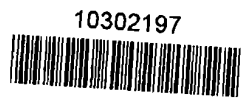


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**TECHNICAL REPORT  
EVALUATION OF MONSANTO'S POLYCHLORINATED BIPHENYL (PCB)  
PROCESS FOR PCB LOSSES AT THE ANNISTON PLANT**

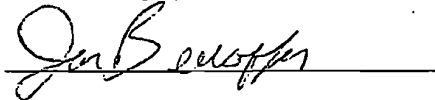
**United States v. Pharmacia Corporation (f/k/a Monsanto Company) and Solutia,  
Inc., Civil Action Number CV-02-PT-0749-E, in the United States District Court for  
the Northern District of Alabama.**

March 2005

**Prepared for:**  
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Jon L. Beihoffer



Handwritten signature of Jon L. Beihoffer, underlined.

NATIONAL ENFORCEMENT INVESTIGATIONS CENTER  
Denver, Colorado

CONTENTS

EXECUTIVE SUMMARY .....3  
INTRODUCTION .....3  
AROCOR PRODUCTION.....3  
AIR EMISSIONS.....7  
EFFLUENT DISCHARGES .....8  
OTHER PCB WASTE .....10  
REFERENCES .....12  
DOCUMENTS.....13

TABLES

1 Estimated and Annual Production for Aroclors at the Anniston Plant .....5  
2 Comparison of Biphenyl Production to Aroclor Production at the Anniston Plant.....6  
3 Annual Production for Biphenyl at the Anniston Plant .....6  
4 Air Emissions of PCBs at the Anniston Plant.....8  
5 Effluent Discharge of PCBs at the Anniston Plant .....10  
6 Other PCB Waste Generated at the Anniston Plant.....11

APPENDIX

- A Curriculum Vitae of Jon L. Beihoffer (3 pages)

**The Contents shows all information contained in this report  
and provides a clear indication of the end of the report.**

An evaluation of PCB losses from Monsanto's polychlorinated biphenyl (PCB) process at the Anniston plant has been conducted. This included estimates of losses to the air, wastewater discharges, and other waste. The data used in this evaluation were from Monsanto's documents. The documents used in this evaluation are listed in the reference and document section, or noted in the text.

## EXECUTIVE SUMMARY

PCBs were marketed under the trade name "Aroclor" by Monsanto. This report provides an estimate that the Anniston plant produced about 680 million pounds of Aroclors from 1929 to 1971. This report also provides estimates of air emissions of about 60,000 pounds of PCBs, wastewater discharges of about 1.8 million pounds of PCBs, and generation of at least 87 million pounds of other PCB-containing waste. These estimates of PCB losses are likely conservative because of the following:

- The loss data used in these calculations were from 1969 and 1970, which likely represents technology and efficiency improvements over earlier years resulting in low estimates of releases prior to 1969.
- Sampling problems occurred which caused low values.
- These estimates did not include all sources.

## INTRODUCTION

The approach for estimating losses for the Anniston facility was to first estimate the total amount of Aroclors produced using Monsanto's data, when available. Factors for PCB air emissions, PCB effluent discharges, and other PCB waste generated were then calculated using Monsanto's data. These factors were established by dividing mass loss data by the annual production of Aroclors for that period. This was necessary because these factors are dependent on the capacity or production of the plant (i.e., the more product produced, the more emissions, discharges, and waste generated). The total amount of Aroclors produced was multiplied by these factors to estimate the mass of PCB air emissions, PCB effluent discharges, and PCB waste generated.

## AROCLOR PRODUCTION

The Anniston plant produced Aroclors between 1929 and 1971.<sup>1,2</sup> The approach estimated that the amount of Aroclors produced at the Anniston plant was about 680 million

pounds. Table 1 contains the estimated and annual production for Aroclors used to determine the total amount of Aroclors produced from 1929 to 1971. Monsanto had annual production figures for Aroclors from 1953 to 1971.<sup>3</sup> The annual productions for Aroclors between 1936 and 1952 were derived from the annual production of biphenyl at the Anniston plant. Biphenyl was a raw material used in the production of Aroclors. A factor for Aroclor produced relative to biphenyl was established by comparing the annual production for Aroclors to the annual production for biphenyl between 1953 and 1964, where these data overlapped. An average ratio of annual production for Aroclors to annual production for biphenyl was calculated to be 1.0, with a range of 0.75 to 1.2, from 1953 to 1964. The comparison of annual production for Aroclors to biphenyl is given in Table 2. The annual production for biphenyl from 1936 to 1964 is given in Table 3.<sup>4</sup> Estimating the annual production of Aroclors from biphenyl production is supported by the statement: "By 1946 both plants had doubled their capacity, to give a total production capacity approaching 2 million pounds a month."<sup>1</sup> This gives a total annual production capacity of about 24 million pounds for both plants and about 12 million pounds a year for each plant, since both plants had similar design capacities.<sup>5</sup> This compares well with the Aroclors annual production estimate of 10.5 million pounds from the annual biphenyl production in 1946. Aroclor production started on December 16, 1928 with a capacity of 3,000 lbs/day or about 1,095,000 lbs/year.<sup>1</sup> A value of 1 million pounds was used for the annual production for Aroclors from 1929 to 1934. The plant's annual capacity was calculated to be about 3.59 million pounds per year in 1935 which was used as the annual production.<sup>6</sup>

The estimate of 680 million pounds of Aroclors produced at the Anniston plant from 1929 to 1971 is supported by the following comparison. Between 1930 and 1975, about 1.4 billion pounds of PCBs were produced in the U.S. by Monsanto.<sup>7</sup> Monsanto produced Aroclors at the Anniston plant from 1930 to 1971 and at the Krummrich plant from 1936 to 1977. The Anniston and Krummrich plants had similar design capacities.<sup>5</sup> It is likely that the Anniston plant produced about half the Aroclors produced by Monsanto or about 700 million pounds because both plants operated for about the same time at about the same design capacity.

Table 1

ESTIMATED AND ANNUAL PRODUCTION FOR AROCLORS AT THE  
 ANNISTON PLANT

Year	Aroclors (lbs)	Year	Aroclors (lbs)
1929	1,000,000 <sup>1</sup>	1951	16,811,568 <sup>2</sup>
1930	1,000,000 <sup>1</sup>	1952	15,258,086 <sup>2</sup>
1931	1,000,000 <sup>1</sup>	1953	16,326,000
1932	1,000,000 <sup>1</sup>	1954	13,607,000
1933	1,000,000 <sup>1</sup>	1955	17,106,000
1934	1,000,000 <sup>1</sup>	1956	23,052,000
1935	3,000,000 <sup>3</sup>	1957	24,848,000
1936	1,569,800 <sup>2</sup>	1958	22,309,000
1937	2,944,596 <sup>2</sup>	1959	23,691,000
1938	2,798,628 <sup>2</sup>	1960	26,310,000
1939	3,999,171 <sup>2</sup>	1961	26,122,000
1940	6,535,428 <sup>2</sup>	1962	24,398,000
1941	9,071,685 <sup>2</sup>	1963	25,605,000
1942	10,457,882 <sup>2</sup>	1964	27,793,000
1943	10,457,882 <sup>2</sup>	1965	33,984,000
1944	10,457,882 <sup>2</sup>	1966	40,736,000
1945	10,457,882 <sup>2</sup>	1967	45,536,000
1946	10,457,882 <sup>2</sup>	1968	48,683,000
1947	11,844,079 <sup>2</sup>	1969	33,629,000
1948	12,137,409 <sup>2</sup>	1970	35,362,000
1949	12,272,150 <sup>2</sup>	1971	1,962,000
1950	12,406,891 <sup>2</sup>		
<b>Aroclors Production from 1929-71 = 679,997,901 lbs</b>			

- 1 An estimate, the plant's annual capacity was reported to be 1.095 million pounds per year in 1928 (Reference 1).
- 2 Aroclor production estimated from biphenyl annual production.
- 3 An estimate, the plant's annual capacity was reported to be 3.59 million pounds per year in 1935 (Reference 5).

Table 2

COMPARISON OF BIPHENYL PRODUCTION TO AROCLOR PRODUCTION AT THE  
 ANNISTON PLANT

Year	Biphenyl (lbs) <sup>1</sup>	Aroclors (lbs)	Aroclor/Biphenyl
1953	18,891,053	16,326,000	0.864
1954	18,103,186	13,607,000	0.752
1955	17,315,320	17,106,000	0.988
1956	21,874,905	23,052,000	1.054
1957	22,672,999	24,848,000	1.096
1958	18,943,755	22,309,000	1.178
1959	20,287,113	23,691,000	1.168
1960	24,761,859	26,310,000	1.063
1961	25,285,622	26,122,000	1.033
1962	25,796,954	24,398,000	0.946
1963	26,956,764	25,605,000	0.950
1964	32,109,634	27,793,000	0.866
<b>Average Aroclor/Biphenyl = 0.996, minimum = 0.752, and maximum = 1.178</b>			

Table 3

ANNUAL PRODUCTION FOR BIPHENYL AT THE ANNISTON PLANT<sup>1</sup>

Year	Biphenyl (lbs)	Year	Biphenyl (lbs)
1936	1,569,800	1951	16,811,568
1937	2,944,596	1952	15,258,086
1938	2,798,628	1953	18,891,053
1939	3,999,171	1954	18,103,186
1940	6,535,428	1955	17,315,320
1941	9,071,685	1956	21,874,905
1942	10,457,882	1957	22,672,999
1943	10,457,882	1958	18,943,755
1944	10,457,882	1959	20,287,113
1945	10,457,882	1960	24,761,859
1946	10,457,882	1961	25,285,622
1947	11,844,079	1962	25,796,954
1948	12,137,409	1963	26,956,764
1949	12,272,150	1964	32,109,634
1950	12,406,891		

<sup>1</sup> Reference 4

## AIR EMISSIONS

Some air emission sources from the production of Aroclors were tank vents, hydrochloric acid (HCl) scrubbers, blow tank jets, vacuum jets, drumming operations, charging the still, filtration, earth treatment, tank car and tank truck loading, surface area evaporation, and leaks and spills.<sup>8-11</sup> The estimated air emissions of PCBs are 60,000 pounds. The data used are given in Table 4. The estimate was conducted by first finding an air emission factor (AEF) in the documents. This AEF was multiplied by the total Aroclor production to give the total mass of PCB air emissions.

Monsanto calculated what was termed "maximum theoretical" daily atmospheric losses of 12.76 lbs/day for a capacity rate of 53 million lbs/yr in 1971.<sup>8</sup> The AEF was established by multiplying this daily loss by 365 days and dividing by the capacity rate. The "maximum theoretical" daily atmospheric loss was conservative because it only considered the drumming operation, tank car loading, Montar drumming station, and HCl scrubber. Further, there were problems with sampling. The following excerpts from Monsanto's documents support the conservative nature of this estimate.

- The mix tanks had PCB losses to the atmosphere in the range of 4 to 5 lbs/day, which was due to the nitrogen purge of these tanks. (PCB Environmental Problem November Status Report," December 7, 1970, MONS 099414)
- "Some problems have been encountered in sampling and analysis at Anniston which account to some degree for the low values. The prime sampling problem is the inefficiency of the scrubbers at very high sampling volumes. (i.e. The scrubber is not 100% efficient at high air flow rates)." (P.C.B. Levels in Ambient Air at Anniston Plant, December 29, 1970, DSW 014062)
- The most severe Aroclor vapor concentrations were encountered during charging the still, filtering, earth treatment, and drawing out the hot Aroclor into the drums (Report No. 2892, "Interim Report on Aroclor in Gases," June 17, 1953, MONS 058951)
- "All Aroclors were stored at 150°F." (EPA 560/6-76-05, "PCBs in the United States Industrial Use and Environmental Distribution," Task 1, February 25, 1976, Final Report, p57)
- "Nitrogen blanketing is provided on storage tanks to eliminate any "breathing" of the tanks and resultant PCB escape." (EPA 560/6-76-05, "PCBs in the United States Industrial Use and Environmental Distribution," Task 1, February 25, 1976, Final Report, p63)
- "Mist eliminators have been installed in vapor lines to eliminate the possibility of PCBs leaving the manufacturing area through these lines." (EPA 560/6-76-05, "PCBs in the

United States Industrial Use and Environmental Distribution," Task 1, February 25, 1976, Final Report, p63)

- "In May, 1935, the operators in distilled Aroclors, both Badger and 1269, began to develop a severe type of dermatitis. At that time ventilation in both operations was most inadequate and the men were exposed to dust and flume from the hot Aroclor." (Diphenyl and Chlorinated Diphenyl Derivates, June 1935, p114)

Table 4

AIR EMISSIONS OF PCBs AT THE ANNISTON PLANT

Air Emission Factor (AEF) of PCBs per Million lbs of Aroclors Produced				
Year	Daily Factor (lbs/day)	Yearly Factor (lbs/yr)	Aroclor Production (million lbs/yr)	AEF (lbs/million lbs)
1970	12.76 <sup>1</sup>	4,657	53 <sup>1</sup>	87.9

<sup>1</sup> Reference 8

Air Emissions of PCBs at the Anniston Plant			
Years	Total Aroclors (million lbs)	AEF (lbs/million lbs)	Air Emissions of PCBs (lbs)
1929-71	679.997901	87.9	59,755

**EFFLUENT DISCHARGES**

The sources of PCB effluents included the hydrochloric acid (HCl), chlorinator, still room, and warehouse sewers. <sup>12</sup> At times, the chlorinator and still room sewers had an Aroclor phase. <sup>12</sup> The major losses from the warehouse sewer were due to spills while drumming or flaking. These spills were swept to the sewer during floor clean-up. <sup>12</sup> The HCl scrubber jets sewered 11.84 lbs/day of PCB in 1970. <sup>13</sup> These sewers discharged into the Snow Creek – Choccolocco Creek watershed. <sup>12, 14, 15, 17, 18</sup>

About 1.8 million pounds of PCBs are estimated as discharged by the sewers from the production of Aroclors at the Anniston plant. This estimate is likely conservative due to sampling problems with two-phase systems of water and free Aroclors. <sup>14</sup> Table 5 gives the data for this estimate.

Monsanto reported an Aroclor loss of >250 lbs/day at the Anniston plant in 1969. <sup>12, 14, 15</sup> A Monsanto report noted: ">250 lbs/day is used for the 1969 figure because improved analytical methods and actual measurement of material from the catch tank and coalesce have shown that

the losses were approximately 10 times as high as reported in 1969.”<sup>15</sup> The Aroclor loss of 250 lbs/day is used to derive an effluent discharge factor (EDF) for the years from 1929 to 1969. This EDF was established by multiplying daily mass loss by 365 days and dividing by the annual production of Aroclors for 1969.

Aroclor losses were reported as 8.9, 16, 32, and 88 lbs/day in 1970.<sup>15-18</sup> The average of these losses is 36 lbs/day. This value was used to calculate an EDF for 1970 and 1971, as described above. The lower daily losses in 1970 were due to various controls and practices put in place by Monsanto to reduce losses of PCB. These included sumps, catch tank, coalescer, skimmers, curbing in drum loading area, stopping the practice of washing up spilled Aroclors into the sewers, neutralization pit clean out, and water flow reduction.<sup>14, 15, 17-19</sup>

The EDF for 1929 to 1969 was multiplied by the sum of annual productions for this period to give the total PCB effluent discharges. The same approach was used for the period of 1970 to 1971. The PCB effluent discharges for the two periods were summed to give the total mass of PCB effluent discharges for 1929 to 1971.

The following excerpts from Monsanto's documents give some perspective to losses of PCBs from effluent discharges.

- “That a problem exists at Anniston is evident because “free” globes of aroclors can be seen in Snow Creek.” (“Aroclor Clean-Up From Plant Effluents,” May 12, 1969, DSW 0135781)
- “Investigation has shown that the waters receiving streams below the Anniston Plant contain significant (parts per million) concentrations of PCBs. More ominous perhaps is the fact that sediment in the bottom of these streams miles below our plants may contain up to 2% Aroclor.” (Report of Aroclor “AD HOC” Committee, October 2, 1969, DSW 014621)
- “They also indicate significant amounts of Aroclors in the mud and water of Choccolocco and Snow Creeks a considerable distance (15-20 miles) downstream from the Anniston Plant.” (Aroclor Losses at the Anniston Plant,” July 21, 1970, DSW 013204)
- “The Department of Interior and/or state authorities could monitor plant outfall and find ppm of chlorinated biphenyls at Krummrich or Anniston anytime they choose to do so.” (Report of Aroclor “AD HOC” Committee (Second Draft, October 2, 1969, DSW 164922)

Table 5

EFFLUENT DISCHARGE OF PCBs AT THE ANNISTON PLANT

Effluent Discharge Factor (EDF) of PCBs per Million lbs of Aroclors Produced				
Year	Daily Factor (lbs/day)	Yearly Factor (lbs/yr)	Aroclor Production (million lbs/yr)	EDF (lbs/million lbs)
1969	250 <sup>1</sup>	91,250	33.629	2,713
1970	36 <sup>2</sup>	13,140	35.362	372

1 Reference 12, 14 and 15

2 Average of 8.9, 16, 32, and 88 lbs/day in 1970. References 15-18

Effluent Discharges of PCBs at the Anniston Plant from 1929 to 1971			
Year	Total Aroclors (million lbs)	EDF (lbs/million lbs)	Effluent Discharges of PCBs (lbs)
1929-69	642.673901	2,713	1,743,852
1970-71	37.324	372	13,869
1929-71			1,757,721

**OTHER PCB WASTE**

The Anniston plant generated about 19 million pounds of scrap oil or liquid waste of PCBs. Scrap oil was defined as the liquid waste that could be collected without absorbents and handled as liquid at ambient temperatures.<sup>20</sup> Table 6 gives the data used in these calculations. The estimate is based on Monsanto's liquid waste loss of 1 million pounds per year in 1970.<sup>20</sup> The scrap oil factor (SOF) was established by dividing the liquid waste loss mass by the annual production in 1970. Then the SOF was multiplied by the total Aroclor production to give the total mass of PCB scrap oil.

The Anniston plant's "Standard Manufacturing Process for Aroclors," September 1966 and July 1969 approximated Montars at 10 percent of total Aroclor production, and Montars went to the plant's dump.<sup>21,22</sup> Montars 1 through 7 were the still residues from the distillation of Aroclors 1242, 1248, 1254, 1260, 1268, 4465, and 5460.<sup>20</sup> Using this percentage gives about 8 million pounds of Montars being generated from the production of Aroclors. The data for this estimate are given in Table 6.

Summing the estimates of scrap oil and Montar gives 87 million pounds of PCB containing waste generated from the production of Aroclors at the Anniston plant. This is likely a conservative estimate because it does not include filter cakes, cartridges, lab samples, rags for

cleaning, floor dry, customer returns of Aroclors, and spent Therminol (i.e., Aroclors) from the phosphorus pentasulfide (P<sub>2</sub>S<sub>5</sub>) process.<sup>20,23</sup> Estimates were not made for these other PCB containing wastes.

Table 6

OTHER PCB WASTE GENERATED AT THE ANNISTON PLANT

PCB Scrap Oil Factor (SOF) of PCBs per Million lbs of Aroclors Produced			
Year	Yearly factor (lbs/yr)	Aroclor Production (million lbs/yr)	SOF (lbs/million lbs)
1970	1,000,000 <sup>1</sup>	35.362	28,279

<sup>1</sup> Reference 20

PCB Scrap Oil Generated at the Anniston Plant			
Year	Total Aroclors (million lbs)	SOF (lbs/million lbs)	PCB Scrap Oil (lbs)
1929-71	679,997,901	28,279	19,229,622

PCB Montars Generated at the Anniston Plant			
Year	Total Aroclors (lbs)	Montar Factor (%)	PCB Montars (lbs)
1929-71	679,997,901	10 <sup>1</sup>	67,997,790

<sup>1</sup> Reference 21 and 22

PCB Waste Generated at the Anniston Plant			
Year	PCB Scrap Oil (lbs)	PCB Montars (lbs)	PCB Waste (lbs)
1929-71	19,229,622	67,997,790	87,229,412

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APPENDIX A

CURRICULUM VITAE OF JON L. BEIHOFFER

(3 pages)

Curriculum Vitae

**Name:** Jon L. Beihoffer

**Position Title:** Chemist

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**Education:** M.S. Degree - Environmental Chemistry  
1984 - University of Montana  
Missoula, Montana

B.S. Degree - Chemistry Major  
1981 - University of Minnesota - Duluth  
Duluth, Minnesota

**Professional Experience:**

From 1986 to date, Jon Beihoffer has served as a chemist with the U.S. Environmental Protection Agency (EPA) at the National Enforcement Investigations Center (NEIC) in Denver, Colorado. He plans, performs, and coordinates laboratory work for enforcement cases, and prepares reports. His duties also include defending work in legal proceedings and participating in field investigations. During his tenure with NEIC, he has developed technical expertise in the environmental and analytical chemistry of many organic pollutants. His analytical instrumentation specializations include nuclear magnetic resonance spectroscopy; mass spectrometry; and gas and liquid chromatography. He has gained considerable knowledge of environmental regulations, especially those dealing with sampling and testing for RCRA and the CWA. He has testified for the government at three criminal trials and has given a deposition and written a report for one civil case. He has worked or is currently working on several CERCLA cost recovery cases (in chronological order: Sauget Area 1, Sauget, Illinois; Tennessee Products, Chattanooga, Tennessee; and Fairmont Coke, Fairmont, West Virginia)

Prior to 1986, he worked at the Environmental Research Center at the University of Nevada - Las Vegas for 2 years performing gas chromatography/mass spectrometry analysis, and was a Research and Teaching Assistant at the University of Montana Department of Chemistry in Missoula, Montana for 3 years.

**Presentations:**

"The Usefulness of Nuclear Magnetic Resonance (NMR) Spectrometry in Environmental Applications" J. Beihoffer and J.L. Seidel. *14<sup>th</sup> International Forensic Science Symposium*: October 2004

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