PRELIMINARY RESULTS ON THE USE OF POTASSIUM PERMANGANATE TO COUNTERACT THE EFFECTS OF ROTENONE ON FISH

J. M. LAWRENCE *
Alabama Polytechnic Institute Agricultural Experiment Station
Auburn, Alabama

Compounds containing rotenone have become widely used in fishery management in the past 20 years (Krumholz, 1948; Solman, 1949). Present-day fishery biologists use rotenone for many types of problems, including such problems as killing all the fish in a lake or pond, sampling a fish population in a lake or stream, and killing only a part of the fish population in a body of water. In all of these practices, one disadvantage is the length of time required for the toxic effects of the chemicals to dissipate. Normally, in waters having a temperature of 70° F. or higher, one must allow 5 to 7 days to elapse from the time of treatment until it is safe to restock with fish. In sampling a stream population, a kill will be obtained for a considerable distance below the sample area before the concentration is dilute enough to be no longer toxic to fish.

Experiments have been and are continuing to be conducted by the A. P. I. Agricultural Experiment Station to determine whether toxicity of rotenone to fish can be counteracted by addition of some chemical to the water. The results of this work to date are summarized in this report.

As most chemists working with rotenone have observed that the compound is fairly easily oxidized when exposed to air and light (Leonard, 1939), one of the first tests on the control of its toxicity was to treat the water with a strong oxidizing agent. One of the cheapest and most active oxidizing agents, yet not toxic to fish at low concentrations, is potassium permanganate. This chemical, at concentrations approaching 2 p. p. m., is used extensively in ponds as a treatment for bacterial and fungal infections of minnows (Prather *et al.*, 1953).

TOXICITY OF POTASSIUM PERMANGANATE TO POND FISH

The toxicity of potassium permanganate to bluegills, *Lepomis macrochirus* Rafinesque, largemouth bass, *Micropterus salmoides* (Lacépède), goldfish, *Carassius auratus* (Linnaeus), and to fathead minnows, *Pimephales promelas* Rafinesque, was determined in aquaria at temperatures of 58° and 68° F. The fish were allowed to live in the aquaria for 48 hours prior to the treatment with potassium permanganate. The results of these tests indicated that in aquaria at 68° F., the minimum concentration of potassium permanganate that would kill bluegills was 3 p. p. m.; largemouth bass, 4 p. p. m.; goldfish, 6 p. p. m.; and fathead minnows, 5 p. p. m. At a temperature of 58° F., the minimum concentration of potassium permanganate that was lethal to the bluegills, bass, and fatheads was 5 p. p. m.; and to goldfish, 7 p. p. m.

To determine the length of time that potassium permanganate remained lethal to fish, the dead fish were removed as soon as they died in those aquaria that contained lethal concentrations of the chemical. These aquaria were restocked 24 hours after treatment; and, in all concentrations ranging from 3 to 7 p. p. m., there was 100 percent survival of the three species of fish being tested.

USE OF POTASSIUM PERMANGANATE TO MAKE WATER SAFE FOR FISH AFTER ROTENONE POISONING

A. *Tests in Aquaria.*—The first expermients with potassium permanganate and rotenone were conducted in aquaria that contained bluegills, goldfish, fathead minnows, and largemouth bass as test animals. The firsh were allowed to live in the aquaria for 48 hours before treatment. Then a concentration of 0.05 p. p. m. rotenone (1 p. p. m. Noxfish, an emulsifiable preparation that contained 5 percent rotenone) was added to the test aquaria. In some of these aquaria a concentration of 2 p. p. m. potassium permanganate was added after

* Prepared for publication in The Progressive Fish-Culturist (Printed Vol. 18, No. 1—January, 1956).

the fish became distressed, whereas in other aquaria no treatment with potassium permanganate was applied. In each series of tests control aquaria were maintained, and the survival in all controls was 100 percent. The results of these tests are summarized in Table I.

TABLE I

SUMMARY OF EXPERIMENTS IN AQUARIA TO COUNTERACT TOXIC EFFECTS OF ROTENONE BY USING POTASSIUM PERMANGANATE AFTER FISH BECAME DISTRESSED

Temp. (° F.)	*Kind of Fish**	*Rotenone* (*p. p. m.*)	*Time to Show Distress* (*minutes*)	*Potassium Permanganate Added at First Signs of Distress* (*p. p. m.*)	*Time for Recovery* (*minutes*)	*Survival after 48 Hours* (*percent*)
81	Bluegills	0.05	20	2	30	40
	Bluegills	.05	20	0		0
	Goldfish	.05	20	2	30	75
	Goldfish	.05	20	0		0
68	Fatheads	.05	23	2	30	100
	Bass	.05	30	2	45	100
58	Bluegills	.05	40	2	30	100
	Fatheads	.05	40	2	30	100
44	Bluegills	.05	95	2	45	40
	Fatheads	.05	95	2	45	95
	Bass	.05	95	2	60	100

Each group of tests also included two or more control aquaria. The survival in these controls was 100 percent.

* Stocking: (All aquaria, 15-gallon capacity, filled with 40 liters of water).
81° group: 4 aquaria, 10 bluegills each; 4 aquaria, 10 goldfish each.
68° group: 2 aquaria, 10 fatheads each; 2 aquaria, 4 bass each.
58° group: 2 aquaria, 10 bluegills and 10 fatheads each
44° group: 2 aquaria, 10 bluegills and 10 fatheads each; 2 aquaria, 4 bass each

In another series of experiments in aquaria, bluegills, fathead minnows, and largemouth bass were used as test animals. These fish were allowed to live in the aquaria for 48 hours prior to treatment. One group of aquaria in this series was treated with 0.05 p. p. m. rotenone and 1 p. p. m. potassium permanganate at the same time. The other group was treated with 0.05 p. p. m. rotenone and 2 p. p. m. potassium permanganate at the same time. The results are shown in Table II.

The results of all tests revealed that the toxicity of rotenone to fish could be counteracted by the addition of potassium permanganate to the poisoned waters. In these tests approximately 2 parts of potassium permanganate were needed to detoxify 0.05 part of rotenone.

B. *Tests in Ponds.*—Early in the winter of 1954, four 1-acre ponds that had been drained were partly refilled with water. They were treated with a concentration of 0.10 p. p. m. rotenone on December 10, 1954. This treatment killed wild fish in these ponds within 24 hours. The water temperature at that time was 42° F. On December 13, 1954, the ponds were treated with potassium permanganate at the rate of 2 pounds of potassium permanganate per 0.05 pound of rotenone. This gave a concentration of 4 p. p. m. potassium permanganate in the pond water. Cages containing fathead minnows were placed in the ponds 24 hours later. None of these minnows died within the following 24-hour period, and the ponds were restocked with fish on December 15, 1954.

A second field test of this technique was tried on four farm ponds that had been drained and had started to refill with water. To prevent the new experiments from being contaminated with fish that might still be living in the ponds, rotenone at a concentration of 0.10 p. p. m. was applied on January 5, 1955. This treatment killed fish stranded in these ponds within 24 hours. The water temperature on that date of 52° F. Twenty-four hours later, cages containing fathead minnows were placed in the ponds to check the rotenone toxicity at this low temperature. Within 12 hours all the minnows were dead. The ponds were next treated with 2 pounds of potassium permanganate for each 0.05 pound of rotenone that had been added. Fathead minnows in cages were placed

TABLE II

SUMMARY OF EXPERIMENTS IN AQUARIA TO COUNTERACT TOXIC EFFECTS OF ROTENONE TO FISH BY ADDING DIFFERENT CONCENTRATIONS OF POTASSIUM PERMANGANATE AT THE SAME TIME ROTENONE WAS APPLIED

Temp. (° F.)	Kind of Fish*	Added at Same Time Rotenone (p. p. m.)	Potassium Permanganate (p. p. m.)	Additional Potassium Permanganate After Approximate Time (minutes)	Concentration (p. p. m.)	Survival after 48 Hours (percent)
81	Bluegills	0.05	1	55	1	20
	Bluegills	.05	1	60	1	64
	Bluegills	.05	2	..	..	100
	Bluegills	.05	2	..	..	98
	Bass	.05	1	55	1	40
	Bass	.05	1	70	2	100
	Bass	.05	2	..	..	75
	Bass	.05	2	..	..	75
68	Bluegills	.05	2	..	..	100
	Fatheads	.05	2	..	..	100
	Bass	.05	2	..	..	100
58	Bluegills	.05	2	..	..	100
	Fatheads	.05	2	..	..	100
44	Bluegills	.05	2	..	..	100
	Fatheads	.05	2	..	..	100
	Bass	.05	2	..	..	100

Each group of tests also included two or more control aquaria. The survival in these controls was 100 percent.

* Stocking: (All aquaria, 15-gallon capacity, filled with 40 liters of water).
81° group: 20 aquaria, 10 bluegills each; 10 aquaria, 4 bass each.
68° group: 2 aquaria, 10 bluegills and 10 fatheads each; 2 aquaria, 4 bass each.
58° group: 2 aquaria, 10 bluegills and 10 fatheads each.
44° group: 2 aquaria, 10 bluegills and 10 fatheads each; 2 aquaria, 4 bass each.

in the ponds 1 hour after this treatment. A check at the end of 24 hours showed that in two of the ponds all of the minnows were alive, but in the other two ponds all of the minnows were dead. Minnows were again added to these two toxic ponds 48 hours later, and, at the end of another 24-hour test period, all of these minnows were dead. These two ponds then received an application of potassium permanganate at a concentration of 4 p. p. m. on January 12, 1955. The surface water temperature at that time was 40° F. Fathead minnows in cages were again placed in the ponds 24 hours after this second treatment. At the end of a 24-hour test period, there was 25 percent loss of minnows in one pond and 75 percent mortality in the other.

As these ponds were in the process of refilling and were only partly full at the time of treatment, it is believed that the volume of water was overestimated; thus, the concentration of rotenone was in excess of 0.10 p. p. m. If such were the case, the concentration of the potassium permanganate was considerably greater than 4 p. p. m. when the first test cages containing fathead minnows were added. Thus, it appears probable that the fatheads were killed by the potassium permanganate rather than by the rotenone. The later treatments with potassium permanganate would have aggravated this condition and continued to kill the test fish.

To study further the problems that were encountered in the ponds that have just been described, twelve 0.25-acre ponds were poisoned with a 0.05 p. p. m. concentration of rotenone on April 25, 1955. This treatment killed wild fish within 2 hours. To neutralize the toxicity of this rotenone, potassium permanganate at a concentration of 2 p. p. m. was applied 24 hours later as a water solution. A test cage containing 10 fathead minnows was placed in each pond 24 hours after the potassium permanganate treatment. These cages were checked daily for mortality of fatheads; there were no deaths within the next 11 days. The surface water temperature during the period ranged from 71° to 82° F.

Another series of six 0.25-acre ponds was poisoned with rotenone at the rate of approximately 0.05 p. p. m. on April 26, 1955, and the results were the same

as those described in the preceding paragraph. These ponds were treated with a 2-p. p. m. concentration of potassium permanganate 24 hours later. On these six ponds the potassium permanganate was applied by broadcasting the crystals over the pond surface. Two cages containing two bluegills each were placed in each pond 24 hours after the potassium permanganate treatment. One cage was put in the surface waters, and the other cage was placed 5 feet deep. Within the next 24 hours, the mortality in these cages ranged from 50 to 100 percent, except in two ponds where there were no deaths in the cages at 5 feet.

Another group of eight 0.25-acre ponds was treated with 0.05 p. p. m. rotenone on June 1, 1955. Twenty-four hours later these ponds received a treatment with a 2-p. p. m. concentration of potassium permanganate as a water solution. On the following day two cages containing 10 fathead minnows were placed in each pond. One cage was put in the surface water, and the other cage was placed 5 feet deep. When checked 24 hours later, there was one dead fish in one of the surface cages and one dead fish in one of the cages at 5 feet.

These field tests showed that 2 parts of potassium permanganate detoxified 0.05 part of rotenone in pond waters, and that this concentration of potassium permanganate was not lethal to bluegills or fathead minnows 24 hours after application. The tests also indicated that the application of potassium permanganate as a water solution was more effective in detoxifying the rotenone than an application of potassium permanganate in crystalline form.

USE OF POTASSIUM PERMANGANATE IN ROTENONE-SAMPLING OF STREAMS

A further test of the effectiveness of potassium permanganate in counteracting the toxicity of rotenone was conducted by Dr. J. S. Dendy and his fishery class during the fall of 1954 in Uchee Creek, Russell County, Alabama. For several years Dendy and his classes have used rotenone to sample fish populations in small streams near Auburn. In these studies a seine has always been placed across the stream on the downstream edge of the sample area. This seine prevented movement of fish into and from the poisoned area on the downstream side and gave some idea of the kill to be expected from the drift of the poison with the current. Those fish killed below the seine were recorded separately. The kills that were obtained in the sample area and in the stream below are shown in Table III.

TABLE III

TOTAL NUMBER OF POUNDS OF FISH COLLECTED BY USING ROTENONE WITH AND WITHOUT POTASSIUM PERMANGANATE

Year	Location	*Total Number of Pounds of Fish Collected*		*Chemicals Used*	
		In Sample Area	*Below Sample Area*	*Rotenone in Sample Area (p. p. m.)*	*Potassium Permanganate Below Sample Area (pounds)*
1952	Sougahatchee Creek:				
	Station 3	3.73	3.38	0.1	0
	Station 6	3.33	.56	.1	0
	Station 7	5.84	4.32	.1	0
	Loblockee Creek:				
	Station 5	2.84	3.29	.1	0
1953	Little Uchee Creek:				
	Station 1	0.93	0.45	0.1	0
	Station 1A	.09	.38	.1	0
	Station 2	1.30	.35	.1	0
	Station 3	.28	.21	.1	0
	Station 4	.95	6.63	.1	0
	Station 5	6.20	41.20	.1	0
1954	Uchee Creek:				
	Station 1	5.34	0	0.1	6.0
	Station 2	17.70	0	.1	15.0
	Station 3	7.30	0	.1	15.0

During the fall of 1954, Dendy used the same techniques of sampling the streams as in previous years. In addition, burlap bags containing potassium permanganate were dragged back and forth across the stream just below the downstream seine throughout the period the fish were dying in the sample area. The pounds of fish killed by the various methods are compared in Table III.

It is evident that in these three tests the postassium permanganate was very efficient in counteracting the lethal effects of rotenone on the downstream side of the seine. A very interesting event occurred at Station 3 in Uchee Creek. During the sampling operation, a fisherman some 100 yards below the seine was catching fish. The water in the area was then a dark purple, owing to potassium permanganate.

USE OF POTASSIUM PERMANGANATE TO REDUCE KILL OF LARGEMOUTH BASS AFTER PARTIAL POISONING OF PONDS WITH ROTENONE

Considerable numbers of largemouth bass are often killed in the course of poisoning the edges of farm fishponds to reduce the populations of small and intermediate-sized bluegills (Swingle, Prather, and Lawrence, 1953). The struggling of the bluegills may attract these bass into the poisoned area, or they may move into the area in the evening or after nightfall to feed. As the concentration of rotenone in the edge of a partially poisoned pond exceeds 0.05 p. p. m., many of the bass that come into the edge may be killed even some hours after the rotenone has been applied.

The application of potassium permanganate to counteract the toxicity of rotenone to fish after partial poisoning was tried on several larger ponds operated by the station. The rotenone was applied in a double line around the ponds and allowed to kill small and intermediate-sized bluegills, usually for 1.5 to 2 hours. The edges of the ponds were then treated with potassium permanganate by dragging burlap bags containing the chemical behind motorboats. The amount of rotenone used for partial poisoning of each pond and the amount of potassium permanganate used to detoxify the rotenone are noted in Table IV. Also shown in Table IV are the numbers of bass killed in these ponds by partial poisoning with and without treatments of potassium permanganate.

TABLE IV

NUMBERS OF LARGEMOUTH BASS KILLED BY PARTIAL POISONING OF PONDS BY USING ROTENONE WITH AND WITHOUT POTASSIUM PERMANGANATE

Pond Area (acres)	*Rotenone Used (pounds)*	*Potassium Permanganate Added (pounds)*	*Large Bass Killed (number)*
26	5.6	100	7
26	2.0	0	38
12	2.0	0	29
22	3.2	0	53
26	2.4	100	14

USE OF POTASSIUM PERMANGANATE TO CONFINE FISH-KILL TO AREA WHEN SAMPLING FISH POPULATIONS WITH ROTENONE

It is often desired to sample the standing crop of fish in a body of water by poisoning a selected area with rotenone and then collecting the dead fish. When such operations are attempted, difficulties with movement of the rotenone outside the sample area are often encountered. Such movement will kill fish that were outside the selected area, thus giving erroneous results.

In an attempt to reduce as much as possible this kill of fish outside a pond area selected for sampling, the following field techniques were tried. On August 9, 1955, a 1-acre sample area of a 22-acre pond was marked and poisoned with a 0.05-p. p. m. concentration of rotenone. Concurrent with the application of rotenone, potassium permanganate at a concentration of 2 p. p. m. was applied a few feet to the outside of the sample-area boundaries by towing bags containing the chemical behind a motorboat. On the following day, another 1-acre sample area in this pond was selected and treated in the manner just

described. A 1-acre sample area in a 26-acre pond was also treated in the same manner on this second date.

The field observations on the effectiveness of this potassium permanganate block were very favorable. In all three areas the number of fish in distress outside the poisoned area was negligible, estimated to be less than 2 percent of the total number killed. The second-day pickup was also small, indicating that the poisoned waters did not move as a block into an untreated area and kill large numbers of fish. Also, there were very few bass to be picked up on the second day, contrary to the situation when potassium permanganate was not used.

SUMMARY AND CONCLUSIONS

It is evident that potassium permanganate is capable of counteracting the toxicity of rotenone to fish and/or oxidizing rotenone to a nontoxic form. Where tap water was used in aquaria, the toxicity of 0.05 p. p. m. rotenone was effectively counteracted by means of 2 p. p. m. potassium permanganate over a temperature range from 44° to 81° F.

In field trials on ponds and streams, concentrations of potassium permanganate ranging from 2.0 to 2.5 p. p. m. successfully neutralized the toxicity of a 0.05-p. p. m. concentration of rotenone.

In aquaria at a temperature of 81° F., the minimum concentration of potassium permanganate that killed bluegills was 3 p. p. m.; largemouth bass, 4 p. p. m.; and fathead minnows, 5 p. p. m. At a temperature of 58° F., the minimum concentration of potassium permanganate that killed bluegills and largemouth bass was approximately 5 p. p. m.

The use of potassium permanganate apparently had no harmful effects on the waters treated; rather, it is probable that, owing to its fungicidal action, this chemical may have beneficial effects on any fish present or that are added immediately to such treated waters.

Further research on all phases of this detoxifying technique is needed. There is need for more information concerning the concentrations of rotenone and potassium permanganate that are toxic to various fish, as well as the proportional amounts of potassium permanganate required to neutralize completely the rotenone in waters containing different concentrations of salts and organic matter. The appropriate concentrations and method of applying the potassium permanganate to the poisoned area are virtually untouched fields of research.

LITERATURE CITED

Krumholz, L. A. 1948. The use of rotenone in fisheries research. Jour. Wildl. Mgt. 12(3) : 305-317.

Leonard, J. W. 1939. Notes on the use of derris as a fish poison. Trans. Am. Fish. Soc. 68 (1938) : 269-280.

Prather, E. E., J. R. Fielding, M. C. Johnson, and H. S. Swingle. 1953. Production of bait minnows in the Southeast. A. P. I. Agr. Expt. Sta. Cir. 112, 72 pp.

Solman, V. E. F. 1949. History and use of fish poisons in the United States. Publ. Dominion Wildl. Serv. 15 pp. Ottawa.

Swingle, H. S., E. E. Prather, and J. M. Lawrence. 1953. Partial poisoning of overcrowded fish populations. A. P. I. Agr. Expt. Sta. Cir. 113, 16 pp.