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THE TOXICITY OF PHOSSY WATER TO SELECTED FRESHWATER ORGANISMS.(U)
MAR 78 J G PEARSON, P F ROBINSON, E S BENDER

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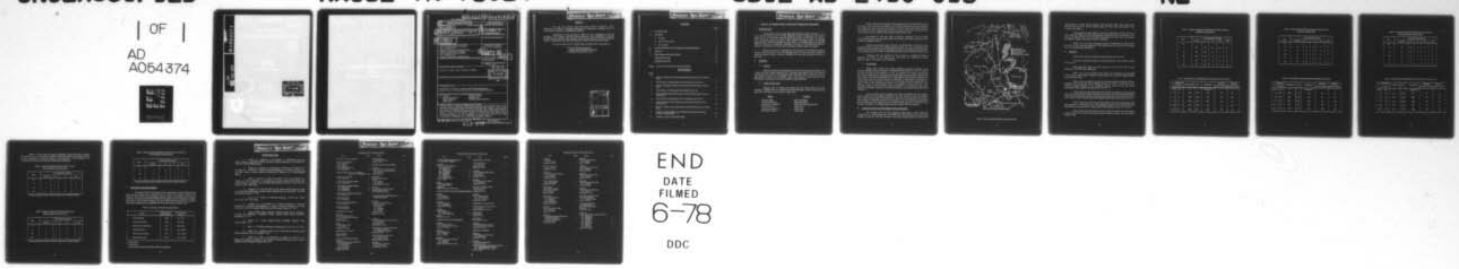

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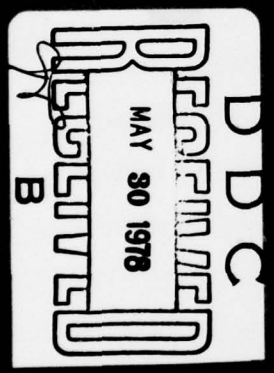

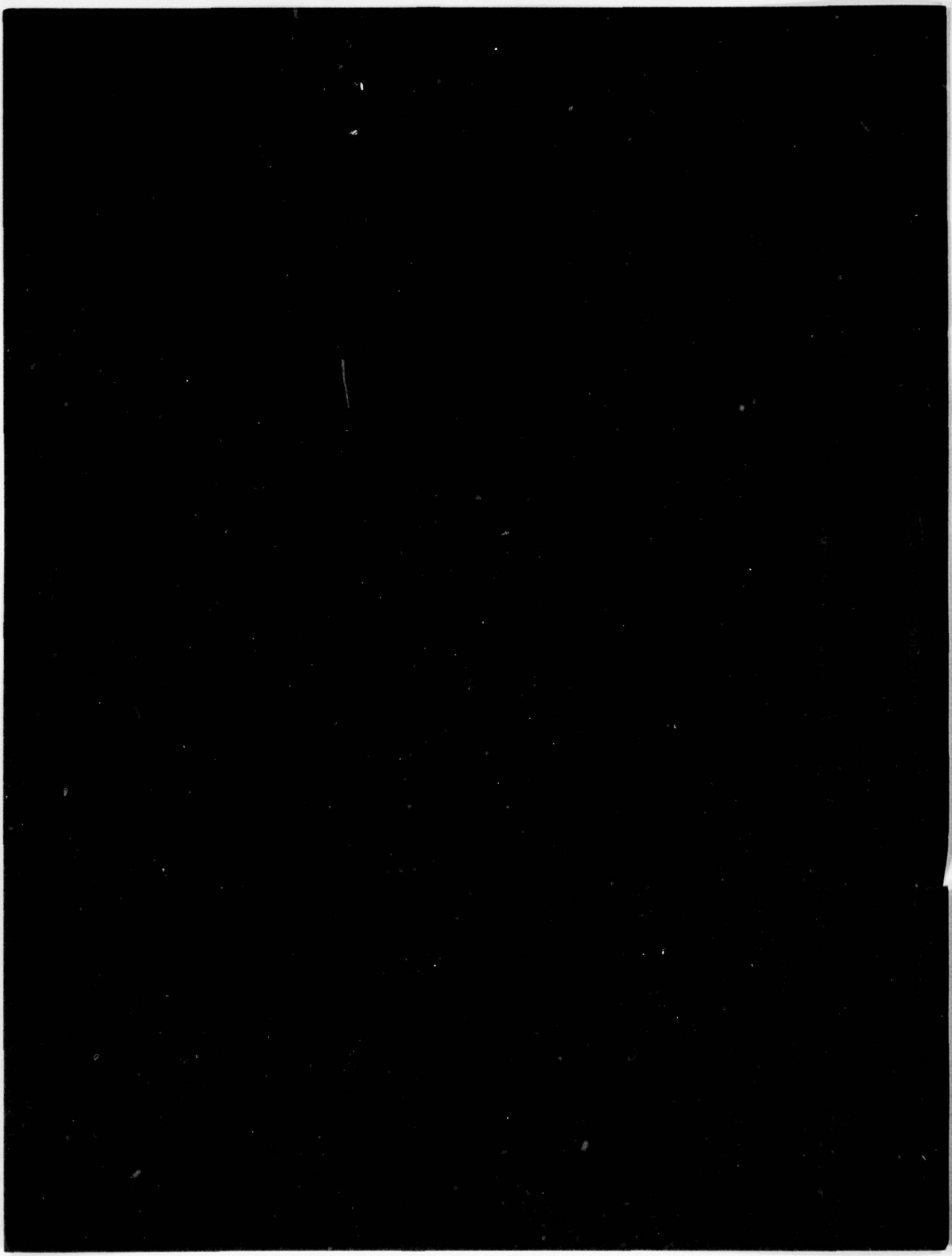

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

(U) Six species of freshwater organisms were exposed to the wastewater from a white phosphorus munitions filling facility, Pine Bluff Arsenal, Pine Bluff, Arkansas, in stated toxicity tests. Both fish (*Gambusia affinis* and *Lepomis macrohirus*) and benthic macroinvertebrates (*Glyptotendipes sp., Palaemonetes kadiakensis, Chaoborus punctipennis,* and *Branchiura sowerbyi*), endemic to the area, were tested for periods of up to 96 hours. The median effective concentration (EC50) for all the invertebrates was between the LC50 for the bluegill (*L. macrochirus,* 29.0 µg/l P_4) and the mosquito fish (*G. affinis,* 75 µg/l P_4).

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PREFACE

The work was authorized under PAA Project 57T4114, Subproject 3, Task 2, Development of Methods to Minimize Environmental Contamination; Ecological Surveys of Environmental Conditions at USDARCOM Installations.

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TOXICITY OF PHOSSY WATER TO SELECTED FRESHWATER ORGANISMS

I. INTRODUCTION.

During pollution surveys at Pine Bluff Arsenal (PBA), Pine Bluff, Arkansas,[1,2] it was found that the discharge from the white phosphorus munitions filling plant was having an adverse impact on the receiving creek and further downstream on Yellow Lake. The discharge from this facility (known as phossy water) contains substantial amounts of elemental phosphorus (P_4). Elemental phosphorus has been shown to be extremely toxic to marine fish[3] (lethal at 1.0 μg/l) and to significantly accumulate in the livers of cod (25,000 times ambient).[4] Only Isom[5] has reported any toxicity data on freshwater organisms, namely the bluegill.

Because of the lack of information on the toxicity of P_4 to freshwater organisms and the known occurrence of P_4 in the discharge, aquatic toxicity tests were conducted on freshwater organisms endemic to PBA in November 1974. This report describes the results of those tests.

II. METHODS.

A. Chemical.

Elemental phosphorus determinations were made by gas-liquid chromatography with a flame photometric detector specific for P_4.[6] All phossy water samples (50 ml) were extracted with benzene and the extract was immediately frozen. Using this method, the detection limit was approximately 0.5 ppb, and reproducible results were obtained at approximately 1.0 ppb. Water-quality determinations were made according to standard methods.[7]

B. Aquatic Toxicity Tests.

Organisms used for testing were collected from the Yellow Lake area with the exception of bluegills which were obtained from a local fish hatchery. Species collection sites are given below. (See figure for site location in Yellow Lake.)

Species	Location
Gambusia affinis	Below old spillway
Lepomis macrochirus	Local fish hatchery
Palaemonetes kadiakensis	Yellow Lake (near eastern shore)
Glyptotendipes sp.	Yellow Lake 4
Chaoborus punctipennis	Yellow Lake 1
Branchiura sowerbyi	Yellow Lake 1

All test animals were maintained in the laboratory for at least 24 hours before they were tested. Yellow Lake water from station 11 was used for holding water and also for dilution water during the toxicity tests. The only exception to the above was the water used for bluegills. The bluegills were held in dechlorinated tap water for at least 2 weeks prior to being tested; this water was also used as the dilution water during the bluegill toxicity tests.

Both species of fish were tested in glass jars containing 15 liters of water (15 to 20 fish/container). All invertebrate species were tested in glass dishes containing 1.0 liter of water (5 organisms/container).

Because of the reactive nature of the P_4 in the phossy water, all tests were set up immediately after the phossy water discharge sample was taken. Just prior to initiating the fish toxicity test, 50 ml samples from each concentration were taken for P_4 analysis. P_4 concentrations in the invertebrate test were based on calculated values from a known solution of phossy water.

Preliminary tests were conducted on all six species to establish the order of magnitude of toxicity of the phossy water. Final tests were conducted on three species: *G. affinis, L. macrochirus,* and *P. kadiakensis.*

C. Data Analysis.

Median effect (EC50's and LC50's) calculations were made according to the maximum likelihood method of Finney.[8] A computerized probit analysis was used to calculate the values of a and b in the equation $Y = a + bX$. "X" represents the toxicant concentration and Y is the normal deviate of the proportion of fish dying at the concentration, with the value of 5.0 added to eliminate the possibility of "Y" being negative. After a and b are calculated, the median effect value can be easily derived. The proportion of 50% mortality corresponds to a normal deviate of 0 and, therefore, a Y value of 5, so the median effect value is simply the X for which $a + bX = 5$. The 95% confidence interval was computed for each median effect value according to Bliss.[9] In those cases where only one partial kill was obtained, the median effect value and its confidence interval were calculated according to the moving average angle method of Harris.[10]

In some toxicity tests, the response at the lower concentration was zero mortality, and the response at the next higher concentration was 100% mortality. In such "all-or-nothing" cases, a probit analysis could not be performed. In these cases, the median effect concentrations were estimated by taking the square root of the product of the two consecutive concentrations between which there was a jump from zero to 100% mortality. These two concentrations were also used as estimates of a confidence interval about the median effect concentration.

III. CHARACTERISTICS OF THE PHOSSY WATER DISCHARGE.

The wastewater from the white phosphorus filling plant is piped underground northwesterly to a small settling pond. The overflow from this pond flows into an open ditch through a V-notch weir. The upper 10 meters of the ditch contains limestone to precipitate the

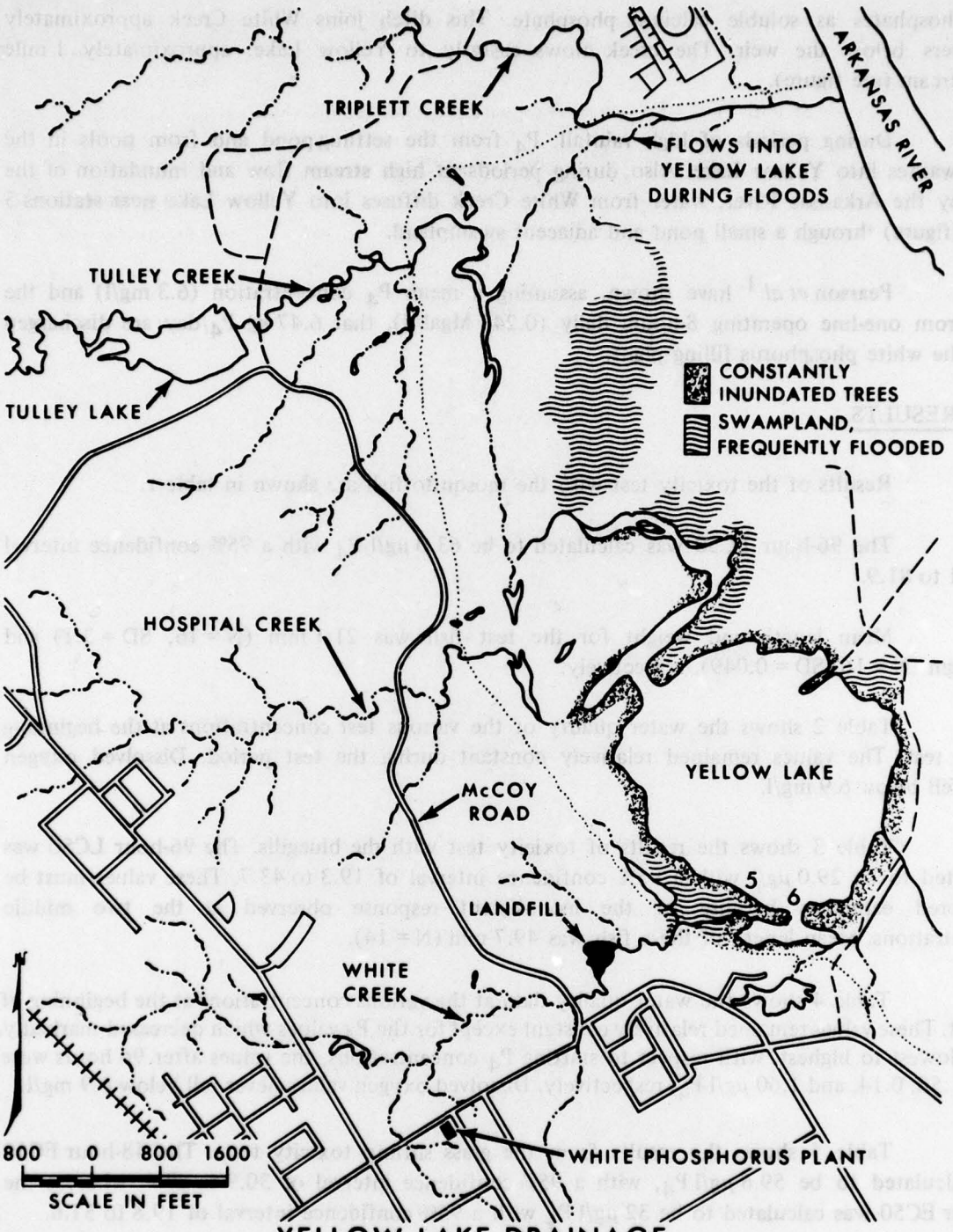

Figure. Phossy Water Discharge Site and Receiving Water

orthophosphates as soluble calcium phosphate. This ditch joins White Creek approximately 50 meters below the weir. The creek flows easterly to Yellow Lake, approximately 1 mile downstream (see figure).

During periods of high rainfall, P_4 from the settling pond and from pools in the creek washes into Yellow Lake. Also, during periods of high stream flow and inundation of the Lake by the Arkansas River, water from White Creek diffuses into Yellow Lake near stations 5 and 6 (figure) through a small pond and adjacent swampland.

Pearson *et al.*[1] have shown, assuming a mean P_4 concentration (6.3 mg/l) and the flow from one-line operating 8 hours daily (0.243 Mgal/d), that 6.47 kg P_4/day are discharged from the white phosphorus filling plant.

IV. RESULTS.

Results of the toxicity test with the mosquito fish are shown in table 1.

The 96-hour LC50 was calculated to be 63.0 μg/l P_4 with a 95% confidence interval of 45.1 to 81.9.

Mean length and weight for the test fish was 21.1 mm (N = 16, SD = 3.1) and 0.093 gm (N = 16, SD = 0.049), respectively.

Table 2 shows the water quality of the various test concentrations at the beginning of the test. The values remained relatively constant during the test period. Dissolved oxygen never fell below 6.9 mg/l.

Table 3 shows the results of toxicity test with the bluegills. The 96-hour LC50 was calculated to be 29.0 μg/l with a 95% confidence interval of 19.3 to 43.7. These values must be considered estimates because of the inconsistent response observed at the two middle concentrations. Mean length of these fish was 49.7 mm (N = 14).

Table 4 shows the water quality data at the various concentrations at the beginning of the test. These values remained relatively constant except for the P_4 values which decreased markedly. From lowest to highest, with respect to starting P_4 concentrations, the values after 96 hours were 0.28, 1.58, 0.14, and 1.60 μg/l P_4, respectively. Dissolved oxygen values never fell below 6.9 mg/l.

Table 5 shows the results from the grass shrimp toxicity tests. The 48-hour EC50 was calculated to be 59.6 μg/l P_4, with a 95% confidence interval of 30.9 to 88.4; whereas the 96-hour EC50 was calculated to be 32 μg/l P_4 with a 95% confidence interval of 19.8 to 51.6.

Table 6 shows the water quality data at the various concentrations at the beginning of this toxicity test. As before, these values remained relatively constant, with the probable exception of P_4.

Table 1. Number of Mosquito Fish (*Gambusia affinis*) Surviving Exposure to Phossy Water

Time	Concentration P_4 (µg/l)				
	Control	21	73	192	220
hr					
0	20	20	20	20	20
24	20	20	15	1	0
48	20	20	9	0	0
72	20	20	6	0	0
96	20	20	6	0	0

Table 2. Water Quality at the Beginning of the Mosquito Fish Toxicity Test

P_4	Dissolved oxygen	Temperature	pH	Conductivity	Alkalinity (mg/l as $CaCO_3$)	Hardness (mg/l as $CaCO_3$)
µg/l	mg/l	°C		µmhos/cm^2		
0	7.5	20.5	7.60	190	65	50
21	7.4	20.5	7.50	195	60	60
73	7.3	20.5	7.29	200	55	55
192	6.9	20.5	6.96	210	55	40
220	6.7	20.5	6.75	220	50	25

Table 3. Number of Bluegills (*Lepomis machrochirus*) Surviving Exposure to Phossy Water

Time	Concentration P_4 (μg/l)				
	Control	1.2	11	34	60
hr					
0	15	15	15	15	15
24	15	15	11	15	14
48	15	15	11	15	1
72	15	15	11	15	0
95	15	15	11	12	0

Table 4. Water Quality at the Beginning of the Bluegill Toxicity Test

P_4	Dissolved oxygen	Temperature	pH	Conductivity	Alkalinity (mg/l as $CaCO_3$)	Hardness (mg/l as $CaCO_3$)
μg/l	mg/l	°C		μmhos/cm^2		
0	8.95	20.25	7.72	190	60	50
1.2	8.70	20.5	7.68	170	65	55
11	8.75	20.5	7.65	180	65	60
34	8.75	20.5	7.55	180	60	50
60	8.70	19.95	7.55	120	60	60

Table 5. Number of Grass Shrimp (*Palaemonetes kadiakensis*) Surviving Exposure to Phossy Water

Time	Concentration P_4 (µg/l)				
	Control	21	73	192	220
hr					
0	12	13	11	11	14
24	12	13	11	4	4
48	12	11	4	0	0
72	12	9	2	0	0
96	12	9	2	0	0

Table 6. Water Quality at the Beginning of the Invertebrate Toxicity Tests

P_4	Dissolved oxygen	Temperature	pH	Conductivity	Alkalinity (mg/l as $CaCO_3$)	Hardness (mg/l as $CaCO_3$)
µg/l	mg/l	°C		µmhos/cm^2		
0	8.9	21.0	8.35	305	70	70
21	8.8	21.0	8.30	300	65	75
73	8.8	21.0	8.20	288	70	75
192	8.9	21.0	8.10	285	65	70
220	8.6	21.0	7.95	280	60	70

Tables 7, 8 and 9 show the results of preliminary toxicity tests with *B. sowerbyi*, *Glyptotendipes* sp. and *C. punctipennis*, respectively. These data indicate that the 48-hour EC50's for these organisms are somewhere between 12 and 120 $\mu g/l\ P_4$. It was estimated to be 37.9 $\mu g/l\ P_4$ for all species (see methods for details of the calculations).

Table 7. Number of Sludge Worms (*Branchiura sowerbyi*) Surviving Exposure to Phossy Water

Time	Concentration P_4 ($\mu g/l$)*			
	Control	1.2	12	120
hr				
0	5	5	5	5
24	5	5	5	5
48	5	5	5	1

* Nominal concentrations: based on a solution of phossy water containing 120 $\mu g/l\ P_4$.

Table 8. Number of Midge Larvae (*Glyptotendipes* sp.) Surviving Exposure to Phossy Water

Time	Concentration P_4 ($\mu g/l$)*			
	Control	1.2	12	120
hr				
0	5	5	5	5
24	4	4	4	0
48	4	4	4	0

* Nominal concentrations: based on a solution of phossy water containing 120 $\mu g/l\ P_4$.

Table 9. Number of Phantom Midge Larvae (*Chaoborus punctipennis*) Surving Exposure to Phossy Water

Time	Concentration P_4 (μg/l)*			
	Control	1.2	12	120
hr				
0	5	5	5	5
24	4	5	5	3
4	5	5	5	0

* Nominal concentrations: based on a solution of phossy water containing 120 μg/l P_4.

V. DISCUSSION AND CONCLUSIONS.

The results from all of the toxicity tests are summarized in table 10. Review of this table shows that phossy water is extremely toxic as a result of its P_4 content. Bentley[11] has shown the 96-hour LC50 of pure P_4 ranges from 6 to 73 μg/l for fish tested under laboratory conditions. He has also shown that the 48-hour EC50 ranges from 30 to 560 μg/l for invertebrate species tested under the same conditions. The data in table 10 show good agreement with these values, again indicating the P_4 is responsible for the toxicity observed in phossy water.

Table 10. Summary of Aquatic Toxicology Results

Species	Median effect concentration	95% Confidence interval
Gambusia affinis	75.0[a]	66.1–85.1
Lepomis macrochirus	29.0[a]	19.3–43.7
Palaeomonetes kadiakensis	59.6[b]	30.9–88.4
Glyptotendipes sp.	37.9[c]	12.0–120.0[c]
Chaoborus punctipennis	37.9[c]	12.0–120.0[c]
Branchuria sowerbyi	37.9[c]	12.0–120.0[c]

[a] 96-Hour LC50.

[b] 48-Hour EC50.

[c] "All-or-nothing" responses (see method for details of the calculations).

LITERATURE CITED

1. Manuel, K. L., Bender, E. S., and Pearson, J. G. EB-TR-76038. Results of Aquatic Surveys at Pine Bluff Arsenal, Pine Bluff, Arkansas, September 1973–October 1974. April 1976. UNCLASSIFIED Report.

2. Pearson, J. G., Bender, E. S., Taormina, D. H., Manuel, K. L., Robinson, P. F., and Asaki, A. E. EO-TR-76077. Effects of Elemental Phosphorus on the Biota of Yellow Lake, Pine Bluff Arsenal, Arkansas, March 1974–January 1975. December 1976. UNCLASSIFIED Report.

3. Zitko, V., Aiken, B. E., Tibbo, S. H., Beshc, K. W. T., and Anderson, J. M. Toxicity of Yellow Phosphorus to Herring (*Culpea herrengus*), Atlantic Salmon (*Salmo salar*), Lobster (*Homarus americanus*), and the Beach flea (*Gammarus oceanicus*). J. Fish. Res. Bd. Canada *27*, 1379–1384 (1970).

4. Jangaard, P. M. The Role Played by the Fisheries Research Board of Canada in the "Red Herring Phosphorus Pollution Crises in Placentia Bay, New Foundland." Fish. Res. Bd. Canada Circular No. 1. 1972.

5. Isom, B. G. Toxicity of Elemental Phosphorus. J. Water Poll. Control Fed. *32*(12), 1312–1316 (1960).

6. Ackman, R. G., and Addison, R. F. Direct Determination of Elemental Phosphorus by Gas-Liquid Chromatography. *In:* Effects of Elemental Phosphorus on Marine Life. pp 181–186. P. M. Jangaard, Editor, Fish. Res. Bd., Canada Circular No. 1. 1972.

7. American Public Health Association. Standard Methods for the Examination of Water and Wastewater. 13th Edition. 874 pp. American Public Health Association. Washington, D. C. 1971.

8. Finney, D. J. Probit Analysis. 333 pp. Cambridge University Press. London, England. 1971.

9. Bliss, C. I. The Statistics of Bioassay. Academic Press, Inc. New York, N. Y. 1952.

10. Harris, E. K. Confidence Limits for the LD50 Using the Moving Average Method. Biometrics 424–432. September 1959.

11. Bentley, R. E., Dean, J. W., Hollister, T. A., Leblanc, G. A., Sauter, S., and Sleight, B. N. Laboratory Evaluation of the Toxicity of Elemental Phosphorus (P_4) to Aquatic Organisms. EG&G Bionomics, Wareham, MA (1977).

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US Army Engineer Waterways Experimental Station Environmental Systems Division PO Box 631 Vicksburg, MI 39180	1
Commander US Army Armament Materiel Readiness Command Attn: DRSAR-ASN Attn: DRSAR-IMB-C Attn: DRSAR-ISE Attn: DRSAR-LC Attn: DRSAR-PDM Attn: DRSAR-SA Attn: DRSAR-SF Attn: DRSAR-SR Rock Island, IL 61299	 1 1 2 1 1 1 1 1