

BIODEGRADATION (OECD 301E)

TEST SUBSTANCE

Identity: A mixture containing perfluorooctanesulfonate, which may also be referred to as PFOS, FC-95, or as a component of FC-203A. (1-Octanesulfonic acid) (CAS # 2795-39-3).

Remarks: The 3M production lot number was not provided. The test sample is FC-203 NFP which is equivalent to FC-203A. Current information indicates it is a mixture of 1.34% PFOS, 25% diethylene glycol butyl ether, 67.85% water, 2.66% Sultone foamer, 3% sodium octyl sulfate, 0.1% sodium lauryl sulfate, and 0.05% tolyltriazole.

The following summary applies to a mixture with incompletely characterized concentrations of impurities. Data may not accurately reflect the biodegradability of the fluorochemical component of the test sample.

METHOD

Method: Modified OECD Screening Test, OECD 301E with DOC Analysis

Test type: Static acute

GLP: No

Year Completed: 1984

Analytical monitoring: Dissolved organic carbon (DOC)

Statistical methods: Results were determined by calculation of the % DOC removal and graphic interpretation.

Test organism source: A 50:50 mix of soil extract and secondary effluent. The secondary effluent was the supernatant of an activated sludge mixed liquor sample taken from an aeration basin at the Metro Wastewater Treatment Plant, St. Paul, MN, while the soil was a mixture of fresh, sandy loam garden soils obtained from Ramsey and Washington Counties in Minnesota.

Test condition:

Dilution water: Not given.

Mineral nutrient medium: Nutrient medium per OECD 301E method using either synthetic vitamin solution or yeast extract.

Stock and test solution preparation: Solutions were prepared on a weight/volume basis by dissolving the test substance in OECD nutrient medium. Initial concentrations were brought to the following DOC concentrations: sodium benzoate 20 mg DOC/L, linear alkylbenzene sulfonate (LAS) ~15 mg DOC/L, and the test substance ~40 mg DOC/L.

Test vessels: Not given.

Incubation conditions: Not given.

Number of concentrations: one for test substance yeast extract, one sodium benzoate yeast extract, one sodium benzoate vitamin solution, and one LAS yeast extract, all in duplicate.

Test substance flask conditions: Not given.

Total suspended solids and pH on day of testing: Not given.

Element Basis: Decrease in dissolved organic carbon.

Remarks: There is no mention of blank controls, therefore it is questionable whether they were included in the study

RESULTS

Nominal concentrations: Reference standards: sodium benzoate at 20 mg DOC/L and LAS at ~15 mg DOC/L; test substance: ~ 40 mg DOC/L.

Element values: 28-day degradation:

Duplicate 1 = 87.2%

Duplicate 2 = 96%. Mean value = 92%.

Remarks: Testing was conducted on a mixture as described in the Test Substance Remarks field. The values reported apply to that mixture and not the fluorochemical proportion alone.

CONCLUSIONS

The test substance % degradation based on the mean DOC removal was 92% after 28 days.

The reference substance, sodium benzoate, obtained 95% degradation by 7 days, however, the LAS only obtained 43% by 28 days.

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DATA QUALITY

Reliability: Klimisch ranking 3. Study lacks complete description and records of the method followed, as well as raw data records. The inoculum is not properly characterized. There is no characterization of the test substance purity, and the study lacks analytical confirmation of the amount of fluorochemical proportion in the solutions.

REFERENCES

The studies were conducted by the 3M Company, Environmental Laboratory, St. Paul, MN, Lab Request number 9611, 1984.

OTHER

Last changed: 6/26/00

(Important — If report is printed on both sides of paper, send two copies to TCC.) Guidelines on reverse side.

KEYWORDS: Lab Code	CURRENT OBJECTIVE:
Other Keywords	To test the repeatability of the modified OECD Screening Test in measuring the biodegradability of Light Water products.
	REPORT ABSTRACT: This abstract information is distributed by the Technical Communications Center to alert 3M'ers to Company R&D.
	This study again used the modified OECD Screening Test to evaluate the biodegradability of Antwerp Light Water products. The products studied in this set of tests were FC-203, FC-203 NFP (equivalent to FC-203A), and FC-600. Also tested was U.S. FC-203 Lot 3072. One of these products, FC-203 NFP, was also included in the previous set of tests done in 1980. The results of this testing were consistent with previous OECD Screening Test studies on Light Water products. The results indicate that all of the tested products are readily biodegradable.

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MODIFIED OECD SCREENING TEST ON FC-203, FC-203A, AND FC-600

INTRODUCTION

This study was undertaken to demonstrate the biodegradability of two Light Water (L/W) products, FC-600 and FC-203, using the internationally recognized Modified OECD Screening Test⁽¹⁾. This testing was requested by 3M Germany because of inconsistency in the results of past biodegradation tests done on these products.

Modified OECD Screening Tests conducted in 1980 by the 3M Environmental Laboratory showed that three L/W products were highly biodegradable⁽²⁾. The products tested were FC-203A (previously identified as FC-203 NFP), FC-206, and FC-3017 (FC-206 freeze protected). Greater than 90% of the dissolved organic carbon (DOC) of these 3 products was removed during the 1980 testing. See Table 1 for a summary of these results.

Table 1

Results of 1980 Testing on Light Water Products

<u>Product</u>	<u>% Degradation at Day:</u>				
	<u>7</u>	<u>14</u>	<u>21</u>	<u>27</u>	<u>28</u>
FC-203 NFP ¹	13	85	93	91	93
FC-206	23	90	94	93	92
FC-3017 ²	37	94	96	96	95
Hydroquinone ³	89	92	97	94	93

Footnotes:

¹ FC-203 NFP is nonfreeze protected FC-203 and is equivalent to FC-203A.

² FC-3017 is freeze protected FC-206.

³ Hydroquinone was the reference product.

These 1980 results contradict those of H. Hellmann and D. Muller⁽³⁾ who used a similar test method, the TOC Degradation Test⁽⁴⁾. Hellmann's TOC (total organic carbon) test results, however, are an exception from normally obtained results. His finding of 8% TOC removal for FC-3017 and 6% TOC removal for FC-206 in the 21-day long TOC Degradation Test contradict his own BOD₅/COD data. His 5-day biochemical oxygen demand (BOD) results were 50%⁵ and 40% of the chemical oxygen demand (COD) of FC-3017 and FC-206, respectively. This is a significant level of degradation for a 5-day BOD test. These opposite results within his own paper clearly are an inexplicable discrepancy.

Hellmann's TOC Degradation Test results are also inconsistent with BOD₂₀/COD measurements made by the 3M Environmental Laboratory and by other independent laboratories on 3M AFFF products. Such results typically show BOD₂₀ values to range between 60% and 90% of the COD. For example, a collection of such data on 3 U.S. military specification AFFF products manufactured by 3M is shown in Table 2.

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Table 2

BOD, Carbonaceous BOD, and COD Data on Mil-Spec AFFF Product

<u>Lab</u>	<u>BOD₂₀</u> <u>(mg/kg)</u>	<u>C-BOD₂₀</u> <u>(mg/kg)</u>	<u>COD</u> <u>(mg/kg)</u>	<u>BOD₂₀</u> <u>COD</u>	<u>C-BOD₂₀</u> <u>COD</u>
<u>FC-203 C Lot 501</u>					
3M	580,000	600,000	730,000 740,000	.79	.81
Pace	800,000*	730,000*	810,000 730,000		
Serco	440,000	440,000	737,000	.60	.60
Capsule	570,000	620,000	950,000	.6	.65
Galbraith	616,000	671,000	776,450	.79	.86
inoculum #1					
Galbraith	670,000	641,000	776,450	.86	.82
inoculum #2					
Average	575,000	594,000	782,000	.73	.75
S. D.	85,000	90,000	80,000	.12	.12

* Calculated BOD's from different dilutions were very inconsistent.

<u>FC-206C Lot 502</u>					
3M	290,000	290,000	380,000 360,000	0.78	0.78
Pace	350,000	370,000	450,000	0.78	0.82
Serco	240,000	260,000	370,000	0.65	0.70
Capsule	260,000	320,000	410,000	0.63	0.78
Galbraith	416,500	411,000	407,250	1.02	1.01
inoculum #1					
Galbraith	395,500	374,000	407,250	.97	.92
inoculum #2					
Average	325,000	338,000	396,000	.81	.83
S. D.	73,000	57,000	33,000	.16	.11

<u>FC-780B Lot 501</u>					
3M	240,000	230,000	320,000 330,000	.74	.71
Pace	250,000	250,000	350,000	.71	.71
Serco	210,000	220,000	287,000	.73	.77
Capsule	240,000	230,000	360,000	.67	.64
Average	235,000	232,000	329,000	.71	.71
S. D.	17,000	13,000	28,000	.03	.05

METHODS AND MATERIALS

1. Procedure

Testing was performed in accordance with the OECD Guidelines for testing of chemicals adopted May 12, 1981. (1)

2. Chemicals

The reference materials used were laboratory grade sodium benzoate, ($C_6H_5NaO_2$) F.W. = 144.11 and linear alkylbenzene sulfonate (LAS). The LAS solution used was a 5.68% active solution supplied by the U.S. Environmental Protection Agency as a reference material for biodegradation testing. The Light Water (L/W) test materials used were U.S. FC-203 Lot 3072 provided in 1983 by the Commercial Chemicals Division, FC-203 and FC-600 samples provided by E.T.S.L. Antwerp in 9/82 and FC-203 NFP provided by E.T.S.L. in 1980. Antwerp provided no lot numbers with their samples. FC-203 NFP (nonfreeze protected) is equivalent to FC-203A.

Prior to testing, the L/W and reference materials were dissolved in the OECD nutrient solution and brought to the following initial DOC concentrations: sodium benzoate 20 mg/l, LAS approximately 15 mg/l, and L/W products approximately 40 mg/l. The L/W TOC was higher than that used in previous testing (20 mg/l) because our experience has shown that L/W at 40 mg/l is not toxic. Also higher concentrations improve the accuracy of the TOC analysis.

For this study, nutrient solutions were prepared using both vitamin sources allowed by the OECD Screening Test, yeast extract and synthetic vitamin solution. This was done to determine if the vitamin source affected the extent of L/W degradation.

INOCULUM

The inoculum was a 50/50 mixture of soil extract and secondary effluent prepared in accordance with OECD procedures. The soil, which was extracted, was a mixture of fresh, sandy loam garden soils obtained from Ramsey and Washington Counties in Minnesota. The secondary effluent sample was the supernatant of an activated sludge mixed liquor sample taken from an aeration basin at the St. Paul Metro Wastewater Treatment Plant. The combined inoculum was passed through Whatman 54 filter paper prior to usage.

INSTRUMENT

The organic carbon analyzer used was a Dohman DC-52A. Its sensitivity limit is approximately 2 mg of carbon per liter.

SAMPLE HANDLING AND STORAGE

The sample preservation method used was that prescribed by the manufacturer of the organic carbon analyzer.⁽⁵⁾ The method involves adding 1 drop of concentrated HCl per 10 ml of filtered sample. This brings the samples to less than pH 2. The samples were stored under refrigeration in vials with aluminum foil lined caps. Our experience is that this storage method can preserve L/W containing samples for several months without affecting the DOC. All DOC analyses on samples from this study were done within one week of its completion.

RESULTS AND DISCUSSION

Table 3 summarizes the results of this study. This table shows that sodium benzoate, the reference compound, was nearly completely degraded (95%) within 7 days. Every replicate of all of the L/W products showed greater than 80% TOC removal within the 28-day test period. Seven of the ten test flasks containing the various L/W products showed greater than 90% TOC removal. The average DOC removal for all four L/W product was greater than 90%.

The results of this testing are shown graphically in Figures 1 and 2. These results are averaged, and because of this, do not show the actual pattern of degradation in the individual cultures. Figure 3 is an example graph of 2 cultures degrading the same product, FC-203 NFP. It shows that once degradation of this product began that it was very rapid, but that the lag prior to the onset of degradation was variable. The reason for this variability between the duplicate cultures was not known nor was it expected. It may have been due to the fact that the cultures received different levels of viable microorganisms capable of degrading the major components of the Light Water products. Thus, the population of bacteria with these capabilities had to build up in the cultures prior to the onset of rapid (exponential) degradation.

Review of the data in Table 3 indicates that results of replicate testing of the other L/W products also varied considerably at days 7, 14, and 21. Again, this variation appears to be due primarily to the length of the lag phase prior to the onset of biodegradation. However, due to the small number of samples taken, one frequently could not tell how long biodegradation of individual L/W containing cultures took following the initial lag.

Table 3

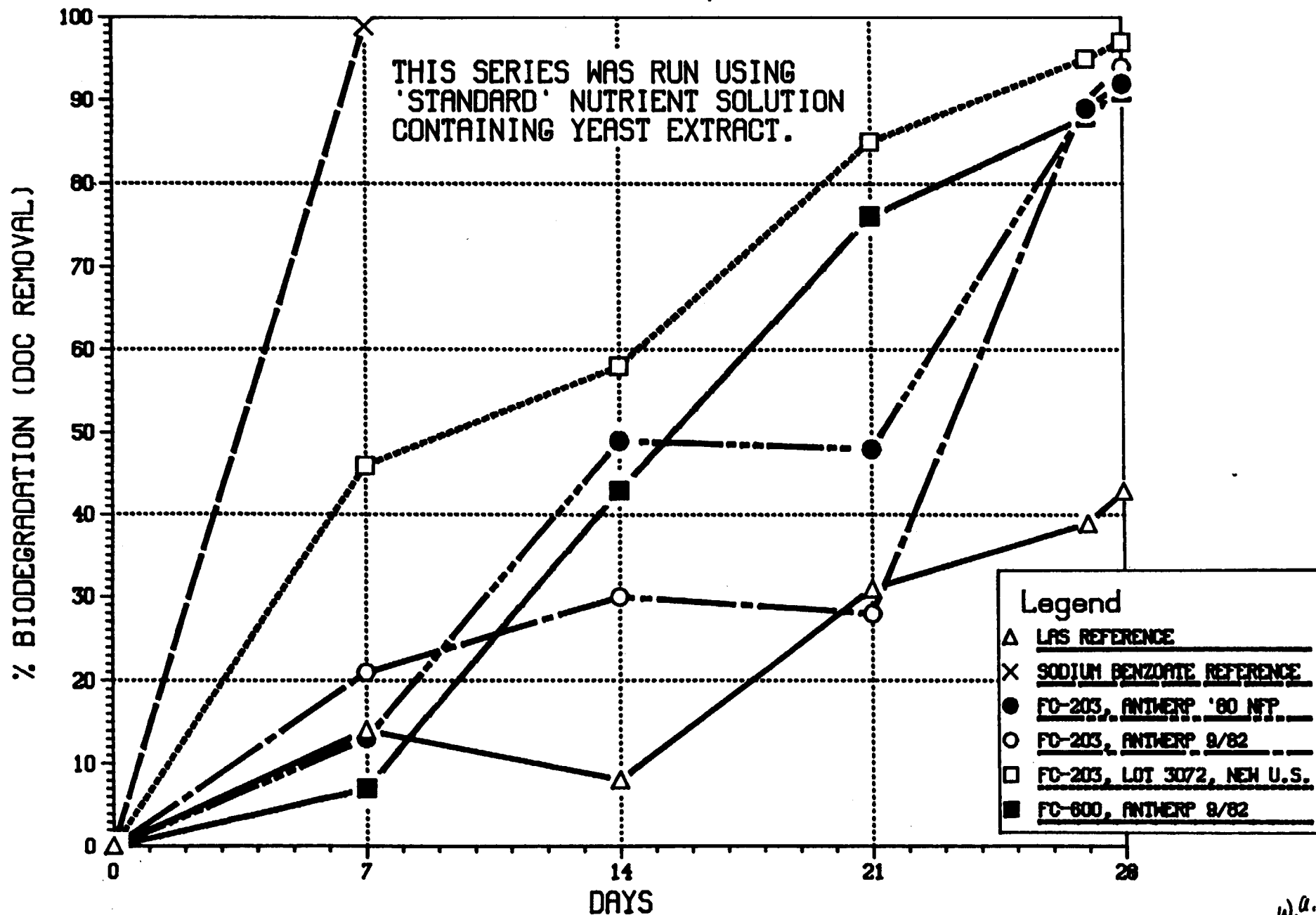
Biodegradation of LIGHT WATER Products and Reference Materials

Product/Vitamin Source	% DOC Removal After X Days					
	<u>7</u>	<u>14</u>	<u>17</u>	<u>21</u>	<u>27</u>	<u>28</u>
Sodium Benzoate/Yeast-1 ⁽¹⁾	98.8					
Sodium Benzoate/Yeast-2	99.6					
Sodium Benzoate/Vit.-1 ⁽²⁾	94.4					
Sodium Benzoate/Vit.-2	88.6					
Mean	<u>95</u>					
FC-203 ⁽³⁾ /Yeast-1	11.7	30.5	-- ⁽⁴⁾	28.4	89.8	95.3
FC-203/Yeast-2	29.5	29.1	--	27.0	91.0	92.1
FC-203/Vit.-1	29.4	32.6	--	27.7	80.5	83.6
FC-203/Vit.-2	24.8	88.6	--	90.2	95.6	95.2
Mean						<u>92</u>
U.S. FC-203/Yeast-1	26.9	25.1	--	79.2	95.5	96.5
U.S. FC-203/Yeast-2	64.3	90.8	--	90.7	96.0	97.5
Mean						<u>97</u>
FC-203A ⁽⁵⁾ /Yeast-1	12.6	8.5	--	11.0	86.4	87.2
FC-203A/Yeast-2	13.2	89.1	--	85.1	92.5	96.0
Mean						<u>92</u>
FC-600 ³ /Yeast-1	6.6	75.5	--	-- ⁽⁶⁾	89.3	94.2
FC-600/Yeast-2	7.7	10.5	--	76.3	87.0	88.8
Mean						<u>91</u>
LAS/Yeast-1	22.8	7.8	25.1	30.8	49.1	52.1
LAS/Yeast-2	5.9	8.8	20.4	-- ⁽⁶⁾	29.7	33.4
Mean						<u>43</u>

- Footnotes: (1) Used yeast extract as vitamin source.
 (2) Used OECD synthetic vitamin solution as vitamin source.
 (3) From Antwerp 1982.
 (4) 17-day samples were only taken for LAS.
 (5) From Antwerp 1980. Originally labelled FC-203 NFP.
 (6) Sample contaminated, not used.

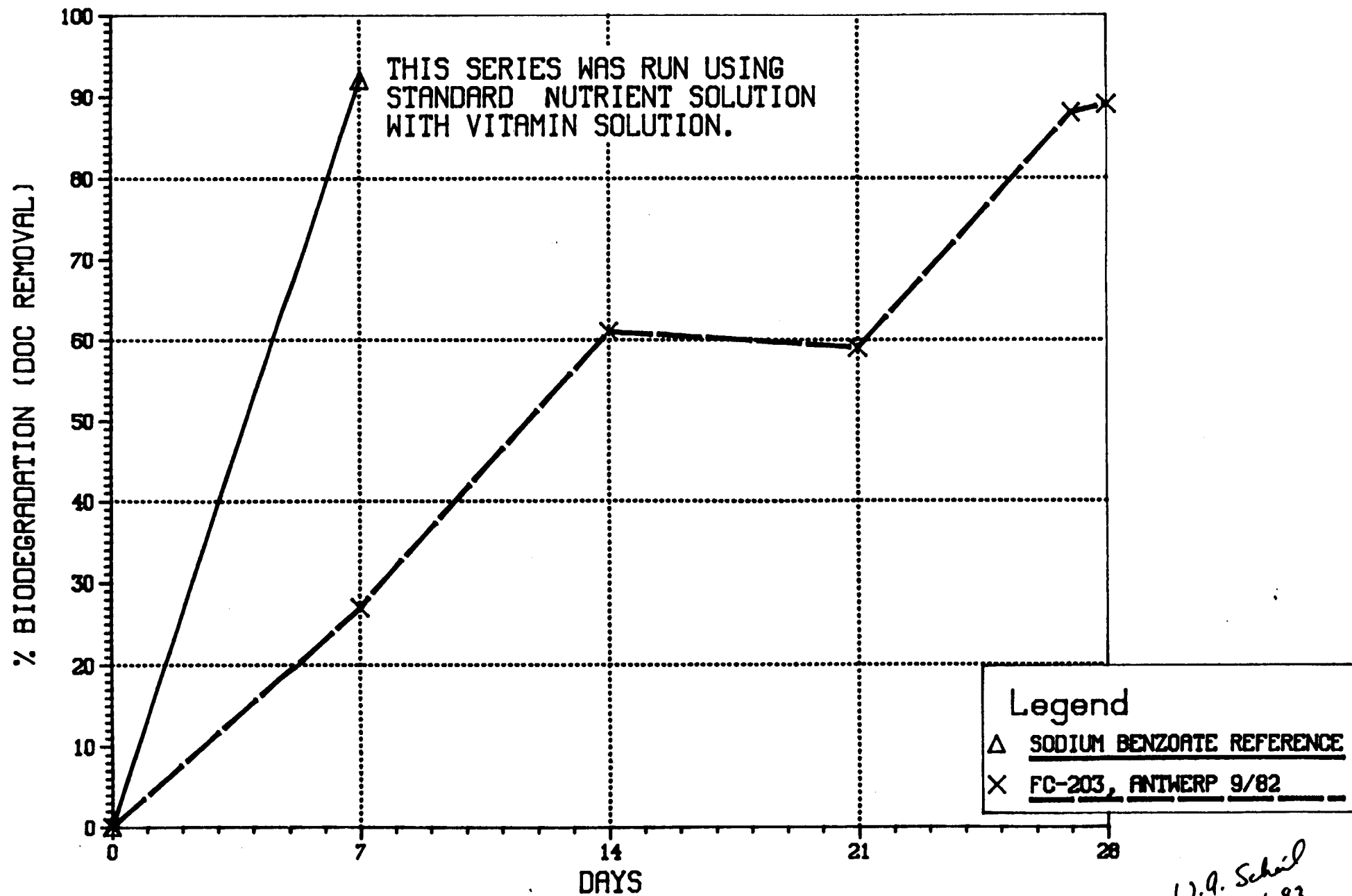
Figure 1

READY BIODEGRADABILITY: Modified Screening Test
OECD 301E -- Adopted 12 May 81
Environmental Lab Request No. 9611



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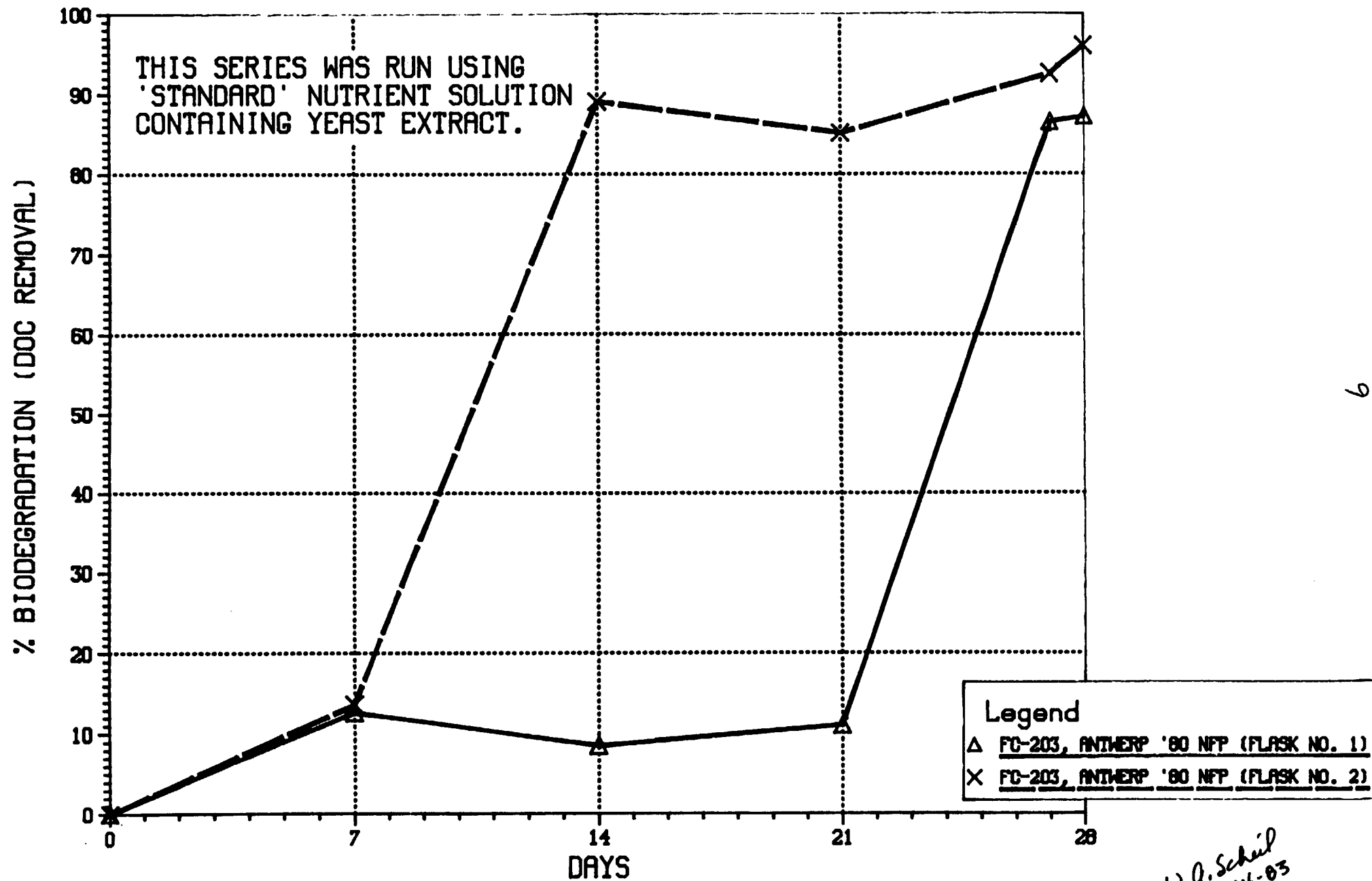
READY BIODEGRADABILITY: Modified Screening Test
OECD 301E -- Adopted 12 May 81
Environmental Lab Request No. 9611



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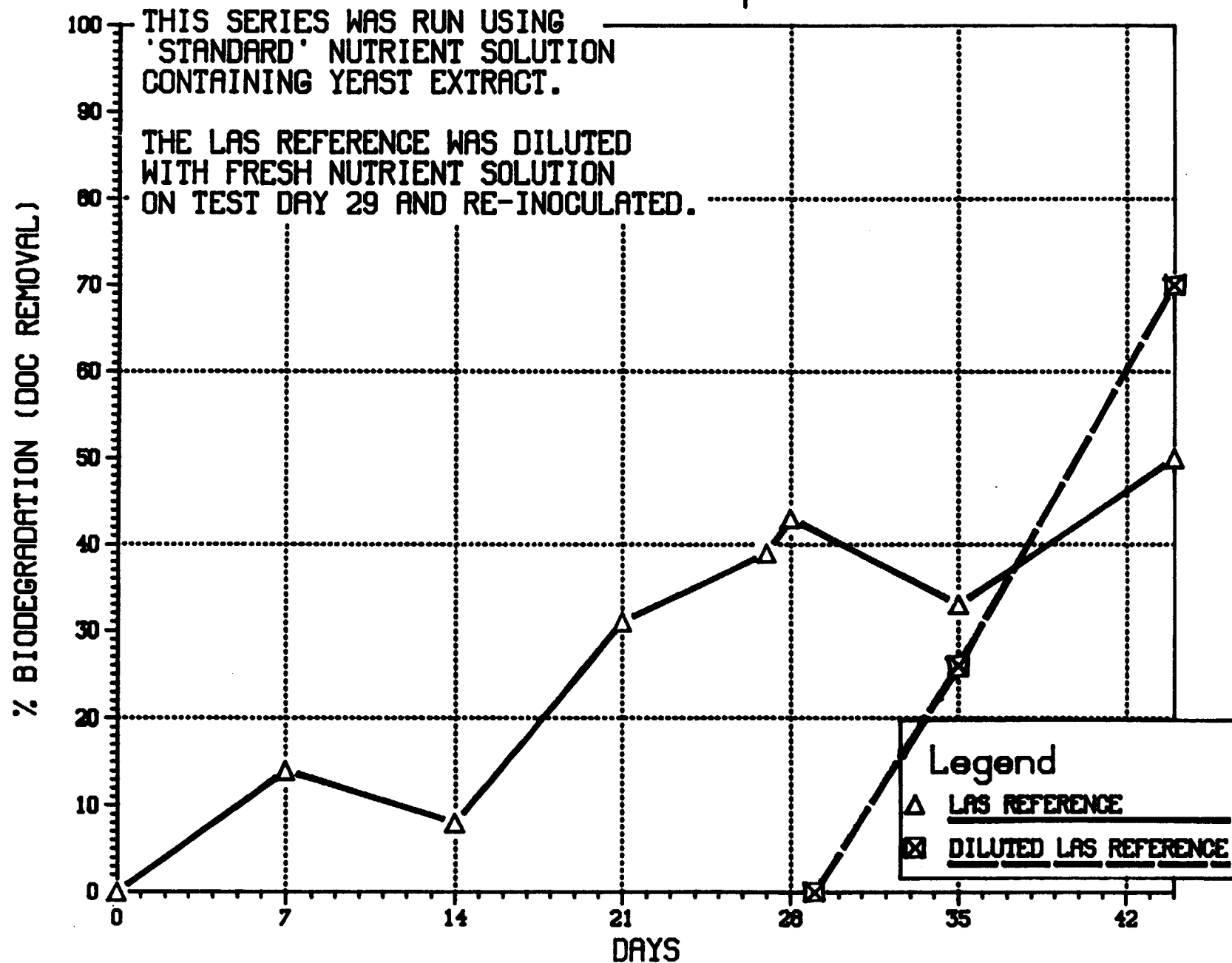
Figure 3

READY BIODEGRADABILITY: Modified Screening Test
OECD 301E -- Adopted 12 May 81
Environmental Lab Request No. 9611



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READY BIODEGRADABILITY: Modified Screening Test
OECD 301E -- Adopted 12 May 81
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The modified OECD Screening Test is intended for use on single chemical substances. L/W products, on the other hand, are aqueous solutions containing a mixture of chemicals. Pure chemicals, which have greater than 70% loss of DOC within 28 days, are regarded by the OECD guidelines as being readily biodegradable. Also, this result has to be reached within 10 days of the DOC removal first exceeding 10%. Only one of the replicates of each of the four L/W products tested met this second OECD requirement of 70% degradation within 10 days of first reaching 10% degradation. This requirement, however, is not realistically applicable to L/W or other formulated products (mixtures). The chemicals within mixtures will frequently have differing susceptibilities to biodegradation. Readily degradable chemical components of such products may start to degrade immediately, while the onset of degradation of other chemicals in these products may be delayed. Thus, disregarding this second criteria, which is not reasonable for mixtures of chemicals, the results show that the mixture of chemical components in each of these products is readily biodegradable.

Cultures tested with the synthetic vitamin solution showed, on average, a slightly lower level of DOC removed than cultures using yeast extract as the vitamin source. Future OECD screening tests should thus use yeast extract since the synthetic vitamin solution is more difficult to prepare and does not give improved degradation.

LAS, which is a readily biodegradable and commonly used surfactant in detergents, did not degrade fully under these test conditions. This occurred in spite of the fact that its concentration was only 15 mg/l of DOC compared to the 40 mg/l of DOC used for the Light Water products. The reason for the slow rate of LAS biodegradation appears to be that LAS⁽⁶⁾ inhibited microbial degradation at the test concentration. To check this hypothesis, at the end of the 28-day test period, the remaining LAS containing test cultures were split and half were diluted to twice their volume with fresh inoculated nutrient media. At this point, the rate of degradation in the diluted cultures increased substantially. Seventy percent of the DOC remaining at the time of dilution was removed within 15 days. Results of this work on LAS are shown graphically in Figure 4. Another researcher, has similarly reported a low level of biodegradation of LAS in the modified OECD screening test. D. Liu found that Marlon A (dodecylbenzene sulfonate) had a half life of 39 days.⁽⁷⁾

CONCLUSIONS

The present studies repeated the findings of previous OECD Screening Tests on Light Water products done by the 3M Environmental Laboratory. Both sets of tests showed that L/W products are "readily biodegradable." In all cases, the average DOC removal for L/W products was greater than 90% after 28 days. L/W products were much more degradable than the very commonly used and "readily biodegradable" surfactant, LAS.

REFERENCES

- (1) Organization for Economic Cooperation and Development, Guidelines For Testing of Chemicals, Section 301 E, Ready Biodegradability: Modified OECD Screening Test, May 12, 1981.
- (2) E. A. Reiner, Biodegradation of "LIGHT WATER" Products in OECD Test 6/80, 3M Technical Report No. 40, Dept. 0535, Project 9970012600, 6/30/80.
- (3) Dr. H. Hellmann and D. Muller, "Environmental Impact of Fire Extinguishing Foam Compounds (Umweltgefahr durch Feuerlosch-Schaummittel).\" The study was carried out by the West German Institute of Hydrology (Bundesanstalt für Gewässerkunde), April 18, 1979.
- (4) D. Muller and T. Tittizer, "The TOC Degradation Test - A Process to Test Organic Materials for Complete Biodegradation (Der TOC - Abbaupröfung - ein Verfahren zur Prüfung von Organischen Substanzen auf Vollständigen Biologischen Abbau).\" Developed at the Bundesanstalt für Gewässerkunde, Koblenz, Z. F. Wasser-und Abwasser-Forschung (1979).
- (5) Dohrman DC-52A Operating Manual, 4th Ed., 1978.
- (6) R. D. Swisher, Surfactant Biodegradation, pages 16-17 and 147, Marcel Dekker, Inc., 1970.
- (7) D. Liu, Study on Biodegradation of Aniline and Marlon A, Biodeterioration 5, Edited by T. A. Oxley and S. Barry, 1983.