
# BIODEGRADABILITY AND TOXICITY OF LIGHT WATER

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**Lab Environmental Studies Branch**

**NOVEMBER 1971**
**Final Report**



**AIR FORCE MATERIEL COMMAND**
**AIR FORCE RESEARCH LABORATORY**
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**UNITED STATES AIR FORCE**

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



| 1. REPORT DATE *(DD-MM-YY)* | 2. REPORT TYPE | 3. DATES COVERED *(From - To)* |
|---|---|---|
| 01-11-71 | Final | |

**4. TITLE AND SUBTITLE**

Biodegradability and Toxicity of Light Water

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**

Edward E. Lefebvre

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**

USAF Environmental Health Laboratory
Kelly AFB TX 78241

**8. PERFORMING ORGANIZATION REPORT NUMBER**

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

Air Force Materiel Command
Air Force Research Laboratory
711th Human Performance Wing
Airman Systems Directorate
Wright-Patterson Air Force Base, OH 45433

**10. SPONSORING/MONITORING AGENCY ACRONYM(S)**

AFRL/RHXX

**11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S)**

**12. DISTRIBUTION/AVAILABILITY STATEMENT**

Distribution Statement A: Approved for public release.

**13. SUPPLEMENTARY NOTES**

AFRL-2023-2662, cleared 20 July 2023

**14. ABSTRACT**

Light Water is a liquid film-forming surfactant used in extinguishing fires associated with fuels and oils such as those found in aircraft crashes. This product is potentially a serious pollutant because of its high chemical and biochemical oxygen demand.

This report outlines studies conducted on the pure concentrate and recommendations for disposal. Since the term "Light Water" covers a series of formulations, all data has been obtained from the 3M product designated FC-199.

**15. SUBJECT TERMS**

Light Water, Fire-fighting, Bench-scale

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT: | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON (Monitor) |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | Edward Lefebvre |
| Unclassified | Unclassified | Unclassified | SAR | | 19b. TELEPHONE NUMBER *(Include Area Code)* N/A |

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# BIODEGRADABILITY AND TOXICITY OF LIGHT WATER®

November 1971

EHL(K) 71-36

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N O T I C E

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## I. SUMMARY

Light Water® is a liquid film-forming surfactant used in extinguishing fires associated with fuels and oils such as those found in aircraft crashes. This product is potentially a serious pollutant because of its high chemical and biochemical oxygen demand. However, Light Water® is amenable to biological treatment under controlled conditions of flow. Holding ponds for waste oxidation or for later transfer to a treatment facility are suggested.

## II. INTRODUCTION

There are presently large quantities of film-forming foam in the Air Force inventory for the purpose of fighting fires especially from aircraft crashes. Protein-type foams have been used for several years but new technology has demonstrated better performance from surfactant-type foams. One particular brand is a Minnesota Mining and Manufacturing Company (3M) product called "Light Water®." Because of the ultimate run-off of the foam materials into the waterways, the pollution potential is a matter for concern that has prompted HQ USAF/SGPAAP to request biodegradability and treatment information. This report outlines studies conducted on the pure concentrate and recommendations for disposal. Since the term "Light Water" covers a series of formulations, all data has been obtained from the 3M product designated FC-199.

## III. DISCUSSION

### A. USE

Light Water® is supplied in liquid form as a concentrate. Dilution during actual operations reduces the concentration to approximately six percent. Training exercises will use up to 400 gallons of the concentrate or in excess of 5,000 gallons of waste. Emergency landings of aircraft which require that the runway be foamed may use up to 1,000 gallons of concentrate or approximately 16,500 gallons of waste water.

### B. COMPOSITION

Light Water® is a surfactant with a measured specific gravity of 1.02 and a pH of 4.6 in the concentrated form. The concentrate is diluted to approximately 60,000 ppm (6% v/v) during fire-fighting operations. The chemical oxygen demand of the concentrate is 550,000 mg/l. Figure 1 is a time-plot of the biochemical oxygen demand (BOD). The $BOD_5$ is 110,000 mg/l and the $BOD_{20}$ is 303,000 mg/l. Because of the dilution during fire-fighting operations, the $BOD_5$ and $BOD_{20}$ of the resulting solution is calculated to be 6,600 mg/l and 18,000 mg/l respectively. The calculated COD is 33,000 mg/l for the diluted mixture.

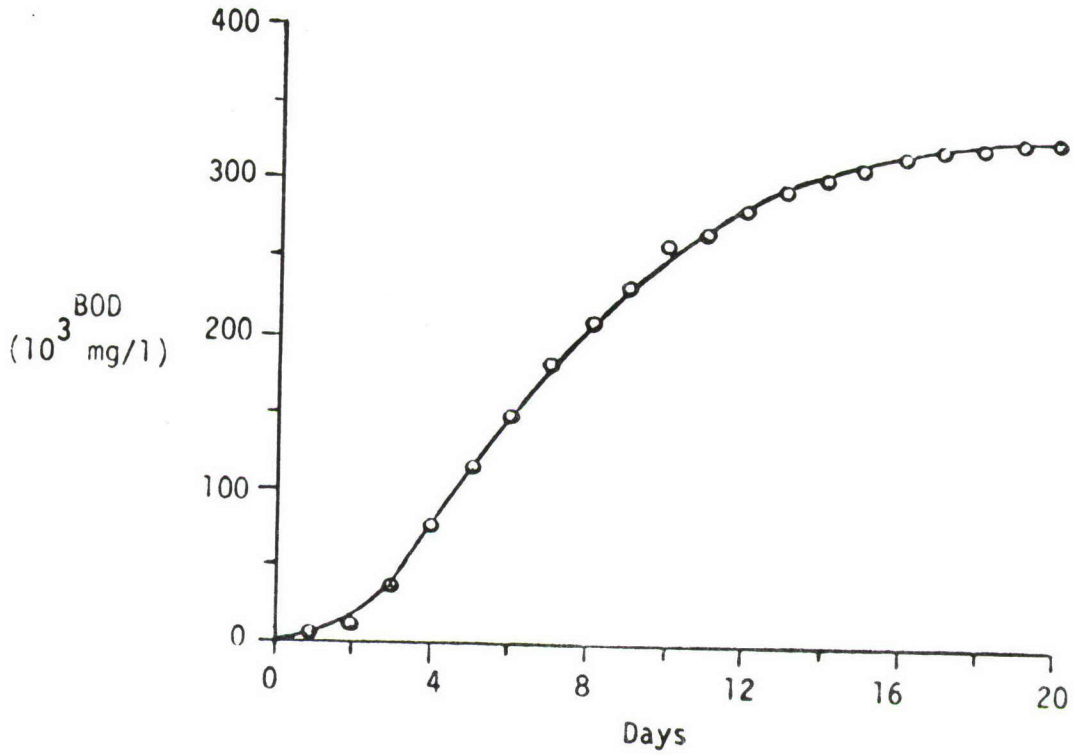


FIGURE 1. BIOCHEMICAL OXYGEN DEMAND OF LIGHT WATER® (FC-199)

C. WARBURG RESPIROMETER STUDIES

1. Figure 2 shows the oxygen uptake using the Warburg Respirometer at various concentrations of the foam. Samples were prepared by combining 20 percent activated sludge from a domestic sewage treatment plant, 70 percent glucose/glutamic acid solution (150 mg/l of each) and the remaining 10 percent foam concentrate in deionized water to provide the desired final concentration.

2. Toxic effects to the microorganisms were exhibited in concentrations greater than 2,500 ppm (0.25% v/v) and total toxicity at 20,000 ppm (2% v/v) in 4 hours. This would indicate that at least a 24-fold dilution of the resultant, already-dilute mixture from a fire-fighting exercise would be necessary to remove the acute toxicity to microorganisms normally found in a sewage treatment facility.

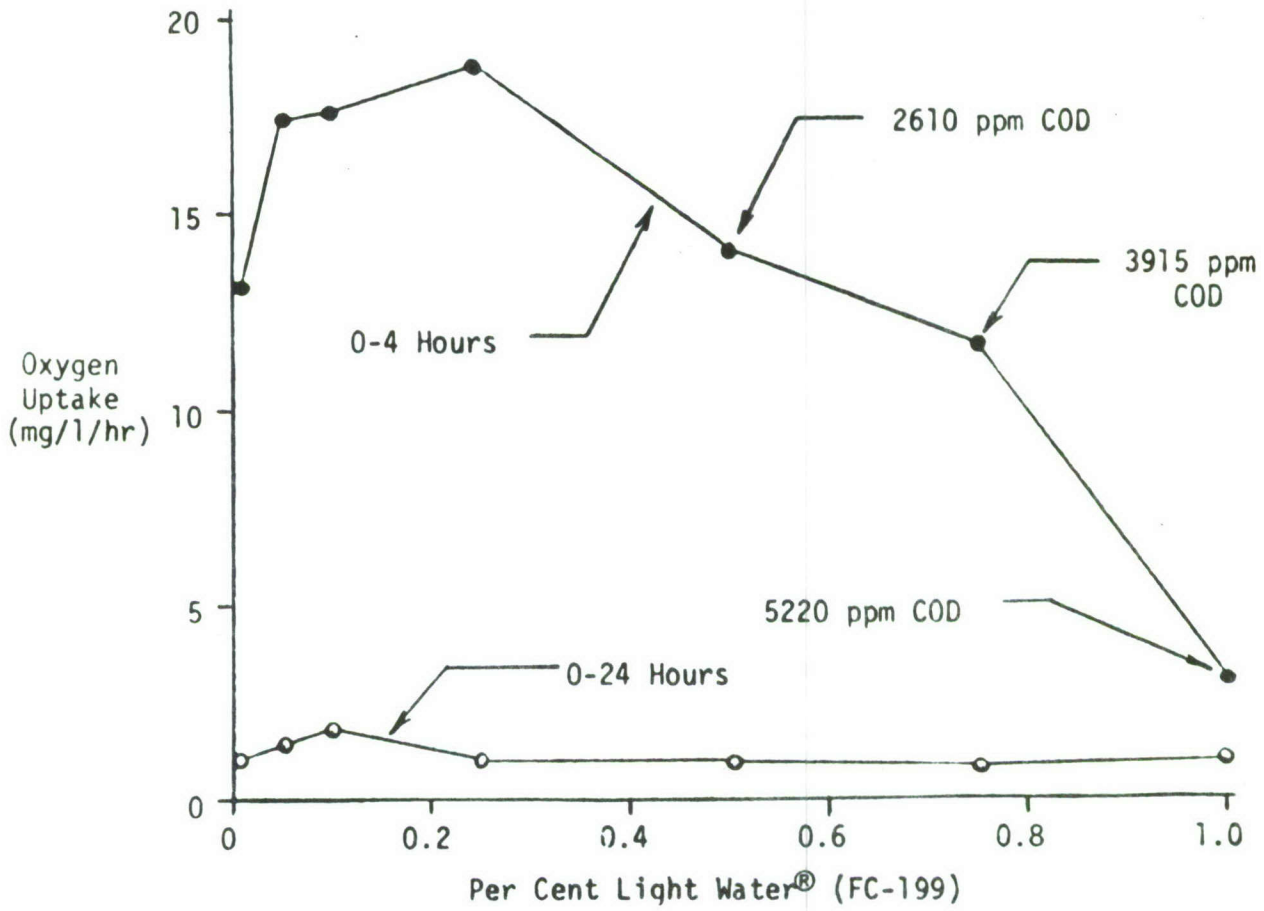


FIGURE 2. OXYGEN UPTAKE OF VARYING CONCENTRATIONS OF LIGHT WATER® USING THE WARBURG RESPIROMETER

D. TOXICITY STUDIES

An aerated dynamic bioassay using fathead minnows (Pimephales promelas) was conducted. The median weight of the 150 test animals was 0.396 gm. Five concentrations and a control were replicated five times using five test animals for each replicate. Figure 3 shows the change in $LC_{50}$ with time. The 96-hour $LC_{50}$ was 398 ppm (v/v).

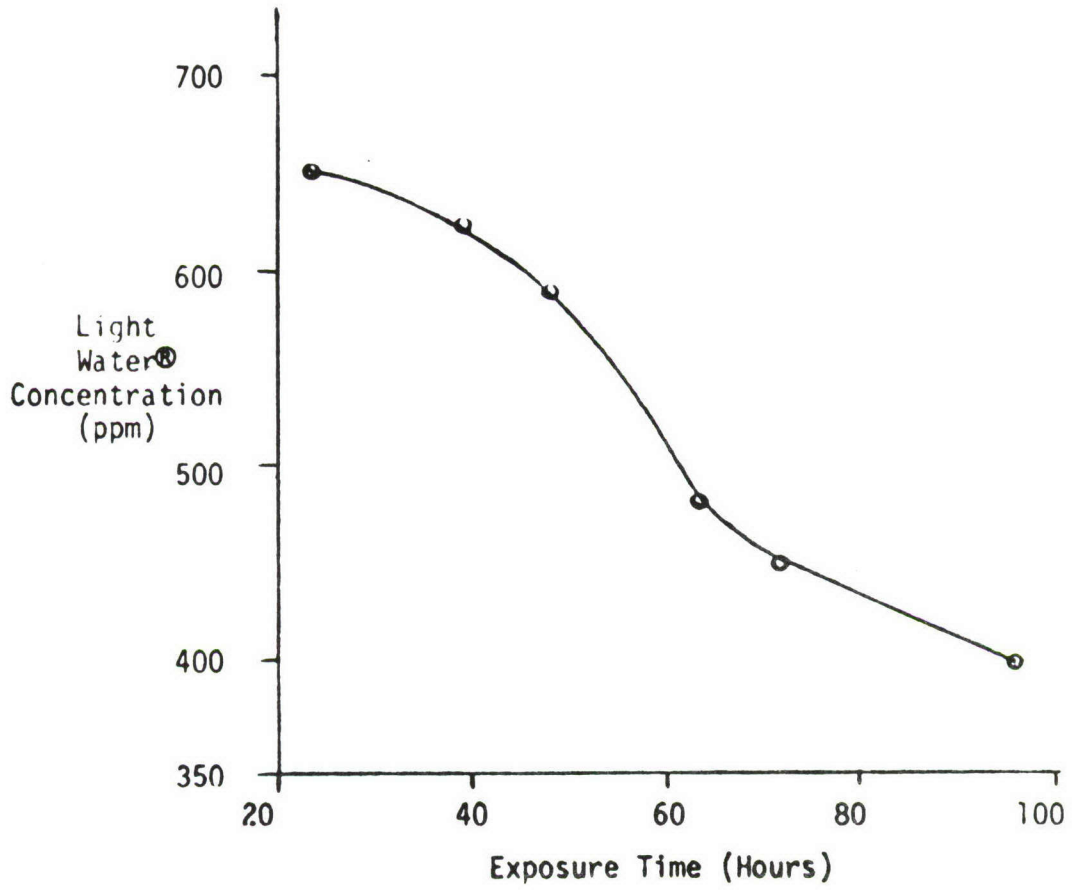


FIGURE 3. CHANGES IN $LC_{50}$ OF PIMEPHALES PROMELAS WITH TIME

E. PILOT PLANT STUDIES

1. To determine biodegradability of the foam concentrate, a bench-scale activated sludge pilot plant was fed the concentrate with a synthetic sewage of glucose and glutamic acid. Table 1 is a summary of influent and effluent parameters. Initially, the plant was fed 100 ppm foam concentrate in a glucose/glutamic acid solution (150 mg/l each) for a period of 24 days for acclimation. Detention time in the plant was 12 hours and mixed liquor suspended solids were wasted when the concentration exceeded 2,000 mg/l. The average MLSS for that period was maintained at 2,005 mg/l. $BOD_5$ and COD removals were 92 percent and 73 percent respectively during the acclimation period.

Table 1
SUMMARY OF 68-DAY BENCH-SCALE
ACTIVATED SLUDGE PILOT PLANT STUDY

| Dates | Light Water® Concentration | Detention Time | COD (mg/l) | | | BOD (mg/l) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Inf | Eff | % Rem | Inf | Eff | % Rem |
| 2-25 Jun 71 | 100 ppm | 12 hours | 317 | 86 | 73 | 213 | 17 | 92 |
| 26-30 Jun 71 | 200 ppm | 12 hours | 233 | 56 | 77 | 189 | 9 | 95 |
| 1-31 Jul 71 | 250 ppm | 12 hours | 354 | 33 | 91 | 284 | 7 | 96 |
| 1-6 Aug 71 | 250 ppm | 6 hours | 374 | 59 | 84 | 305 | 6 | 98 |

2. After acclimation, the plants were fed for a short four-day period at 200 ppm foam concentrate in glucose/glutamic acid solution (150 mg/l each). The concentration of the foam was then raised to 250 ppm for a period of 32 days. The $BOD_5$ and COD removals were 96 percent and 91 percent respectively. Nitrification was evident with the 12-hour detention time. Ten fathead minnows of various sizes were placed in the effluent from the pilot plant into a flow-through tank on the 30th day of the 250 ppm feed.

3. The detention time of the plant was decreased to six hours on the 63rd day. Sludge carryover occurred during the night filling the minnow tank with sludge. There was no mortality and the sludge was cleared. The fish were returned to the effluent and were alive at the termination of the plant on the 68th day after a total exposure of eight days.

4. Table 2 summarizes influent and effluent parameters for a second activated sludge bench-scale pilot plant. Synthetic sewage of composition shown in Table 3 was used and fed to the plant for six days. Detention time in the plant was six hours. A concentration of 150 ppm (v/v) foam was added for another six days. Finally, a concentration of 500 ppm (v/v) foam was fed for seven days. Removal percentages of $BOD_5$ and COD were excellent. Nitrification was inhibited by the increase in foam concentrate.

Table 2
SUMMARY OF 19-DAY BENCH-SCALE
ACTIVATED SLUDGE PILOT PLANT STUDY

| Dates | Light Water® (ppm) | COD (mg/l) | | | $BOD_5$ (mg/l) | | | $NO_3$(mg/l) | | MBAS(mg/l) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inf | Eff | % Rem | Inf | Eff | % Rem | Inf | Eff | Inf | Eff |
| 13-18 Aug 71 | 0 | 341 | 47 | 86 | 210 | 9 | 96 | 1.2 | 110 | 0.32 | 0.68 |
| 19-24 Aug 71 | 150 | 430 | 36 | 92 | 271 | 16 | 94 | 1.0 | 31 | 1.05 | 0.68 |
| 25-31 Aug 71 | 500 | 565 | 59 | 90 | 318 | 14 | 96 | 1.1 | 7 | 1.37 | 0.53 |

Table 3
COMPOSITION OF SYNTHETIC SEWAGE IN 19-DAY
BENCH-SCALE ACTIVATED SLUDGE PILOT PLANT STUDY

| | |
|---|---|
| Glucose | 160 mg/l |
| Peptone | 160 mg/l |
| Urea | 28.6 mg/l |
| $NaHCO_3$ | 102 mg/l |
| $KH_2PO_4$ | 32.5 mg/l |
| Tap Water | |

## IV. CONCLUSIONS

1. Acute toxicity to activated sludge microorganisms was exhibited by Light Water® at 0.25% (v/v) (2,500 ppm). The expected dilution when used in fire-fighting operations would result in a probable concentration of 6% v/v (60,000 ppm).

2. The 96-hour $LC_{50}$ to fathead minnows was 398 ppm v/v. The 24-hour $LC_{50}$ was 650 ppm v/v.

3. Concentrations of Light Water® up to 500 ppm v/v can be fed to biological treatment system and still maintain over 95% $BOD_5$ removal. However, nitrification is greatly inhibited with only six hours detention time. Nitrification was excellent up to 250 ppm v/v concentrate fed with a 12-hour detention time.

4. Fathead minnows showed no mortality in plant effluent from a treatment plant being fed 250 ppm v/v concentrate with a six hour detention time. They lived in the effluent for a period of eight days at which time the plant was terminated.

## V. RECOMMENDATIONS

1. Whenever possible, waste water containing in excess of 20 ppm Light Water® film-forming foam concentrate should not be discharged directly to a stream containing aquatic life.

2. Since training operations are controllable, waste water from fire-fighting training should first be passed through a gravity oil separator. The waste should then be detained in a pond for controlled treatment, such as pumping to a sewage treatment facility or natural oxidation and decomposition.

## DISTRIBUTION LIST

| | |
|---|---|
| USAF/SGPAAP<br>Wash DC 20333 | 2 cy |
| USAF/PREEU<br>Wash DC 22033 | 1 cy |
| AFLC/SGP<br>Wright-Patterson AFB OH 45433 | 1 cy |
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