RECENT INVESTIGATIONS ON THE USE OF SODIUM ARSENITE AS AN ALGACIDE AND ITS EFFECTS ON FISH PRODUCTION IN PONDS

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The control of filamentous algae and submerged weeds in farm fish ponds is one of the major problems confronting biologists in the Southeast. The presence of filamentous algae or submerged weeds in ponds will seriously reduce fish production by robbing the phytoplankton of plant nutrients present in pond water, as well as seriously interfering with harvest of fish either by fishing or draining. In addition weed growths may provide so much cover that bass cannot adequately reduce the number of small fish and the ponds tend to become unbalanced. Control of underwater weeds and filamentous algae is necessary in the southern states to reduce breeding of anopheline mosquitoes, which are the vectors of malaria.

Apparently Surber (1931) was the first to recommend the use of sodium arsenite for chemical control of certain filamentous algae and submerged weeds in ponds. The concentrations of sodium arsenite recommended by various investigators has varied from 2.0 p.p.m. As_2O_3 (Surber, 1931) to 10 p.p.m. As_2O_3 (Mackenthum, 1955). Those generally recommended and used in ponds vary from 4.0 to 8.0 p.p.m. As_2O_3. According to Mackenthum (1955), bluegill and crappie fingerlings survived a concentration of 12 p.p.m. As_2O_3 for 6 days. In aquaria experiments conducted at this Station, largemouth bass fingerlings (1 inch in length) withstood a concentration of 10 p.p.m. As_2O_3 for one week. Surber and Meehean (1931) indicated that mayfly nymphs and chironomid larvae were killed at concentrations of 2.5 to 4.0 p.p.m. As_2O_3. Damsel and dragonfly nymphs were able to withstand concentrations of sodium arsenite ranging from 10.5 to 21.0 p.p.m. As_2O_3. These latter invertebrates, however, are not of great importance as fish food in farm ponds.

This investigation had two objectives: first, to determine the effectiveness of sodium arsenite as a control agent for *Pithophora;* and second, to determine the effects of repeated applications of 4 and 8 p.p.m. As_2O_3 as sodium arsenite on bottom organism and fish production in treated ponds. While such rates of application may seem high they are not unreasonable since many hatcheries and pond owners have exceeded these rates of treatment in trying to control *Najas, Hydrodictyon,* and *Pithophora.*

EFFECTS OF SODIUM ARSENITE AS AN ALGACIDE

Pithophora: Experiments conducted at this Station indicated that the branched algae *Pithophora* may be controlled by one or more applications of sodium arsenite at a concentration of 4.0 p.p.m. As_2O_3. However, there were some instances where two applications of sodium arsenite at the above concentration gave poor control of this alga.

Best results were obtained if sodium arsenite was applied while the alga was in an active growing stage. Much poorer control resulted when the filaments of the alga became dark and were filled with akinetes. This appeared to result from germination of large numbers of akinetes in these filaments following the sodium arsenite treatments. Applications of sodium arsenite to ponds in the spring before thermal stratification or in the fall after the overturn of the waters occurs, appeared more effective than applications made during hot weather. When the ponds waters were thermally stratified, poor kills of *Pithophora* at depths greater than 4 to 5 feet were often encountered from treatments with sodium arsenite.

In several ponds that were treated with 4 or more p.p.m. As_2O_3 as sodium arsenite, good control of *Pithophora* was obtained for one summer, but in the following season the ponds were again infested with this alga. This growth apparently came from akinetes that were unaffected by the sodium arsenite.

Hydrodictyon: In hatchery ponds the net alga, *Hydrodictyon,* has been successfully controlled by treating with sodium arsenite just as the ponds were starting to refill. The water was allowed to collect until there was a maximum depth of 2 feet over the bottom, then a concentration of approximately 4.0 p.p.m. As_2O_3 as sodium arsenite was applied over the water surface. These applications were made in late winter or early spring. No further trouble with *Hydrodictyon* occurred during the spring or summer.

On one pond where this practice was neglected, a heavy growth of *Hydrodictyon* appeared during the early summer. This alga was treated with approximately 2 p.p.m. As_2O_3 as sodium arsenite, which broke most of the attached masses from their anchorage. These filaments floated to the surface but continued to live. Three subsequent applications of sodium arsenite at 2-week intervals, using approximately 3 p.p.m. As_2O_3 for each treatment failed to control this alga.

It appears that *Hydrodictyon* may reach a stage of growth where the cell walls become resistant to chemical penetration.

METHOD OF APPLYING SODIUM ARSENITE FOR CONTROL OF ALGAE

The method of applying sodium arsenite recommended by Surber (1931) was to spray a dilute solution of the chemical over the weed masses, being especially careful to maintain the same concentration over each section of the pond. This method of application is hazardous to the operator, and in addition drift deposits of sodium arsenite may collect on marginal vegetation all around the pond. These deposits will kill such vegetation and are dangerous to grazing livestock.

A simple method of applying liquid sodium arsenite to ponds was developed to overcome these difficulties. This consisted of placing a drum containing the arsenite in a boat powered by an outboard motor and running the concentrated chemical through a valve and hose attachment directly from the drum into the propellor wake of the outboard motor (Figure 1). The boat was run in ever decreasing circles on the pond to help ensure fairly even distribution of the arsenic. This method of application prevented any dangerous contact with the chemical by the operators, and there was no drift of the poison onto vegetation above the water line.

To check uniformity of distribution of the arsenite applied by this latter method, samples of water were collected at different points and depths from several large ponds at various times intervals following treatments. The arsenic content was determined by the Gutzeit method. These analyses indicated a fairly uniform concentration of approximately 3 p.p.m. As_2O_3 in the upper 2.5 feet of water within 24 hours after treatment. At this time the concentration in waters at depths greater than 6 feet was from a trace to 0.3 p.p.m. As_2O_3. The concentration in the upper 2.5 feet of water dropped to approximately 1.5 p.p.m. As_2O_3 within 48 hours after treatment and continued to decrease gradually for the next 3 weeks. In the deeper waters 48 hours after treatment, the concentration was approximately 0.5 p.p.m. As_2O_3 and remained fairly constant for the next 3 weeks. At the end of 24 days, the concentration in the top waters of the ponds ranged from 0.3 to 0.5 p.p.m. while in the deeper portions (8 to 12 feet) the concentration ranged from 0.3 to 0.8 p.p.m. As_2O_3. Six months after treatment of a 22-acre pond with 4 p.p.m. As_2O_3 as sodium arsenite, there was still a concentration of 0.06 p.p.m. As_2O_3 in the surface water.

PHOSPHORUS CONTENT OF WATER FOLLOWING ARSENITE TREATMENT

In one large pond treated with sodium arsenite, the phosphorus content of the water increased from a trace immediately prior to treatment to approxi-

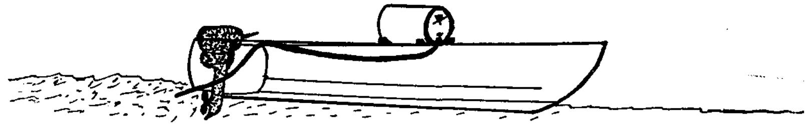

Figure 1. Sketch showing the arrangement of a sodium arsenite drum

mately 0.6 p.p.m. 5 days later. Similar results were obtained in other ponds treated with sodium arsenite. It would appear that the arsenic replaced phosphorus in the bottom muds and perhaps in the plankton as well. There was no death of plants during this period to account for this release of phosphorus. It is probable that this increase in soluble phosphorus partially explains why ponds treated with sodium arsenite often produce a heavy plankton growth within a few days after treatment.

EFFECTS OF SODIUM ARSENITE ON BOTTOM ORGANISMS AND FISH PRODUCTION IN PONDS

Six one-quarter-acre ponds were stocked with bluegills (*Lepomis macrochirus*), at a rate of 300 per acre, on May 10 and 11, 1955. All ponds were fertilized at the same rate and on the same dates. Two of these ponds were randomly selected as controls and received no treatment of sodium arsenite. Two other ponds received two applications of 4 p.p.m. As_2O_3 and the remaining two ponds received two applications of 8 p.p.m. As_2O_3. The applications of sodium arsenite were made on June 14 and July 15, 1955, the treatment dates being one month apart. This interval was selected, since this was about the time that had elapsed when two applications of sodium arsenite had to be made to obtain control of *Pithophora* in other ponds.

Chemical analyses of the pond water showed a fairly persistent concentration of As_2O_3 in these pond waters 2 months after the last treatment of sodium arsenite was applied (approximately 1 p.p.m. As_2O_3 in ponds receiving 4 p.p.m. applications and 3.5 p.p.m. As_2O_3 in ponds receiving 8 p.p.m. applications).

Samples of bottom organisms in the control and treated ponds were collected every 2 weeks throughout the summer. In the ponds that received two applications of 4 p.p.m. As_2O_3, the average number of bottom organisms per square foot was 34 percent less than the mean for the control ponds, whereas, in the two ponds that received two applications of 8 p.p.m As_2O_3, the average number was reduced by 45 per cent.

The ponds were drained on September 23 and 24, 1955. The average production per acre of bluegills for the control ponds was 144 pounds; for the ponds treated with two applications of 4 p.p.m. As_2O_3, production was 84 pounds; and, for the ponds treated with two applications of 8 p.p.m. As_2O_3, it was 52 pounds (Table I). This was an average reduction of 42 and 65 percent, respectively, for the two rates of application of arsenic. This decrease was accounted for by the reduction in numbers of small fish.

TABLE I

SUMMARY OF BOTTOM ORGANISM AND FISH PRODUCTION TESTS (5 MONTHS DURATION) IN PONDS TREATED WITH SODIUM ARSENITE DURING 1955, 1956

Ponds	*F-14*	*F-15*	*F-20*	*F-21*	*Control*	*Control*
1955—Sodium arsenite applications *	Two 4 p.p.m.	Two 8 p.p.m.	Two 8 p.p.m.	Two 4 p.p.m.	None	None
Bottom organism prod. (% of control mean)	105.1	34.5	77.2	25.5	75.1	124.9
Bluegill production † (pounds per acre)						
1 inch group	74.4	5.3	2.0	14.8	75.2	77.5
2 " "	12.4	1.2	15.4	3.2	22.4	21.2
3 " "	1.6	0.5	2.6	0.1	...	...
4 " "	0.2	0.8	..	..	...	...
5 " "	..	..	..	..	...	...
6 " "	7.3	14.2	7.6	2.6	12.6	20.0
7 " "	29.7	20.8	24.4	13.0	26.0	30.0
8 " "	5.0	2.4	6.4	5.0	...	...
9 " "	..	..	..	..	3.8	...
TOTAL	129.6	45.2	58.4	38.7	140.1	148.7

TABLE I—*Continued*

SUMMARY OF BOTTOM ORGANISM AND FISH PRODUCTION TESTS (5 MONTHS DURATION) IN PONDS TREATED WITH SODIUM ARSENITE DURING 1955, 1956

Ponds	*F-14*	*F-15*	*F-20*	*F-21*	*Control*	*Control*
Fish production (% of control mean)	89.8	31.3	40.4	26.8	97.0	103.0
Management between 1955 and 1956 Tests	Refilled and drained once dry 4 months		Refilled and drained two times		Refilled and drained two times	
1956—Sodium arsenite applications*	4 p.p.m.	4 p.p.m.	4 p.p.m.	4 p.p.m.	None	None
Bottom organism prod. (% of control mean)	220.0	71.9	88.6	46.3	72.1	127.9
Bluegill production ‡ (pounds per acre)						
1 inch group	0.4	0.5	22.1	10.5	23.9	34.0
2 " "	0.2	0.2	20.2	49.7	49.8	16.0
3 " "	. .	0.2	32.1	3.3	5.0	. .
4 " "	4.0	0.8	16.0	1.5	4.8	1.2
5 " "	45.2	74.5	36.4	54.8	55.6	70.0
6 " "	35.2	10.0	0.6	35.6	10.8	18.0
TOTAL	85.0	86.2	127.4	155.4	149.9	139.2
Fish production (% of control mean)	58.8	59.6	88.1	107.5	103.7	96.3

* Expressed as p.p.m. As_2O_3.
† Ponds stocked with 300 bluegills per acre on May 10-11, 1955. Ponds drained September 23-24, 1955.
‡ Ponds stocked with 1,000 bluegills per acre on May 17, 1956. Ponds drained October 17, 1956.

As a result of the 1955 tests, numerous questions arose concerning causes of the decreases in bluegill production (primarily reproduction) in ponds treated with sodium arsenite. Notable among these questions were the following:

1. Would a single application of 4 p.p.m. As_2O_3 as sodium arsenite materially reduce bluegill production?
2. Would repeated or yearly applications of sodium arsenite to a pond cause an accumulative decrease in fish production?
3. What factors were primarily responsible for reduction or absence of bluegill reproduction in ponds receiving heavy applications of arsenic?
4. Could arsenic be eliminated from a pond by repeated draining and refilling?

The 1956 tests were set up to obtain as much information as possible concerning the foregoing questions. The one-quarter-acre ponds used in that year's tests were treated with 4 p.p.m. As_2O_3 as sodium arsenite. Included in this series were two ponds that had not received a previous sodium arsenite treatment, the two ponds that received two applications of 4 p.p.m. As_2O_3 in 1955, the two ponds that got two treatments of 8 p.p.m. As_2O_3 in 1955, and two untreated control ponds.

A note concerning the operation of the previously treated ponds from October, 1955 to May, 1956 is necessary. Two ponds, one that had received 4 p.p.m. and one that had received 8 p.p.m. As_2O_3, were drained in September, immediately refilled, again drained in December and left dry until May, 1956. The other two previously treated ponds were refilled in October, drained in December, and refilled. One of these ponds was stocked with golden shiner minnows. The minnows remained in this pond until May, 1956. During that period approximately 400 pounds of organic meals was applied as feed. The other pond had no fish and no feed, but was also drained in May, 1956. Both ponds were immediately refilled following the May draining.

The ponds used in the 1956 tests were stocked with bluegills on May 17, 1956. Approximately nine weeks later, the ponds were treated with sodium arsenite. During this pre-treatment period, the bluegills reproduced (as indicated by seining) in all ponds except the two (F-14, F-15) that were allowed to remain dry four months during the winter of 1956. On July 24 the ponds were treated with sodium arsenite at the rate of 4 p.p.m. As_2O_3. There were no young bluegills in these two ponds (F-14, F-15) by mid-August, but a light hatch was found by seining in mid-September.

Samples of bottom organisms were collected at two-week intervals throughout the test period. In the two ponds that received two applications of 4 p.p.m. As_2O_3 in 1955 and one application of 4 p.p.m. As_2O_3 in 1956, the average number of bottom organisms was 33.0 percent greater than in the control ponds. However, in this pair of ponds the one that was drained and refilled twice between the 1955 and 1956 experiments had a 53.7 percent reduction in number of bottom organisms. The pond drained and refilled only once and left dry four months between the 1955 and 1956 experiments had a 120 percent increase in numbers of bottom organisms. In the other pair of ponds that had two applications of 8 p.p.m. As_2O_3 in 1955 and one application of 4 p.p.m. As_2O_3 in 1956, the average number of bottom organisms was 20 percent less than in the control ponds. The pond that was drained and refilled two times and received organic meals between the 1955 and 1956 experiments had a 11.4 percent decrease in numbers of bottom organisms, whereas, the pond refilled and drained only once and left dry for four months between the 1955 and 1956 experiments had a 28.1 percent decrease in numbers of bottom organisms.

In addition to the bottom organism studies, tow-net samples of the plankton were taken periodically during the summer of 1956. Prior to the treatment with sodium arsenite, there was a good population of microcrustacea in all ponds included in this test, except the two (F-14, F-15) that had been previously treated with sodium arsenite and had remained dry for four months during the winter of 1956. In these two ponds there was a scarcity of copepods and cladocera, but a considerable number of rotifers were present. Following the application of 4 p.p.m. As_2O_3 as sodium arsenite on July 17, there was practically a complete kill of copepods and cladocera in all treated ponds, plus a severe reduction in the rotifer population. This absence of copepods and cladocera persisted in most ponds until mid-August. However, in the two ponds that had remained dry for four months between the 1955 and 1956 experiments, there was a scarcity of microcrustacea until the ponds were drained in October, 1956.

The ponds were drained on October 17, 1956 and the fish counted and weighed (Table I). In the two ponds receiving only 4 p.p.m. As_2O_3 in 1956, there was contamination by other species in one and unexplained overstocking of the bluegills in the other. Thus, due to these interferences, no reliable information on bluegill or bottom organism production was obtained. The average production of bluegills in the two ponds that had received two applications of 4 p.p.m. As_2O_3 in 1955 and one application of 4 p.p.m. As_2O_3 in 1956 was 16.8 percent less than in the control ponds. Of these two ponds, the one that was drained and refilled two times between the 1955 and 1956 experiments had a 7.5 percent increase in bluegill production, whereas, the pond drained and refilled only once and left dry for four months had a 41.2 percent reduction in bluegill production. In the two ponds receiving two applications of 8 p.p.m. As_2O_3 in 1955 and one application of 4 p.p.m. As_2O_3 in 1956, there was an average of 26.1 percent reduction in bluegill production as compared with that of the control ponds. In the pond that was refilled and drained two times and received organic meals between the 1955 and 1956 experiments, there was a 11.8 percent decrease in bluegill production. In the other pond refilled and drained only once and left dry for four months, there was a 40.4 percent reduction in bluegill production.

The exact cause or causes of these differences in each pair of treated ponds in the 1956 tests are unknown. It was probably because of leaching resulting from the second refilling and draining. This indicates the necessity of further investigation into the beneficial effects of leaching of the arsenic from a treated pond either by a heavy overflow or by draining.

A summary of the 1955 and 1956 arsenic treatments, management practices between tests, the bottom organism and fish production for each year is given in Table I.

EFFECTS OF SODIUM ARSENITE ON BLUEGILL AND BASS REPRODUCTION

In a number of lakes in Alabama that had been recently treated with sodium arsenite, delayed bluegill reproduction as well as poor growth of small bass was observed during the early summer of 1956. The retarded bluegill reproduction and poor growth of bass was, in general, more pronounced in those lakes treated in the early spring of 1956 than in those treated in the fall of 1955. However, in some fall-treated lakes where there was no overflow of water during the winter (1955-56), a considerable concentration of arsenic was still present in the water during the spring of 1956. In one such case, a pond was treated in early summer of 1954 and again in 1955 with 4 p.p.m. As_2O_3. There was no overflow of water during the winter of 1954-55 of 1955-56 and the water from this pond contained a concentration of 1 p.p.m. As_2O_3 in May, 1956. The bass in this pond reproduced lightly in 1956, but greaw at an abnormally slow rate and the bream did not reproduce until the latter part of June, one month after the normal spawning date for this section.

In one experimental pond two 4 p.p.m. As_2O_3 applications on June 14 and July 11, 1955, reduced but failed to control *Pithophora.* This chemical was also responsible, apparently, for the repression of reproduction of fathead minnows for at least one month following the second application. There was no overflow of water from this pond throughout the entire test period. The arsenic concentration in the pond water 10 weeks following the second application of sodium arsenite was 0.7 p.p.m. As_2O_3.

These data all indicate the harmful effects that concentrations of 4 p.p.m. or greater As_2O_3 as sodium arsenite may have upon fish populations in treated ponds. However, there are indications that the arsenic may be partially removed from the bottom soils of ponds by repeated draining and refilling or by heavy winter overflow. The use of organic meals as fish feeds may also be of some benefit in offsetting the harmful effects of arsenic on fish production in a pond.

It is still unknown what effects the build-up of arsenic in soils by repeated applications of 4 p.p.m. As_2O_3 will have on fish production. It is evident that more than one such application during a single season will reduce bluegill production.

SUMMARY

A new method of applying sodium arsenite to fish ponds for algae control employed the use of a valve and hose attachment to the drum of concentrated chemical, thus permitting the release of the chemical directly into the propellor wake of an outboard motor. This prevented the chemical from coming in contact with the operator, and also prevented hazardous drifts of arsenic onto terrestial vegetation.

Chemical analyses of the water from ponds treated with 4 p.p.m. As_2O_3 as sodium arsenite indicated a uniform distribution (approximately 3 p.p.m. $As_2 O_3$) of arsenic in the upper 2.5 feet of water within 24 hours after treatment. The amount of soluble arsenic was rapidly reduced by organic and inorganic combination and, at the end of 24 days after treatment, the concentration from the surface to a depth of 12 feet ranged from 0.3 to 0.8 p.p.m. As_2O_3.

The use of one or more applications of 4 p.p.m. As_2O_3 as sodium arsenite will produce fairly satisfactory control of *Pithophora* in a majority of fish ponds if applied while the alga is in an active growing stage. However, under certain conditions two applications of sodium arsenite at the above rate have failed to give satisfactory control of *Pithophora* and *Hydrodictyon.*

In experimental ponds two applications of 4 p.p.m. As_2O_3 as sodium arsenite applied one month apart reduced the number of bottom organisms an average of 34 percent and reduced bluegill production an average of 42 percent as compared with those of the control ponds. Two applications of 8 p.p.m. As_2O_8 as sodium arsenite, applied one month apart, reduced the number of bottom organisms an average of 45 percent and reduced bluegill production an average of 65 percent as compared with production in control ponds.

In later experiments where one application of 4 p.p.m. As_2O_3 as sodium arsenite applied the following year to ponds that had the previous year received two applications of 4 p.p.m. As_2O_3, the average number of bottom organisms was 33 percent greater, but the bluegill production was an average of 17 percent

less than in control ponds. An application of 4 p.p.m. As_2O_3 to ponds that the previous year had received two applications of 8 p.p.m. As_2O_3 reduced the numbers of bottom organisms an average of 20 percent and reduced bluegill production an average of 26 percent. However, one pond in each of these tests had been drained and refilled only once and left dry for four months, and the other pond had been drained and refilled twice between the 1955 and 1956 tests. In each test the pond drained and refilled two times gave a higher bluegill production than did the ponds that were drained and refilled only once and left dry for four months between the tests.

In a number of lakes and ponds in Alabama that had been recently treated with sodium arsenite to control *Pithophora,* delayed bluegill reproduction as well as poor growth of young bass was observed during the early summer of 1956.

An application of 4 p.p.m. As_2O_3 as sodium arsenite to ponds killed all of the microcrustacae and greatly reduced the population of rotifers. This absence of microcrustacae existed for almost two months in experimental ponds. This absence of food for small fish probably explains, at least in part, the reduced numbers and poor growth observed in numerous ponds which had been treated with sodium arsenite.

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STRIPED BASS FOR ARKANSAS?

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The anticipation and chance of catching a trophy size, 20 to 30 pound fish should be reason enough for Arkansas' effort to establish striped bass (*Roccus saxatilis*) in its public waters. Requiring no special fishing skill, especially during the season when the striped bass are feeding on the schooling gizzard shad, makes them more desirable for a state which caters to the out-of-state and tourist fishermen.

From a biological standpoint, the striped bass might be the answer to a fisheries biologist's dream in the control of the ever present and usually overabundant gizzard and threadfin shad population. The striped bass is very vicious and predaceous (feeding extensively on gizzard shad, threadfin shad, and herring in the Santee-Cooper Reservoir, S. C.) always pursuing, darting in, slashing, and feeding on the schooling shad.

Also the striped bass, if established, would fill in a niche in the large impoundments in Arkansas. There are hundreds and hundreds of acres of open water bare of fish, except the gizzard shad which are numerous. It is thought that this would be a typical habitat of the striped bass, competing with no other predaceous fish in the open water.

Conscious of the need of striped bass in Arkansas, two biologists with the necessary equipment for marginal seining were detailed to the Santee-Cooper Reservoir, South Carolina, in early November, 1956, to secure a stock of fingerling bass. Since marginal seining for the small striped bass was relatively new, little encouragement, but full cooperation, was given by the South Carolina Wildlife Resource Department.

Upon arrival, a small holding pond was rented to hold the fish until a load was secured. After several attempts it was learned that night seining was more successful, and several professional minnow seiners were hired. The shore line