The Acute Toxicity of a Yellow Phosphorus Contaminated Diet to Brook Trout (*Salvelinus fontinalis*)[1]

by
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SUMMARY

Yellow phosphorus (P_4) contaminated cod muscle (P_4, 4-11 µg/g) and liver (P_4, 194 µg/g) were lethal when fed to brook trout. The symptoms of P_4 poisoning were identical to those observed when this element is present in water (FLETCHER et al. 1970), namely, external redness, hemolysis and reduced hematocrits. The approximate toxic dosage of P_4 ranged from 1.23 - 2.73 mg.

INTRODUCTION

A recent series of experiments have demonstrated that when yellow phosphorus is present in seawater or freshwater it is extremely toxic to fish and invertebrates (ZITKO et al. 1970, FLETCHER et al. 1970, FLETCHER et al. 1971, FLETCHER and HOYLE 1972). It has also been shown that when these animals are exposed to yellow phosphorus they accumulate this element in their tissues (DYER et al. 1970, FLETCHER 1971). These results suggested the following question: Are tissues which accumulate this element toxic to other species of fish? This note describes an experiment showing that yellow phosphorus contaminated cod muscle and liver tissues are lethal when consumed by brook trout.

MATERIALS AND METHODS

Yearling brook trout (Salvelinus fontinalis) (50 - 200 gm) were obtained from Cobequid fish

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hatchery, Nova Scotia. At the laboratory they were maintained in flowing, charcoal filtered freshwater (5 - 8°C) and were fed an ad libitum supply of Purina Trout Chow for at least two months.

Experimental groups consisted of five trout which were held in 90cm x 90cm tanks containing approximately 250 l of water flowing at four to eight liters per minute. None of the fish were fed for two weeks prior to experimentation.

The yellow phosphorus contaminated cod tissues were obtained by exposing cod (Gadus morhua) to water containing 5 mg/l yellow phosphorus for approximately one hour. The fish were then killed and aliquots of liver and muscle tissue were removed and stored at -30°C until use.

There were four experimental groups of trout. One was fed yellow phosphorus contaminated cod liver (phossy liver) and another yellow phosphorus contaminated cod muscle (phossy muscle). The two control groups were fed uncontaminated cod liver and muscle tissue respectively. Each group of trout was fed a maximum of 18 gm of tissue per day. Each fish was removed from its tank when dead, and a hematocrit was obtained from a caudal blood vessel.

The concentration of yellow phosphorus in the cod and trout tissues was determined by gas-liquid chromatography (ADDISON and ACKMAN 1970).

RESULTS

The LT50's (time to 50% mortality) and the amounts of yellow phosphorus consumed by the trout are presented in Table 1.

Phossy Liver. The yellow phosphorus concentration of the liver fed to the trout was 194 µg/gm.

All the trout ate vigorously during the first two days of feeding. However, on the third and fourth days the fish appeared lethargic and ate very slowly. None of the fish responded readily to such sudden stimuli as banging on the side of the tank, or splashing the surface of the water. On the fifth day, none of the trout ate any phossy liver and two of them showed distinct signs of external redness. From this time on the phossy liver fed trout did not eat, even when they

were offered uncontaminated liver or muscle tissue. Since the phossy liver fed trout did not eat, food was withheld from the control liver fed group. On the sixth day all of the phossy liver fed fish exhibited a red external appearance. By day 21 this redness was no longer evident and the gills of the fish had become almost white.

TABLE 1

The toxicity of yellow phosphorus contaminated cod liver (phossy liver) and cod muscle (phossy muscle) when fed to brook trout

Feed	LT50 (hr)	Range (hr)	P_4 Eaten µg	µg fish/ day	µg/gm fish/ day
Phossy Liver	600	216-1248	2730	682	5.73
Phossy Muscle	1400	1080-1824	1230	23.6	0.16

At death the hematocrits of the phossy liver fed trout were significantly lower than those of the controls (Table 2).

The livers of the experimental group were considerably larger than those of the control fish. No significant differences were observed between the spleen weights of the two groups (Table 2).

Yellow phosphorus was only detectable in the first two trout to die (216 and 240 hours). The average concentrations (µg/gm) found were as follows: intestinal contents 0.28, brain 0.33, spleen 0.25, muscle 0.13, liver 0.02.

Phossy muscle. The yellow phosphorus concentrations of the phossy muscle fed to the trout ranged from 4 - 11 µg/gm.

All of the trout ate rapidly for the first 18 days of feeding. However, by the twenty-first day their rate of eating had slowed perceptibly. The first fish appeared "red" on the twenty-sixth day, and by the thirty-first day of feeding all of the fish had taken

TABLE 2

A comparison of the hematocrits and body, liver and spleen weights of trout fed yellow phosphorus contaminated and uncontaminated cod tissues

Feed	Body Wt.	Hematocrit	Liver		Spleen	
	(gm)	%	(gm)	(%Body Wt)	(gm)	(% Body Wt)
Phossy Liver	119** ±18.8	3.22*** ±3.25	2.93** ±0.80	2.45** ±0.49	0.12 ±0.043	0.10 ±0.036
Control Liver	77.9 ±15.3	26.3 ±4.35	1.03 ±0.40	1.31 ±0.33	0.14 ±0.072	0.19 ±0.088
Phossy Muscle	146 ±19.4	6.94*** ±5.72	4.80*** ±0.858	3.28*** ±0.439	0.20 ±0.046	0.138 ±0.021
Control Muscle	131 ±32.9	29.7 ±4.53	1.24 ±0.37	0.941 ±0.058	0.15 ±0.06	0.11 ±0.035

All values are expressed as mean ± standard deviation

** $P < 0.01$

*** $P < 0.001$

on a red external appearance. By day 40 the red external color had disappeared, and the trout's consumption of phossy muscle had declined to approximately one half (9 gm) of their initial intake. All of the trout stopped eating by day 52.

At death, the hematocrits of the phossy muscle fed trout were significantly greater than those of the control trout (Table 2).

Yellow phosphorus was not detectable (<0.002 µg/gm) in any of the trout tissues.

DISCUSSION

The results of this experiment indicate that the tissues of fish exposed to yellow phosphorus contaminated water can be lethal if they are consumed by other fish.

One implication of this observation is that during the yellow phosphorus incident of Long Harbour, Newfoundland (IDLER 1969) a number of fish species could have consumed yellow phosphorus contaminated fish and exhibited symptoms of phosphorus poisoning without coming into direct contact with the contaminated water. This, in part, may explain why some fish species were observed dead and dying at considerable distances from the polluted site.

The concentration of yellow phosphorus in the tissues of the trout fed phossy liver were relatively low. This suggests that yellow phosphorus will not be concentrated to any significant extent when passed from one organism to another through the food chain.

The toxic dosage of yellow phosphorus to mice and rats has been reported as 0.5 mg and 3.5 mg, respectively (CAMERON and PATRICK 1966). These values are comparable to those obtained for trout in the present study and suggest that the oral toxicity of this element to trout and mammals is of a similar order of magnitude.

At present it is not known whether yellow phosphorus exerts its major lethal effect on an external structure (such as gill epithelium) or an internal region of the body. To date the evidence seems to favour the latter. Yellow phosphorus has been shown to accumulate in the tissues of fish exposed to

water containing this element (DYER et al. 1970). This indicates that yellow phosphorus has the potential to directly affect any region of the fish. The present feeding experiment demonstrates that yellow phosphorus can exert its lethal effects internally.

The enlarged livers observed in the phosphorus treated groups is possibly a reflection of the increased activity of the liver in removing the excess hemoglobin from the plasma.

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