A Survey. Sources of Mercury Pollution and Potential Human Exposure, U.S.

Prepared for the Mercury Task Force

by

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Mercury Pollution in the U.S. by Source Category

I. Mining[1]

a) Assume an emission factor of 1 1 tons of dust lost per 1,000 tons of mined ore processed

b)

Industry	Tonage (Est)	Conc. of Hg	Tons Dust Lost
Mercury	268,000	5lbs/Ton	294
Zinc	18,000,000	1	20,000
Lead			
Copper	223,752,000	.5	245,000

c) Assume the above industries emit 50% of the mercury from dusting in ore processing operations

d) 1.255 x 2 = 2.5 tons Hg emitted per year

e) Assume 1971 data is applicable to 1974.

II. Smelting[1]

1) Primary Mercury Processing

a) Total production in 1971 was 1,339,794 lbs.

b) Assuming an average of 5 lbs/Ton then the tonnage of ore mined was

(1,339,794 lbs)/(5lb/Ton) = 267,959 Tons

c) Designers indicate that approximately 1600 SCFM of stack gases are emitted for each 100 T/D of ore furnaced.

d) Using the above information, 25 lbs. of Hg are emitted for each 100 tons of ore processed.

e) [267,959 Tons/(100 Tons)] x (25lbs/100 Tons) = 67,000 lbs or 33.5 tons

f) Assume 1971 data is applicable for 1974

2) Secondary Mercury Production[1]

a) Secondary mercury production in 1971 was 16,670 flasks.

b) EPA data indicate a retort operates at a flow rate of 20 CFM and effluent gases have a concentration of 5000 ug/m^3

c) A typical mercury sludge charge is 300 lbs and has a 50% Hg content

d) Emissions per charge (20)(1440)(.005)/35 31 = 4 8g for each 150 lbs (2 flasks) of Hg produced

e) Probably most of the mercury emissions from this operation occur with manual charging and discharging of the ore, therefore for estimation purposes 10 times the effluent emission will be assumed to come from opening and closing of the retort. Total emissions per flask

(4 8g + 48g)/2 = 26.4g/flask

f) 1971 emissions were

(16,670)(26.4g/fl.)/(454g/lb.)(2000lb/Ton) = 5 tons

g) Assume 1971 data is applicable to 1974

3) Non-Ferrous Ore Processing[1]

a) Mercury is found in all primary non-ferrous ores in trace amounts varying from 05 to 600 ppm. During the extraction of the non-ferrous metals from their associated ore concentrates, mercury is volatilized and becomes part of either waste or process gas streams. Representative samples of the non-ferrous industries' zinc, lead, and copper concentrates have been collected and their Hg content determined by neutron activation analysis.

b) Direct atmospheric emissions of mercury from non-ferrous ore processing has initially been calculated to be

Industry	Concentrate Processed (1×10^6 Ton/Yr)	Emissions (Tons/Yr)	Avg Emission Factor (lb/Ton Conc)
Primary Lead	1	11	.01
Primary Zinc	1.8	5	.012
Primary Copper	6.5	35	.011

The following assumptions were used in estimation of these figures

(1) The samples of non-ferrous concentrate which were collected and analyzed are representative of the non-ferrous process input.

(2) All of the mercury which is contained in the process input is volatilized during the first major pyrometallurgical step.

(3) All primary non-ferrous operations which do not pass their first-step pyrometallurgical gas stream through an acid plant will emit 100 percent of their mercury input to the atmosphere

(4) All primary non-ferrous operations which do pass their first-step pyrometallurgical gas stream through an acid plant will emit 10 percent of the mercury input to the atmosphere. The remaining 90 percent of the mercury input will be absorbed by the produced acid and collected by various acid plant equipment

(5) Assume 1971 data is applicable to 1974

III. Fossil Fuel Combustion

Coal

a) The best current estimate of the mercury content in coal (U.S.) is .18 ppm[1]. Based on a consumption of 522,000,000 tons[2] and the assumption that 90% of the mercury is volatilized, the total atmospheric emissions are·

(522)(.18)(.9) = 85 tons

b) Assuming that the 10% not emitted remains in the ashe and is disposed of in a landfill, the total mercury entering land via coal combustion is.

(522)(.18)(.1) = 9 tons

Oil

a) Using a Hg content of .06 ppm[1] as an average, an annual oil consumption figure of 1,560,638 million pounds and the assumption that 90% of the mercury is volatilized the total atmospheric emissions from oil combustion is

(780)(.06) - 47 tons (.9) = 42 tons

b) Assuming that the 10% not emitted remains in the ash and is disposed of in a landfill, the total mercury entering the land environment via oil combustion is.

(.1)(47) = 5 tons

Natural Gas

a) Using a 1967 figure for World Consumption of natural gas of 6 x 10^8 Tons/Yr and an average mercury content of .04 ppm, the worldwide releases of mercury from natural gas are 20 tons yr [3]

b) Assume that the U.S. consumes 50% of the world total for 1967 and 90% volatilization of mercury in the gas.

(.9)(.5)(20) = 9 tons

c) Assume that 10% of the mercury remains in the ash and is deposited in a landfill. Total contribution from natural gas combustion to mercury introduced into land

(.1)(.5)(20) = 1 ton

IV. Chlor-alkali Industry

a) According to a 1973 Battelle Report, the annual discharge of mercury to waters was 10 tons.[4]

b) Of the 30 chlor-alkali plants in the U.S., 24 were reported to Battelle. The average discharge for the 24 plants was 654 6 lbs/year. For estimation purposes this average annual discharge rate was also assigned to the 4 plants that no data was available for.

c) It is assumed that the reported discharges are typical of the daily discharge rates for these plants.

d) An average of 10 lbs of mercury is emitted to the atmosphere for every 100 tons of chlorine produced.[3]

e) Assuming that all plants are operating at the production rates as reported to Battelle[4] then the total tonnage of chlorine produced annually is 4,065,370 tons/yr. Cl_2.

f) Total atmospheric emissions are:

(10 lbs Hg)(4065 4 tons Cl_2) = 40,654 lbs Hg or 20 3 tons

V Batteries

a) An estimated 400 tons of mercury will be used by the batteries industry with a 9% recycling of mercury annually.[5]

(.09)(400) = 36 tons

b) It is assumed that the remaining 364 tons of mercury eventually gets into the environment.

c) Twenty-seven percent of all mercury contained in batteries is eventually incinerated.[6]

(.27)(364) = 98 3 tons

d) Of that 98.3 tons mercury incinerated it is estimated that 18 5% remains in ash and is deposited in landfills.[6]

(.185)(98.3) - 18 2 tons to landfills from incineration ash

e) The remaining 81 5% or 80 1 tons of mercury is volatilized and released to the atmosphere.[6] 80 tons to air

f) The remaining 73% or 266 tons of mercury is deposited directly into landfills.[6] Total mercury to landfills 266 + 18 = 284 tons.

VI. Paint Industry and Paint Application

a) Total mercury to be used in paint industry, estimated for 1974 is 460 tons.[5]

b) Assume a Davis emission factor of 5 lbs mercury per ton of Hg used in paint manufacture.[1] Emissions are

(460 tons)(5 lbs/ton)/(2000 lbs/ton) = 1 1 tons

c) Assume a Davis emission factor of 65% of the mercury used in paints is emitted within 3 years after application. There were 327 tons of mercury used in paint in 1971.[1]

d) Emissions in 1974 from paint produced in 1971 alone are (.65)(327) = 213 tons

e) Thirty-two percent of the mercury used in paint manufacture is released directly to the water environment [3] (32)(460) = 147 tons

It is assumed that this 1967 data is still applicable. No other information was available.

f) 4 2% of the total mercury used in paints is entered into the environment through disposal of containers and subsequent dumping into landfills[7](.042)(460)=19 tons

VII Catalyst

a) Seventy-five tons estimated to be used in 1974 for use as a catalyst [5]

b) The most recent information available to me on the amount of mercury released by catalytic uses of mercury is from 1967[3]

c) Assuming that this information is applicable to 1974 patterns of mercury discharge

(1) 11% is released into the atmosphere from plants using mercury as a catalyst (11)(75) = 8 tons

(2) 39% is released directly into water from plants using mercury as a catalyst (.39)(75)=29 tons

(3) The remaining 37 tons is unaccounted for. Certainly some is contained in the products manufactured, but how much is unknown

VIII. Dental

a) Projected 1974 usage - 75 tons of mercury[5]

b) Assume a Davis emission factor of 1% during preparation.[1] (.01)(75) - .75 tons

c) The FDA has estimated that 25% of the mercury used in dental preparations are lost in particles of amalgum which are scraped off the tooth or fall into the mouth and subsequently spit out into dental bowels and hence to sewers.[8]

(.25)(75) = 19 tons

d) The remaining 74% is put into teeth and will be considered as never entering the environment. Of course some of this would get into the environment but in no way could this amount be estimated with current information.

IX. Agriculture

a) Projected 1974 consumption for agricultural uses - 60 tons [5]

b) Assume a Davis report emission factor of 50% of the mercury sprayed is emitted.[1]

c) Using a ratio based on 1969 data, 29% of the mercury used in agriculture is sprayed [1]

(.29)(60)(5) = 9 tons emitted to air

d) It is assumed that the remaining 51 tons are released directly onto land and enter the environment as pollutants.

X. Pharmaceuticals

a) Projected 1974 consumption 27.5 tons[5]

b) Davis report emission factor is 410 lbs. Hg emissions per ton of mercury used in anticiptics, skin prep, and preservatives.[1]

(410 lbs/ton)(27.5)/(2000 lbs/ton) = 5.6 tons

c) It is assumed here that the remaining 22 tons is released into the aquatic environment via human disposal and waste treatment plants.

XI. Paper and Pulp

a) Projected 1974 usage 11.5 tons[5]

b) From 1967 data compiled by David Klein[3]

(1) 60% of the mercury used enters the aquatic environment

(.6)(11.5) - 6.9 tons

(2) 40% is emitted to the atmosphere.

(.4)(11.5) = 4.6 tons

XII Laboratory Uses

a) Most recent figure for annual consumption is from 1968. 69 tons It is assumed that this figure is applicable to 1974.[7]

b) Assume that 10% of the mercury consumed in the laboratory is lost to the atmosphere.[1]

(1)(69) - 6.9 tons

c) From 1967 data 62% is lost to the aquatic environment.[3]

(.62)(69) = 43 tons

XIII. Animal Manure

a) USDA estimates that 50% of all animal manure is recycled and 50% is released directly into the environment [9]

b) Total tonnage of feed grains produced in the U.S was 282,500,000 tons.[10]

c) Using .142 ppm as an average mercury content figure.[11]

(.142)(282 5) = 40.1 tons Hg

d) Assuming that 97% of the total amount of mercury ingested by animals eating feed grains is emitted in waste

(.97)(40.1) = 39 tons

amount released to environment (.5)(39) = 19.5 tons

e) It is assumed that at least .5 tons are released annually by other animals therefore upping the tonnage to 20 tons/yr of mercury released into the land environment

f) It is assumed that 100% of the wastesnot collected enter directly into the land environment

XIV Incineration

a) Using an estimate of 30,000,000 tons of wood and paper products incinerated annually with an average Hg content of .9 ppm.

(30)(9) = 27 tons

b) Assumed that 100% of the mercury is volatilized.

XV. Sewage Plants

a) David Klein has reported influent Hg concentrations ranging from .6 to 27 ppb. and from 5 to 3 ppb in effluents from 13 plants in Wisconsin [12]

b) Using an effluent concentration average of 1 ppb the annual discharge of mercury amounts to 1000 lb/yr per million people served by the plant.

c) For estimation purposes we will use 1 ppb as being the national average of mercury concentration in sewage effluents

d) Using 250 million as the population of the U S., and mercury discharges of 1,000 lbs/yr per million people

(250)(1000)
(250)(1000 lbs/person)/(2000 lb/ton) = 125 tons

Sludge

a) Assume 35% of all dried sludge in incinerated and 65% is deposited in landfills

b) An EPA task force indicated in 1971 that the average mercury content of dried sewage sludge is 4.3 ppm.[1]

c) In 1971, 1,022,000 tons of dried sewage sludge were incinerated Assuming 100% volatilization and 0% collection of this mercury the total atmospheric emissions from sludge incineration was·

(4.3)(1.022) = 4.4 tons

d) If 4.4 tons of mercury is 35% of the total amount of mercury tied up in sewage sludge then the total contribution from sewage sludge of mercury to land was· 8.2 tons

XVI. Lamps and Tubes

a) 1971 projected usage - 312.5 tons[5]

b) Assume a Davis emission factor of .4% Hf is emitted to the atmosphere during manufacture.[1]

(04)(312 5) = 12.5 tons

c) 300 tons are available for recycling

d) Of the 300 tons available for recycling 52% is actually recycled and the remaining 48% goes to landfills.

(.48)(300) = 144 tons to landfills

XVII. Controls

a) Projected 1974 usage - 105 tons of mercury.[5]

b) Assume a Davis emission factor of .4% of the Hg is emitted to the atmosphere during manufacture [1]

(.04)(105) = 4 2 tons

c) 100 8 tons are available for recycling

d) Of the 100 8 tons available for recycling 52% is actually recycled and 48% goes to landfills.

(.48)(100 8) = 48 tons to landfills

XVIII. Other

a) Projected 1974 mercury consumption 156 tons[5]

b) Assume a Davis emission factor of 1% loss to the atmosphere.[1]

c) 154.4 tons available for recycling

d) Of the 154.4 tons available for recycling, 52% is actually recycled and 48% will be assumed to go to landfills

(48)(154 4) = 48 tons to landfills

References

1. Roy, Sims L "Emissions of Mercury in the U.S. by Source Category", 1971.

2. U.S Bureau of Mines, Minerals Yearbook, 1970, Volume II Area Reports Domestic

3. Klein, David, "Sources and Present Status of the Mercury Problem" 1971.

4. Battelle Memorial Institute, "Reported Mercury Discharge from Chlor-Alkali Plants in the U.S." 1973.

5. Garrett, David, "1974 Mercury Input/Output Balance" 2/26/74

6. "Transport of Heavy Metals From Dry Batteries" 1970

7. Pacific Northwest Laboratories, "Criteria Document for Mercury", November 1973.

8. Lambou, Victor, "Report on the Problem of Mercury Emissions into the Environment of the United States." January 27, 1972.

9. Dr. Calvert, United States Department of Agriculture Telephone Conversation, April 10, 1974.

10 Stanford Research Institute, Chemical Economics Handbook, 1974

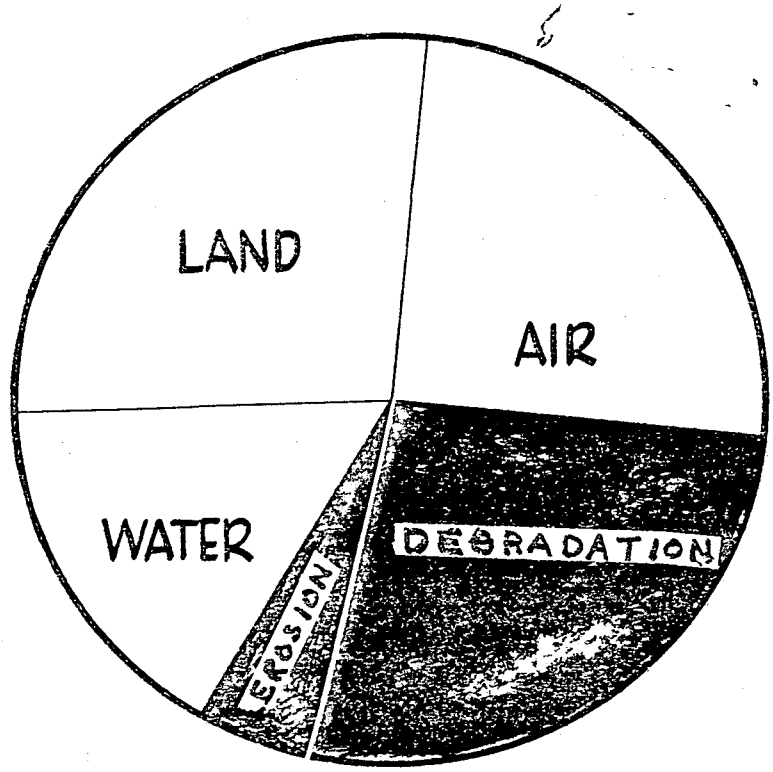
11 Table 19, Estimate of Potential Human Exposure to Mercury in the United States. 1974

12. Klein, David, "Mercury in the Environment", May, 1973

			Air		Water		Land		Total	
Source	Tons Hg [illegible] of Consumed	Est % Loss	% Loss to	Tons	% Loss To	Tons	% Loss To	Tons	Loss Tons	Comments
Mining	2.5	100	100	2.5	-	-	-	-	2.5	
Smelting										
Mercury	34	100	100	34	-	-	-	-	34	
Other Ores	51	100	100	51	-	-	-	-	51	
Fuels										
Oil	47	100	90	42	-	-	10	5	47	
Coal	94	100	90	85	-	-	10	9	94	
Nat. Gas	10	100	90	9	-	-	10	1	10	
Chlor-Alkali	478	6.3	4.2	20.3	2.1	10	-	-	30.3	
Lamps, Tubes	312.5	46.4	.4	12.5	-	-	46	144	156.5	54% recycled
Batteries	400	91	20	80.1	-	-	71	284.2	364	9% internal recycle
Controls	105	48.4	.4	4.2	-	-	46	48	52.2	52% recycled
Paint	460	100							380	
Paint Application			46.3	*213	-	-	4.1	19		*65% will be emitted in 3 yr
Manufacture			.2	1.1	32	147				
Catalysts	75	50	11	8	39	29	-	-	37	
Dental	75	26	1	.75	25	19	-	-	20	
Agriculture	60	100	15	9	-	-	85	51	60	
Pharma	27.5	100	20	5.5	80	22	-	-	27.5	
Paper & Pulp	11.5	100	40	4.6	60	6.9	-	-	11.5	
Lab Use	69	72.3	10	6.9	62	43	-	-	49.9	
Other	156	48.4	1	1.6	-	-	47.4	74	75.6	52% recycled
[illegible]	40	50	-	-	-	-	50	20	20	
Engineering	27	100	100	27	-	-	-	-	27	
Sewage Plants										
Effluents	125	100	-	-	100	125	-	-	125	
Sludge	12.6	100	35	4.4	-	-	65	8.2	12.6	
Totals	2672.6	63	23	623	15	402	25	663	1,688	

MERCURY POLLUTION BALANCE, U.S.

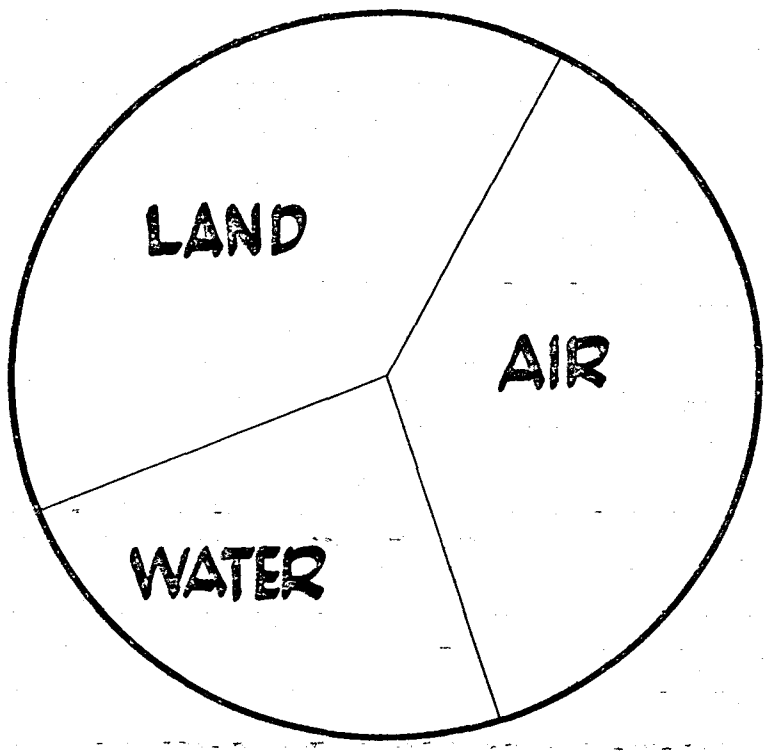
TOTAL MERCURY IN TONS: 2,483



SOURCE	TONS	% OF TOTAL
NATURAL PROCESSES ■		
EROSION	130	5
DEGRADATION & EVAPORATION	665	27
HUMAN CONTRIBUTION □		
TO AIR	623	25
TO WATER	402	16
TO LAND	663	27

SOURCES OF HUMAN INTRODUCTION

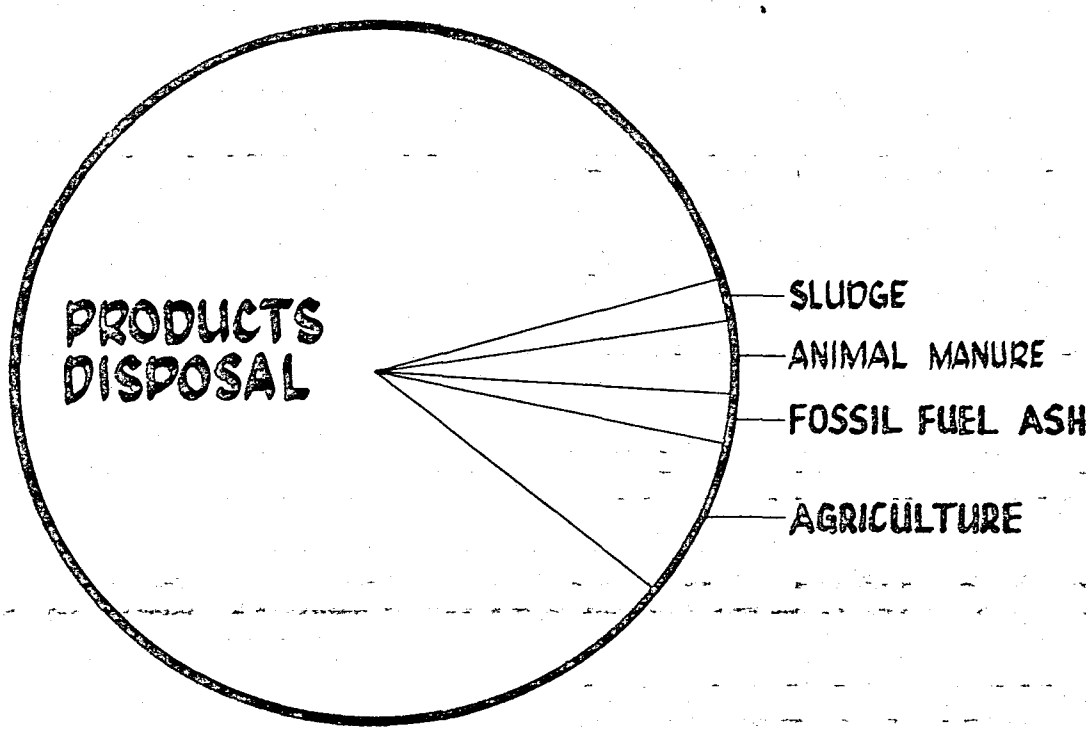
TOTAL IN TONS: 1,688



SINK	TONS	% OF TOTAL
AIR	623	37
WATER	402	24
LAND	663	40

DEPOSITION INTO LAND

TOTAL TONS: 663

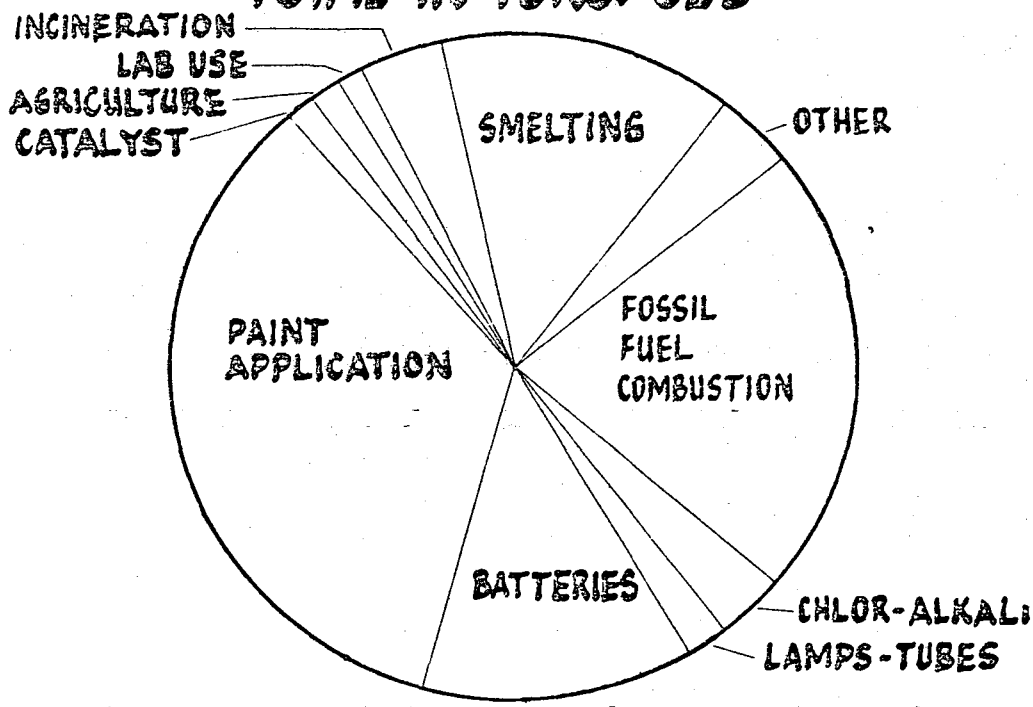


SOURCE	TONS	% OF TOTAL
ANIMAL MANURE	20	3.0
FOSSIL FUEL ASH	15	2.3
SLUDGE	8.2	1.2
AGRICULTURE	51	7.7
PRODUCTS DISPOSAL	569	85.8

INCL: BATTERIES, LAMPS, TUBES, SWITCHES, CONTROLS, THERMOMETERS, BAROMETERS, ETC.

MERCURY EMISSIONS TO AIR

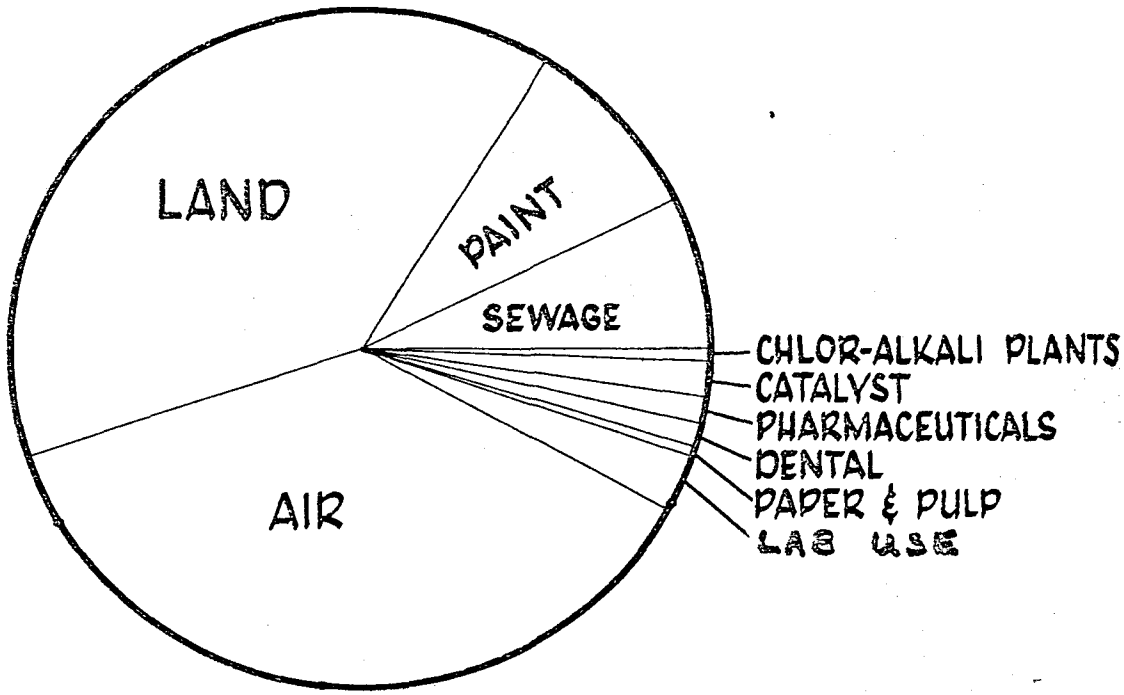
TOTAL IN TONS: 623



SOURCE	TONS	% OF TOTAL
SMELTING	85	13.7
FOSSIL FUEL COMBUSTION	136	21.8
CHLOR-ALKALI	20.3	3.3
LAMPS, TUBES	12.5	2
BATTERIES	80.1	12.9
CONTROLS	4.2	.7
PAINT APPLICATION	213	34.2
PAINT MANUFACTURE	1.1	.2
CATALYST	8	1.3
AGRICULTURE	9	1.4
PHARMACEUTICALS	5.5	.9
PAPER AND PULP	4.6	.7
LAB USE	6.9	1.1
OTHER	2.35	.4
INCINERATION	27	4.3
SLUDGE INCINERATION	4.4	.7
MINING	2.5	.4

MERCURY INTO WATER

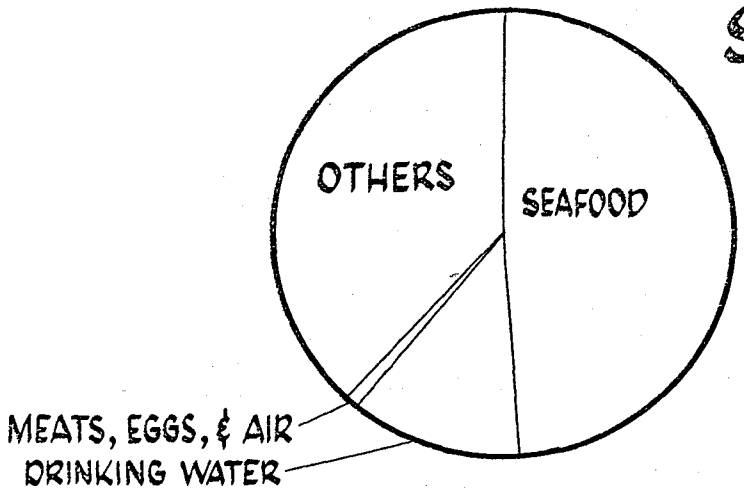
TOTAL TONS: 1,688



SOURCE	TONS	% OF TOTAL
AIR	623	36.9
LAND	663	39.3
CHLOR-ALKALI PLANTS	10	.6
PAINT	147	8.7
CATALYST	29	1.7
DENTAL	19	1.1
PHARMACEUTICALS	22	1.3
SEWAGE PLANT EFFLUENTS	125	7.4
PAPER AND PULP	6.9	.4
LAB USE	43	2.5

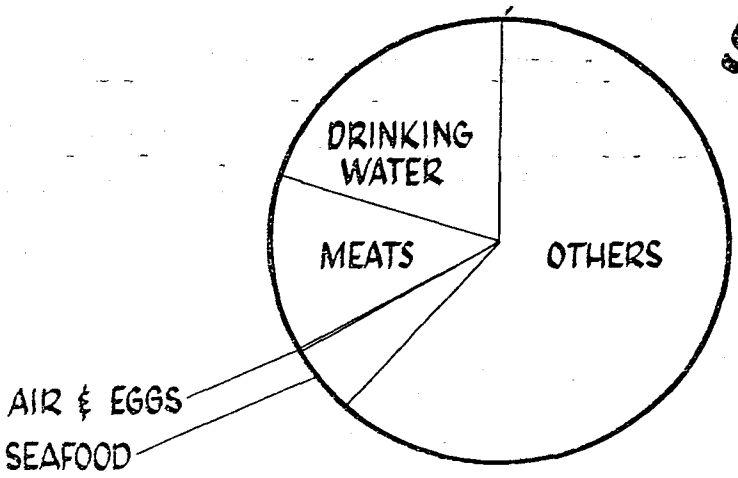
POTENTIAL EXPOSURE TO MERCURY

FISHEATER'S DIET



SOURCE	% OF INTAKE
SEAFOOD	48.94
OTHERS	38.03
DRINKING WATER	12.29
AIR	.09
MEATS	.6
EGGS	.05

AVERAGE DIET

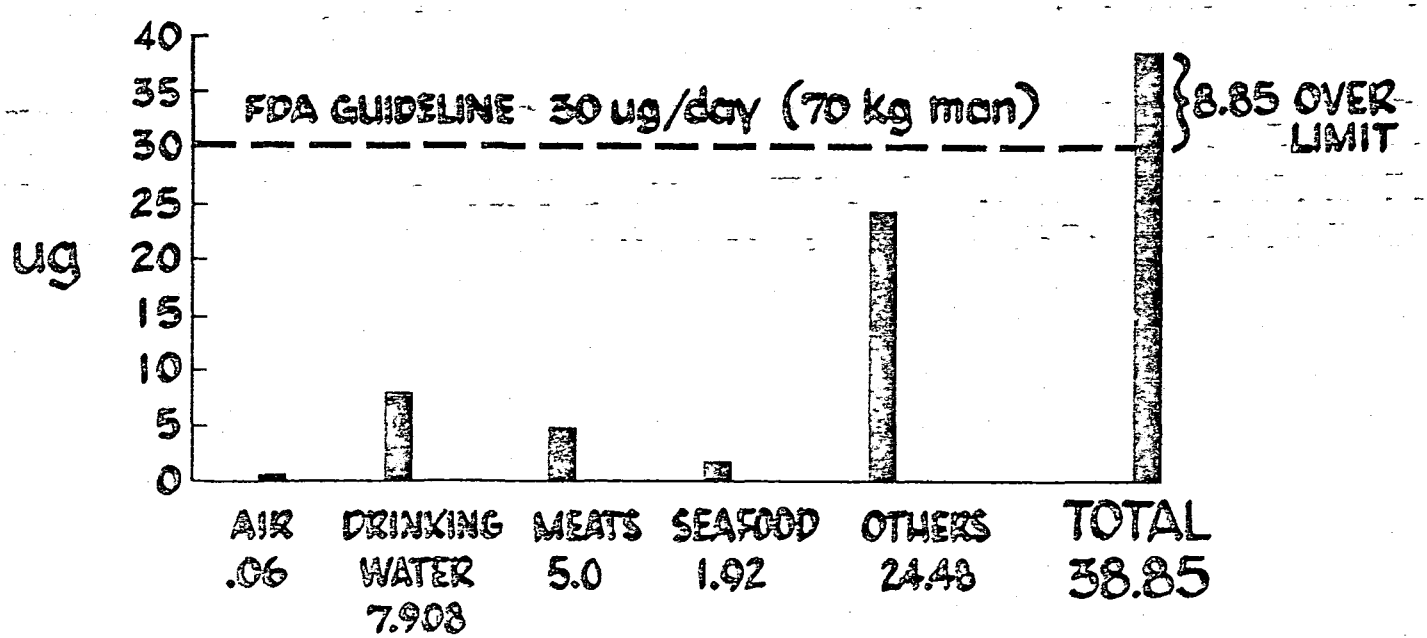


SOURCE	% OF INTAKE
OTHERS	63.02
DRINKING WATER	20.35
MEATS	12.87
SEAFOOD	4.94
EGGS	.077
AIR	.15

POTENTIAL EXPOSURE TO MERCURY

AVERAGE DIET

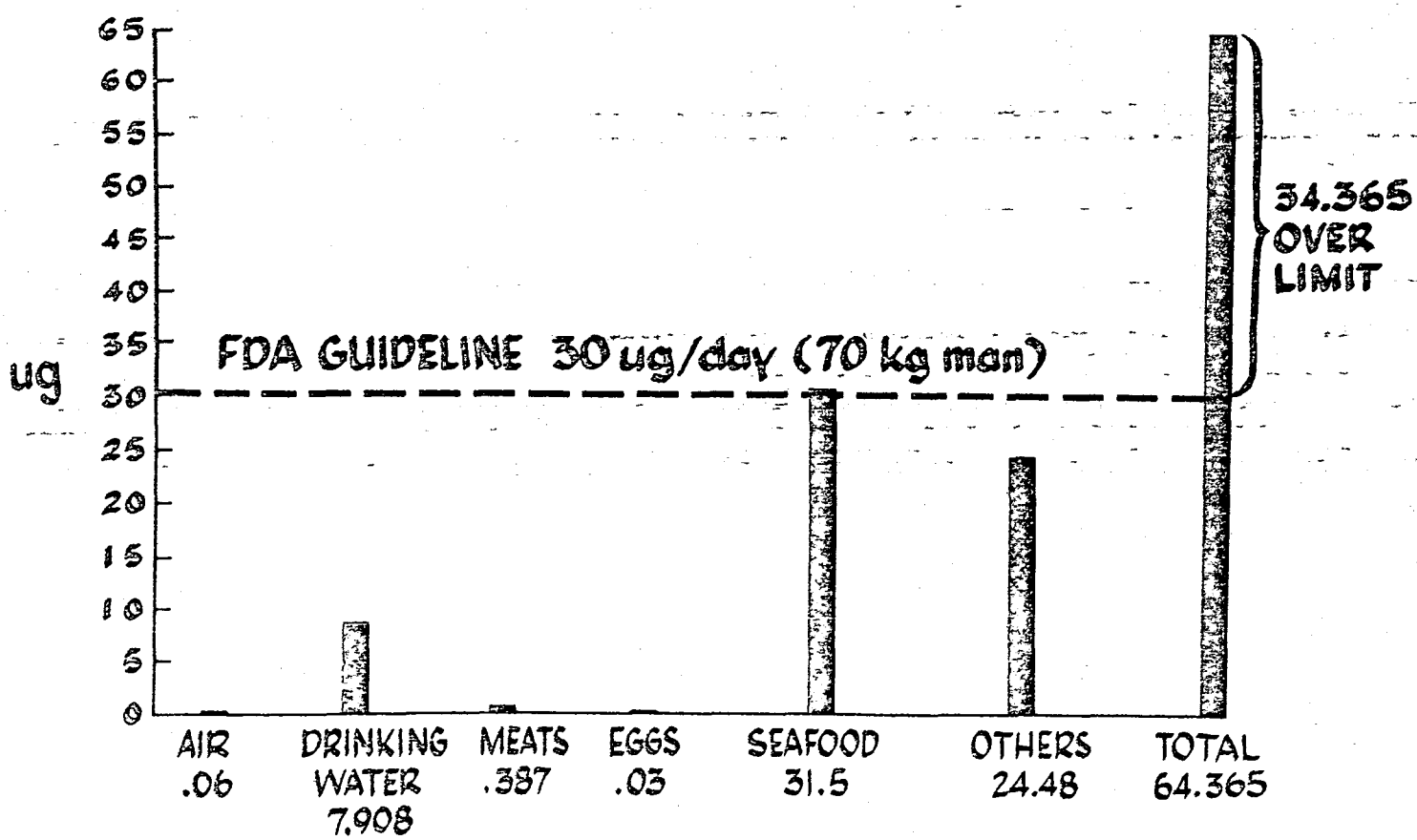
ROUTE	%METHYL	DAILY INTAKE	AVERAGE HG. LEVEL	EST. EXPOSURE (IN ug.) NON-METHYL	METHYL
AIR	0	$12 M^3$	$5 ng/M^3$	.06	0.0
DRINKING WATER		2L	4ppb	7.9	.008
FOODS					
MEATS	70	168gm	.03ppm	1.5	3.5
EGGS	80	4.4gm	.007ppm	.005	.025
SEAFOOD	100	10gm	.192ppm	0.0	1.92
OTHERS	2	1282.4gm	.019ppm	24.0	.48



POTENTIAL EXPOSURE TO MERCURY

FISHEATER'S DIET

ROUTE	% METHYL	DAILY INTAKE	AVERAGE HG. LEVEL	EST. EXPOSURE (in ug.) NON-METHYL	METHYL
AIR	0	$12 M^3$	$5 ng/M^3$	.06	0.0
DRINKING WATER		2 L	4ppb	7.9	.008
FOODS					
MEATS	70	13 gm	.03ppm	.117	0.27
EGGS	80	4.4 gm	.007ppm	.005	.025
SEAFOOD	100	165 gm	.192ppm	0.0	31.5
OTHERS	2	1,282.4 gm	.019ppm	24.0	.48



MERCURY DISCHARGES BY SIC CODE

(ACCORDING TO PERMIT APPLICATIONS IN THE RAPP FILE)

SIC CODE	#	MIN	MAX	MEDIAN	MEAN
1000 - METAL MINING	19	0.001	1.031	0.014	0.169
1200 - BITUMINOUS COAL AND LIGNITE MINING	12	0.001	4.754	0.021	0422
1300 - OIL AND GAS EXTRACTION	17	0.001	1.000	0.029	0.207
1400 - MINING & QUARRYING OF NONMETALLIC MINERALS-EXCEPT FUELS	16	0.002	1.299	0.014	0.145
2000 - FOOD AND KINDRED PRODUCTS	1	0.001	0.001	0.001	-
2200 - TEXTILE MILL PRODUCTS	8	0.001	0201	0.017	0.042
2400 - LUMBER AND WOOD PRODUCTS	19	0.001	1.588	0.183	0.506
2600 - PAPER AND ALLIED PRODUCTS	86	0.002	2.394	0.060	0.205
2700 - PRINTING AND PUBLISHING	1	2.000	2.000	2.000	-
2800 - CHEMICALS AND ALLIED PRODUCTS	143	0.001	1.999	0.030	0.170
2900 - PETROLEUM REFINING AND RELATED INDUSTRIES	11	0.011	1.000	0036	0.311
3000 - RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS	1	0.012	0.012	0.012	-
3200 - STONE, CLAY, GLASS, AND CONCRETE PRODUCTS	7	0.001	0.679	0.006	0101
3300 - PRIMARY METAL INDUSTRIES	73	0	3.299	0.052	0302
3400 - FABRICATED METAL PRODUCTS	20	0	1.000	0010	0.106
3500 - MACHINERY EXCEPT ELECTRICAL	4	0.002	0.539	0.007	0.139
3600 - ELECTRICAL EQUIPMENT & SUPPLIES	21	0	0.150	0006	0016
3700 - TRANSPORTATION EQUIPMENT	6	0.001	0.005	0.002	0.002
3800 - MEASURING, ANALYZING AND CONTROLLING INSTRUMENTS	1	0.229	0.229	0229	-
4900 - ELECTRIC, GAS AND SANITARY SERVICES	17	0.001	1.200	0.016	0117
7300 - BUSINESS SERVICES	1	0.014	0.014	0.014	-
9100 - EXECUTIVE, LEGISLATIVE AND GENERAL GOVERNMENT	3	0.004	0.434	0006	0148
	487				

MARCH 1974

EFFECT OF PROPOSED MERCURY STANDARDS BASED ON RAPP WATER PERMIT APPLICATIONS

EFFLUENT STANDARD	% DISCHARGERS AFFECTED	% DISCHARGES ELIMINATED
0.1 LBS/DAY	31	76
0.2	24	62
0.3	17	52
0.4	14	45
0.5	13	38
0.6	10	32
0.7	10	27
0.8	9	22
0.9	8	21
1.0	4	14
1.1	2	12
1.2	2	11
1.3	2	10
1.4	2	9
1.5	2	8
1.6	1	7
1.7	1	7
1.8	1	6
1.9	1	6
2.0	1	5
2.1	1	5
2.2	1	4
2.3	1	4
2.4	1	4
2.5	.4	3