, it seems that the non-fibrous decomposition products would be perhaps less permanently implanted in the lung tissues if inhaled, and less likely to be a persistent source of localized irritation.

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R.L.C.

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Estimate of Total Oil Consumption in 1 year

11" drum brake

$$29.22 \text{ in}^3 \times 16.39 \times 1.80 = 860 \text{ g} \times \frac{10,000 \text{ mi/yr}}{35,000 \text{ g/yr}} = 246 \text{ g/yr/car}$$

11" disc / 11" drum

$$\text{disc: } 13.6 \text{ in}^3 \times 16.39 \times 1.85 = 411 \text{ g} \times \frac{10,000}{42,000} = 98 \text{ g/yr/car}$$

$$\text{drum: } 15.9 \text{ in}^3 \times 16.39 \times 1.80 = 466 \text{ g} \times \frac{10,000}{42,000} = 111 \text{ g/yr/car}$$

$$\text{total: } 209 \text{ g/yr/car}$$

10" drum brake

$$12.84 \text{ in}^3 \times 16.39 \times 1.80 = 526 \text{ g} \times \frac{10,000}{35,000} = 150 \text{ g/yr/car}$$

10" disc / 10" drum

$$\text{disc: } 10.2 \text{ in}^3 \times 16.39 \times 1.85 = 309 \text{ g} \times \frac{10,000}{21,000} = 88 \text{ g/yr/car}$$

$$\text{drum: } 8.34 \text{ in}^3 \times 16.39 \times 1.80 = 246 \text{ g} \times \frac{10,000}{35,000} = 70 \text{ g/yr/car}$$

$$\text{total: } 158 \text{ g/yr/car}$$

9" drum brake

$$16.54 \text{ in}^3 \times 16.39 \times 1.75 = 475 \text{ g} \times \frac{10,000}{28,000} = 170 \text{ g/yr/car}$$

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81.2

Average brake lining wear on U.S. based Ford car

sales of 1968:

$$\begin{array}{ccccc} 9'' \text{ drum} & 10'' \text{ drum} & 10'' \text{ disc/drum} & 11'' \text{ drum} & 11'' \text{ disc/drum} \\ 0.043 \times 170 & + 0.286 \times 175 & + 0.1036 \times 158 & + 0.27 \times 246 & + 0.293 \times 209 \end{array}$$

$$= 7.3 + 50.0 + 16.4 + 67.1 + 61.3 = 202.1 \text{ g/car/yr}$$

based on typical proving ground life and 19,000 miles/yr

Assuming 10^8 vehicles in U.S.

$$10^8 \times 202.1 \text{ g/car/yr} \times \frac{1 \text{ lb}}{454 \text{ g}} \times \frac{2000 \text{ lb}}{2 \times 10^3 \text{ lb}} = 22,200 \text{ tons/yr}$$

Fraction of total from disc brakes:

$$\frac{\frac{88}{158} \times 16.4 + \frac{98}{209} \times 61.3}{202.1} = \frac{9.13 + 28.8}{202.1} = 0.158$$

so that $0.158 \times 22,200 = 4,160 \text{ tons}$ of disc brake
are worn and 18,040 tons of drum brake are worn

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Leaving consumed: ~202 g

$$\frac{\text{can/yr}}{10,000 \text{ mi/yr}} = 20 \frac{\text{mg}}{\text{mi/can}}$$

Approximately 75% is emitted as particulates
or 15 $\frac{\text{mg dust}}{\text{mi/can}}$

Typical lead concentration in urban air spheres
is about $2 \mu\text{g}/\text{m}^3$ (1967), JAPCA, Apr. 1969, 19, p 587.

Est. of Cr. P.
lead concentration
in 1967

Assuming $2.5 \text{ g Pb/gal} \times 0.75 \text{ emitted} = 125 \frac{\text{mg Pb}}{\text{mi}}$
15 mi/gal

$$\text{Leaving dust conc.} = \frac{2 \times 10^{-3} \frac{\text{mg Pb}}{\text{m}^3} \times 15 \frac{\text{mg dust}}{\text{mi}}}{125 \frac{\text{mg Pb}}{\text{mi}}} = 0.00024 \frac{\text{mg}}{\text{cu m}}$$

If typical CO conc. is say 10 ppm in
urban atmosphere and 70% is due to cars

$$\left(7 \times 10^{-6} \frac{\text{cu m CO}}{\text{cu m air}} \times \frac{28 \text{ g CO}}{28 \times \text{CO}} \times \frac{10^3}{\text{cu m}} \times \frac{10^3 \text{ mg}}{\text{g}} \right) = 8.2 \frac{\text{mg}}{\text{cu m}}$$

and if average car today emits, say
60 g CO/mi,

$$\text{Leaving dust conc.} = \frac{8.2 \frac{\text{mg CO}}{\text{cu m}} \times 15 \frac{\text{mg dust}}{\text{mi}}}{60,000 \frac{\text{mg CO}}{\text{mi}}}$$

$$\times 10^{-6} \frac{202 \text{ g}}{\text{yr}} \times \frac{1}{10,000 \text{ mi/yr}} = 2.02 \times 10^{-6} \frac{\text{g}}{\text{mi}}$$

$$2.02 \times 10^{-6} = 2.02 \times 10^{-6}$$

$$= 0.00205 \frac{\text{mg}}{\text{cu m}}$$

	Premium	% of sale
July 1967	2.93	~45%
Jan 1967	2.72	
	<u>25.65</u> 2.83	

	Regular	% of sale
July 1967	2.47	~55%
Jan 1967	2.06	
	<u>24.53</u> 2.27	

Ethyl Corp
 Caroline Quality Survey
 Jan + June 1967

$$\begin{aligned}
 .5 \times 2.83 + .55 \times 2.27 &= \\
 1 + 1.25 &= 2.52
 \end{aligned}$$

May of Natl
 1968 Pet
 for % premium sales

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Automotive Industries, Mar 15, 1969
51st Annual Engineering Specifications & Statistics

1968
9"

Drum

Disk/Drum

FALCON

10" 272,000
267,000
36,200
67,000

70,000
40,000
82,500
42,000

FALCON
MUSTANG
MUSTANG
COURT

11 33,300
32,400
276,000
55,300

20,500
17,300
125,000
123,000
65,000
57,000
21,000
175,000

COURT
MUSTANG
MUSTANG
LTD
T-BIRD
LINCOLN
MERC
WAGON

11" Tot 617,500 (27.3%)

663,800 (29.3%)

10" Tot 647,200 (27.6%)

234,500 (10.3%)

9" Tot 97,000 (4.3%)

1361,700

897,300

2260,900

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10" Drum Brake (rimmed, type 17070")
 side

	Front		Rear		
	P _{ri}	S _{ec}	P _{ri}	S _{ec}	
L	846	1685	846	1685	
W	285	285	435	1.75	
Eff	.18	.18	.18	.18	
W _{eff}	.72	.81	.72	.81	
Vol	1.74	3.57	1.43	2.72	
Vol ₁	1.72	3.57	1.39	2.72	2.38
Vol ₂	1.72	3.57	1.12	2.32	3.57
					1.72
					9.92

Total Volume Wear $(1.72 + 3.57 + 1.12 + 2.32) \times 2 = 17.84 \text{ in}^3$

Total asbestos wt = $17.84 (16.39) (1.80) (53) = 278 \text{ grams}$

for 30,000 mi life
 @ 10,000 mi/year

93 grams/year asbestos in wear debris
 Filter in debris: $0.01 \times 278 \times \frac{0.7}{1.3} \times \frac{10,000}{30,000} = 6.22 \text{ g/year}$

10" Disk/Drum

Side	5.1 in	4.12	Total wt 18.58 in ³
W _{eff}			
Vol			

Total asbestos wt = $(2) 5.1 (16.39) (1.80) (53) + 4.12 (16.39) (1.80) (53) (2) = 223 \text{ g}$

for 30,000 mi life
 @ 10,000 mi/year

64 grams/year asbestos in wear debris

Filter in debris: $0.01 \times 223 \times \frac{0.7}{1.3} \times \frac{10,000}{30,000} = 6.22 \text{ g/year}$

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9" Drum Brake (rimmed, type t-070)
Std.

FRONT		REAR	
PR	SEC	PR	SEC
L 2.16	2.22	2.16	2.22
W 2.25	2.25	1.50	1.50
t _{1/2} .15	.18	.15	.18
1.16 .22	.91	1.16 .22	.91
correct for effect of gravity in wear			
V ₁ 2.27	3.22	1.515	2.15
V ₂ 1.74	3.22	1.16	2.15
V₃ 1.16	3.22	1.16	2.15
Total wear volume (1.74 + 3.22 + ^{1.16} 3.22 + ^{2.15} 2.15) = 16.54 in ³			

total asbestos vol = 16.54 (16.39) (1.75) (.95) = 260 grams

for 20,000 miles life (Ant Hogen)
of 10,000 miles/year

93 grams asbestos in wear debris/year

Compare to front wheel
is not a factor for primary wear secondary
wear is not

$$\text{Asbestos in debris} = 260 \times \frac{.27}{.25} \times \frac{10,000}{20,000} = 1.18 \text{ g wear/gm}$$

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pass car
90 million registration in U.S.

16 million
16 million trucks & buses.

$$9 \times 10^7 \text{ car} \times 100 \text{ lb/car/yr} \times \frac{1 \text{ ton}}{2000 \text{ lb}} \times \frac{1 \text{ yr}}{45 \text{ yr}} = 10,000 \text{ ton/yr}$$

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Ave asbestos wear in brakes of pass cars/year
(based on Ford car sales 1968)

	7"	10" drum	10" disk	11" disk	11" disk/drum
4.0	93(.043)	93(.28)	64(.10X)	122(.67)	88(.293)
26.6					
6.6					
34.9					
25.8	4.0	+ 26.6	+ 6.62	+ 34.9	+ 25.8 = 97.9
97.9					

97.9 g/car/year based on typical
proving ground lining life and an
estimation of 60,000 miles of wear
per year

Fiber in wear debris, assuming 1% fiber in
debris, and debris is 70% of original lining:

$$0.043 \times 1.18 + 0.286 \times 1.22 + 0.103 \times 1.1 + 0.223 \times 1.72 + 0.293 \times 1.47 =$$

$$0.051 + 0.349 + 0.115 + 0.470 + 0.470 = 1.415 \text{ g/car/year}$$

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Estimate of Steady-State Content of Asbestos Particulates in Air from Brake Lining Wear

Assumptions:

Normal at. by at. particulate
ventilation in city: 15,000 particles/cc
air mass: 200 particles/cc

1. Air mixes vertically to height of 1000 ft
2. Life of average aerosol particle is 8 days
3. 1% of wear debris is asbestos fiber
4. 1.6 times asbestos worn is wear debris
5. 11,000 tons/year asbestos worn in U.S.
6. 2% of vehicle miles travelled as in Detroit in an area 100 sq. miles.
7. No side mixing outside 100 sq mile area.
8. All of asbestos fiber is ultimate fibril, 1/1000 inch diameter x 20/1000 inch long, density 2.28/cc

Over 100 sq. mi, 2% of Vehicle Miles in U.S., 1% of Wear Debris is Ultimate Fiber

$$11,000 \frac{\text{tons asbestos}}{\text{year (U.S.)}} \times \frac{1.6 \text{ tons dust}}{\text{ton asbestos}} \times \frac{0.01 \text{ ton fiber}}{\text{ton dust}} \times \frac{0.02 \text{ ton (wear)}}{\text{ton (year (U.S.))}} \times \frac{1 \text{ year}}{365 \text{ days}} \times 8 \text{ days}$$

$$\rightarrow \times 2000 \frac{\text{lb.}}{\text{ton}}$$

$$100 \text{ mi}^2 \times (5280)^2 \frac{\text{ft}^2}{\text{mi}^2} \times 1000 \text{ ft}$$

$$= \frac{11 \times 10^3 \times 1.6 \times 10^{-2} \times 2 \times 10^{-2} \times 8 \times 2 \times 10^3}{3.65 \times 10^2 \times 10^2 \times (5.28)^2 \times 10^3 \times 10^3} = 5.53 \times 10^{-11} \frac{\text{lb-fiber}}{\text{ft}^3}$$

$$5.53 \times 10^{-11} \frac{\text{lb}}{\text{ft}^3} \times 8 \times 10^{17} \frac{\text{fibers}}{\text{lb}} = 4.43 \times 10^7 \frac{\text{fibers}}{\text{ft}^3} = 1560 \frac{\text{fibers}}{\text{cc}}$$

$$5.53 \times 10^{-11} \frac{\text{lb}}{\text{ft}^3} \times 454 \times 10^3 \frac{\text{mg}}{\text{lb}} \times \frac{35.23 \text{ ft}^3}{\text{m}^3} = 8.85 \times 10^{-4} \frac{\text{mg}}{\text{m}^3}$$

In Over Continental U.S., All U.S. Trucks, 1% of Wear Dust is Ultimate Fiber

$$\text{Land area of U.S.} \approx 3000 \times 1250 \text{ mi} = 3.75 \times 10^6 \text{ mi}^2$$

$$4.43 \times 10^7 \times \frac{100 \text{ mi}^2}{3.75 \times 10^6 \text{ mi}^2} \times \frac{1}{0.02} = 59,100 \frac{\text{fibers}}{\text{ft}^3} = 2 \frac{\text{fibers}}{\text{cc}}$$

Air Over Continental U.S., All U.S. Trucks, All of Original Asbestos is Ultimate Fiber

$$\frac{5.91 \times 10^9}{0.016} = 3.7 \times 10^6 \frac{\text{fibers}}{\text{ft}^3} = 131 \frac{\text{fibers}}{\text{cc}}$$

Air Over Earth, Double U.S. Truck Usage, All of Original Asbestos is Ultimate Fiber.

$$\text{Area of earth} \approx 4\pi (4000 \text{ mi})^2 = 2.01 \times 10^8 \text{ mi}^2$$

$$3.7 \times 10^6 \times 2 \times \frac{3.75 \times 10^6}{2.01 \times 10^8} = 138,000 \frac{\text{fibers}}{\text{ft}^3} = 5 \frac{\text{fibers}}{\text{cc}}$$

Air Over Earth, Double U.S. Truck Usage, 1% of Wear Dust is Ultimate Fiber

$$138,000 \times 0.016 = 2200 \frac{\text{fibers}}{\text{ft}^3} = \frac{1 \text{ fiber}}{13 \text{ cc}}$$

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Maximum Number of Fibers Per Pound of Asbestos

Assume divided into ultimate fibrils, 1/1000000 in.

$$\frac{1 \text{ fiber} \times 454 \text{ g/lb}}{\frac{\pi}{4} \times (10^{-4})^2 \text{ in}^2 \times 20 \times 10^{-6} \text{ in} \times 16.39 \frac{\text{cm}^3}{\text{in}^3} \times 2.28 \frac{\text{g}}{\text{cm}^3}} = 8 \times 10^{17} \frac{\text{fibers}}{\text{lb.}}$$

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Total vehicle miles traveled,
All road systems, 1999 calendar year:

208,454,044,986

Total MVs registered in Texas ¹⁹⁹⁹

17,962,300

1960 data Cuyahoga County 1,721,300
Ohio Population 9,706,000 } 5.43%
178,555,000 } Ohio

10,652,017 population in 1970

Vehicles Fitted + Registered

www.bts.gov/pg.pdf

~~1970~~ Total passenger cars

1970
89,243,557

1997
129,748,704

Total Motorcycles

2,824,098

3,826,373

Total other 2-axle

14,210,591

+20%

70,224,082

Trucks, single unit

3,681,405

5,293,358

Trucks, combination

905,082

1,789,968

Buses

377,562

697,548

1.4

2800 lbs
x 16

Cuyahoga

500 sq mi
x 640 → 448,000 oz.

2800 =

320,000 acres

1,280,000

.035 oz

100x100

.0035 oz in
every 1000 sq ft

640 ac/sq mi

10,000 cu ft ①

Vehicle MILES (in millions)

Passenger cars

917,000

1,502,000

Motorcycles

3,000

10,100

Other

123,000

850,000

Trucks

62,200

191,300

Buses

4,500

6,800

139 tons per year = 7 1/2 tons on the state of OHIO
26.5 million acres
100,000,000 residential lots 15,000 pounds
41,330 sq miles ← OHIO