POLYCHLORINATED BIPHENYL BIODEGRADATION STUDIES

The threat of continued accumulation of polychlorinated biphenyl (PCB) residues in the environment is responsible for much of the apprehension about the future use of these materials. Examination of the data collected to date from both external and internal PCB residue monitoring programs has confirmed that at their previous rate of release some persistent PCB homologs have begun to accumulate in the eco-system. Conversely, it can also be stated that, with the exception of direct high level controllable contamination, PCB homologs with less than 5 chlorine atoms have not accumulated in the ecosystem[1] although they have been released in an unrestricted fashion for many years.

This observation indicates that at the previous rate of release an environmentally compatible PCB product would be one containing no PCB homologs with greater than four chlorines per molecule. As has been previously stated, it is not commercially feasible to produce a product completely free of the persistent homologs. However, it is technically feasible to produce an industrially useful PCB product, Aroclor 1016, which contains significantly (10 to 20 times) lower levels of these persistent homologs.

Two questions remain which must be answered, first to what degree is biological degradation responsible for the disappearance of the "non-persistent" PCB homologs, and secondly, with controlled and restricted usage, will Aroclor 1016 be environmentally compatible.

In an attempt to answer these questions, a number of comparative experimental laboratory studies of the Aroclor products have been carried out to determine the extent to which these materials are degraded by bacterial, avian, mammalian, and aquatic organisms.

Bacterial Degradation - Semi-Continuous Activated Sludge (SCAS) Degradation Studies of Polychlorinated Biphenyls

Introduction

The semi-continuous activated sludge (SCAS) test procedure used to study the primary bacterial degradation[2] of polychlorinated biphenyls is patterned after the test method recommended by the sub-committee on biodegradation test methods of the Soap and Detergent Association for the evaluation of surfactants[3]. This procedure employs sludge from a sewage treatment plant as the source of microorganisms. A specific amount of the material being studied and a synthetic sewage mixture[4] are fed, on a periodic basis to the activated sludge in a specially designed aeration chamber. Aliquots of the mixed liquor (sludge + water) are withdrawn from the chamber shortly after feeding and near the end of the aeration period and analyzed to determine the disappearance rate of the test compound. This cycle is continuously repeated until a steady state[5] is achieved and consistent biodegradation rates are obtained. Details of the procedure may be found in the attached Analytical Chemistry Method 71-32.

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Summary and Conclusions

SCAS testing of Aroclor 1254, Aroclor 1242, Aroclor 1016, MCS 1043, and Aroclor 1221 were carried out over an eight-month period.

Disappearance rate data were obtained during two sampling periods for Aroclor 1254, Aroclor 1242, Aroclor 1016, and MCS 1043. For Aroclor 1221 only one sampling period was employed. In the initial testing of these materials, a feed rate of 1 mg per 24-hour cycle was used. Because the data obtained from the first sampling period for all PCBs studied, except Aroclor 1221, were extremely erratic with little apparent biodegradation, the exposure period between additions of the test material was extended to 48 hours for all materials except Aroclor 1221.

Mean disappearance rates and 95% confidence limits obtained via statistical analysis of the data from the last sampling period are shown in Table I.

TABLE I

Test Material	% Cl (w/w)	Exposure Period (Hrs)	Mean Per Cent Disappearance Rate (Uncorrected)
Aroclor 1221	21	24	64.0 ± 13.6
MCS 1043	30	48	56.2 ± 15.5
Aroclor 1016	41	48	32.9 ± 13.8
Aroclor 1242	42	48	26.3 ± 15.5
Aroclor 1254	54	48	15.2 ± 37.7

It is apparent from inspection of Table I that degradation decreases as the degree of chlorination increases and that because of the uncertainty in the data that it is not possible to differentiate between Aroclor 1242 and Aroclor 1016 with respect to degradability at the 95% confidence level. This is not surprising since Aroclor 1016 constitutes ∿80% of Aroclor 1242 and the resolving power of the test procedure is comparable to this difference.

Subsequent SCAS testing of Aroclor 1221 at a feed level of 1 mg was carried out to establish the significance of volatility losses, the effect of exposure period, and the reproducibility of the test procedure. The results obtained are shown in Table II.

TABLE II
Aroclor 1221

Exposure Period (Hrs)	Aeration Rate (CFH)	Volatility Losses (%)	Mean Per Cent Disappearance Rate	
			Uncorrected	Corrected
24	0.5	16.1	74.9 ± 7.7	58.8
24	0.1	4.5	69.9 ± 17.8	65.4
24	0.1	-	81.0 ± 18.6	-
48	0.1	-	80.6 ± 5.7	-

The data in Table II demonstrate that volatility losses can and do occur and that these losses are a function of the aeration rate and hence also the vapor pressure of the test material in question. It

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is, therefore, reasonable to assume that as the degree of chlorination increases that volatility losses would become insignificant.

The fact that the corrected disappearance rates do not vary with aeration rate also indicates that the volatile components of Aroclor 1221 are subject to degradation and that even if they were not lost in this manner they should not appreciably effect the observed degradation rate.

The mean uncorrected Aroclor 1221 disappearance rates for the 24-hour and 48-hour exposure periods were for all practical purposes equivalent, establishing that when dealing with complex mixtures, a simple linear extrapolation of disappearance rates as a function of exposure period is not valid.

Electron-capture gas chromatography analyses of samples taken at the end of the aeration cycle showed that the lower level of chlorination the greater the changes in the homolog distribution. For Aroclor 1221, the dominant monochloro- and dichlorobiphenyl homologs almost completely disappear after 24 hours of exposure to activated sludge. Similar changes in the ratio of the higher chlorinated homologs to lower ones were noted for the other PCBs studied with the exception of Aroclor 1254. For Aroclor 1254, no significant change in the homolog distribution was observed.

At the feed levels employed, no toxic effects toward the activated sludge were observed for any of the test compounds.

Results and Discussion

The sampling and analytical procedures employed in the disappearance rate determination of a test compound during a cycle were as follows: A 20-ml sample of the mixed liquor (activated sludge + liquor) was withdrawn one hour after feeding and at the end of the aeration period. The sample of mixed liquor was then extracted and the extract concentrated according to the procedure given in Analytical Chemistry Method 71-18. The concentration of test compounds was then determined either by an ultraviolet (UV) spectroscopic or electron-capture gas chromatographic (EC-GC) method. Details of the UV methods are given in Analytical Chemistry Method 71-17 and the EC-GC methods in Analytical Chemistry Method 71-35. The disappearance rate was calculated from the following equation:

$$\% \text{ Disappearance Rate} = \frac{C_o - C_n}{C_o} \times 100$$

Where C_o = level of test material present after feeding

C_n = level of test material present after n hours of exposure

Tests were carried out to determine if quantitative recovery of the various test materials from the mixed liquor was achieved by the extraction procedure. Details are given in Analytical Chemistry Method 71-17. Although complete recovery was not achieved in all cases, the recoveries were consistent and independent of concentration level. The calculated disappearance rates should, therefore, not be affected significantly.

Since the level of chlorination is the most significant factor in the relative biodegradability of the PCBs, the homolog distribution of the various test materials is given in Table III.

TABLE III
HOMOLOG DISTRIBUTION OF POLYCHLORINATED BIPHENYL PRODUCTS

Homolog No. of Cl Per Biphenyl Molecule	Aroclor 1254 (54% Cl)	Aroclor 1242 (42% Cl)	MCS 1016 (41% Cl)	MCS 1043 (30% Cl)	Aroclor 1221 (21% Cl)
0	0.05	0.01	0.02	0.11	19.00
1	0.06	0.70	1.00	23.4	54.10
2	0.32	15.50	19.70	71.3	20.40
3	0.78	49.40	57.30	5.2	3.90
4	22.99	24.80	21.20		2.30
5	47.38	8.70	0.80		0.25
6	19.75	0.85	0.05		
7	4.62				
8					
9	3.96				
10					

Feeding of the Aroclor 1254, Aroclor 1242, Aroclor 1016, and MCS 1043 units was started on 8-10-70 at a feed level of 1 mg per 24-hr cycle. These units were sampled for approximately one month starting with the first day of feeding. All analyses were carried out by electron-capture gas chromatography. The data obtained were extremely erratic. A statistical analysis of the data (Statistics Special Study 70-22) using the Student's t test indicated that at the 95% significance level, only MCS 1043 showed evidence of biodegradation. Both Aroclor 1016 and Aroclor 1242 showed some evidence of biodegradation, but neither was significant at the 95% level. Aroclor 1254 showed no evidence of biodegradation. In order to detect biodegradation at the 95% level of significance in 20 observations, about one-half of the test materials must be degraded in a cycle. The lack of significant biodegradation during the first sampling period was probably due in part to the need for an acclimation period by the bacterial sludge. Subsequent spot checks on the unit, however, indicated that the data obtained were still erratic. Because of the apparent slow rate of biodegradation of these materials, the cycle time was increased to 48 hours in the hope that larger differences would be observed between the before and after feeding samples.

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Feeding of the Aroclor 1221 unit was started on 10-27-70 at a feed level of 1 mg per 24 hours. Aroclor 1221, because of its higher rate of disappearance was maintained on the 24-hour cycle. Sampling of the unit was started 1-25-71 and completed 1-29-71. Analyses were carried out by electron-capture gas chromatography.

The final sampling period for the Aroclor 1254, Aroclor 1242, Aroclor 1016, and MCS 1043 units at a feed rate of 1 mg per 48-hour cycle was started 2-8-71 and completed 3-8-71. Both UV and EC-GC analyses were carried out; the UV data was used to determine the overall disappearance rate and the EC-GC to monitor the change in homolog distribution.

In Figures 1-1 to 4-2, the observed data from which the mean disappearance rates were calculated are shown for both sampling periods for Aroclor 1254, Aroclor 1242, Aroclor 1016, and MCS 1043. In Figure 5, similar data for Aroclor 1221 is shown for a single sampling period. In the top chart of each figure the total mg found in the unit at the beginning and end of each cycle is plotted versus the elapsed time in days after the start of the test. The after feeding sample is denoted by the solid circle; the before feeding sample by the arrowhead; the connecting line indicates the amount lost during each cycle. In the lower chart of each figure, the disappearance rate obtained is plotted versus elapsed time. In Table IV the mean disappearance rate and 95% confidence limits obtained for the test compound during the various sampling periods are given. Since the analyses for Aroclor 1221 were carried out by EC-GC, the disappearance rate does not include any decrease in the biphenyl component (see Table III for Aroclor 1221 composition).

TABLE IV

SCAS MEAN DISAPPEARANCE RATES FOR POLYCHLORINATED BIPHENYL PRODUCTS*

Sampling Period/ Cycle Time	Mean Disappearance Rate ±95% Confidence Limits				
	Aroclor 1254	Aroclor 1242	MCS 1016	MCS 1043	Aroclor 1221
1/24 Hours	-29.0±58	11.0±19.5	3.6±19.0	4.7±22.0	
2/24 Hours					64.0±13.6
3/48 Hours	15.2±37.7	26.3±15.3	32.9±13.8	56.2±15.5	

*Identification of feed material in SCAS tests

Aroclor 1254	Lot AK-38
Aroclor 1242	Lot AK-255
Aroclor 1016	Sample No. 1, OR 158591
MCS 1043	Sample No. 2, OR 158591
Aroclor 1221	Lot AK-2

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In order to make certain that the observed disappearance rates were not due primarily to volatility losses, scrubbing experiments on the most volatile test material, Aroclor 1221, were carried out in which the off-gases from the units were passed through a series of three hexane scrubbers during a complete time cycle. Data were obtained at both 0.1 and 0.5 SCFH aeration rates. The data established that at the 0.5 SCFH air flow volatility losses were ∿16%, at an aeration rate of 0.1 SCFH the volatility losses were reduced to ∿5%, while the overall disappearance rate was essentially the same as that obtained at 0.5 SCFH. This means that the components lost by volatilization are for all practical purposes completely degradable and the disappearance rate (64.0%) obtained represents actual biodegradation.

Since the volatility of the PCBs decreases with increasing level of chlorination, the volatility losses should likewise decrease. From the volatility losses observed for Aroclor 1221, one would not expect such losses to be a significant factor in test disappearance rates for MCS 1043, Aroclor 1016, Aroclor 1242, and Aroclor 1254.

From the data in Table IV and Figures 1-1, 2-1, 3-1, 4-1, it is quite apparent that the disappearance rate data obtained for Aroclor 1254, Aroclor 1242, Aroclor 1016, and MCS 1043 during the first sampling period was very erratic. The data obtained during the last sampling period as shown in Table IV and in Figures 1-2, 2-2, 3-2, and 4-2 was a significant improvement. From the latter data, the following ranking in terms of biodegradability can be made:

Aroclor 1221>MCS 1043>Aroclor 1016≅

Aroclor 1242>Aroclor 1254

In Figure 6, the mean disappearance rate is plotted versus the per cent chlorine in the test compound. The mean per cent disappearance rate for biphenyl was obtained in a previous study (Statistics Special Study 71-2). It is apparent that the disappearance rate decreases with increasing levels of chlorination.

As was previously noted, selected samples from the last sampling period were analyzed by EC-GC to monitor changes in homolog and isomer distribution. In Figure 7, chromatograms for Aroclor 1221 are shown.

The top trace is a chromatogram of an Aroclor 1221 standard representative of the feed material. The center chromatogram is that of a sample taken at the end of the exposure period or aeration cycle. The bottom chromatogram is that of an Aroclor 1242 standard run under the same GC conditions as the other chromatograms. The numbers above each peak indicate the dominant homolog represented by that peak according to GC-mass spectroscopic determination.

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It is important to note that the electron-capture detector does not have the same response for all components. The sensitivity of the detector generally increases as the degree of chlorination increases. From the chromatograms in Figure 7, it is apparent that the dominant monochlorobiphenyl and dichlorobiphenyl components of Aroclor 1221 have almost completely disappeared after a 24-hour cycle, while there is an apparent buildup of the minor higher chlorinated isomers. These minor components, because of the increase in detector sensitivity with chlorination level, are amplified in the chromatograms compared to their true weight per unit basis. Comparison of the extract chromatogram to that of the Aroclor 1242 standard shows that these minor components in Aroclor 1221, which are more resistant to degradation, comprise the major components of Aroclor 1242.

In Figure 8, similar chromatograms are shown for MCS 1043. Comparison of the extract chromatogram to that of the standard again shows that the lower chlorinated isomers or homologs disappear more rapidly while a buildup of higher chlorinated components occurs.

In Figures 9 and 10, chromatograms for Aroclor 1016 and Aroclor 1242 extracts and standards are shown. With these more highly chlorinated products, the change in homolog distribution are not as dramatic compared to the lower chlorinated products. The buildup of the more refractory penta- and hexachlorobiphenyl homologs is apparent.

For Aroclor 1254, chromatograms have not been included since no significant change in homolog or isomer distribution was observed during the testing period.

At the conclusion of the final sampling periods for Aroclor 1254, Aroclor 1242, Aroclor 1016, and MCS 1043, feeding of the test compound was stopped. The units were then monitored over a period of time to determine how rapidly the residues remaining from the various test compounds disappeared. In Table V, the mg of residue found at various time intervals after the last feeding are shown. As expected, the lower the level of chlorination the more rapidly the residue disappears. For Aroclor 1254, it is apparent that no significant decrease in the residue occurred over the period studied.

TABLE V

Days After Last Feeding of Test Compound	Mg of Residue			
	Aroclor 1254	Aroclor 1242	MCS 1016	MCS 1043
3	5.38	2.62	2.26	1.24
5	4.50	2.29	1.16	1.06
7	4.94	1.47	1.31	0.70
10	7.42	1.76	1.17	0.75

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Residue Studies for Polychlorinated Biphenyls (PCBs) in Fish, Birds and Mammals

Introduction

Early in 1969, after confirmation of Jensen's[6] identification of PCB residues in Swedish birds and fish, Monsanto began initiating a series of Aroclor toxicity-tissue residue studies. The general objective of these studies was to learn more about the environmental behavior and potential effects of PCBs.

As indicated by the title of this appendix, it will deal only with the results of the residue work. Appendix should be consulted for the results of the toxicity work.

The specific objectives of the tissue residue studies with fish, birds and mammals were to learn more about:

1. tissue storage levels as a function of exposure time and exposure level,

2. the character of the PCB residues retained from the various Aroclor products, and

3. the rate at which PCB residues disappear once exposure ceases.

To date, analyses of tissues collected from nine[7] toxicity-tissue residue studies have been completed. The tissue samples were collected, quick frozen, and shipped by the consultant laboratories to Monsanto Industrial Chemicals Company. Upon receipt, the tissues were analyzed for PCB residues by Monsanto personnel in accordance with Analytical Chemistry Method 71-35.

In the first two tissue collection studies all samples were analyzed. In the subsequent studies, a statistical approach was employed because of the large number of samples In this manner, both the elapsed time and manpower requirements were minimized with little real loss in either accuracy or precision. The approach involved analysis of a balanced sub-set (∿25-30%) of the tissues collected. The data from the balanced sub-set of samples, the appropriate study variables (tissue, exposure period, exposure level, sex, and Aroclor fed), and the most probable variable interactions were then used to generate an interpolation equation via multiple regression analysis. The initial equation was then smoothed by deleting data more than two standard deviations from the predicted values and the variable interaction terms not significant at the 95% confidence level. The final equations were then used to calculate the PCB residue levels in the un-analyzed tissues.

The validity of each of the predicting equations was established in the following manner. The respective residual standard deviations of each equation was compared to those obtained for the equations developed for the two studies in which all samples were analyzed. The 95% confidence limits calculated for these studies from the log of the residual standard deviations indicated that in all studies the actual values determined by analyses would be ∿0.5-2 times the predicted values.

Summary and Conclusions

The most significant conclusion which can be drawn from these residue studies is that it supports what has and is being observed via residue analysis of environmental samples. That is to say, that from a "residue viewpoint", the bulk of the PCB isomers which have been released to the environment (PCBs with less than 5 chlorines) are subject to degradation. Since degradation of these PCB isomers can and does occur at significant rates they in turn should not be a long term threat to the higher members of the food chain.

In Figure 11, the observed PCB residue levels for rats and dogs exposed to Aroclor 1221, Aroclor 1242, Aroclor 1254 and Aroclor 1260 for 90 days is plotted vs the degree of chlorination of the product fed. It graphically illustrates that PCB storage levels decrease exponentially as the degree of chlorination of the product decreases. This exponential decrease simply reflects the refractory PCB content of each product produced via direct chlorination.

Considerable differences were noted in concentration factors as judged by the ratio of the PCB level found in the extractable lipid to the exposure level. Fish were found to be most efficient PCB concentrators followed by chickens, rats and then dogs. The calculated concentration factors observed for Aroclor 1242 are shown in Table VI.

TABLE VI

	Exposure Level (PPM)	Exposure Period	Max. Observed PCB Level in Lipid	Concentration Factor*
Blue Gills	0.1 in wtr.	21 Days	4.0%	400,000
Catfish	0.1 in wtr.	21 Days	3.2%	320,000
White Leghorn Chickens	1.0 in feed	12 Weeks	20 PPM	20
Albino Rats	1.0 in feed	2 Years	9 PPM	9
Beagle Dogs	1.0 in feed	2 Years	2 PPM	2

*NOTE: Factors do not take into account exposure periods

Calculation of concentration factors in this fashion for chickens, rats, and dogs can be misleading. For example, ratio of total PCBs retained to that orally ingested by chickens, rats and dogs is shown in Table VII.

TABLE VII
Test Material - Aroclor 1242

	Exposure Level		
	1 PPM	10 PPM	100 PPM
White Leghorn Chickens	0.11	0.11	0.11
Albino Rats	0.02	0.01	0.003
Beagle Dogs	0.005	0.001	0.0003

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Inspection of the ratios illustrates that the higher members of the food chain are in fact inefficient PCB concentrators.

Decrease of PCB residues was noted with both chickens and dogs placed on PCB free recovery diets. The dogs remobilized the residues more rapidly than chickens. In both studies, the residue levels fell more rapidly the lower the degree of chlorination of the product fed.

Figure 12 illustrates this point. In it the % total PCBs accumulated in the lipid is plotted vs the recovery periods for the Two Year Beagle Dog Study with Aroclor 1242, Aroclor 1254, and Aroclor 1260.

Figures 13-22 are bar graphs constructed from electron capture gas chromatograms of the product fed and the isolated PCB residues. The bar graphs were constructed by normalization to a convenient peak present in each of the chromatograms being compared. The numbers above each bar indicate the dominant homolog or homologs as determined by mass spectrometry. In no case were the residue fingerprints observed to be a function of the exposure level.

Figures 13-15 compare the distributions observed for residues isolated from fish, chickens, rats and dogs exposed to Aroclor 1242, Aroclor 1254, and Aroclor 1260. Inspection of these figures demonstrates that fish absorbed Aroclor 1242 without altering the isomer distribution. Dogs were found to be most effective at selectively degrading the Aroclor products followed by rats and the chickens. The figures also indicate that, with minor exceptions, the lower chlorinated isomers present in each product are more easily degraded.

Figures 16-18 illustrate the make up of the residues isolated from dogs after 2 years of continuous exposure followed by 30 and 60 day recovery periods on PCB free diets. Inspection of these figures reveals that the bulk of the isomers observed in the dogs sacrificed after two years of continuous exposure rapidly degraded once exposure ceases.

Figures 19-21 illustrate the alterations observed when chickens exposed to these three Aroclor products for 12 weeks were placed on recovery diets for 30 days. Although the degradation was less extensive than observed with dogs, the same general trends were noted.

In Figure 22, the isomer distribution of Aroclor 1242 and the residues isolated from rats fed Aroclor 1242 and Aroclor 1016 for 90 days are shown. Although the difference in the total % chlorine in these products is negligible the isomer distribution of the residues are significantly different. This difference can be explained by the fact that the higher chlorinated biphenyl content of Aroclor 1016 relative to Aroclor 1242 has been reduced by a factor of twenty.

The actual residue levels as determined by analysis and interpolation are shown in Tables VIII - XXXII.

REFERENCES

1. Bagley, G. E., Riechel, P., and Cromarite, E., J. of AOAC 53 (1970) 252.

Armour, J. A., and Burke, J. A., JAOAC, 53 (1970) 761.

Zitko, V., Bull. Environ. Contamin. Toxicol., 6 (1971) 464.

Reynolds, L. M., Residue Reviews, 34 (1971) 27.

Prestt, I., Jefferies, D. J., and Moore, N. W., Environ. Pollut. 1 (1970) 3.

Tas, A. C., deVos, R. H., Environmental Science and Technology, 5 #12 (1971) 1216.

Duke, T. W., Lowe, J. I. and Wilson, A. J., Bull. Environ. Contam. Toxicol., 5 (1970) 171.

2. Primary Bacterial Degradation: "Minimum alteration of the chemical structure of the material in question to an extent that the characteristic properties of the original material are no longer evident".

3. Biodegradation Subcommittee. JAOCS 42, 986 (1965); JAOCS 46, 432 (1969).

4. Synthetic Sewage: 30g. dextrose, 20g. nutrient broth, and 13g. dipotassium hydrogen phosphate in one liter of water.

5. Swisher, R. D., Surfactant Biodegradation, Marcel Dekker, Inc., N.Y. (1970) pp 173, 175-186.

6. Jensen, S. (1966) "Report of a New Chemical Hazard", New Scientist (32) 612.

7. IBT B7009 30-Day Tissue Collection Study In Albino Rats with Aroclors

IBT B7298 Two-Year Chronic Oral Toxicity Study of Aroclor 1242, Aroclor 1254, Aroclor 1260 in Albino Rats

IBT P7297 Three-Generation Reproduction Study in Albino Rats with Aroclor 1242, Aroclor 1254, Aroclor 1260

IBT 9888C 90-Day Subacute Oral Toxicity Study of Aroclor 1016,
9888D Aroclor 1221 in Albino Rats

IBT C7299 Two-Year Chronic Oral Toxicity Study of Aroclor 1242, Aroclor 1254, Aroclor 1260 in Beagle Dogs

IBT 9887 90-Day Subacute Oral Toxicity Study of Aroclor 1016,
9885 Aroclor 1221 in Beagle Dogs

7. Continued

IBT J7300 Toxicity, Reproduction and Residue Study of Aroclor 1242, Aroclor 1254, Aroclor 1260 in White Leghorn Chickens

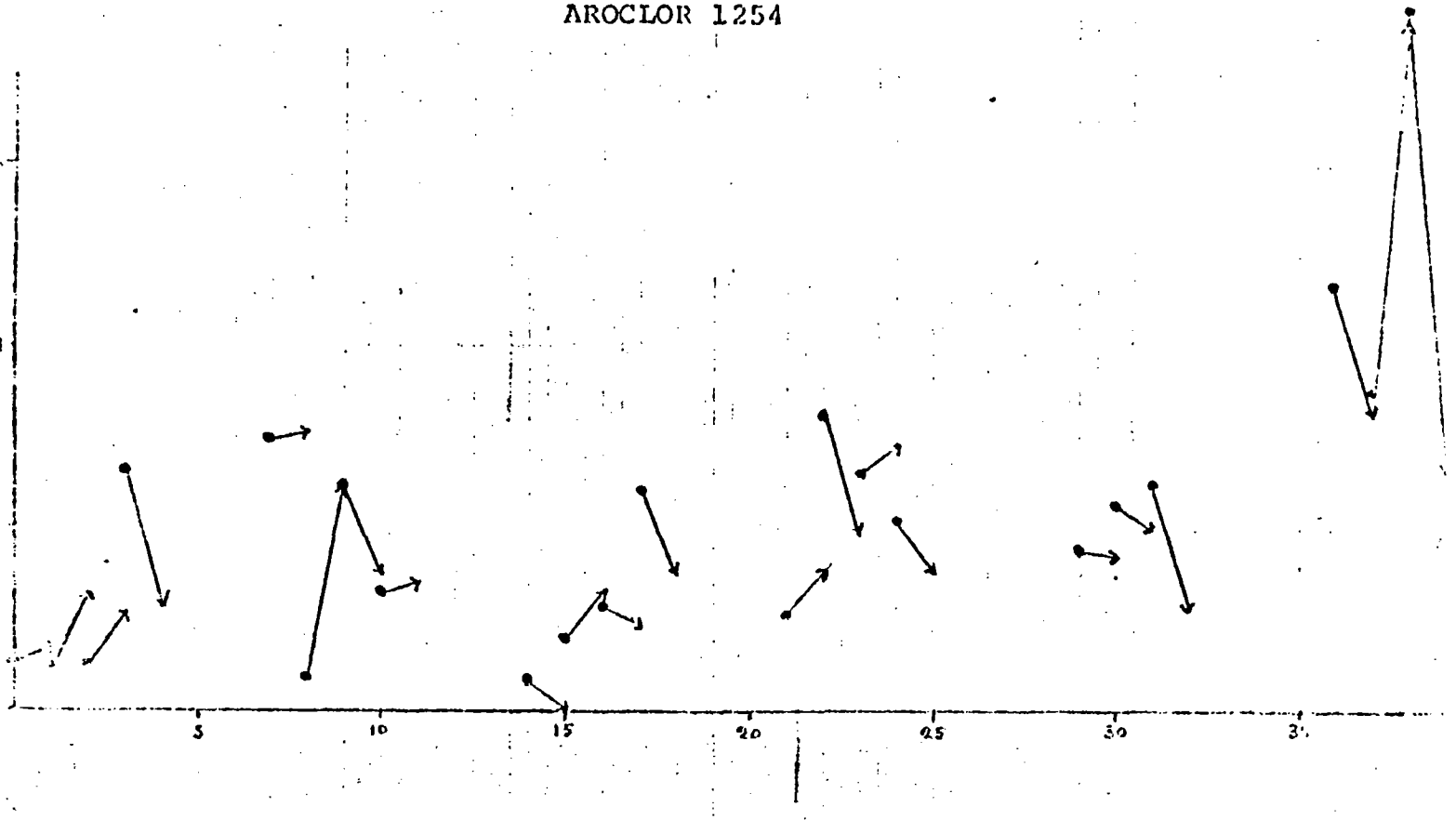
IBT 8746 Toxicity, Reproduction and Residue Study of Aroclor 1242, Lot #AK-255 in White Leghorn Chickens

The following study was carried out at Bionomics, Inc. of Wareham, Massachusetts.

Acute Toxicity of Aroclor 1016, Aroclor 1242, and DDT to Bluegill and Channel Catfish During 21 Days Continuous Exposure to the Chemicals in Water.

SCAS BIODEGRADATION DATA

AROCLOR 1254



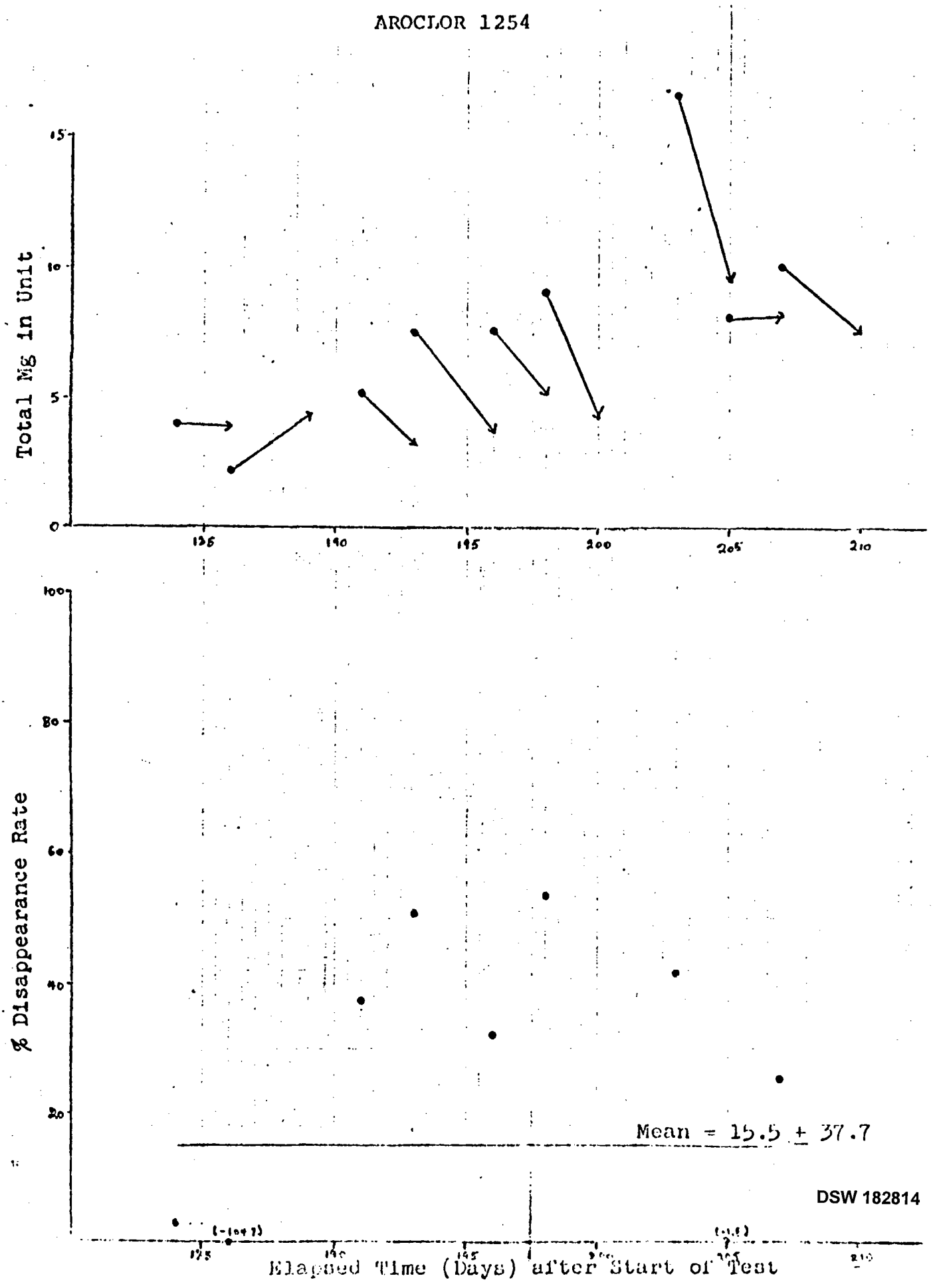
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Elapsed Time (Days) after Start of Test

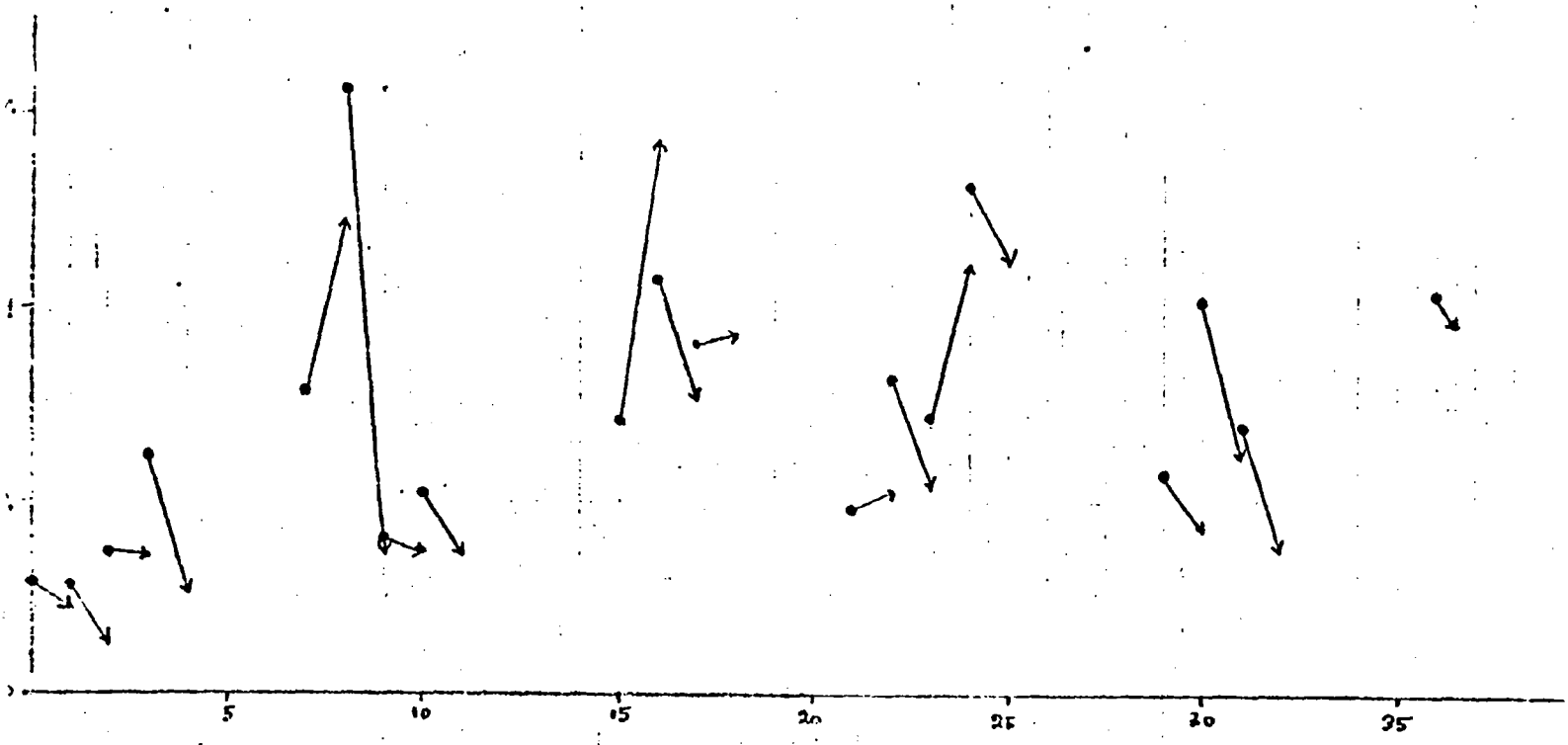
SCAS BIODEGRADATION DATA

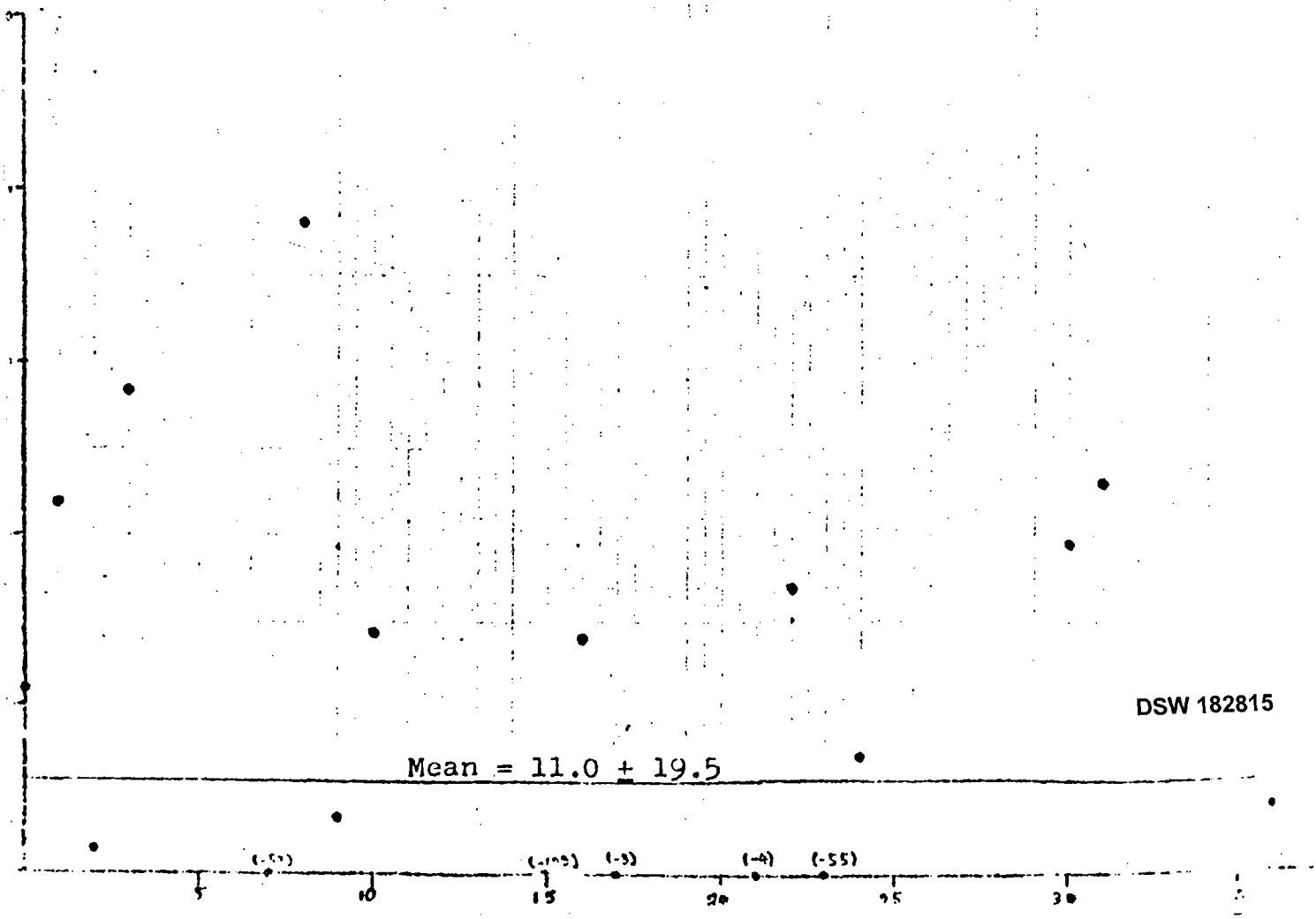
AROCLOR 1254



SCAS BIODEGRADATION DATA

AROCLOR 1242

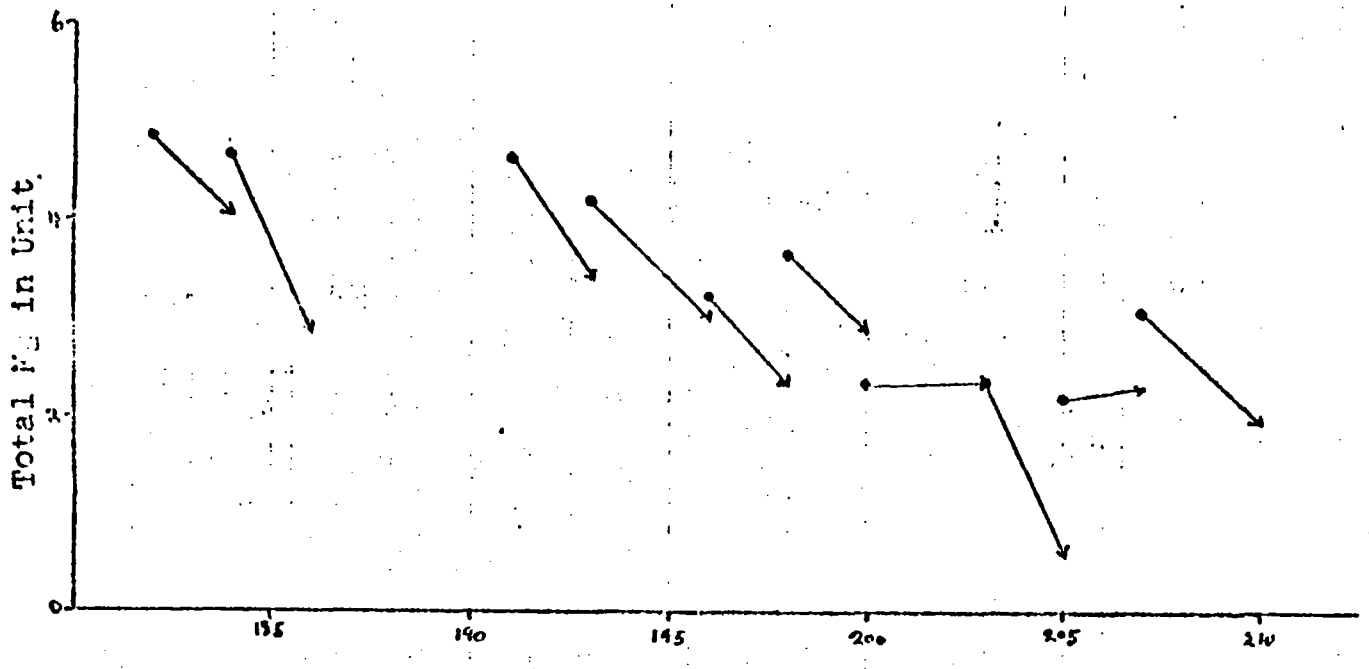


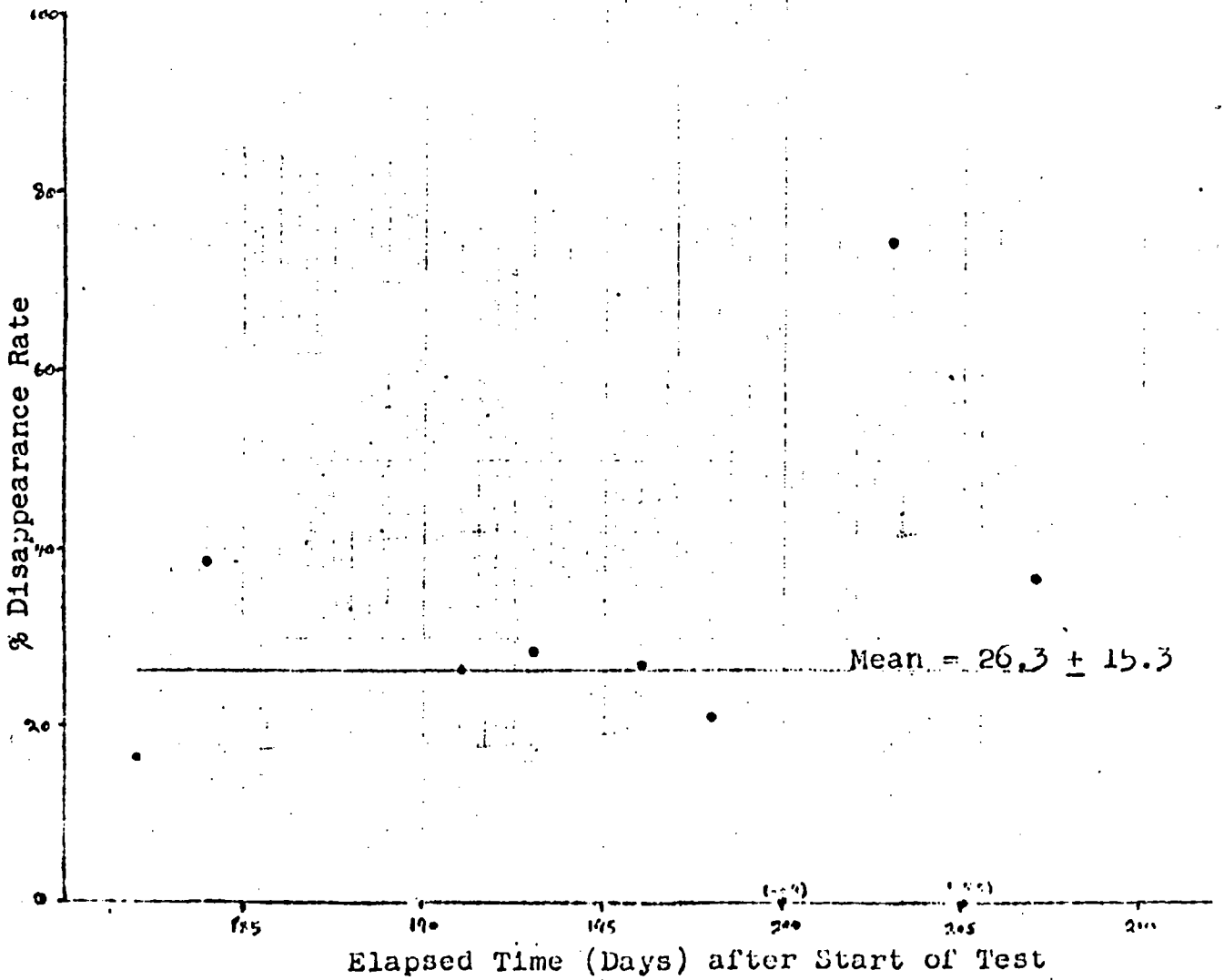


Elapsed Time (Days) after Start of Test

SCAS BIODEGRADATION DATA

AROCLOR 1242

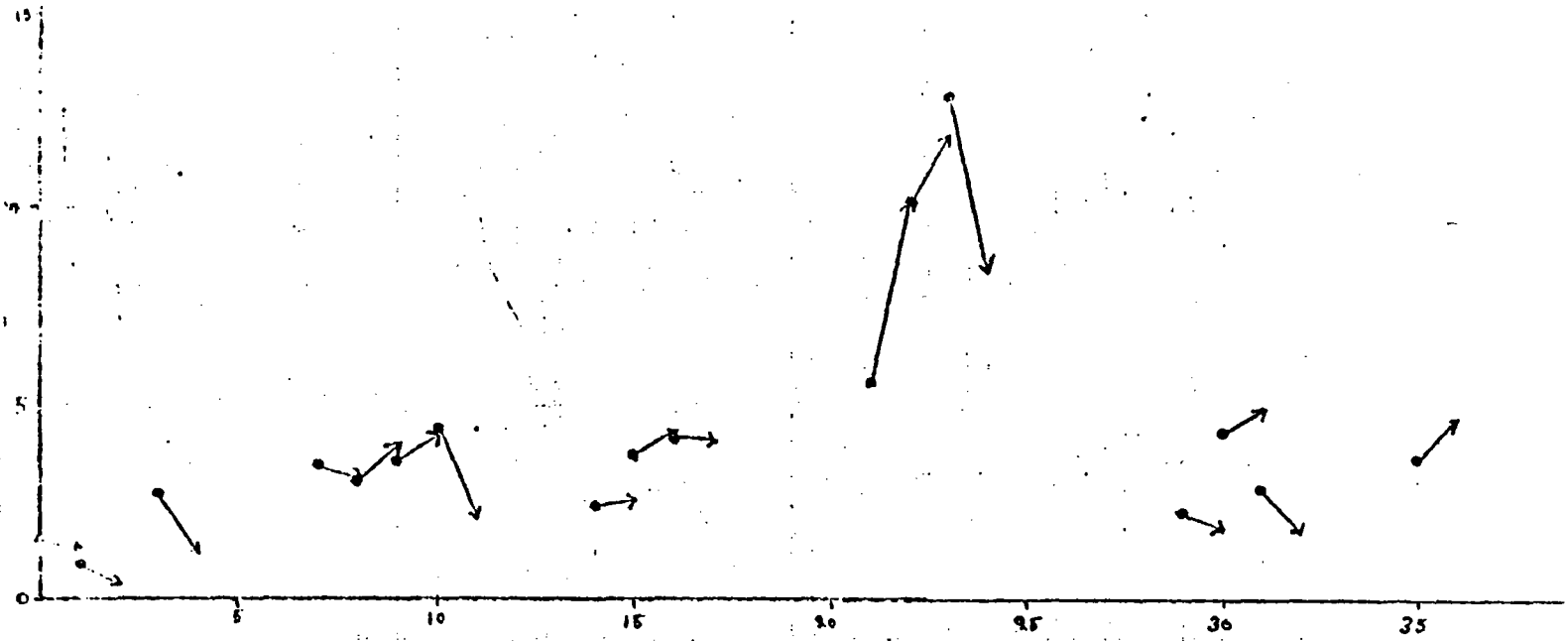




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SCAS BIODEGRADATION DATA

MCS 1016



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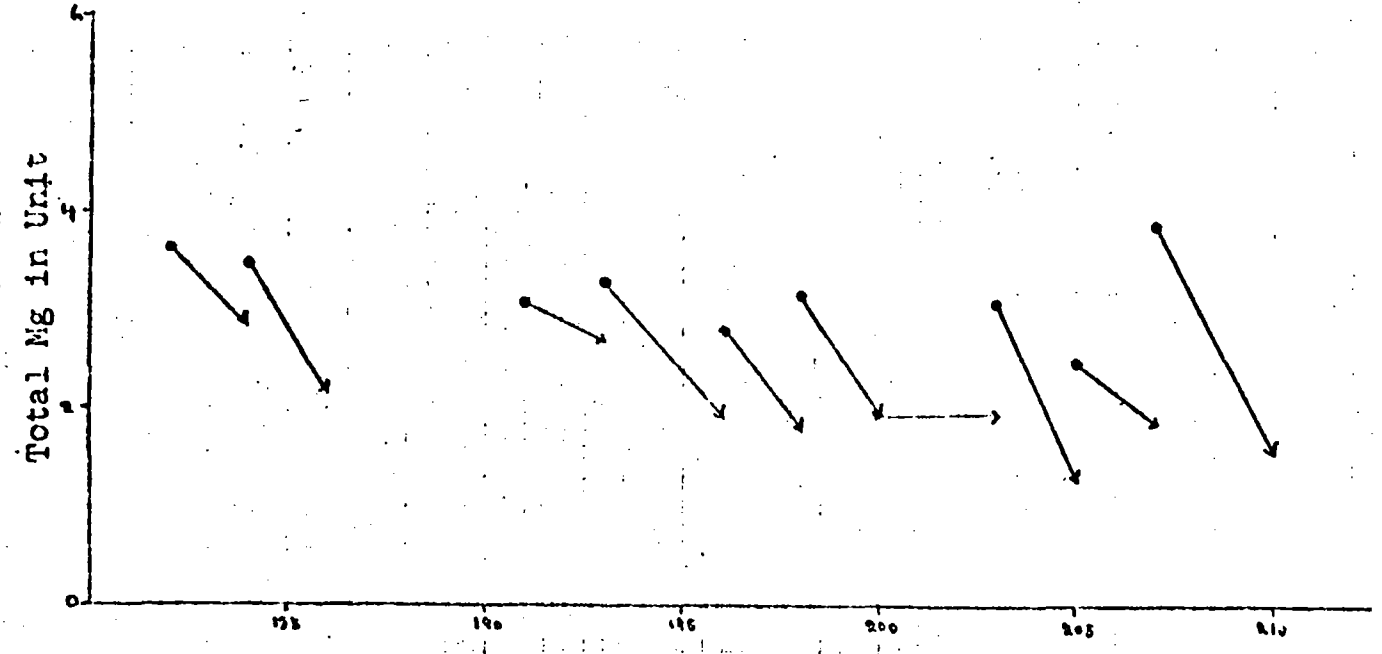
Mean = 5.0 ± 19.0

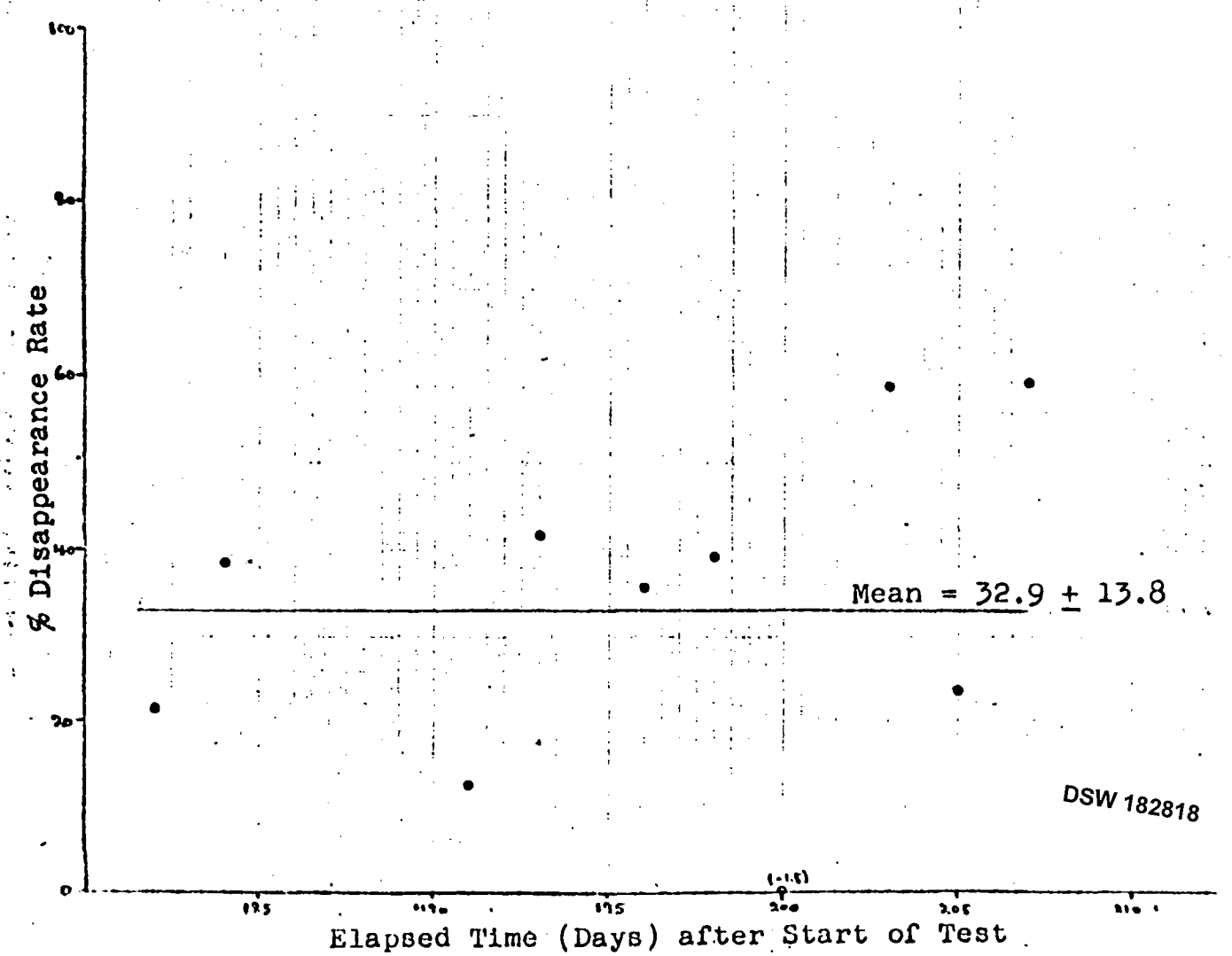
Elapsed Time (Days) after Start of Test

STLCOPCB4050921

SCAS BIODEGRADATION DATA

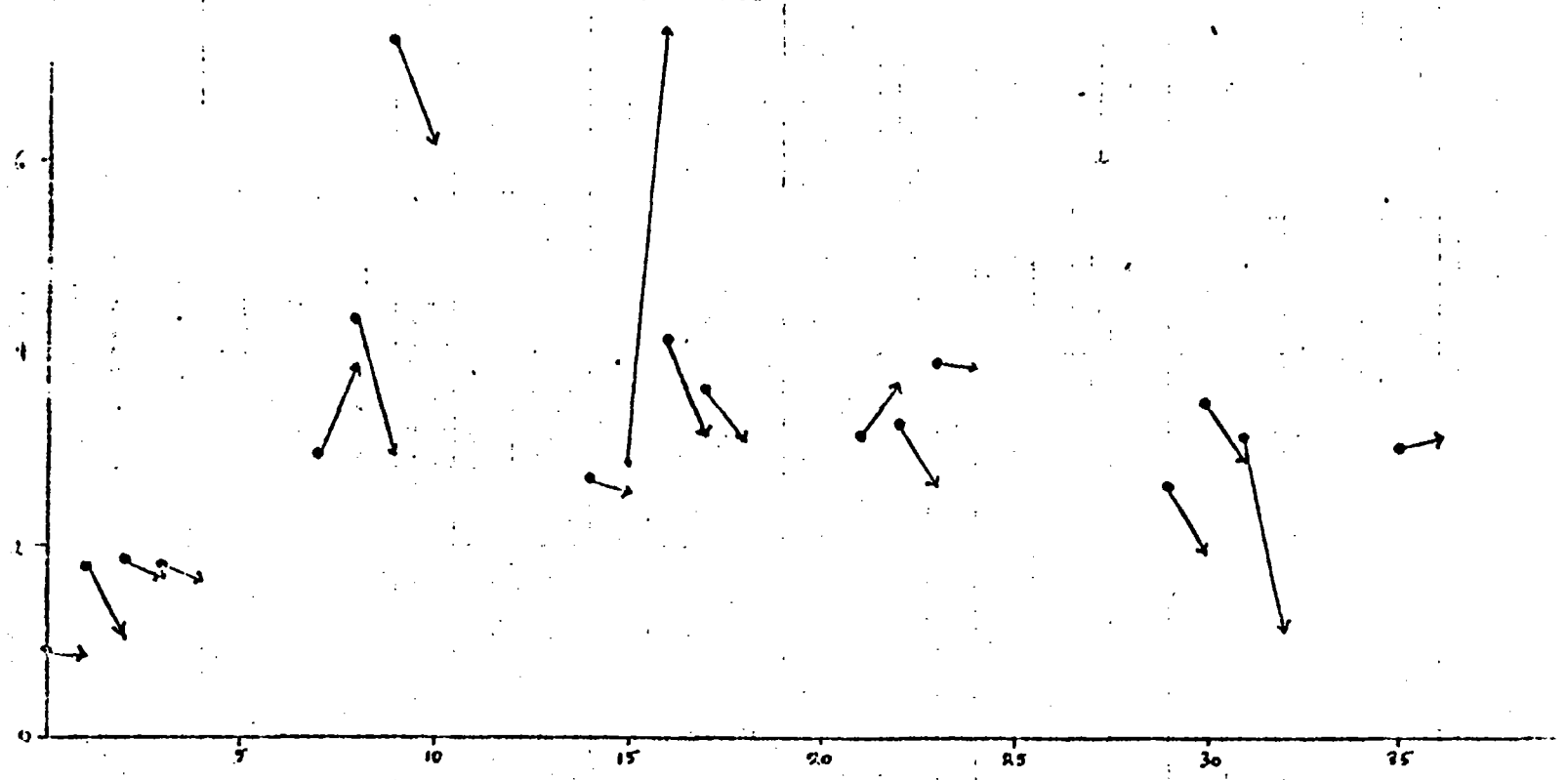
MCS 1016

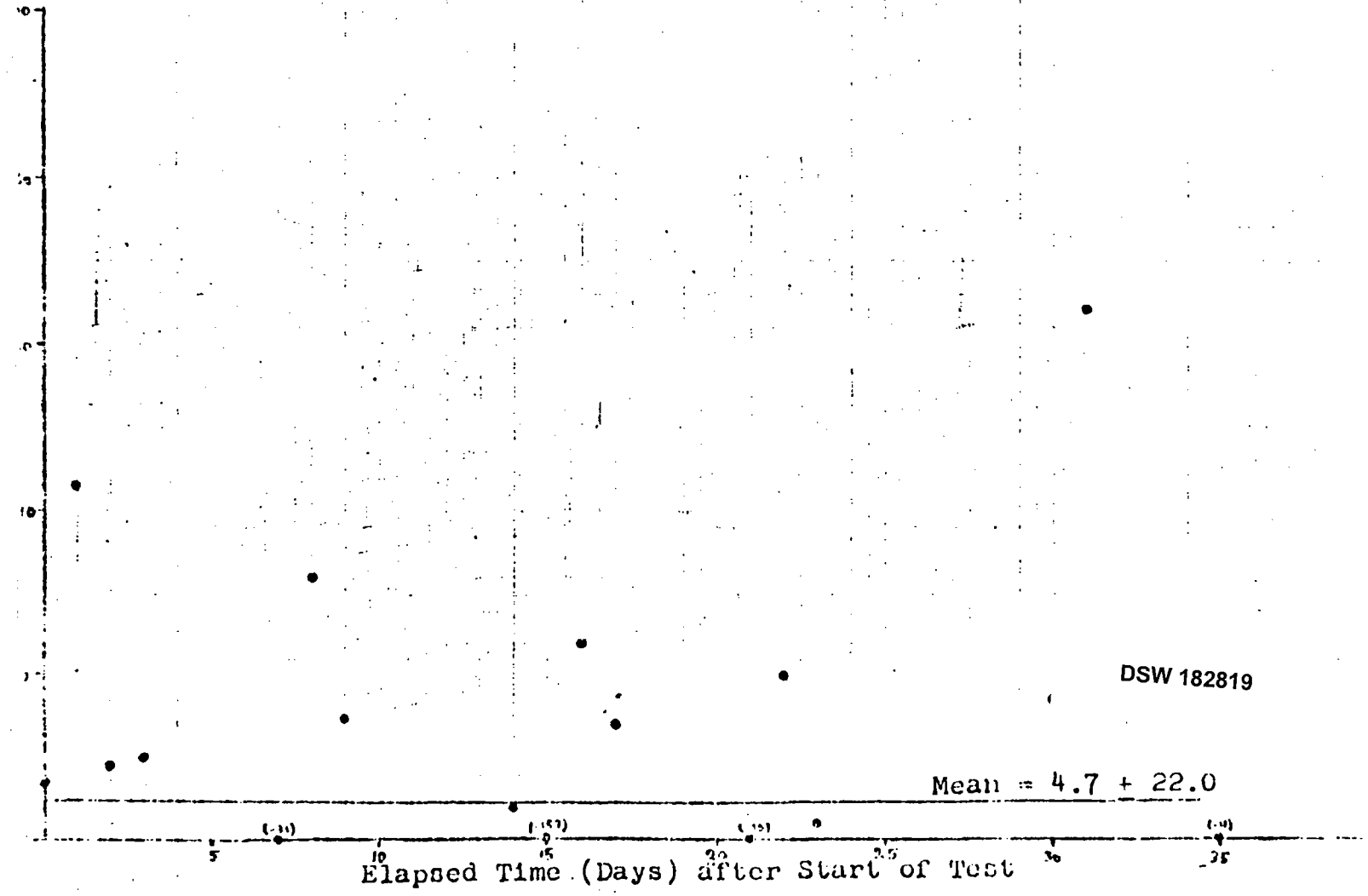




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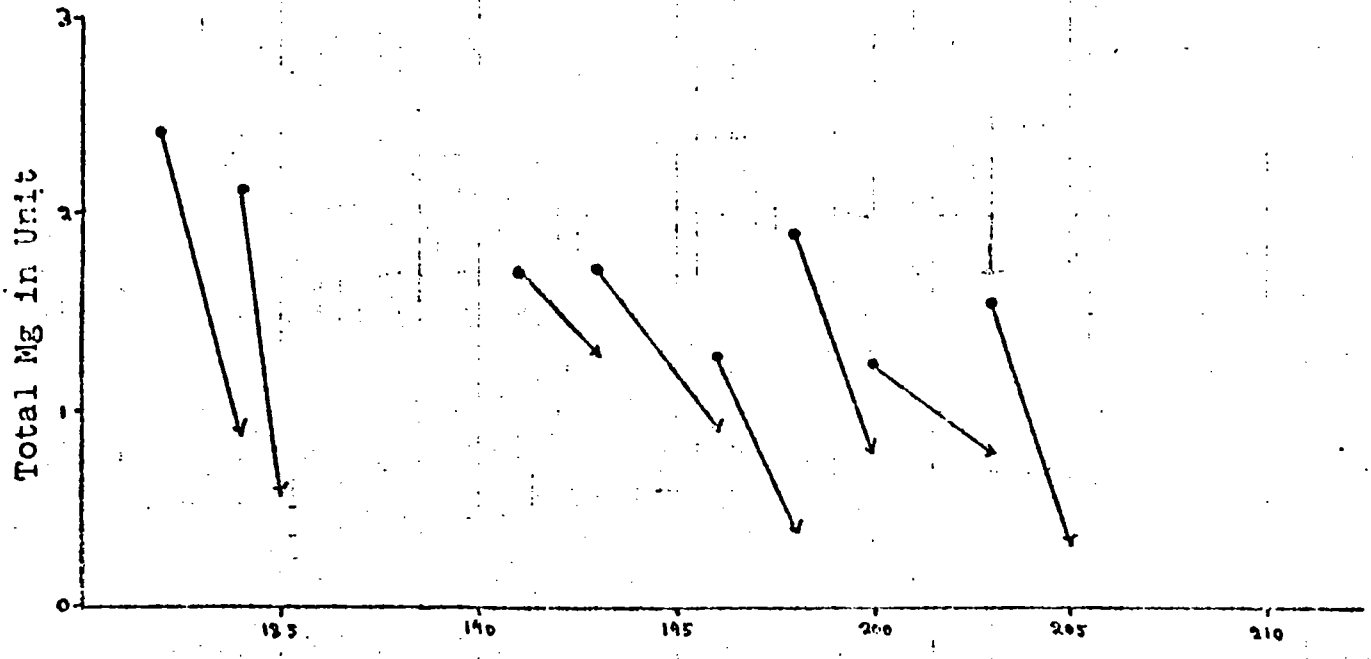
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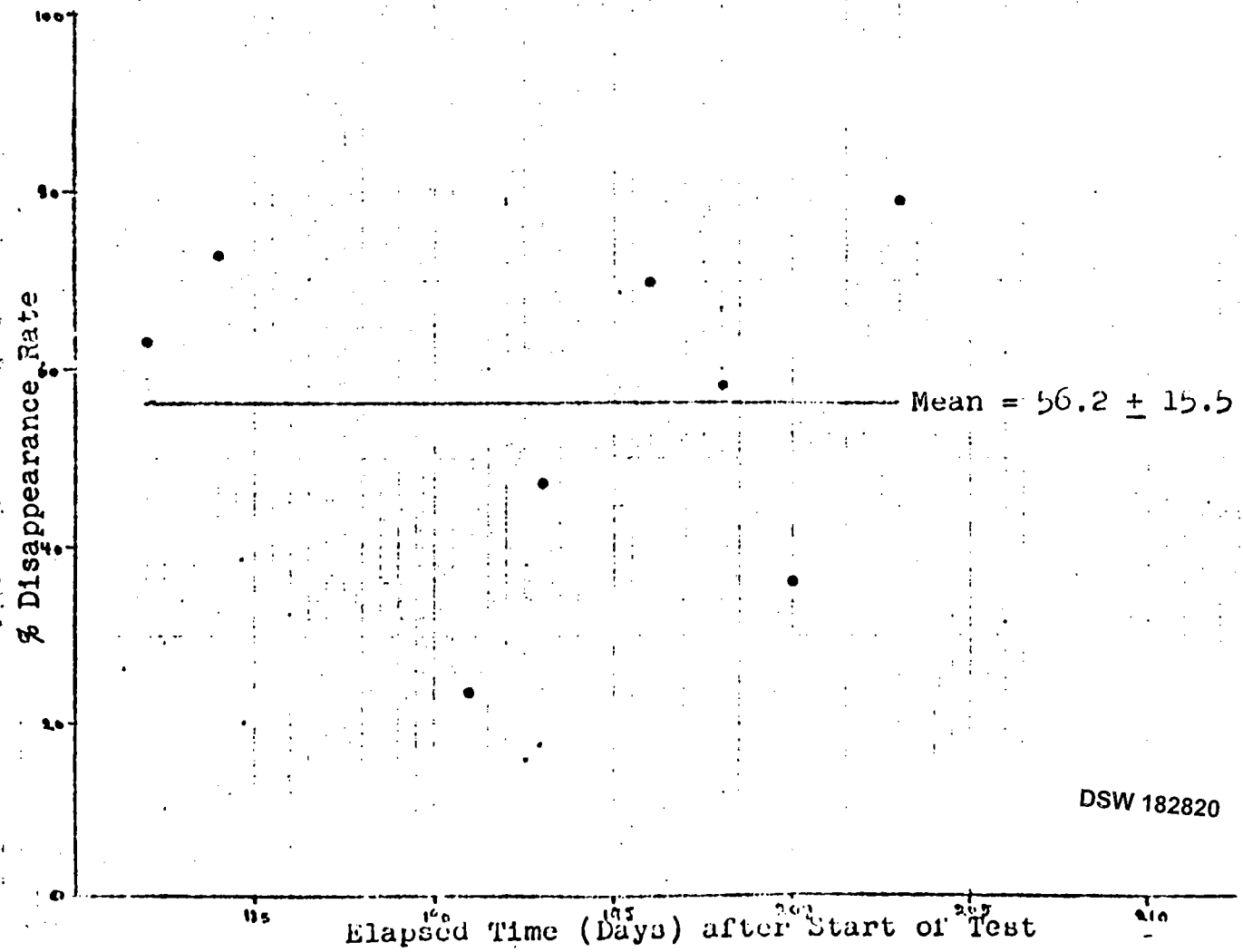




SCAS BIODEGRADATION DATA

MCS 1043





SCAS BIODEGRADATION DATA

AROCLOR 1221

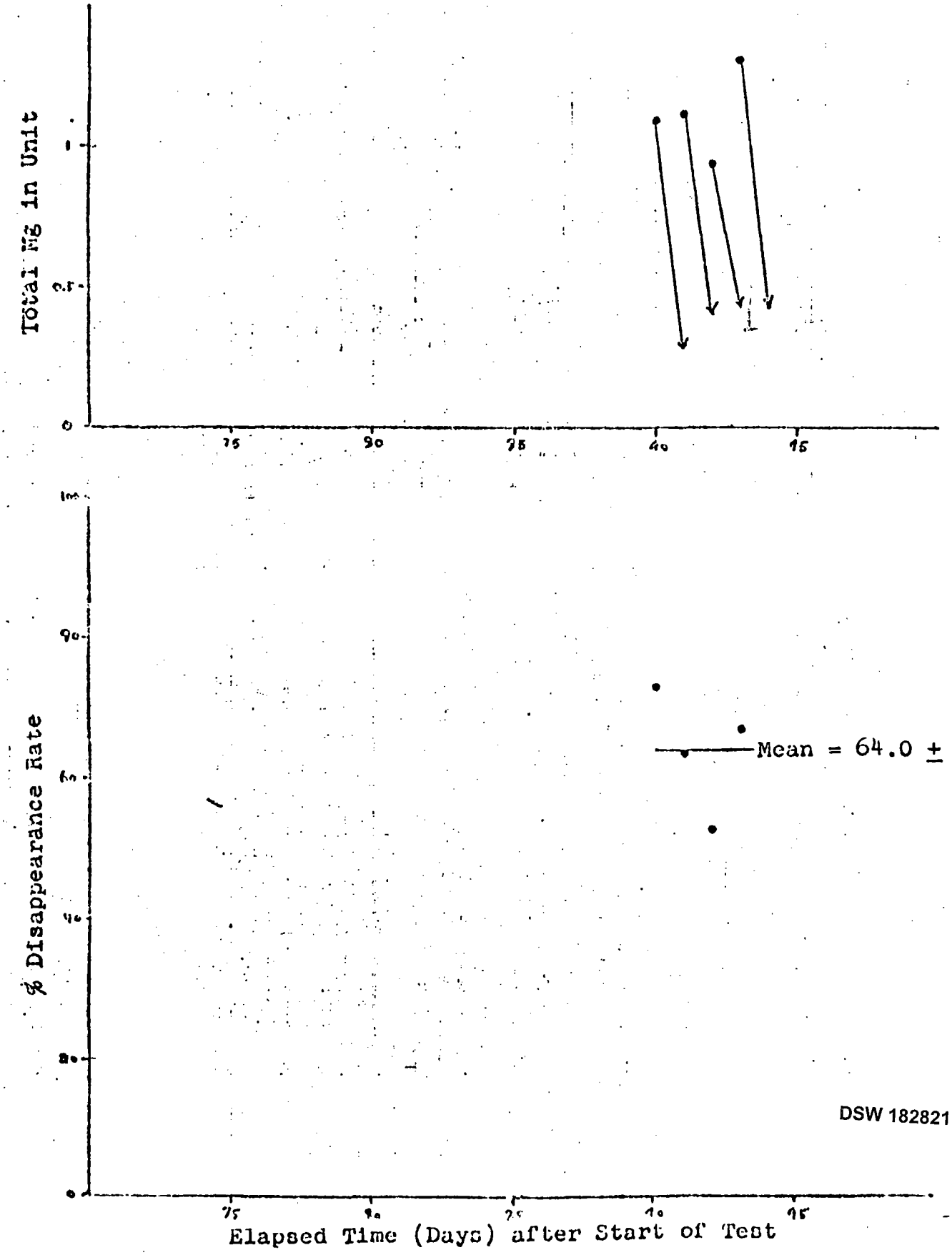
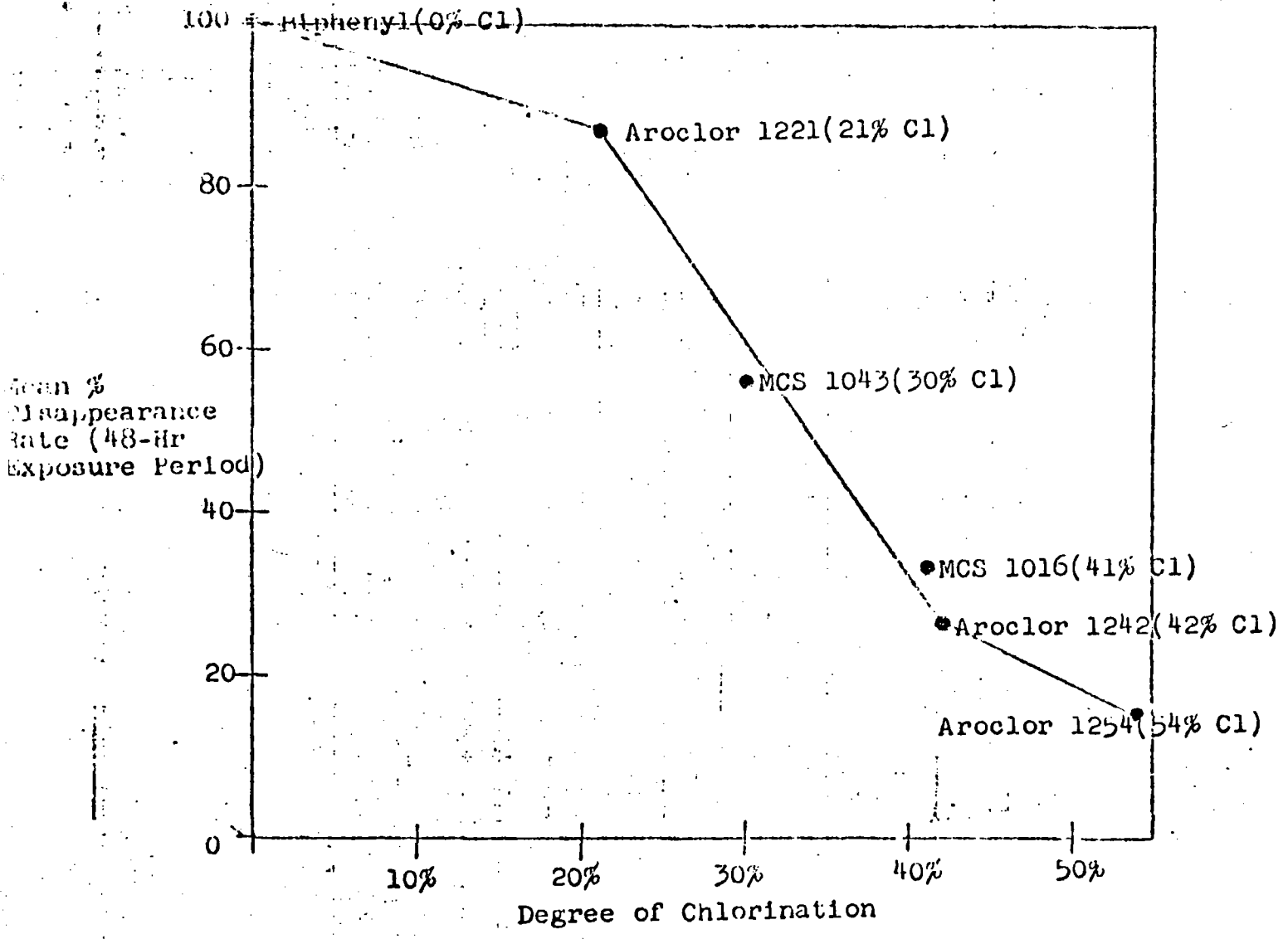
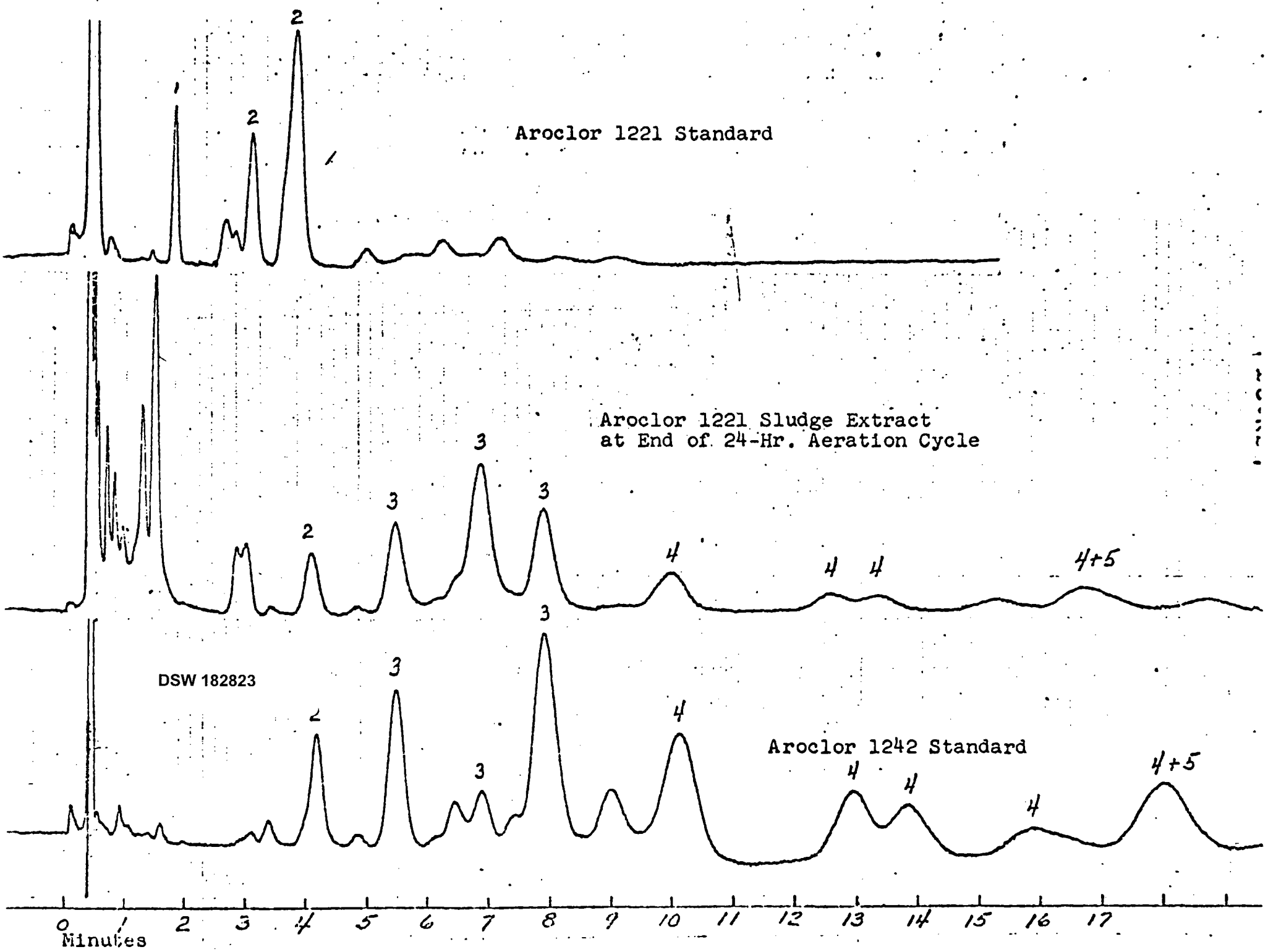


FIGURE 6

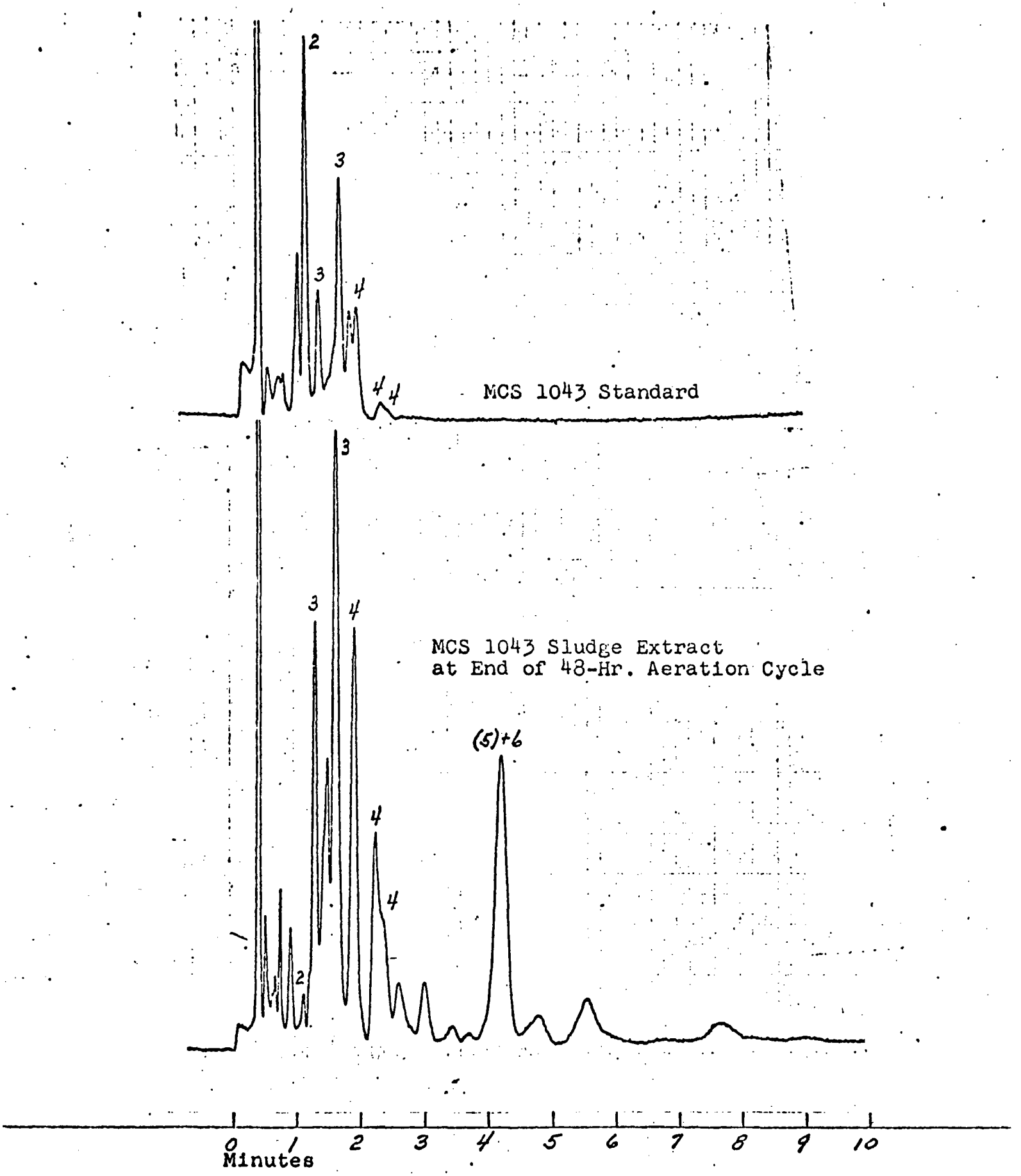
SEMI-CONTINUOUS ACTIVATED SLUDGE (SCAS)
DEGRADATION OF POLYCHLORINATED BIPHENYLS



DSW 182822



STLCOPCB4050927


2
3
3
4
4
4
MCS 1043 Standard
3
3
4
MCS 1043 Sludge Extract
at End of 48-Hr. Aeration Cycle
(5)+6
4
4
2
0
1
2
3
4
5
6
7
8
9
10
Minutes

DSW 182824

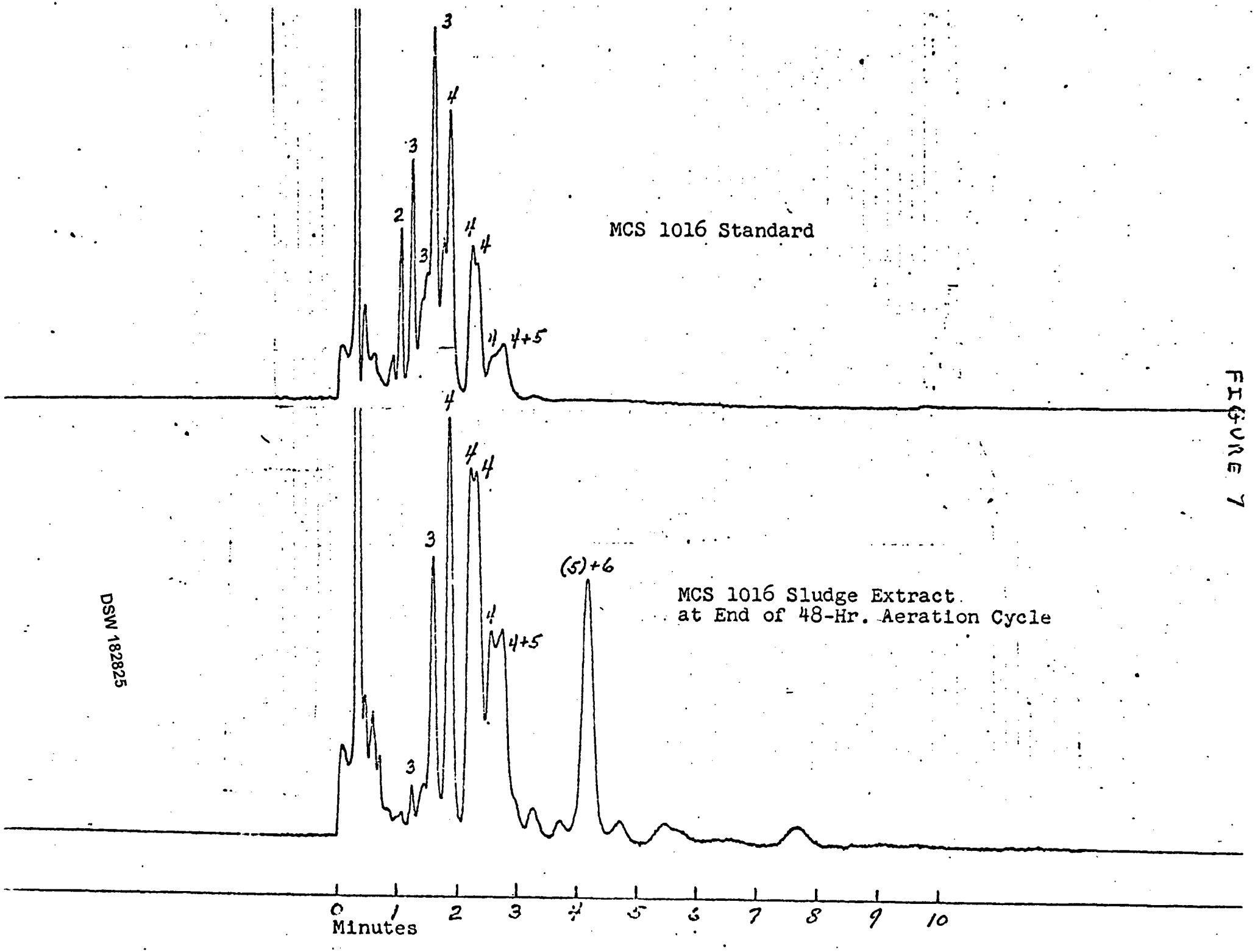
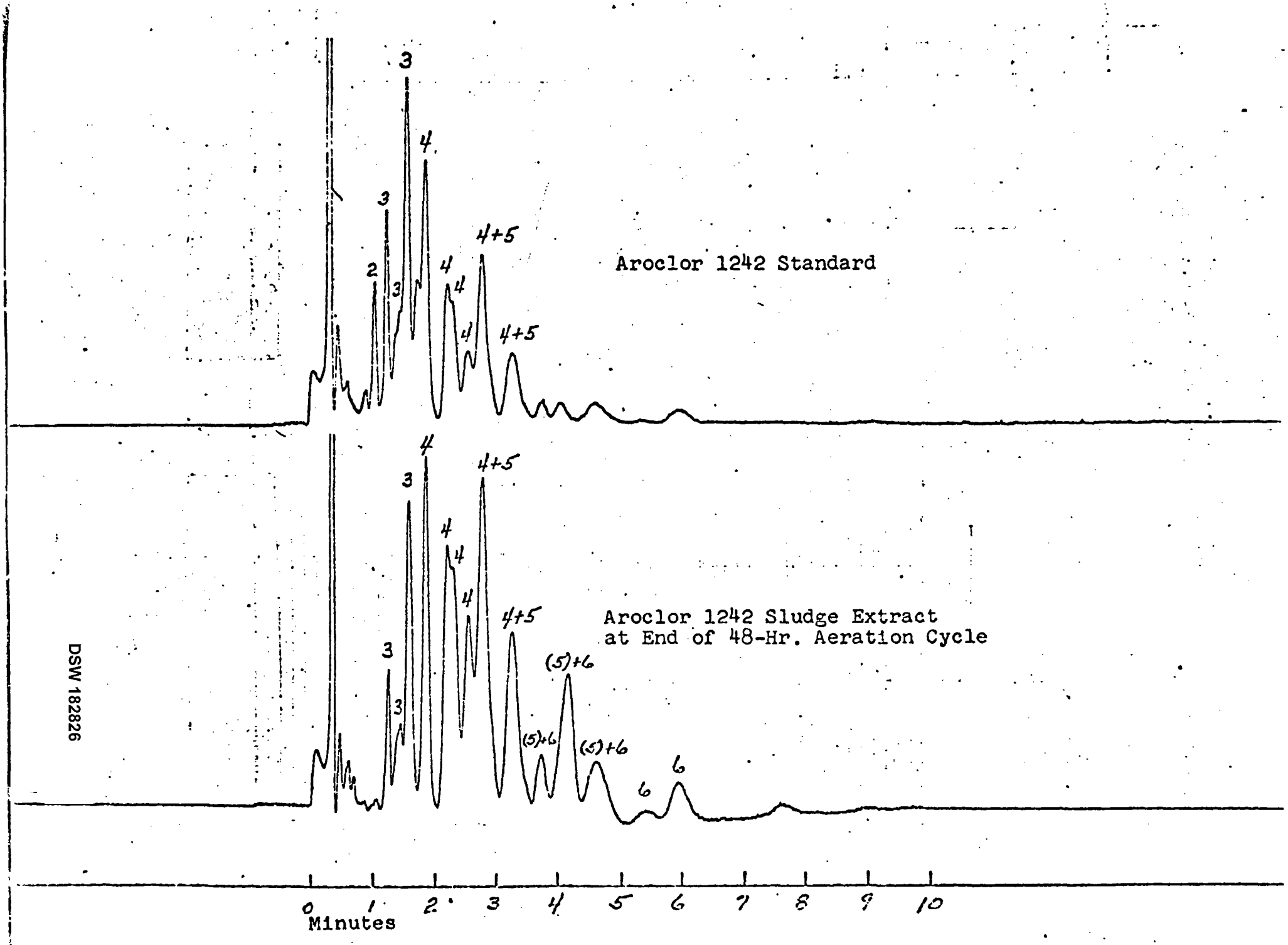


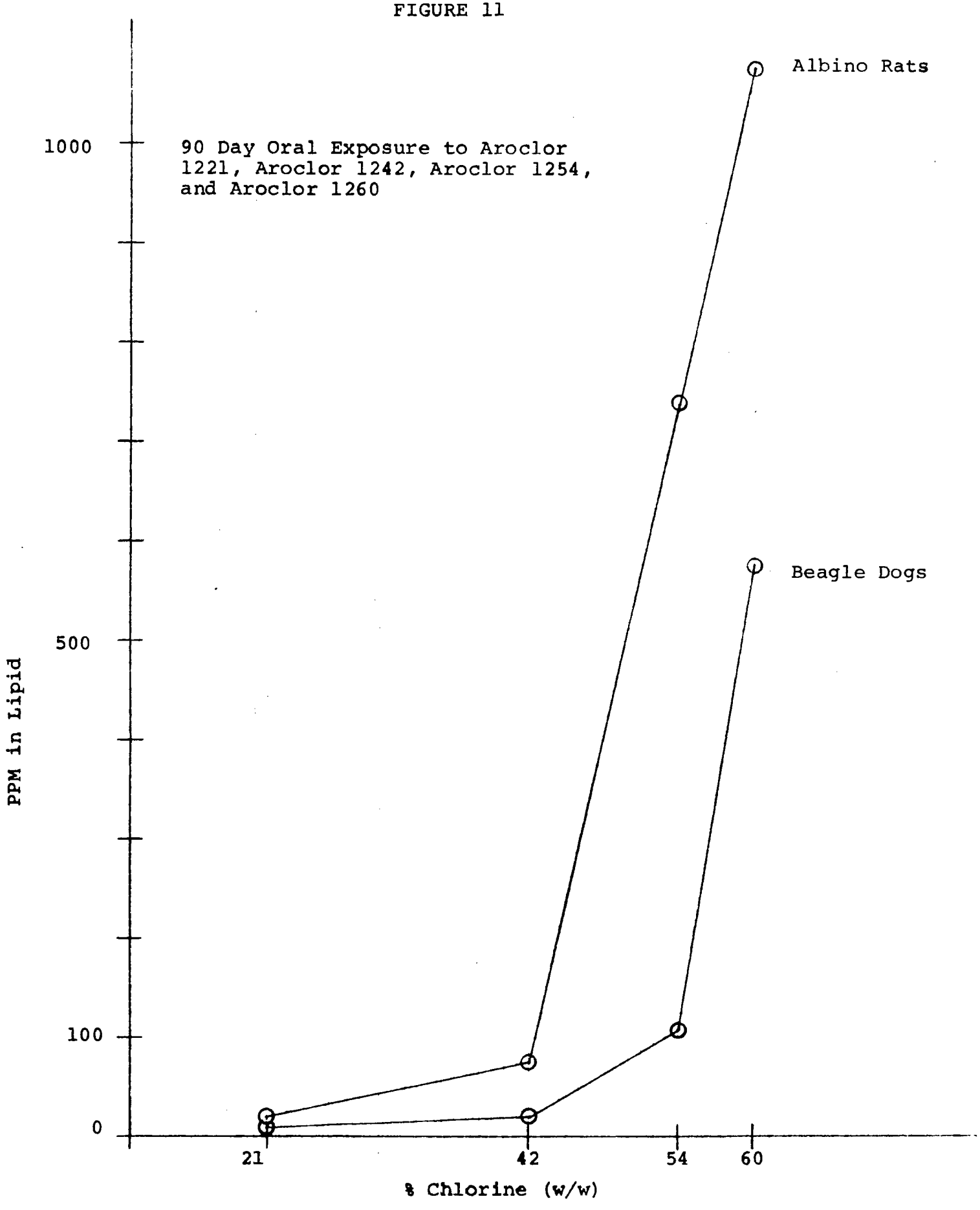
FIGURE 7

STLCOPCB4050929



STLCOPCB4050930

FIGURE 11

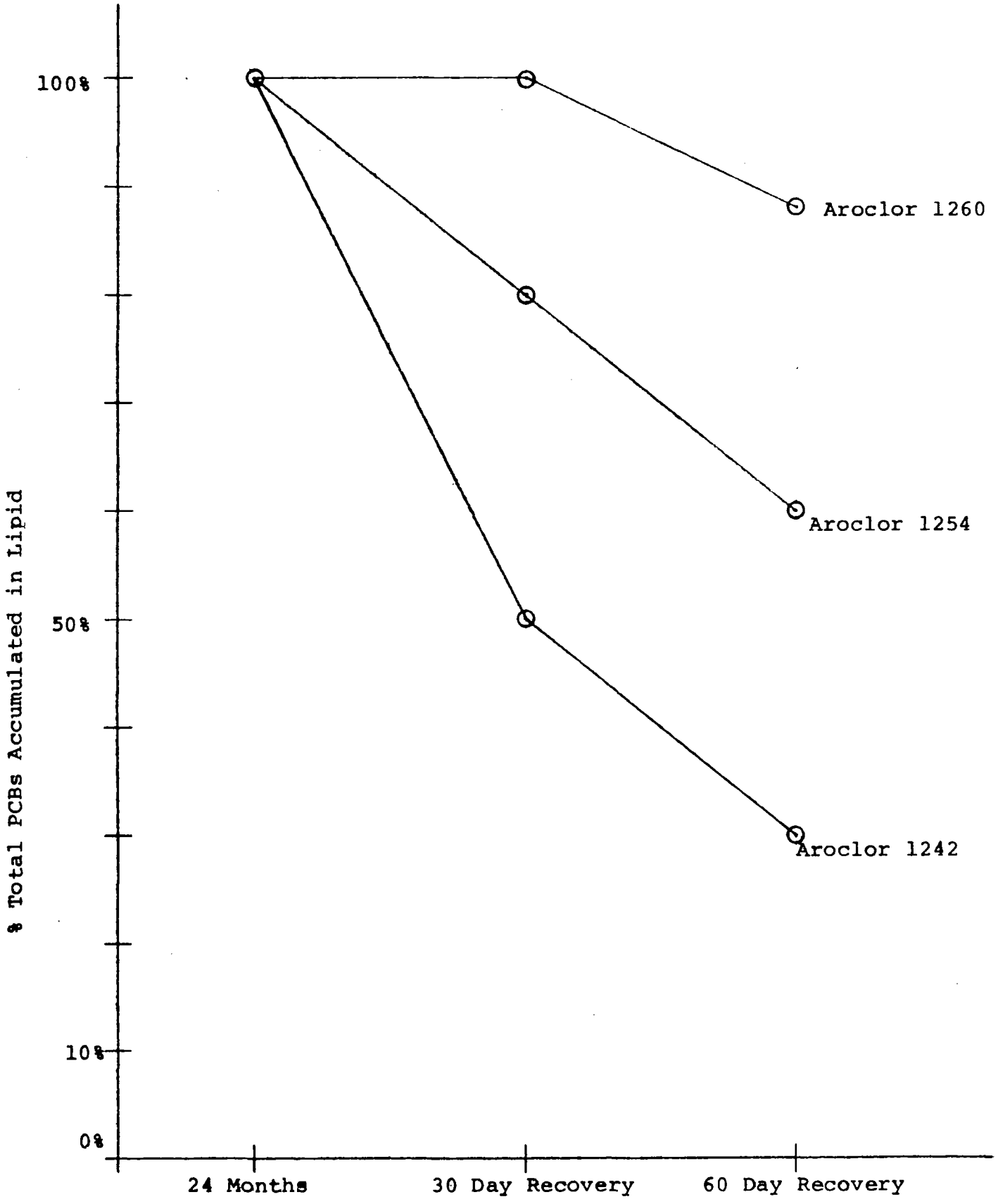


DSW 182827

STLCOPCB4050931

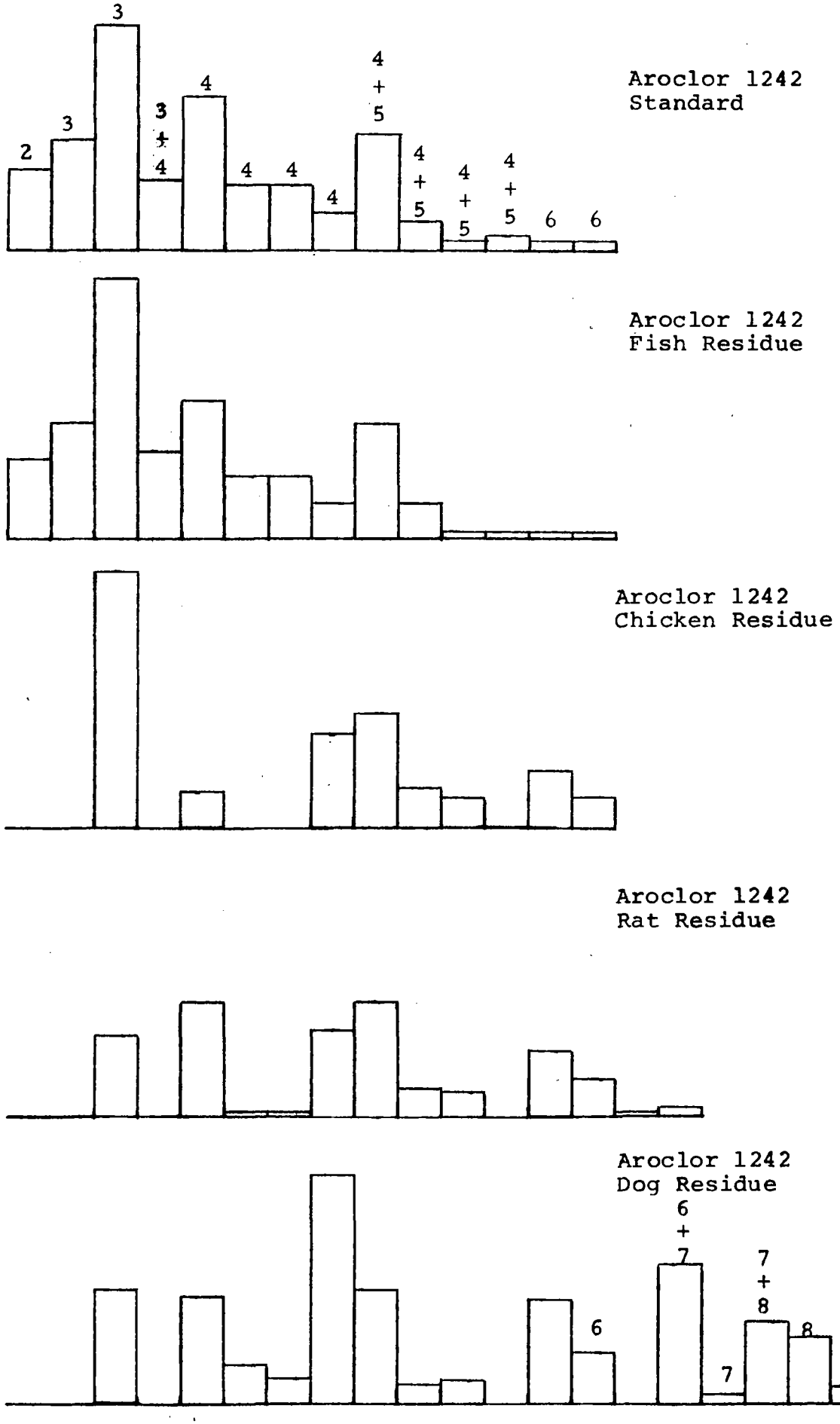
FIGURE 12

Two Year Chronic Oral Toxicity Study of Aroclor 1242, Aroclor 1254 and Aroclor 1260 with Beagle Dogs



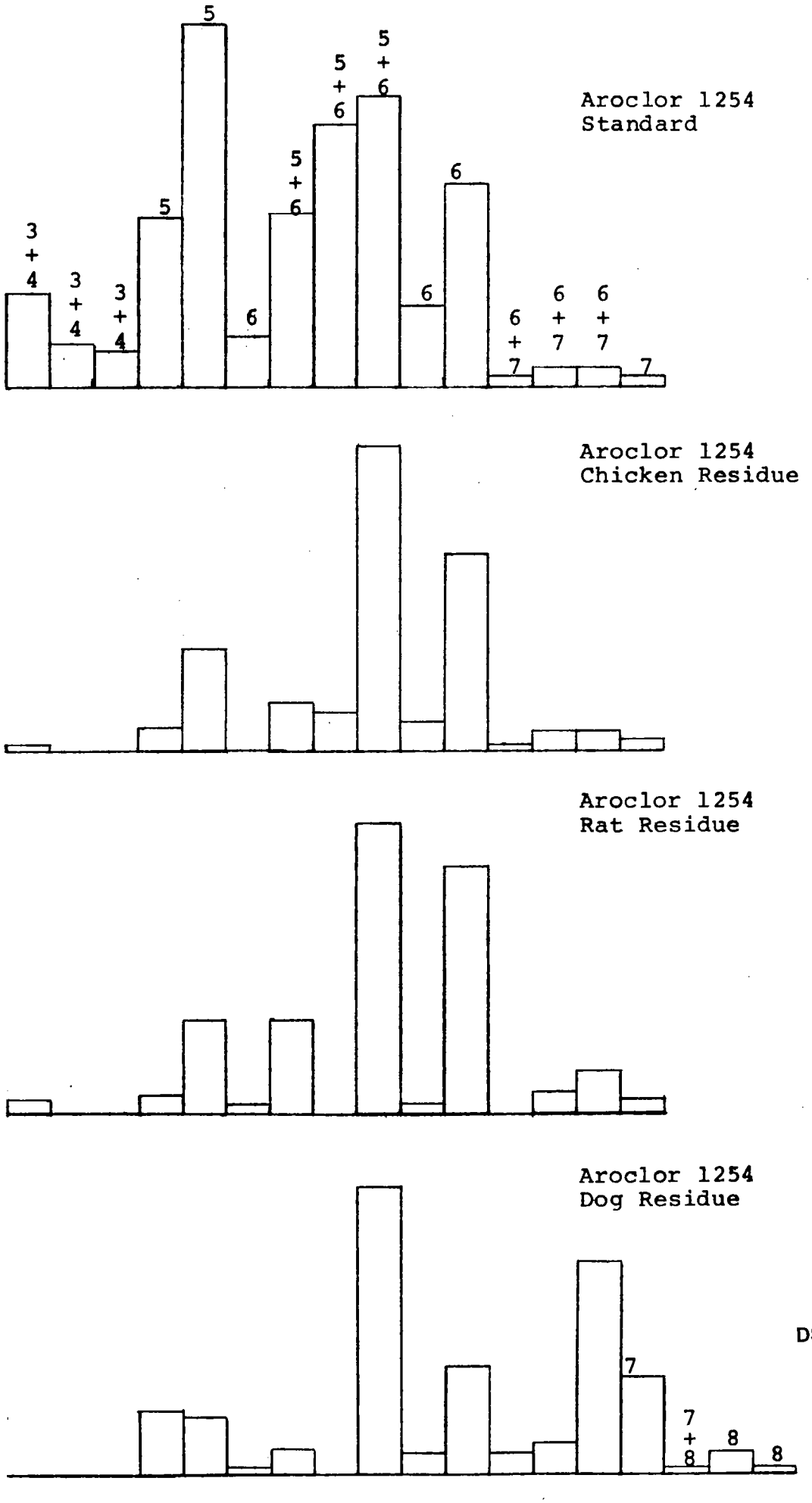
DSW 182828

FIGURE 13



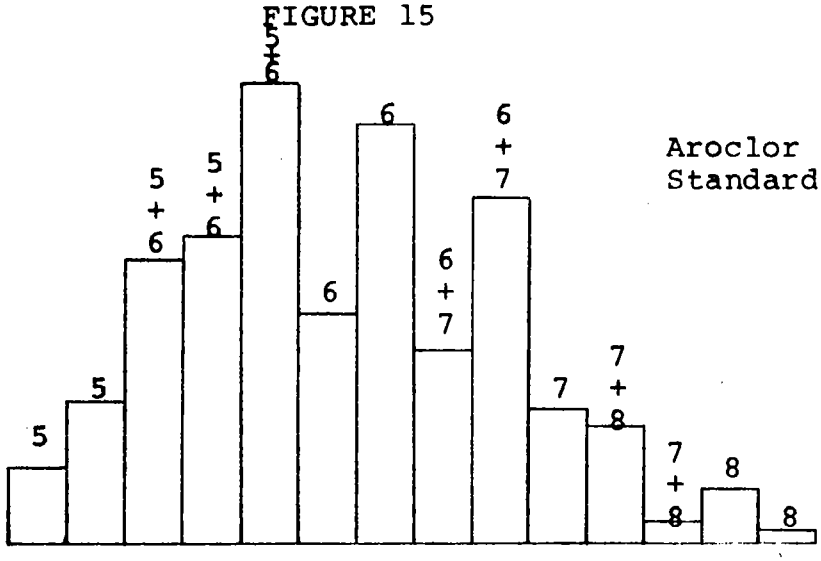
DSW 182829

FIGURE 14

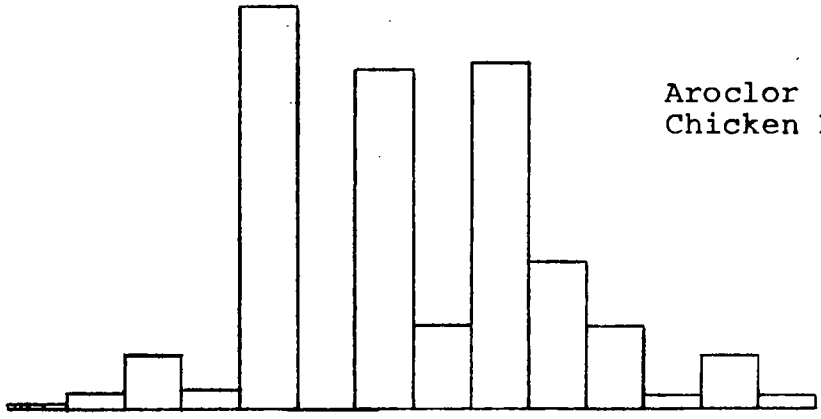


DSW 182830

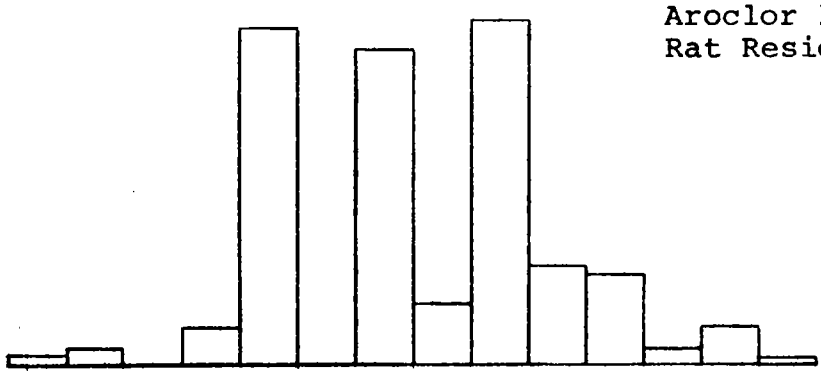
FIGURE 15



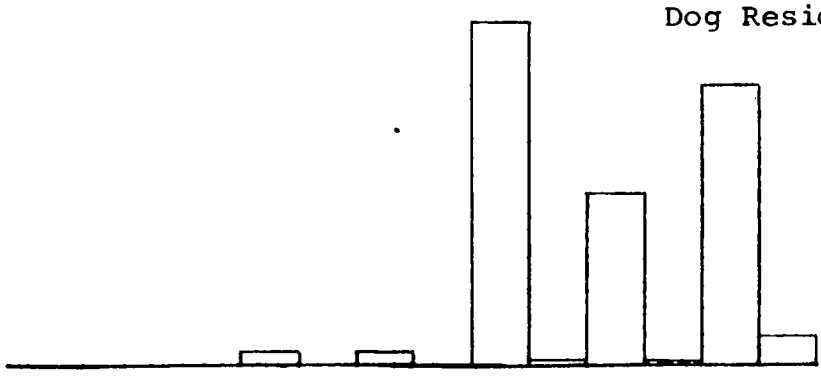
Aroclor 1260
Standard



Aroclor 1260
Chicken Residue



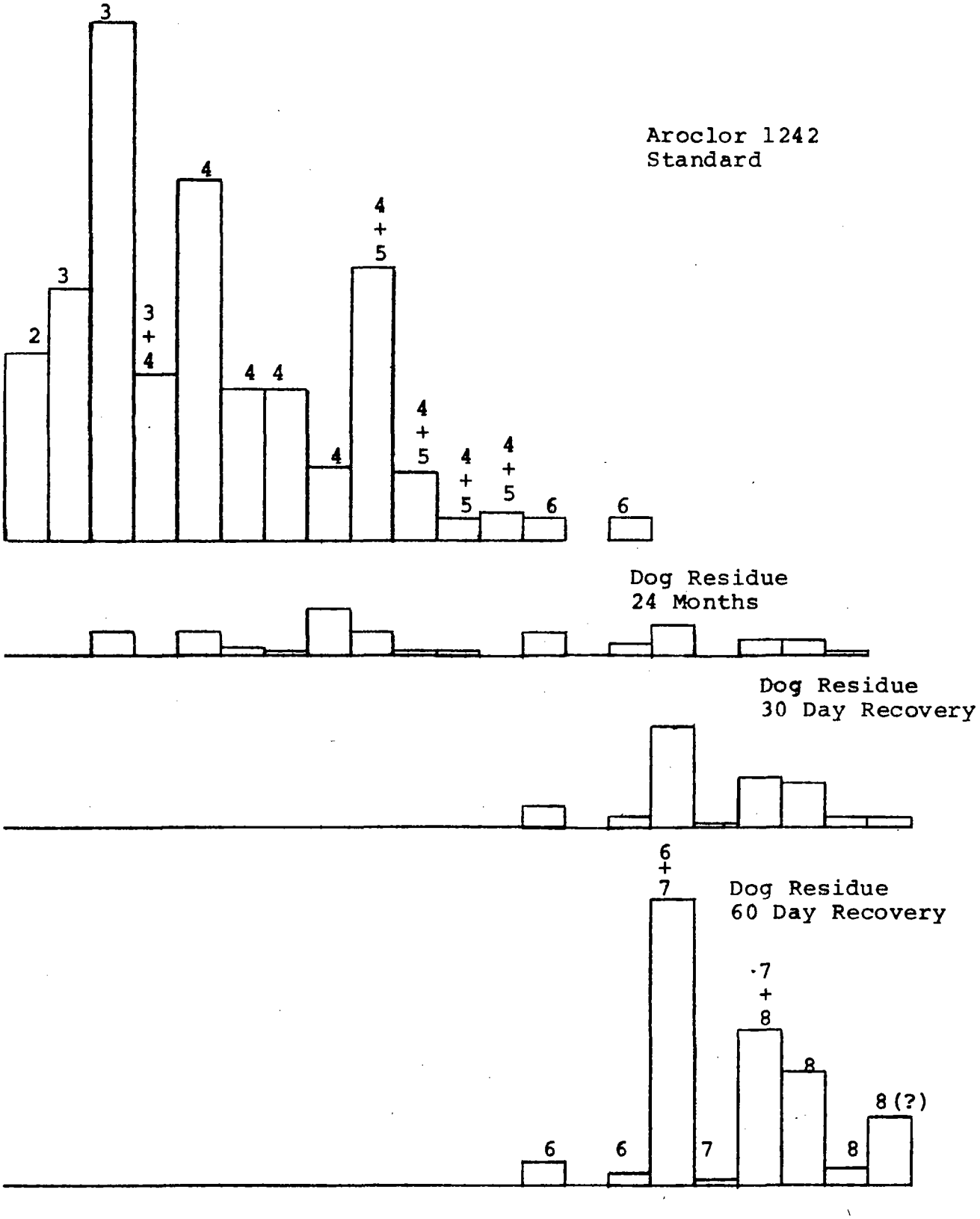
Aroclor 1260
Rat Residue



Aroclor 1260
Dog Residue

DSW 182831

FIGURE 16



DSW 182832

FIGURE 17

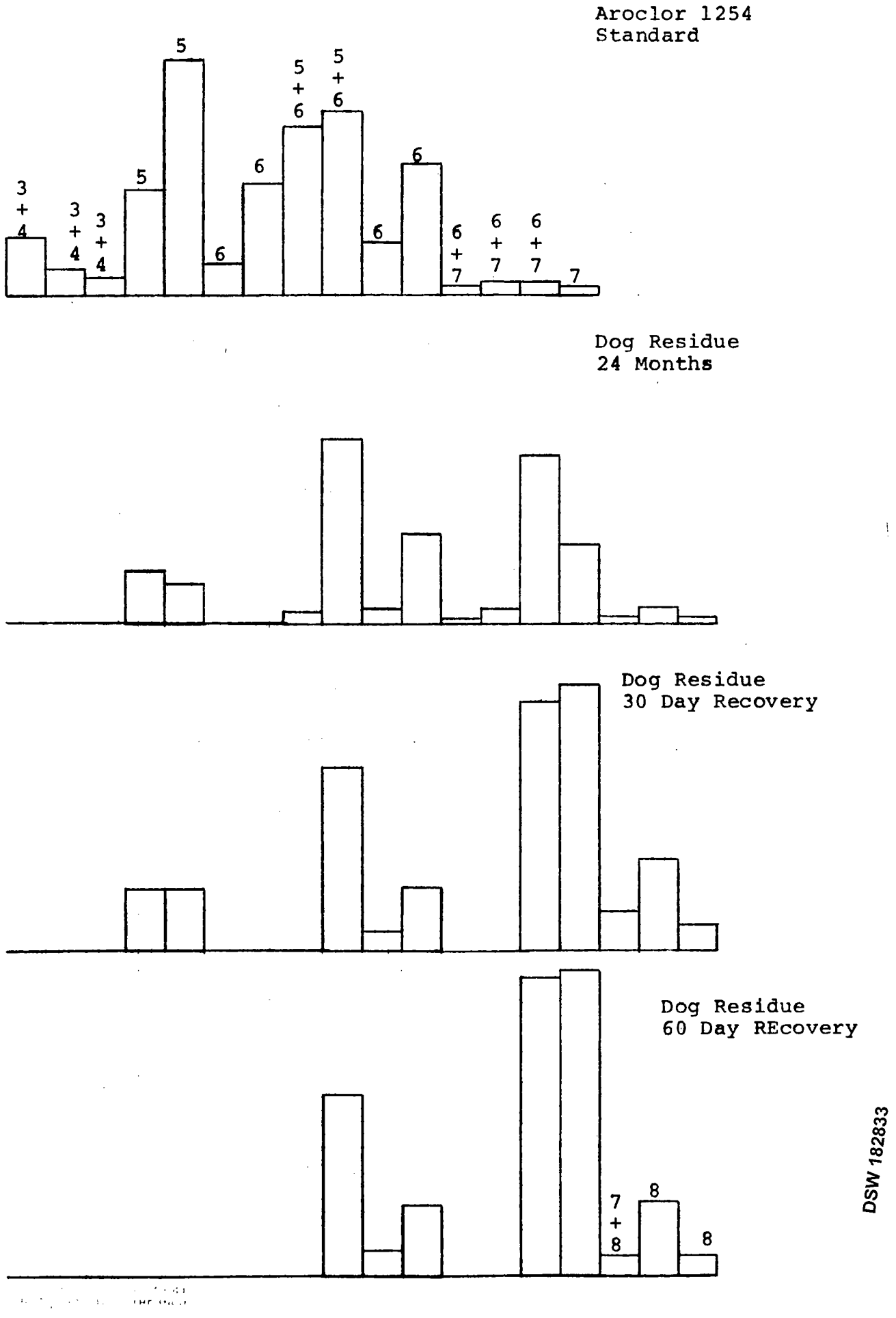
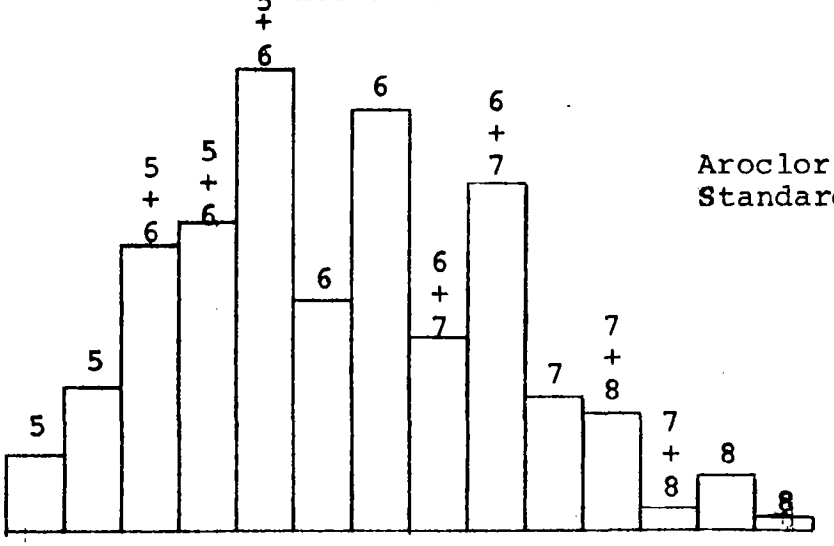
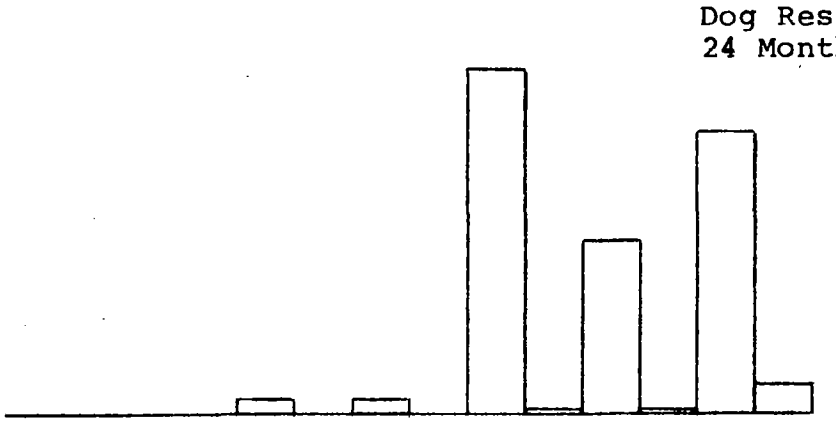
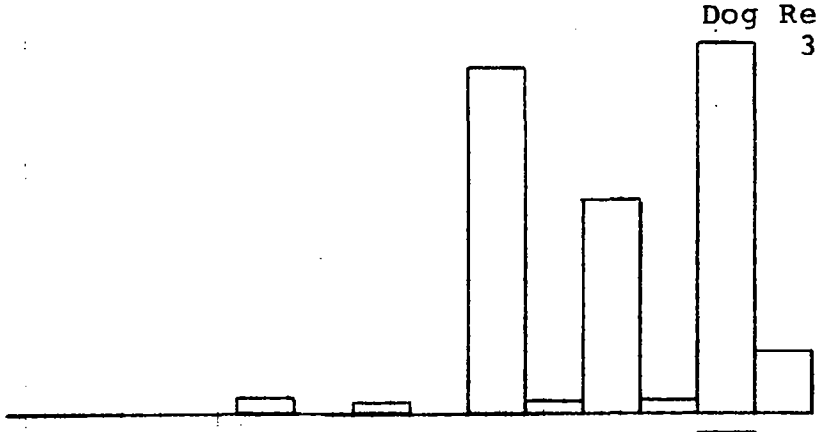
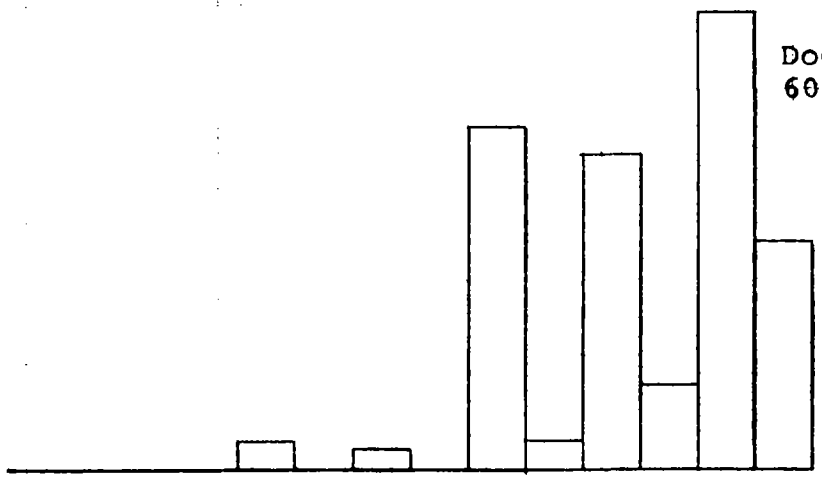

Aroclor 1254
Standard
3 + 4
3 + 4
3 + 4
5
5
6
5 + 6
5 + 6
6
6
6 + 7
6 + 7
6 + 7
7
Dog Residue
24 Months
Dog Residue
30 Day Recovery
Dog Residue
60 Day REcovery
7 + 8
8
8
DSW 182833

FIGURE 18



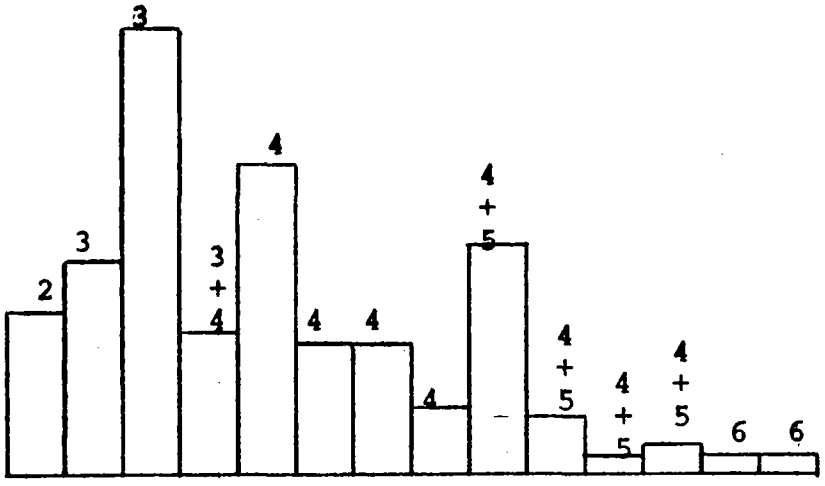




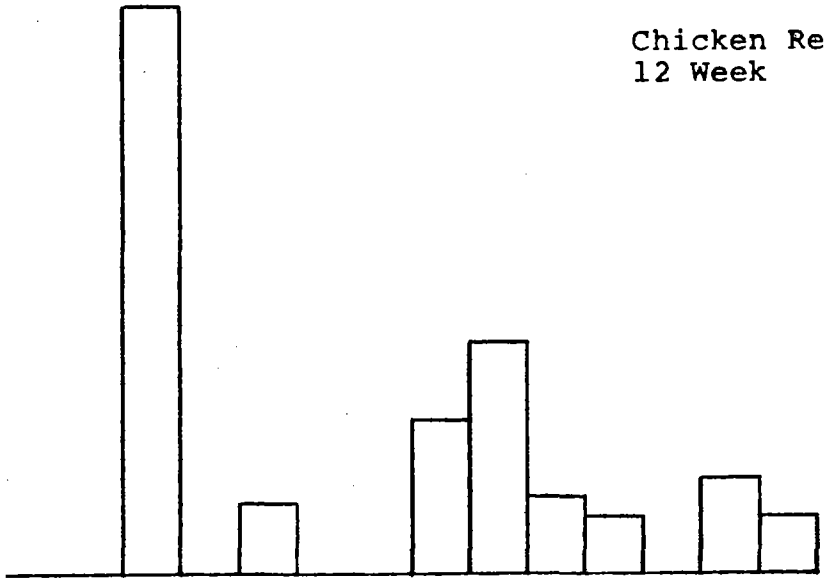


DSW 182834

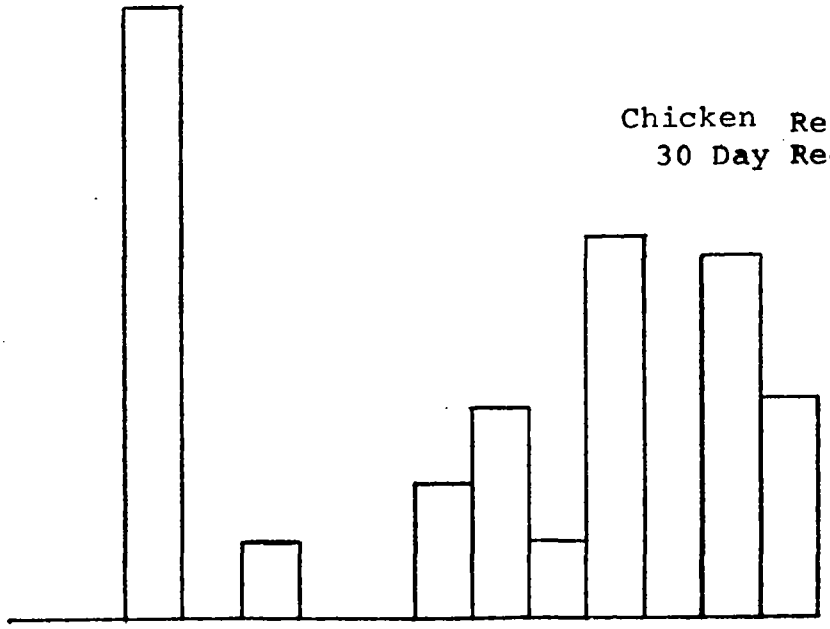
Aroclor 1242
Standard



Chicken Residue
12 Week

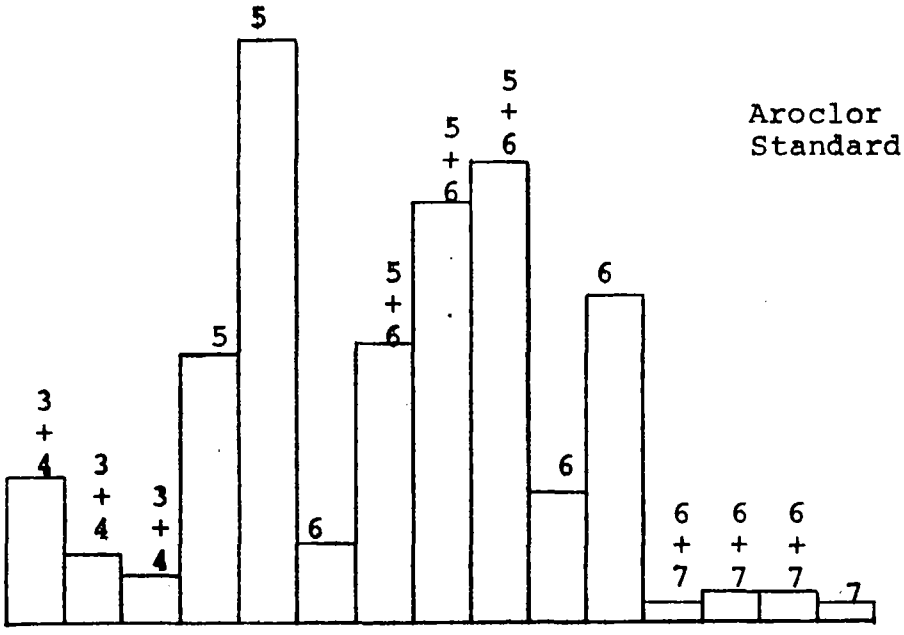


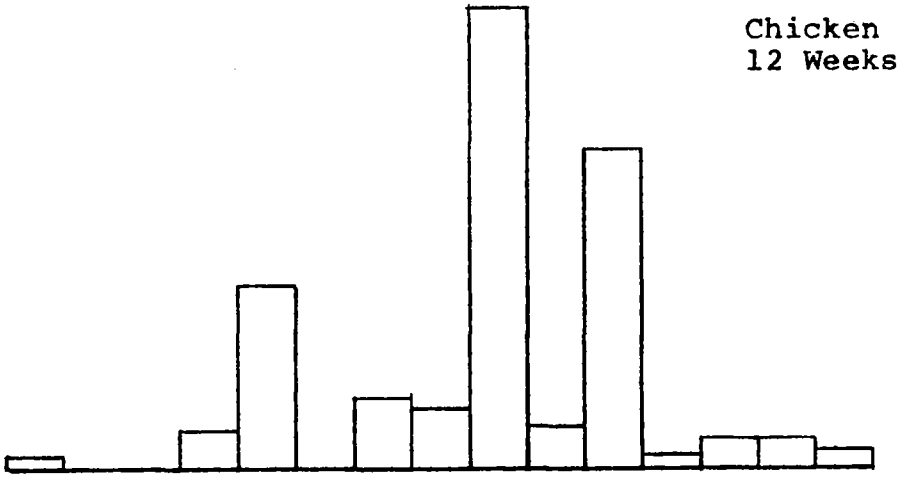
Chicken Residue
30 Day Recovery

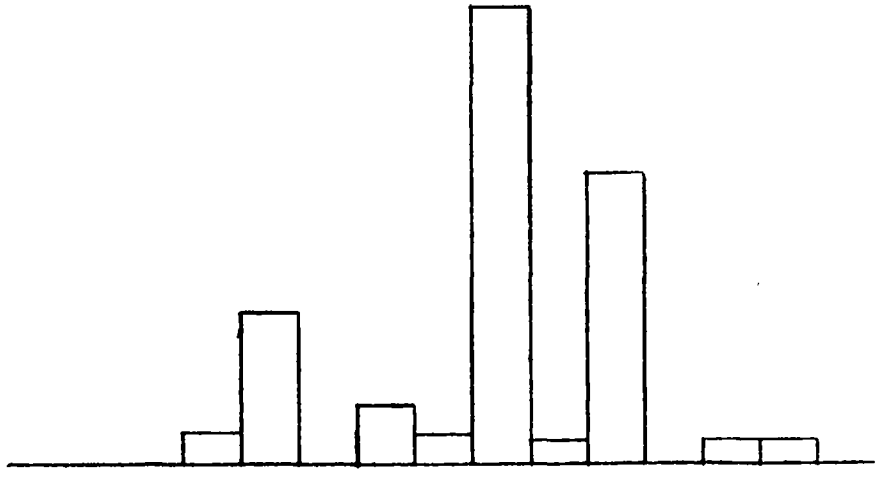


DSW 182835

FIGURE 20

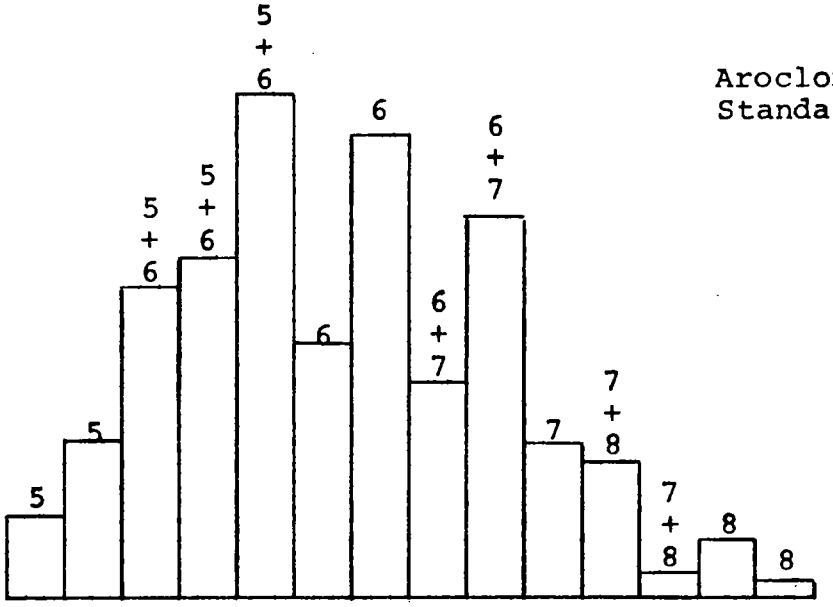




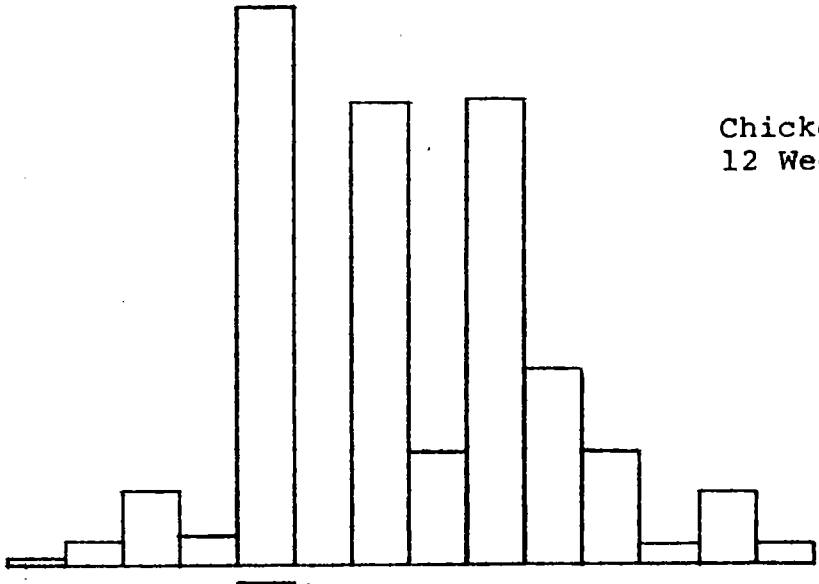


DSW 182836

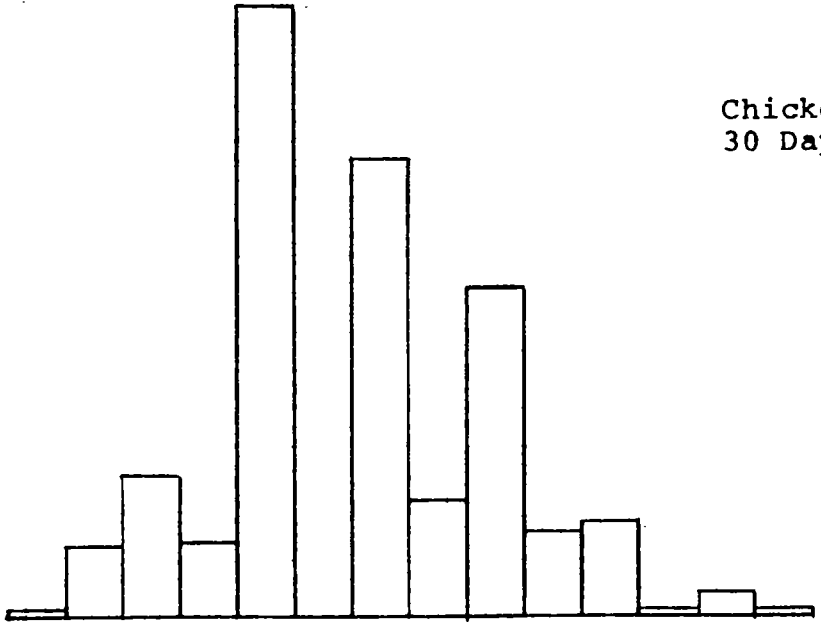
STLCOPCB4050940



Aroclor 1260
Standard



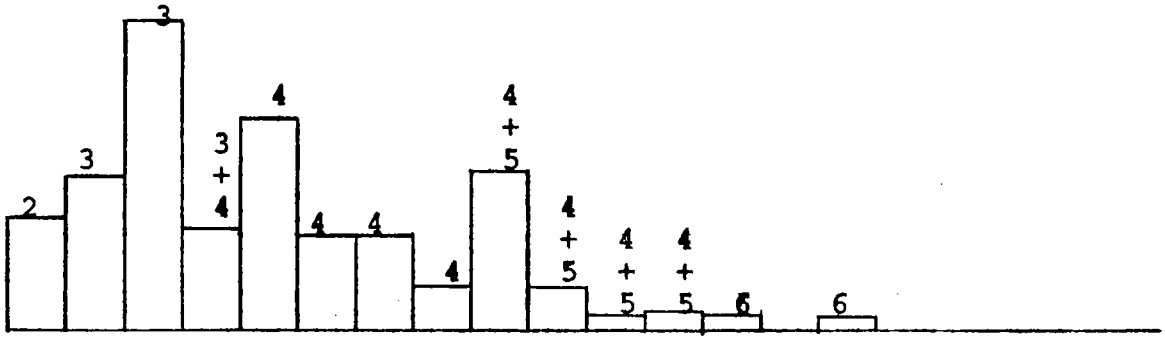
Chicken Residue
12 Weeks



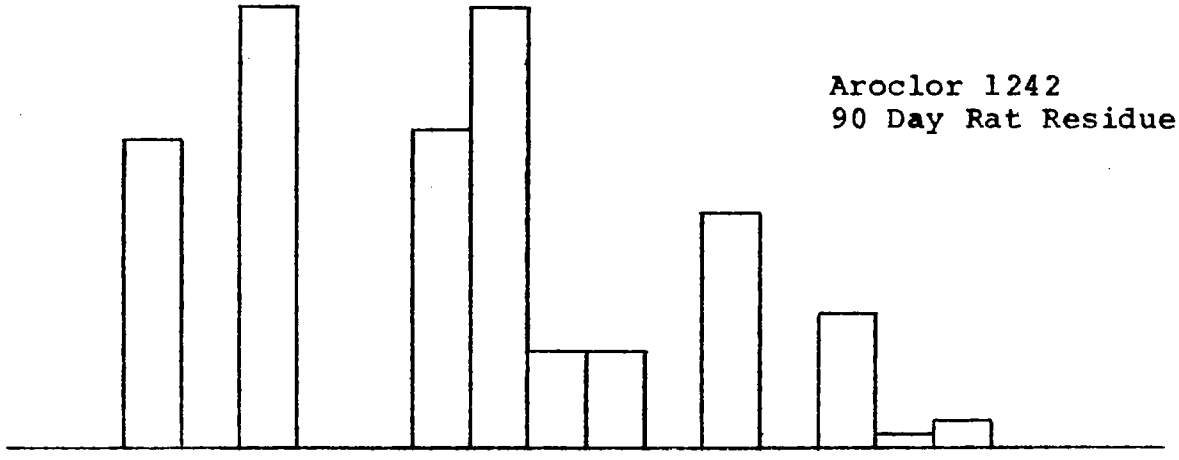
Chicken Residue
30 Day Recovery

DSW 182837

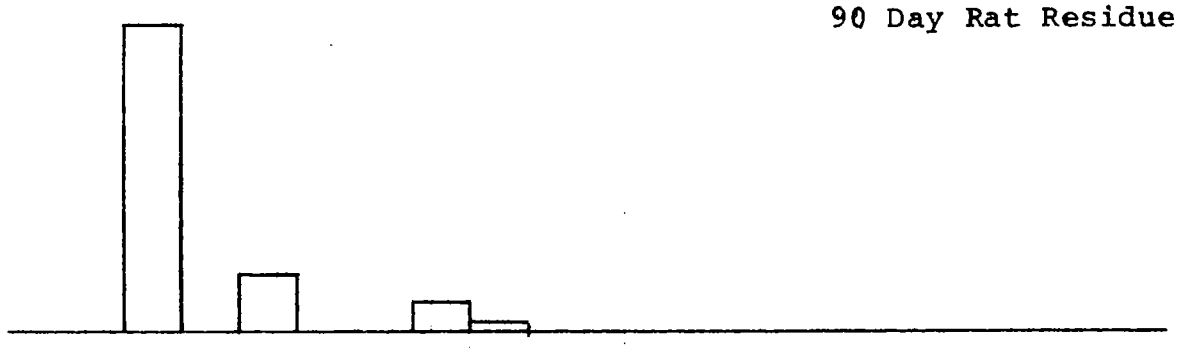
Aroclor 1242
Standard

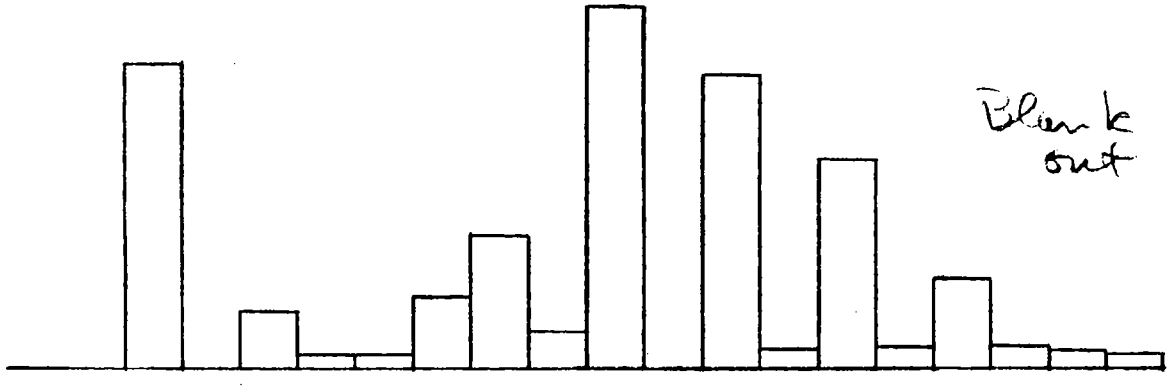


Aroclor 1242
90 Day Rat Residue



Aroclor 1016
90 Day Rat Residue





DSW 182838

TABLE XIII

IBT #B7009 30-Day Tissue Collection Study in Albino Rats with Aroclors

ppm PCB in Rat Tissues (Wet Weight Basis)

Material	Tissue	30 Day Sacrifice				Sacrifice
		300 ppm		1000 ppm		Exposure Level
		♂	♀	♂	♀	Sex
Aroclor 1242	Muscle	5	12	17	29	
	Kidney	1	2	5	2	
	Liver	3	5	10	17	
	Fat	—	276	377	412	
Aroclor 1254	Muscle	56	36	271	167	
	Kidney	8	13	47	156	
	Liver	57	54	176	227	
	Fat	695	660	4660	3430	
Aroclor 1260	Muscle	82	136	266	555	
	Kidney	29	16	72	91	
	Liver	126	125	200	206	
	Fat	2130	2035	9190	11970	

DSW 182839

STLCOPCB4050943

TABLE XIV

IBT #B7009 30 Day Tissue Collection Study in Albino Rats with Aroclors

ppm PCB in Rat Tissues (Lipid Weight Basis)

Material	Tissue	30 Day Sacrifice				Sacrifice
		300 ppm		1000 ppm		Exposure Level
		♂	♀	♂	♀	Sex
Aroclor 1242	Muscle	37	58	736	855	
	Kidney	12	28	276	146	
	Liver	61	220	753	793	
	Fat	—	395	816	722	
Aroclor 1254	Muscle	1396	1274	7735	6202	
	Kidney	655	1895	3325	12972	
	Liver	2370	3358	5318	6678	
	Fat	1094	1289	7208	7544	
Aroclor 1260	Muscle	2470	4849	8879	24111	
	Kidney	2056	2671	5181	7579	
	Liver	3808	6226	6263	10300	
	Fat	3061	3430	13715	19088	

DSW 182840

STLCOPCB4050944

TABLE XV

IBT #B7009 30 Day Tissue Collection Study in Albino Rats with Aroclors

Predicted ppm PCB in Rat Tissues (Lipid Weight Basis)

Material	Tissue	30 Day Sacrifice				Sacrifice
		300 ppm		1000 ppm		Exposure Level
		♂	♀	♂	♀	Sex
Aroclor 1242	Muscle	44	83	608	821	
	Liver	105	199	765	1033	
	Fat	105	199	765	1033	
Aroclor 1254	Muscle	721	1239	5602	6859	
	Liver	1145	1997	4694	5748	
	Fat	1145	1997	4694	5748	
Aroclor 1260	Muscle	2921	4779	17004	19823	
	Liver	3784	6190	11630	13557	
	Fat	3784	6190	11630	13557	

Regression Equation - log ppm PCB = $-0.9861 - 0.2309$ (if muscle) $+ 0.1855$ (% Cl_2) $+ 0.3329$ (log ppm fed) $+ 0.1124$ (if female) $+ 0.1471$ (% Cl_2 if muscle) $+ 0.5306$ (log ppm fed if muscle) $- 0.3994$ (log ppm fed x % Cl_2) $- 0.3552$ (% Cl_2 if female) $- 0.2815$ (log ppm fed if female)

DSW 182841

STLCOPCB4050945

TABLE XVI

IBT # B7298 Two-Year Chronic Oral Toxicity Study of Aroclor in Albino Rats

ppm PCB in Rat Tissues (Wet Weight Basis)

Material	Tissue	1 ppm			10 ppm			100 ppm			Exposure Level
		3 mo.	12 mo.	24 mo.	3 mo.	12 mo.	24 mo.	3 mo.	12 mo.	24 mo.	Sacrifice
Aroclor 1242	Muscle	0.7	1	1.8	1.4	6	14	5	33	73	
	Liver	0.1	0.2	0.5	0.2	0.6	1	0.9	5	5	
	Fat	6	7	6	12	30	43	60	144	220	
Aroclor 1254	Muscle	2	2	13	8	131	98	46	94	352	
	Liver	0.1	0.4	1.2	1	23	6	15	24	133	
	Fat	6	19	45	75	632	315	1208	794	1533	
Aroclor 1260	Muscle	6	8	15	8	50	116	10	419	785	
	Liver	0.2	1	0.8	2	3	5	18	53	107	
	Fat	28	56	50	417	224	298	482	2000	4447	

DSW 182842

STLCOPCB4050946

TABLE XVII

IBT # B7298 Two-Year Chronic Oral Toxicity Study of Aroclor in Albino Rats

ppm PCB in Rat Tissues (Lipid Weight Basis)

DSW 182843

Material	Tissue	1 ppm			10 ppm			100 ppm			Exposure Level
		3 mo.	12 mo	24 mo.	3 mo.	12 mo.	24 mo.	3 mo	12 mo.	24 mo.	Sacrifice
Aroclor 1242	Muscle	8	6	5	16	38	74	76	236	239	
	Liver	11	16	18	26	40	52	77	241	234	
	Fat	6	8	9	13	32	47	67	151	227	
Aroclor 1254	Muscle	10	11	38	96	721 (196)	389	756 (800)	1092	2164	
	Liver	18	24	82	115	914 (292)	307	1137 (2000)	869	1810 (4800)	
	Fat	6	19	55	76	688 (231)	348	329 (900)	860	1894	
Aroclor 1260	Muscle	16	47	44	60	259	436	146 (689)	2247	5154	
	Liver	20	50	56	102	189	442	1677	1752	6310	
	Fat	32	60	62	138	262	354	866	2143	5060	

( ) – Smoothed data, used to develop second regression equation

STLCOPCB4050947

TABLE XVIII

IBT #B7298 Two Year Chronic Oral Toxicity Study of Aroclor in Albino Rats

Predicted ppm PCB in Rat Tissues (Lipid Weight Basis)

Material	Tissue	1 ppm			10 ppm			100 ppm			Exposure Level
		3 mo	12 mo	24 mo	3 mo	12 mo	24 mo	3 mo	12 mo	24 mo	Sacrifice
Aroclor 1242	Muscle	5	8	10	20	32	45	77	133	206	
	Liver	8	12	15	30	48	68	115	199	307	
	Fat	5	8	10	20	32	45	77	133	206	
Aroclor 1254	Muscle	11	21	36	81	163	305	584	1264	2611	
	Liver	17	31	53	121	242	455	870	1884	3893	
	Fat	11	21	36	81	163	305	584	1264	2611	
Aroclor 1260	Muscle	16	30	51	116	234	439	840	1819	3758	
	Liver	19	36	62	140	281	527	1008	2182	4509	
	Fat	20	38	65	147	296	554	1061	2297	4746	

Regression Equation log ppm PCB = 3.3550 − 1.3440 (if 1242) − 0.3696 (if 1254) + 0.2881 (if liver) + 0.8936 (log ppm fed) + 0.0626 (time − 12) − 0.2761 (log ppm fed if 1242) − 0.0246 (time − 12 if 1242)

DSW 182844
STLCOPCB4050948

TABLE XIX

IBT # P7297 Three-Generation Reproduction Study in Albino Rats with Aroclor

ppm PCB in Rat Pups (Wet Weight Basis)

Material	21 Day Sacrifice			Sacrifice
	1 ppm	10 ppm	100 ppm	Exposue Level
Aroclor 1242	0.2	4	32	
Aroclor 1254	2	16	155	
Aroclor 1260	1	8	104	

ppm PCB in Rat Pups (Lipid Weight Basis)

Material	21 Day Sacrifice			Sacrifice
	1 ppm	10 ppm	100 ppm	Exposure Level
Aroclor 1242	67	78	578	
Aroclor 1254	48	170	2328	
Aroclor 1260	21	213	2371	

DSW 182845

STLCOPCB4050949

TABLE XX

IBT # 9888C
9888D

90-Day Subacute Oral Toxicity Study of Aroclor in Albino Rats

ppm PCB in Rat Tissues (Wet Weight Basis)

DSW 182846

		90 Day Sacrifice						Sacrifice
		30 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1016	Muscle	14	4	20	15	8	5	
	Liver	5	1	10	16	4	0.5	
	Fat	24	27	138	193	6	88	

		90 Day Sacrifice						Sacrifice
		1 ppm		10 ppm		100 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1221	Muscle	0.5	0.4	3	1	3	2	
	Liver	0.06	0.1	0.06	0.5	0.2	2	
	Fat	2	4	16	5	36	50	

STLCOPCB4050950

TABLE XXI

IBT # 9888 C
9888 D

90-Day Subacute Oral Toxicity Study of Aroclor in Albino Rats

ppm PCB in Rat Tissues (Lipid Weight Basis)

		90-Day Sacrifice						Sacrifice
		30 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1016	Muscle	28	40	175	16000	4501	4272	
	Liver	160	43	160	376	68	11	
	Fat	30	34	175	294	7	115	

		90-Day Sacrifice						Sacrifice
		1 ppm		10 ppm		100 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1221	Muscle	5	5	29	18	64	74	
	Liver	3	7	4	22	10	65	
	Fat	3	5	19	5	42	56	

DSW 182847
STLCOPCB4050951

TABLE XXII

IBT #9888C 9888D 90-Day Subacute Oral Toxicity Study of Aroclor in Albino Rats

DSW 182848

STLCOPCB4050952

Predicted ppm PCB in Rat Tissues (Lipid Weight Basis)

		* 90-Day Sacrifice						Sacrifice
		30 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1016	Muscle							
	Liver							
	Fat							

		90-Day Sacrifice						Sacrifice
		1 ppm		10 ppm		100 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1221	Muscle	5	5	19	19	76	76	
	Liver	2	8	5	22	14	60	
	Fat	5	5	13	13	36	36	

* Calculation of meaningful regression equation not possible, inconsistent data attributed to sample handling problems.

1221 Regression Equation $\log \text{ppm PCB} = 0.6689 + 0.4427 (\log \text{ppm fed}) - 0.4186 (\text{if liver})$

TABLE XXIII

IBT # C7299 Two-Year Chronic Oral Toxicity Study of Aroclor in Beagle Dogs

ppm PCB in Dog Tissues (Wet Weight Basis)

Material	Tissue	1 ppm						10 ppm						100 ppm						Exposure Level
		24 mo.		30 d.		60 d.		24 mo.		30 d.		60 d.		24 mo.		30 d.		60 d.		Sacrifice
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1242	Muscle	0.07	0.08	0.09	0.06			0.3	0.2		0.2		0.04	0.6	0.5	0.3	0.4	0.5		
	Liver		0.08	0.3	0.04		0.04	0.2	0.1		0.1	0.05		0.6		0.4	0.3			
	Fat	2	2	1	0.5	0.5		1	1		2	1	2	4	4	9	2			
Aroclor 1254	Muscle	0.3	0.08	0.2		0.1	0.1	0.7	0.3		0.7			4	3				3	
	Liver	0.1	0.2		0.2			0.4	0.7			0.5		2	2	1				
	Fat	4	3	2			2	5	4		18			95	73				34	
Aroclor 1260	Muscle	0.2	0.4		1		0.2	1	0.4		6		3	26	10		34	26		
	Liver	0.2	0.1	0.1			0.3	2	0.7	2	1	0.9	1	11	4		2	9		
	Fat	11	14		14		4	101	31	40	47		62	936	221		352	173		

DSW 182849
STLCOPCB4050953

TABLE XXIV

IBT #C7299 Two-Year Chronic Oral Toxicity Study of Aroclor in Beagle Dogs

ppm PCB in Dog Tissues (Lipid Weight Basis)

Material	Tissue	1 ppm						10 ppm						100 ppm						Exposure Level
		24 mo.		30 d.		60 d.		24 mo.		30 d.		60 d.		24 mo.		30 d.		60 d.		Sacrifice
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1242	Muscle	2	2	1	2			6	3		2		1	19	20	10	10	6		
	Liver		4	11	2		2	8	8		9	4		29		23	18			
	Fat	2	3	1	1	0.6		1	2		2	2	2	6	7	13	3			
Aroclor 1254	Muscle	10	4	4		2	2	18	18		9			61	95				32	
	Liver	8	6		9			23	40			43		110	130	111				
	Fat	5	3	3			2	6	10		22			128	132				42	
Aroclor 1260	Muscle	9	7		8		3	78	20		66		37	796	100		491	301		
	Liver	17	13	11			21	175	43	112	135	55	120	762	268		81	659		
	Fat	14	18		20		5	159	39	54	72		78	1261	287		439	238		

DSW 182850
STLCOPCB4050954

TABLE XXV

IBT #C7299 Two-Year Chronic Oral Toxicity Study of Aroclor in Beagle Dogs

DSW 182851

STLCOPCB4050955

Predicted ppm PCB in Dog Tissues (Lipid Weight Basis)

Material	Tissue	1 ppm						10 ppm						100 ppm					
Exposure Level		24 mo		30 d.		60 d.		24 mo.		30 d.		60 d.		24 mo.		30 d.		60 d.	
Sacrifice																			
Sex		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Aroclor 1242	Muscle	2	2	1	1	0.7	0.7	5	4	4	3	2	2	20	10	9	6	6	4
	Liver	3	3	2	2	1	1	10	8	7	5	5	4	28	18	18	12	11	8
	Fat	2	2	1	1	0.7	0.7	5	4	4	3	2	2	20	10	9	6	6	4
Aroclor 1254	Muscle	5	5	4	4	3	3	24	20	20	16	16	13	121	80	100	65	80	54
	Liver	10	10	8	8	6	6	47	38	39	31	33	26	238	156	195	128	157	103
	Fat	5	5	4	4	3	3	24	20	20	16	16	13	121	80	100	65	80	54
Aroclor 1260	Muscle	8	8	8	8	7	7	54	44	50	40	47	38	355	233	333	217	308	202
	Liver	16	16	14	14	14	14	106	84	98	80	91	74	698	457	654	426	605	397
	Fat	8	8	8	8	7	7	54	44	50	40	47	38	355	233	333	217	308	202

Regression Equation – $\log$ ppm PCB = $-1.3450 - 0.0190$ (day recovery) $- 0.3888$ ($\log$ ppm fed) $+ 0.2929$ (if liver) $+ 0.0376$ (% Cl_2) $+ 0.0202$ ($\log$ ppm fed $\times$ % Cl_2) $- 0.0917$ ($\log$ ppm fed - if female) $+ 0.0003$ (day recovery $\times$ % Cl_2)

DSW 182852

STLCOPCB4050956

TABLE XXVI

IBT # 9887
9885

90-Day Subacute Oral Toxicity Study of Aroclor in Beagle Dogs

ppm PCB in Dog Tissues (Wet Weight Basis)

		90 Day Sacrifice						Sacrifice
		30 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1016	Muscle	0.3	0.06	2	0.3	7	1	
	Liver	0.1	0.1	0.4	0.1	1	0.2	
	Fat	8	1	9	3	24	4	

		90 Day Sacrifice						Sacrifice
		10 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1221	Muscle	0.04	0.04	0.2	0.2	0.2	0.2	
	Liver	0.07	0.02	0.2	0.1	0.02	0.2	
	Fat	0.7	0.8	5	3	8	9	

TABLE XXVII

IBT #9887
9885

90-Day Subacute Oral Toxicity Study of Aroclor in Beagle Dogs

ppm PCB in Dog Tissues (Lipid Weight Basis)

		90 Day Sacrifice						Sacrifice
		30 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1016	Muscle	8	1	30	5	69	20	
	Liver	10	6	27	10	90	18	
	Fat	11	2	13	8	36	7	

		90 Day Sacrifice						Sacrifice
		10 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1221	Muscle	0.8	0.8	2	5	27	7	
	Liver	6	2	20	10	1	18	
	Fat	0.9	1	6	6	11	12	

STLCOPCB4050957

TABLE XXVIII

IBT #9887
9885

90-Day Subacute Oral Toxicity Study of Aroclor in Beagle Dogs

Predicted ppm PCB in Dog Tissues (Lipid Weight Basis)

		90 Day Sacrifice						Sacrifice
		30 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1016	Muscle	8	2	20	5	48	12	
	Liver	13	4	35	9	82	22	
	Fat	8	2	20	5	48	12	

		90 Day Sacrifice						Sacrifice
		10 ppm		100 ppm		300 ppm		Exposure Level
Material	Tissue	♂	♀	♂	♀	♂	♀	Sex
Aroclor 1221	Muscle	1	1	5	5	11	11	
	Liver	5	2	25	10	60	21	
	Fat	1	1	5	5	11	11	

1016 Regression Equation $\log \text{ppm PCB} = -0.2759 + 0.7885 (\log \text{ppm fed}) + 0.2382 (\text{if liver}) - 0.5815 (\text{if female})$

1221 Regression Equation $\log \text{ppm PCB} = -0.7730 + 0.7299 (\log \text{ppm fed}) + 0.7178$

STLCOPCB4050958

DSW 182855

TABLE XXIX

IBT #J 7300 Toxicity Reproduction and Residue Study of Aroclor in White Leghorn Chickens

ppm PCB in Chicken Tissues (Wet Weight Basis)

		Residue Sacrifice						30 Day Chick Sacrifice			1st wk	2nd wk	3rd wk	4th wk	1st wk	2nd wk	3rd wk	4th wk	1st wk	2nd wk	3rd wk	4th wk	Final Sacrifice					
		1ppm		10ppm		100ppm		1ppm	10ppm	100ppm	1ppm				10 ppm				100 ppm				1ppm		10ppm		100ppm	
		♂	♀	♂	♀	♂	♀	♂ & ♀	♂ & ♀	♂ & ♀	30 Day Recovery Period												♂	♀	♂	♀	♂	♀
Aroclor 1242	Muscle		0.06				2	0.07	0.05															0.05		0.1		5
	Liver				2			0.4	0.2															0.7		2		45
	Fat	26	17			1430	1231																	4				8
	Eggs			5		38									3	0.6	0.5		26	30	19	24						
Aroclor 1254	Muscle			0.9	0.7			0.02																		0.1		
	Liver		0.8				50	0.09																0.9				27
	Fat			561	189																					73		
	Eggs	0.7				132						2	0.5	0.4						68	75	36						
Aroclor 1260	Muscle		0.2				11	0.06	0.8															0.04				2
	Liver				6			0.09	0.2																	13		
	Fat	153	15			6295	1159																	10				1010
	Eggs	1		13							1	0.7			13	8												

STLCOPCB4050959

DSW 182856

TABLE XXX

IBT #J7300 Toxicity, Reproduction and Residue Study of Aroclor in White Leghorn Chickens

ppm PCB in Chicken Tissues (Lipid Weight Basis)

		Residue Sacrifice						30 Day Chick Sacrifice			1st wk	2nd wk	3rd wk	4th wk	1st wk	2nd wk	3rd wk	4th wk	1st wk	2nd wk	3rd wk	4th wk	Final Sacrifice					
		1 ppm		10 ppm		100 ppm		1 ppm	10 ppm	100 ppm	1 ppm				10 ppm				100 ppm				1 ppm		10 ppm		100 ppm	
		♂	♀	♂	♀	♂	♀	♂♀	♂♀	♂♀	30 Day Recovery Period												♂	♀	♂	♀	♂	♀
Aroclor 1242	Muscle		13				901	9	12															8		30		639
	Liver				52			14	12															10		28		1580
	Fat	30	22			2460	1310																	4				9
	Eggs			37		472									33	5	5		383	361	249	368						
Aroclor 1254	Muscle			517	240			2																		61		
	Liver		18				1475	4																7				1529
	Fat			892	199																					78		
	Eggs	10				1410						14	6	5						1324	626	832						
Aroclor 1260	Muscle		40				6020	5	125															13				827
	Liver				86			6	6																	56		
	Fat	183	16			7580	1308																	11				1084
	Eggs	12		146							13	7			135	71												

STLCOPCB4050960