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FIELD TRIALS OF SODIUM PENTACHLOROPHENATE AS A MOLLUSCACIDE IN FLOWING WATERS IN BRAZIL (*)

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Schistosomiasis is endemic in Brazil and apparently spreading. New foci in widely separated areas are reported in increasing numbers. It is now recognized as one of the most important health problems of the country, especially in the northeastern part of Brazil where rural areas are entirely lacking in sanitary facilities. Washing, bathing, and laundering are usually done in streams and drainage ditches, and water for cooking and drinking is frequently procured from the same sources. *Tropicorbis centimetralis* and *Australorbis glabratus*, the snail intermediate hosts of *Schistosoma mansoni*, occur in such flowing waters very frequently. It was therefore felt that studies on the control of the intermediate hosts in flowing waters of this region would be of value, and a series of trials of molluscacides under field conditions would yield information applicable to other areas as well.

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This report is concerned with the results of field trials in streams with sodium pentachlorophenate, considered one of the most promising molluscacides on the basis of laboratory screening tests by Nolan, Bond, and Mann (1953) and of field experiments in Puerto Rico, Brazil, Dominican Republic, Japan, and Africa. Experiments with this compound applied in irrigation ditches and ponds were reported by Nolan and Berry (1949), McMullen *et al.* (1948 and 1951), Hunter *et al.* (1952), Berry, Nolan and Oliver-Gonzalez (1950), and Pinto, Robert and Penido (1951). Vaughn *et al.* (in press) and Berry (manuscript) have also conducted experiments with this chemical in both static and flowing waters.

In this, the first of several papers on the efficacy of sodium pentachlorophenate under various field conditions in Pernambuco, it is proposed to report the results obtained in tests of the compound employed in various types of flowing streams. Because of the excellent results described in previous reports, it was considered worthwhile to ascertain the effect of the compound when applied under relatively disadvantageous conditions in the field. The trials were therefore set up on the basis of only a few controlled variables such as concentration and duration of treatment. This paper will describe some problems encountered in these studies, and it is hoped that it will provide some suggestions for further work on the application of the molluscacide in routine practice.

The physical features of Pernambuco, in the area where these studies were made, are typical of the most of northeast Brazil. Except for a very narrow littoral region along the Atlantic Coast, most of the area consists of low rolling hills. The elevation ranges from sea level to 300 feet near the coast to a 2000-foot high plateau about 100 miles inland. The plateau is intersected by numerous small rivers along which most of the villages and towns are located. Except during the rainy season, most of the streams are slow-flowing and often become reduced to numerous isolated pools and impounded waters. In the east almost all of this land is divided into large plantations devoted to the cultivation of one crop, sugar cane. Inland, beyond the 70- to 100-mile wide so-called green belt along the coast, the region is a sparsely populated semi-desert, and the incidence of schistosomiasis is very low.

Along the coast the temperature averages about 27° C. the year round, and there is little variation between day and night temperature. During the daylight hours temperatures as high as 38° C. were occasionally observed in parts of some streams but averaged about 28° C. It is slightly cooler during the rainy season from April to September. The annual rainfall ranges from about 50 to 95 inches, most of it falling from March to September.

The snail vectors of schistosomiasis, especially *Australorbis glabratus,* are rarely found in the largest streams, and they appear to prefer the slower and more shallow waters. They are most abundant near villages and small towns. It is interesting that *Tropicorbis* and *Australor-*

bis rarely, if ever, inhabit the same waters. As far as can be ascertained there is not a single proven instance where populations of both genera have been found together in the same area of a stream, although the reasons why they do not live together are not apparent. In Pernambuco, *Tropicorbis* is found in a greater variety of habitats than *Australorbis*, which appears to be more confined to areas that do not normally dry up during the rainless season.

During the two year period of observations snail populations appeared to be greatest during the rainy season and gradually decreased during the dry season when many streams dried up. Each year in the dry stream beds enough specimens of *Australorbis glabratus* and *Tropicorbis* species apparently survive the severe desiccation during the rainless periods to repopulate the waters when the rains come. In some permanent bodies of water, fluctuations in the size of snail populations were observed during the dry and rainy seasons. However, these variations in the number of living snails in these waters were always transitory.

MATERIAL AND METHODS

Commercial sodium pentachlorophenate, about 75 to 79 per cent active ingredient, was supplied as a dust and in one ounce briquettes.

The principal objection to this chemical is that it is extremely irritating to the mucous membranes, and the dust causes severe paroxysms of sneezing. Due to this property, man and animals avoid the chemical and are less likely to be poisoned. The compound killed fish and the edible Ampullarid snail which in some instances were consumed by the natives. Careful follow-ups of these people did not reveal a single case of internal or external poisoning.

The chemical was applied usually at the heads of streams and in some experiments at spaced intervals of about 1000 feet. The amount of chemical to be applied was calculated from the rate of flow for a given number of hours at selected levels downstream. In most streams the rate of flow was determined with the aid of a pigmy current meter. In small brooks it was more convenient to construct a weir and determine the volume of water from the overflow. The briquettes dissolved so rapidly that the actual rate at which the chemical was applied was different from the calculated rate. For this reason the "rate of application" for each experiment was determined from the actual time required for the total amount of compound applied to go into solution.

One method of application consisted of placing the desired number of briquettes in muslin bags which were then suspended in the running water. By another method briquettes, supported on a fine mesh copper screen, were suspended in the water near the surface. The "drip method" was employed to control the rate of application of the molluscacide for a desired number of hours. This was accomplished with an apparatus (Haskins and Dobrovolny, 1953) designed to give a uniform and continuous delivery of the chemical in aqueous solution. Large pools, bogs, and standing water along the banks of some streams were treated with the chemical in the form of wet sprays applied with a "SureShot" hand sprayer, dusts applied with the "Hudson" rotary duster, or with a moist sawdust preparation which was soaked in an aqueous solution of sodium pentachlorophenate (Kuntz, 1951) and applied by hand. In other areas the chemical dust was applied to snail-infested wet banks of the stream.

The rate and extent of dispersion of sodium pentachlorophenate in flowing waters were determined from tests of samples of water collected at selected stations in the streams. The intervals between the stations ranged from 100 to 1500 feet and averaged 500 feet. The readings were made at regular time intervals and continued, usually, until sublethal concentrations of the compound were obtained. The method employed for determining microgram quantities of the chemical was that developed by Haskins (1951).

The last pre-treatment snail survey of each stream was made shortly before the chemical was applied. Post-treatment surveys were made daily the first three days following treatment, then once each during the first, second, and third weeks and about once each month thereafter. The post-treatment surveys were continued usually until marked increases in the snail populations were obvious. In some streams the snail surveys were made during both dry and rainy seasons before the chemical was applied. Streams located as near as possible and comparable to the experimental waters were selected for controls. These were surveyed for snails at monthly or more frequent intervals.

Before making snail surveys markers were placed at 100 foot intervals along the course of the stream. The number of snails collected from each 100 foot long segment was recorded. Collections were made by taking one dip, with a metal dipper-shaped sieve measuring about 8 inches in diameter by 6 inches in depth and fitted to a long wooden handle, from each linear foot along the margin of the stream. In wide water, collections were also made from the middle of the stream. By this method the entire length of each stream was sampled. In some streams population counts were also made from quadrates of five square feet. Comparisons of the two methods indicate that they yield about the same average number of snails in well populated areas. In sparsely populated areas more quadrates were examined. However, in very sparsely populated areas examination of the entire waters was more dependable because of the limited area that could be surveyed in a quadrate. An objection to the use of the quadrates was the extremely spotty distribution of the snail populations in most of the streams of this region. When the chemical was very effective, post-treatment examination of quadrates would be less likely to reveal the presence of living snails than would be the examination of larger areas.

In the field, the snails collected from each area were counted and the living specimens returned to the stream. All the dead and retracted snails were brought into the laboratory and placed in fresh pond water for further observation. Specimens that remained retracted were dissected to determine if they were alive.

The problem of sampling wild life populations is a difficult one. Considerable attention has been given to the statistical aspects of what constitutes a proper sampling technique by Ricker (1948), De Lury (1947), Anscomb (1948), and many others. There seems to be no general agreement other than the fact that animals are not randomly and uniformly distributed over an area.

It is recognized that there must be sampling variations in any estimate of the number of snails. Thus, a report of no snails means only that in the sample none was found. This may mean that actually none was present in the stream, or that so few were present that our sampling procedures missed them. No estimates of the sampling variance in the techniques used here are available. Some of the apparent and unexplained variations in the untreated streams, which are discussed below, are probably due to sampling variation as well as to true fluctuations in the population of the snails.

RESULTS

Dispersion of sodium pentachlorophenate. A greater than calculated decrease in the concentration and the quantity of sodium pentachlorophenate was observed at most test stations in the streams. In Figure 1, the per cent decrease in the amount of sodium pentachlorophenate at various points below the site of administration is shown for five representative streams. The "amount" is designed to represent the total quantity of the chemical it would have been possible to recover from the stream based on the concentrations observed at the different levels of the stream at various times until zero readings were obtained and on the rate of flow of the water. The rate of flow appeared to account for most of the differences in results observed between the streams. The great range in per cent disappearance is pointed up by the contrast (for example) between stream J-1, a rapidly flowing clear stream with a sandy bottom, and stream B-1, a sluggish stream with a muddy bottom which delivered a smaller volume of water in the lower than the upper levels. In general, there is a rather direct relation between the distance downstream and the per cent of chemical unaccounted for.

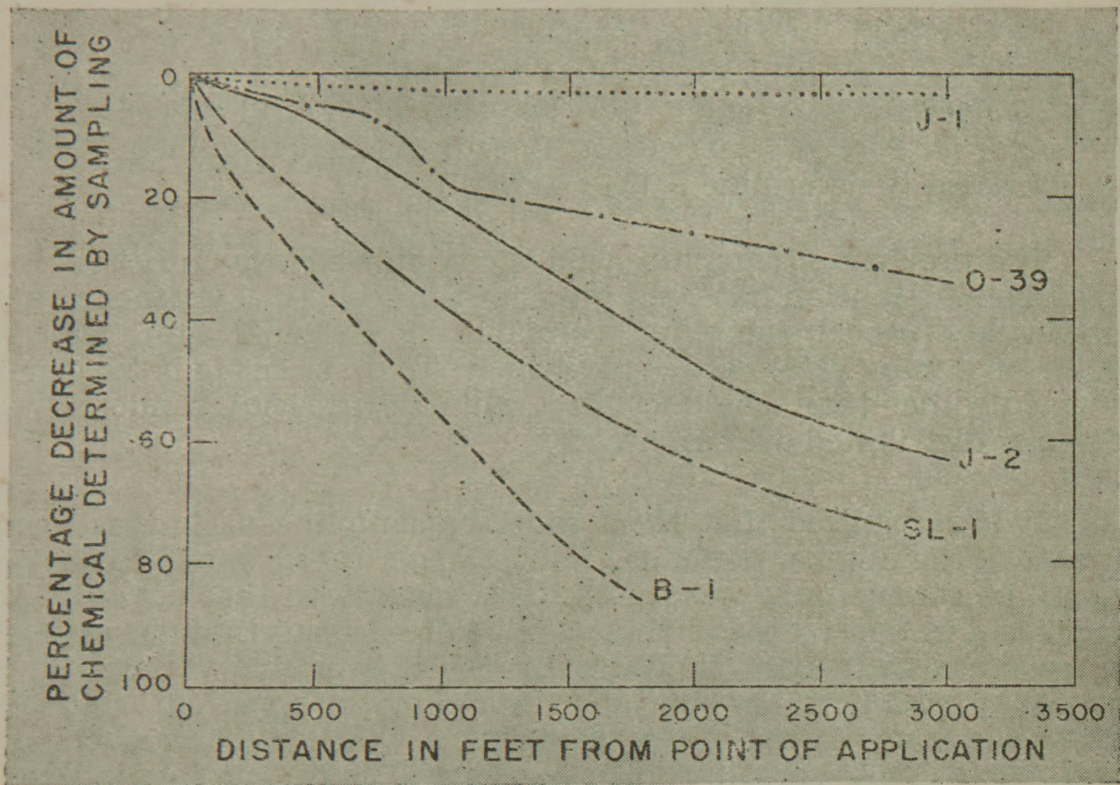

Figure 1. Disappearance of sodium pentachlorophenate in streams.

Figures are based on the total amounts calculated, on the basis of concentration at various times until zero readings were obtained, to have been carried to the points of sampling on the stream.

Stream	Rate of application	Method
J-1	10 ppm for 8 hours	Briquette
0-39	10 ppm for 24 hours	Drip
J-2	26 ppm for 12 hours	Drip
SL-1	10 ppm for 10 hours	Briquette
B-1	20 ppm for 24 hours	Drip

Disappearance of the chemical occurs with both the drip and briquette methods of application. The curves shown in Figure 1 have been smoothed from the actually computed recovery data. The occasional variations in the decline of sodium pentachlorophenate observed in different parts of a given stream also appeared to be due to differences in the rate of flow occasioned, for instance, by the presence of a large pool. In stream 0-39 (Figure 1), the most marked decline in the amount of chemical occured in the area from 0 to 1000 feet. The concentrations of the chemical as determined from samples of water taken at the 1000- and 2000-foot levels of these streams over a period of time are shown in Figures 2 and 3. The relationship of time to the disappearance of the chemical is indicated by examination of the results obtained at selected points in the above streams. In most slow flowing streams as illustrated by J-2, SL-1, and B-1 (Figures 2 and 3), the concentrations were lower and of longer duration than calculated. In the rapid streams

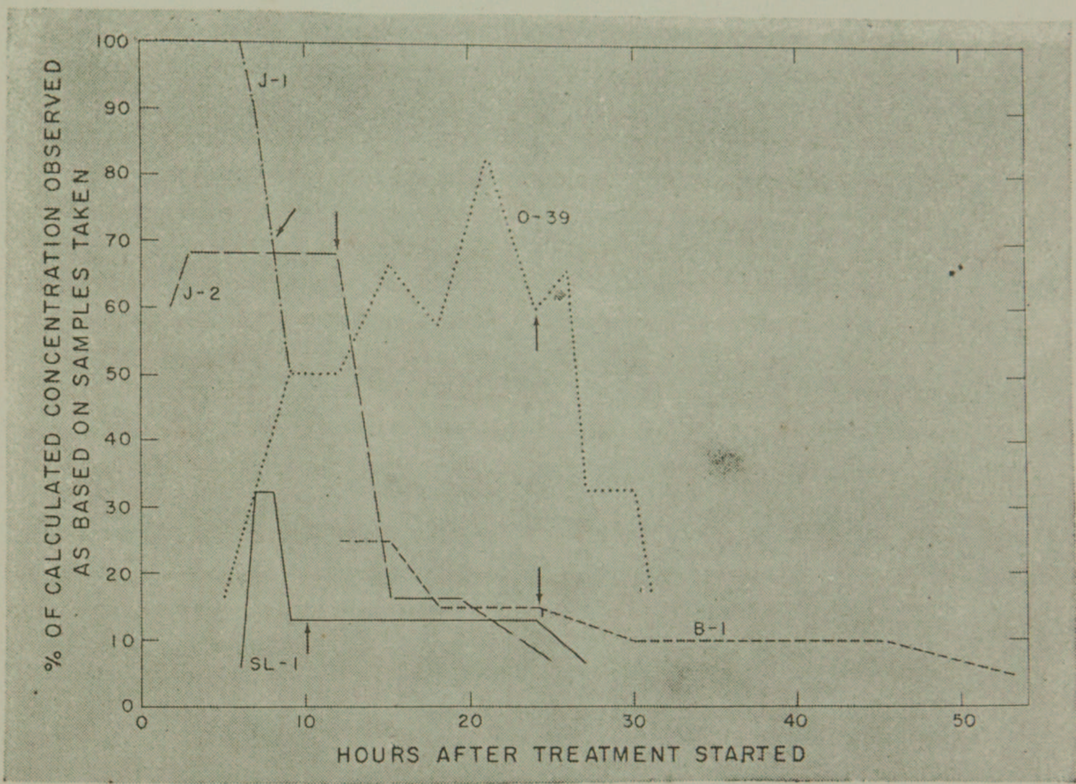

Figure 2. Concentration of sodium pentachlorophenate at 1000 foot level in streams over a period of time expressed in percentage of calculated expected concentration.

Stream	Rate of application	Method
J-1	11 ppm for 8 hours	Briquette
0-39	15 ppm for 24 hours	Drip
J-2	36 ppm for 12 hours	Drip
SL-1	15 ppm for 10 hours	Briquette
B-1	20 ppm for 24 hours	Drip

Arrows indicate end of period of application in each stream.

(J-1), the number of hours during which the concentration of the chemical remained at calculated levels was about equal to the hours of application. Observations on the rate of flow from all streams indicate that the velocity of the current is an important factor in dilution of the chemical. The velocity of the streams ranged from 0.077 to 1.50 feet per second and averaged about 0.55 feet per second. The velocity of 0.077 to 0.250 feet per second may be considered slow, 0.4 to 0.6 feet per second average, and 0.75 feet and above per second rapid for the brooks in this area. The mean reduction in the concentration in the rapid brooks was 20 per cent, in the moderate 50 per cent, and in the

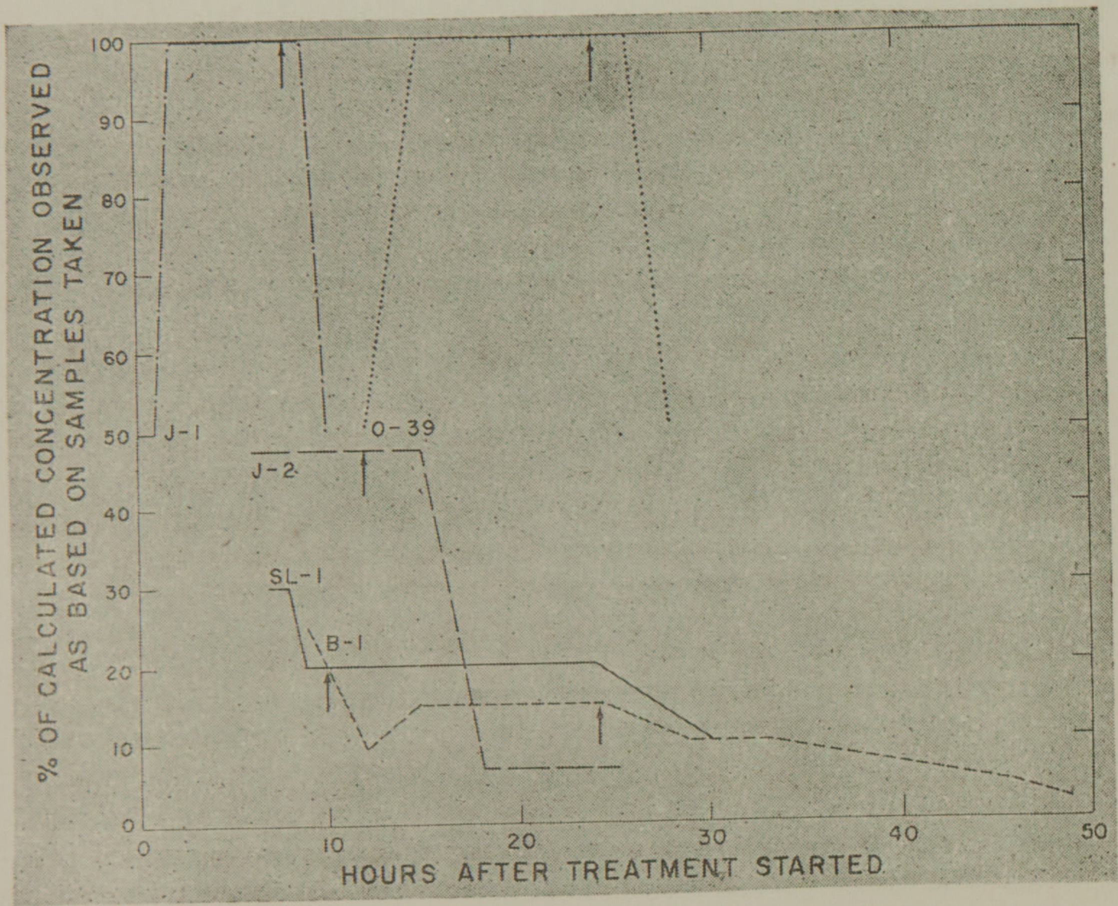

Figure 3. Concentration of sodium pentachlorophenate at 2000 foot level in streams over a period of time expressed in percentage of calculated expected concentration

Stream	Rate of application	Method
J-1	10 ppm for 8 hours	Briquette
0-39	10 ppm for 24 hours	Drip
J-2	31 ppm for 12 hours	Drip
SL-1	10 ppm for 10 hours	Briquette
B-1	20 ppm for 24 hours	Drip

Arrows indicate end of period of application.

slow about 80 per cent. The least dilution of chemical occurred in streams where the flow was rapid and few pools or ponds were present. In some instances most of the observed concentrations were as high as expected (0-39 at 2000 feet), but positive readings were obtained for considerably less than the calculated number of hours resulting in an over-all reduction in the amount of chemical that was carried past a given point in a stream. In only nine instances in all the tests conducted were the actual concentrations as high as calculated. In over one half of the places the determined concentrations were more than 50 per cent lower than expected. The actual data for one stream (J-2) are given as a sample in Table 1.

The concentrations of sodium pentachlorophenate obtained at different levels of streams are illustrated by the results of the experiment shown in Table 1. In this stream the chemical was applied at the zero foot level by the drip method at a rate calculated to give a concentration of 26 parts per million for 12 hours at about the 3700 foot level. The calculated concentrations to be expected at the 500, 1000, and 2000 foot levels were 51, 36, and 31 ppm, respectively. During treatment the concentrations observed at the above levels were considerably lower than calculated. There was a progressive decrease below the point of application, and at 3700 feet downstream the dilution was so great that only a trace of the chemical was observed. In the areas from 1000 to 2500 feet concentrations of 2 ppm (lethal) or more were maintained for 24 hours, although the chemical was applied for only 12 hours. Forty-three hours after treatment was completed only sublethal amounts of the compound were present. The experiment also shows the rate at which the chemical was carried down stream.

Some differences were observed in the results obtained with the briquette and drip methods of application of the compound. Some of the differences are shown by the results obtained 500 feet below the point of application in streams treated by these methods to produce concentrations of 20 ppm (Figures 4 and 5). Although the data from the two methods are not directly comparable because more chemical was applied by the drip method for a longer period of time, the differences are apparent. With the briquette method, the concentrations obtained were frequently much higher than calculated (stream A and D, Figure 4). The high concentrations were due to the rapidity of the dissolution of the briquettes. Had the same amount of chemical as used in the drip method (Figure 5) been applied in the form of briquettes (80 ppm), the concentrations would have been much higher than shown in Figure 4, and the duration of the concentration would probably have been a few hours longer. The rate at which the concentrations decrease after the period of application depends more on the velocity of the stream than on the quantity of chemical applied, (streams J-1 and B-1, Figures 2 and 3). With the drip method some higher concentrations occurred as a result of variations in the flow of the apparatus during adjustment when it was first set up in the stream (streams E and F,

TABLE I. DISPERSION OF SODIUM PENTACHLOROPHENATE IN STREAM J-2 TREATED BY THE DRIP METHOD FOR 12 HOURS

Time in hours after treatment started	Levels in stream where determinations were made							
	500 ft.	1000 ft.	1500 ft.	2000 ft.	2500 ft	3000 ft.	3500 ft.	3700 ft.
	Velocity in feet per second							
	—	.673		.638				.426
	Volume in liters per minute							
	83	114		138				162
	Calculated concentration in ppm for 12 hours							
	51	36		31				26
	Concentration in samples in parts per million							
1	100	—	—	—	—	—	—	—
2	50	25—	2+	—	—	—	—	—
3	25+	25	25	0	—	—	—	—
6	50	25	25—	10+	10	±	—	—
9	50	25	25—	10+	10+	10	5	0
12 *	25+	25	10+	10+	10+	10+	10	±
15	±	10	10	10+	10+	10+	10	±
19	±	10	5	2	2	10	10+	0
25	±	2	2	2—	2—	2	2	0
43	±	±	±	±	±	±	0	0
49	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0

* Treatment completed.

Figure 5). With both methods the concentrations observed were usually lower than calculated.

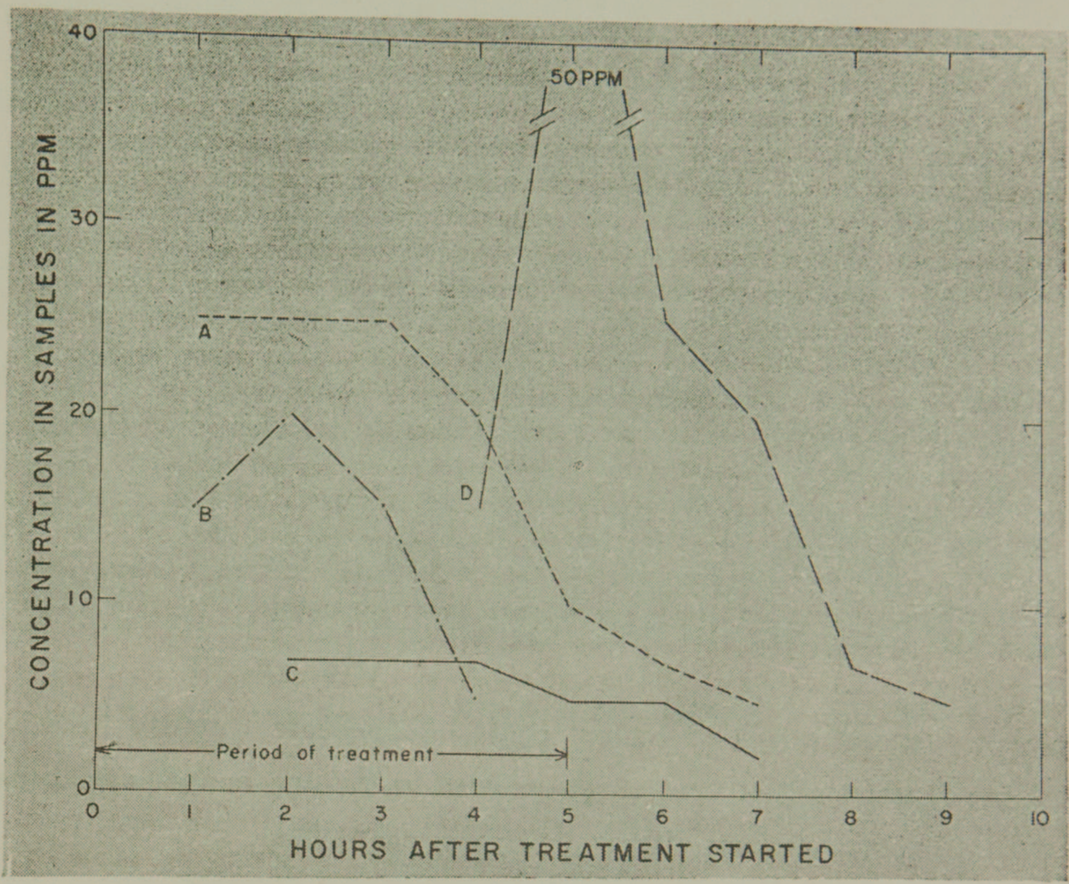

Figure 4. Concentration of sodium pentachlorophenate observed in samples taken at 500 foot levels of four streams treated by the briquette method at calculated concentrations of 20 parts per million.

There are indications that factors other than those mentioned may reduce the concentration of the chemical. Less reduction in the concentrations was observed in some streams with sandy beds (0-39, Figure 1) than in streams with muddy bottoms (SL-1, Figure 1). However, both sandy and muddy bottoms occur along the courses of most streams, and any generalization here about type of bottom is based only on observations on the type of soil found in the major portion of the bed. Pools and impounded waters in streams (J-2, Figure 1) greatly reduced the rate of flow and diluted the chemical.

In most of the areas levels of pentachlorophenol of two or more parts per million were obtained for some time after the molluscacide

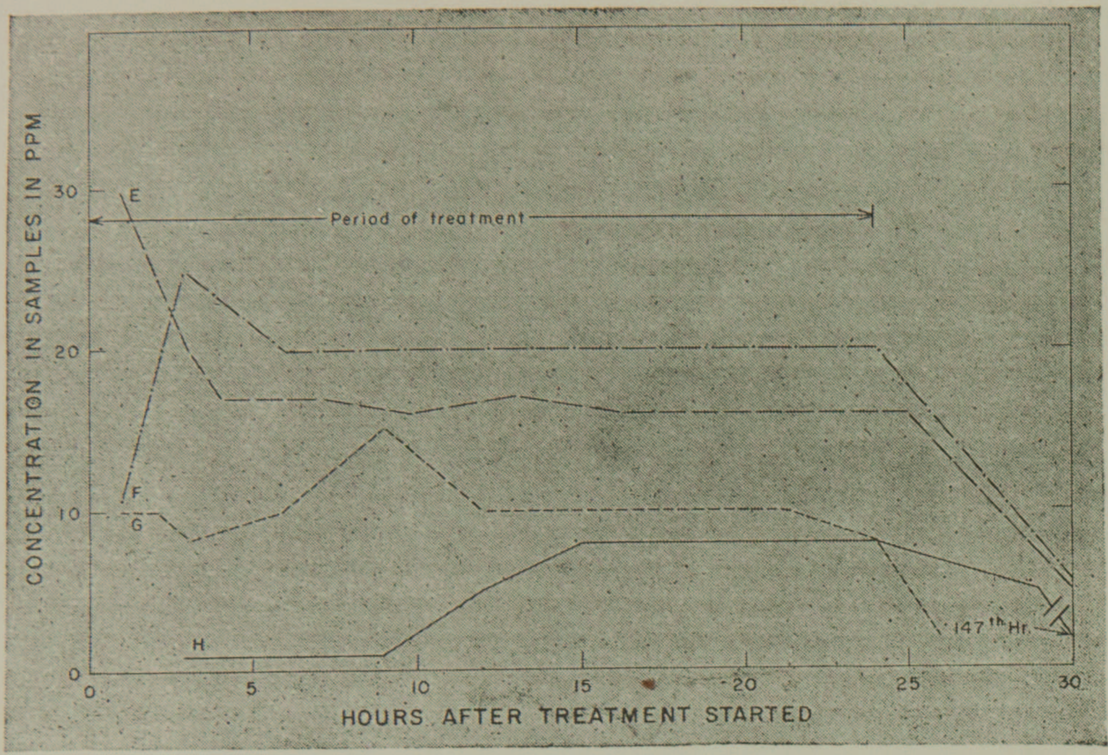

Figure 5. Concentrations of sodium pentachlorophenate obtained in samples taken at 500 foot levels of four streams treated by the drip method at calculated concentrations of 20 parts per million.

was applied. Berry, Nolan and Gonzalez (1950) reported that concentrations of 10 ppm for six hours and 3 ppm for 24 hours were 100 per cent effective against *Australorbis*. In flowing waters, in some instances, observed concentrations as low as 2 ppm maintained 20 or more hours produced a 100 per cent kill of snails (B-1, Figure 3). Taking 2 ppm as lethal concentration, the number of hours lethal concentrations were observed at the 500 and 1000 foot levels of some typical streams are shown in Table 2. Concentrations of two or more parts per million were maintained in one place for 147 hours with application of the compound at a rate of 20 ppm for 24 hours (stream B-1, Table 2). However, generally the persistence of lethal concentrations was only for a few hours at most after cessation of the application. In about one half of the areas lethal concentrations (2 ppm or more) were maintained for a time 25 per cent longer than the time the compound was applied. In only nine instances in all the tests conducted were the concentrations of pentachlorophenol found at various levels of the streams as high as the calculated concentrations to be expected.

TABLE 2. HOURS CONCENTRATION OF TWO PARTS PER MILLION OR MORE WAS MAINTAINED

Rate of application		Method	Stream	Time concentration was maintained at		
ppm	Hours			500 ft.	1000 ft.	2000 ft.
5	24	Drip	PZ-1	26	24	—
10	24	Drip	0-39	26	25	16
20	24	Drip	B-1	147	47	40 *
26	12	Drip	J-2	14	24	19
10	8	Briquette	J-1	8	11	9
13	8	Briquette	0-8	9	9	—
10	10	Briquette	SL-1	22	24	23
20	5	Briquette	SL-2-A	6	6	—
20	5	Briquette	SL-2-B	7	8	—
20	5	Briquette	SL-2-C	8	8	—
20	5	Briquette	SL-2-D	7	9	—
20	5	Briquette	SL-2-E	12	10	—

* 1800 feet.

Effects of a single application of the compound on snails

Concurrently with the tests on the dispersion of pentachlorophenol in flowing waters, a number of observations on the snail populations of the same streams were made.

In the results of these tests, the mortality rate of snails is expressed in percentage based on the reduction in the snail population as compared with the pre-treatment count. It was arbitrarily decided that a population reduction of 90 per cent or more may be considered effective control of snails. Data on the streams treated with one application of sodium pentachlorophenate are shown in Tables 3 to 7 and Figure 6.

The snail mortality was generally higher in the streams receiving the largest dosage of the compound. In 35 field trials a reduction of 90 per cent or more in the snail populations was observed in 30 streams the first week, 18 streams the first month, and 15 streams the second month after treatment. The data from the third month through the sixth month are not entirely comparable with the earlier data because some streams dried up during the severe and prolonged drought in 1952 and 1953, and it was not possible to follow the results of all experiments for a 6-month period. In some streams, effective snail control was observed over one year.

TABLE 3. COMPOSITE DATA ON REDUCTION IN SNAIL POPULATION IN STREAMS OF VARIOUS LENGTHS AND AT DIFFERENT RATES OF APPLICATION OF SODIUM PENTACHLOROPHENATE

Stream unit	Length*	Snail species	Application: Method	Application: Rate** PPM	Application: Rate** Hours	Mean concentration observed*** PPM	Mean concentration observed*** Hours	Percent reduction in number of snails in post-treatment surveys on****: Days 3	Days 7	Months 1	Months 2	Months 3	Months 4	Months 5	Months 6
1	100	*A.*	D	10	18	9	18	90	88	53	50	52	0	—	—
2	100	*A.*	D	10	24	9	27	95	93	85	84	84	0	—	—
3	100	*A.*	B	25	4	9	5	97	100	97	93	94	94	96	96
4	100	*A.*	B	25	4	23	4	100	100	100	100	100	100	100	100
5	100	*A.*	B	40	5	19	11	97	98	94	94	40	—	—	—
6	100	*T.*	B	40	8	40	8	100	100	7	0	—	—	—	—
7	200	*A.*	D	8	24	8	24	100	94	98	85	0	—	—	—
8	200	*A.*	D	10	24	8	24	92	79	48	50	50	0	—	—
9	200	*A.*	B	17	7	14	6	98	98	100	87	85	87	79	79
10	200	*A.*	B	20	8	20	8	99	98	99	98	96	96	96	99
11	200	*A.*	B	25	4	8	6	99	100	100	100	99	99	99	100
12	200	*A.*	B	40	5	17	10	94	99	98	98	0	—	—	—
13	200	*A.*	B	40	5	14	10	95	93	86	86	0	—	—	—
14	200	*A.*	D	40	24	27	26	100	100	100	100	99	—	—	—
15	300	*A.*	D	10	24	9	26	51	68	45	44	44	0	—	—
16	300	*A.*	B	25	4	11	8	100	100	100	100	98	98	98	98
17	300	*T.*	B	48	5	40	5	100	100	100	55	0	—	—	—
18	300	*T.*	B	48	5	15	26	100	100	100	100	0	—	—	—
19	400	*T.*	B	10	8	10	8	50	50	33	10	10	0	0	0
20	400	*T.*	B	10	10	4	21	100	100	100	99	93	93	84	—
21	400	*A.*	B	17	7	11	8	100	96	97	55	54	54	0	0
22	400	*A.*	B	25	4	10	6	100	100	97	96	96	96	96	96
23	400	*T.*	B	60	4	10	8	100	100	100	100	0	—	—	—
24	500	*A.*	D	6	24	6	26	72	68	85	84	84	0	—	—
25	500	*T.*	B	10	10	5	22	100	100	100	100	93	93	0	—
26	500	*A.*	B	13	8	11	9	95	98	95	95	92	89	89	75
27	500	*T.*	D	20	24	3	147	100	100	100	100	100	100	100	0
28	500	*A.*	B	25	4	8	4	100	100	100	0	0	—	—	0
29	500	*T.*	D	40	12	25	27	100	100	100	100	67	0	—	—
30	500	*T.*	D	51	12	45	14	100	100	100	100	100	100	100	—
31	500	*T.*	B	48	5	2	14	100	100	100	100	—	—	—	—
32	600	*T.*	B	10	8	8	9	95	93	90	0	0	0	0	—
33	600	*T.*	B	48	5	11	20	100	100	100	100	—	—	—	—
34	600	*T.*	B	40	5	16	14	100	100	100	100	—	—	—	—

35	700	*T.*	D	10	24	10	26	93	91	81	80	80	0	—	—
36	700	*T.*	B	30	10	—	—	100	100	95	95	90	0	—	—
37	700	*T.*	D	40	12	13	25	90	100	81	59	0	—	—	—
38	800	*A.*	B	18	4	10	10	95	85	65	66	66	50	0	—
39	800	*T.*	B	10	10	2	24	100	100	100	97	0	0	0	—
40	900	*A.*	B	17	7	5	10	98	95	89	87	72	71	50	0
41	900	*T.*	B	10	8	10	10	95	85	65	66	66	50	0	—
42	900	*T.*	B	24	5	—	—	100	100	100	100	—	—	—	—
43	1000	*A.*	D	5	24	4	24	90	92	97	85	—	—	—	—
44	1000	*A.*	B	13	8	6	9	98	98	95	90	88	88	—	71
45	1000	*T.*	D	20	24	2	47	100	100	100	100	100	100	—	—
46	1000	*T.*	B	24	5	—	—	100	100	98	98	—	—	—	—
47	1000	*T.*	B	24	5	—	—	100	100	99	99	—	—	—	—
48	1000	*T.*	D	36	12	15	24	100	100	86	43	28	0	—	—
49	1100	*A.*	B	25	4	2	8	100	100	97	0	0	0	0	0
50	1100	*T.*	B	40	5	16	14	95	95	100	92	—	—	—	—
51	1100	*T.*	D	30	24	13	24	100	100	100	100	100	0	0	0
52	1500	*T.*	B	40	8	—	—	100	100	100	100	50	0	—	—
53	1500	*T.*	D	20	24	2	47	100	100	79	7	0	0	0	—
54	1500	*T.*	D	36	12	12	15	100	100	86	43	28	0	—	—
55	1800	*T.*	D	20	24	2	40	100	100	84	21	0	0	0	—
56	2000	*T.*	D	29	12	9	20	100	100	90	50	0	0	—	—
57	2300	*T.*	B	10	8	8	9	100	90	85	85	85	80	0	—
58	2500	*T.*	B	10	10	2	10	96	100	50	50	0	0	0	—
59	3500	*A.*	D	10	24	9	24	99	99	88	89	63	0	0	—
60	3000	*T.*	D	26	12	9	20	54	100	97	48	66	70	—	—
61	3500	*T.*	B	10	10	8	16	99	99	95	84	17	18	12	—
62	3700	*T.*	D	26	12	1	12	89	100	86	85	67	73	—	—
63	3900	*T.*	B	10	10	—	—	99	99	99	99	—	—	—	—

A. — *Australorbis glabratus.*

T. — *Tropicorbis centimetralis.*

B — Applied by briquette method.

D — Applied by drip method.

* These stream lengths do not include the parts below the first point in the streams where tests of all samples of water were negative for sodium pentachlorophenate.

** Rate of application by briquette method is based on the number of hours required for the chemical to go into solution.

*** Mean concentrations determined from samples taken.

**** Percentages indicate reduction in snail populations based on last pre-treatment survey.

Defining as effective that treatment which produces a decline of 90 per cent or more for a period of two months following treatment of the stream, it is possible to examine various factors contributing to the effectiveness of sodium pentachlorophenate.

In presenting the results on the dispersion of this compound, it was shown that the concentration fell off the further downstream that samples were taken. Thus, as would be expected, a single application at the head of the stream would be least effective for the longest streams. In Table 3 the streams are broken down into various unit lengths so that for all the streams comparisons can be made on the basis of length. The units vary in length, each extends from the site of application to a selected point downstream. In 53 out of 60 units the kill of snails was very satisfactory at 3 and 7 days after treatment. An unsatisfactory kill in the first week after treatment would appear to be due to some fault in application such as an inadequate initial concentration or dispersion. Occasionally, living snails, still ill from the effects of the chemical, found on the third day were dead on the seventh day survey (58 and 59, Table 3). In 6 of the 7 streams where treatment was ineffective the first week, the chemical was applied at concentrations of 10 ppm or less. In other instances concentrations of 10 ppm gave good results suggesting that it may be a problem of dispersion. However, stream J-1 (Figure 1) is an example where the dispersion of the chemical was satisfactory, but nevertheless, the reduction in the snail population at 3 days was only 50 per cent. In this instance snails probably entered the stream from a large spring-fed bog through which it flows and where the treatment was totally ineffective. In the stream units 1, 8, 15, and 24, Table 3, numerous springs harboring many snails were present along the banks and in the stream bed. Attempts to kill snails in this type of habitat were usually not satisfactory. Living snails were also found on the wet banks of some streams (8 to 16, Table 3), and they may have migrated into the flowing waters after treatment. Since these migrations would involve only a few specimens they could explain the gradual reinfestation of some streams but not the sudden appearance of large populations observed during the first week after treatment.

Taking into account all of the streams regardless of the initial effect, the percentages of instances in which treatment was sucessful over a two-month period following application were 52, 56, and 17 per cent in the stream lengths from 0 to 400 feet, 0 to 1100 feet, and 0 to 3700 feet, respectively. During this period 46 per cent of all stream lengths were successfully treated with sodium pentachlorophenate. The reduction in snails was satisfactory in 26 per cent where the drip method was employed and in 59 per cent where the chemical was applied in the form of briquettes.

Excluding those streams where the surveys on the third day and seventh day showed a poor kill, 53 per cent of the streams showed successful treatment during the two-month period after the experiments started (Table 4). The revised results show that 63 per cent of the 0

TABLE 4. EFFECTIVENESS OF TREATMENT ACCORDING TO LENGTH OF STREAM AND METHOD OF APPLICATION

Concentration Application ppm	Length of stream from 0feet to:											
	400 feet			1100 feet			3700 feet			Totals		
	No.	Sat.*		No.	Sat.		No.	Sat.		No.	Sat.	
		No.	%		No.	%		No.	%		No.	%
Results from application by briquette method												
10 or less	1	1	100	3	2	40	4	1	25	8	4	50
11 to 20	3	1	33	3	2	67	—	—	—	6	3	50
21 to 30	5	5	100	6	4	67	—	—	—	11	9	82
31 to 40	4	2	50	2	2	100	1	1	100	7	5	71
41 and over	3	2	40	2	2	100	—	—	—	5	4	80
Totals	16	11	69	16	12	75	5	2	40	37	25	67
Results from application by drip method												
10 or less	2	0	0	2	0	0	1	0	0	5	0	0
11 to 20	—	—	—	2	2	100	2	0	0	4	2	50
21 to 30	—	—	—	1	1	100	3	0	0	4	1	25
31 to 40	1	1	100	3	1	33	1	0	0	5	2	40
41 and over	—	—	—	1	1	100	—	—	—	1	1	100
Totals	3	1	33	9	5	55	7	0	0	19	6	32
Results from both methods												
10 or less	3	1	67	5	2	40	5	1	20	13	4	31
11 to 20	3	1	67	5	4	80	2	0	0	10	5	50
21 to 30	5	5	100	7	5	71	3	0	0	15	10	67
31 to 40	5	3	60	5	3	60	2	1	50	12	7	54
41 and over	3	2	67	3	3	100	—	—	—	6	5	83
Totals	19	12	63	25	17	68	12	2	17	56	31	55

* Sat. = Satisfactory treatments.

to 400 feet group, 64 per cent of the 0 to 1100 feet group and 17 per cent of the 0 to 3700 feet group were successfully treated. The results from the 400 and 1100 feet groups were about equal indicating that there was no great difference in the efficacy of the chemical from the point of application down to the 1100 foot level of the streams. Since more failures in treatment occurred below the 1200 foot level in streams, it would appear that in the type of streams treated, better results could be expected if the chemical were applied in the longer streams at spaced intervals of about 1000 feet.

Comparisons made on the basis of stream lengths (Table 4) show 32 per cent success by the drip method and 57 per cent by the briquette method. The chemical was least effective where it was applied at concentrations of 10 ppm or less, and there were no marked differences in the percentages of satisfactory treatments between the groups where the chemical was applied at rates higher than 10 ppm. This indicates that little is gained by applications over 20 ppm. However, the results were satisfactory in some of the experiments in which the compound was applied at rates of 10 ppm for 10 or more hours. Not only the concentrations but also the duration of application must be considered in appraising the two methods (Table 5). On the basis of hours, the methods of application are not comparable for in all experiments with the drip method, the chemical was introduced into the streams for periods of 12 or more hours, whereas all administrations with the briquette method were completed in 10 or less hours. Also when applied at like concentrations, a greater amount of chemical was dispersed by the drip method. It should be pointed out that most of the unsatisfactory results with the drip method occurred in habitats where the tests with the briquette method were likewise unsuccessful, and also that most experiments with the former method were made at concentrations of 10 ppm or less. Thus, the differences between the two methods were not as great as the data may indicate. The results of all the experiments strongly suggest that applications of the chemical at higher concentrations for about 8 hours are as effective as lower concentrations applied through a longer period of time.

Since the above description of the effects of the chemical on snails dealt with data based on a number of streams, it may be helpful to examine the results of one experiment in more detail. The field trial in stream 0-39 (Table 6) is indicative of the results that may be expected from treatment of the snails in different parts of some of the longer streams. The disappearance of chemical below the site of application in stream 0-39, which was treated by the drip method at a rate of 10 ppm for 24 hours, is shown in Figure 1. In the upper part of the stream from zero to the 2000 foot level only one living snail was found in the three-month period following treatment, and in the lower 1500 feet long area progressive increases in the snail population reduced the over-all effectiveness of treatment. At the end of the 3-month period, the reduction in the snail population of the whole stream was 63 per cent.

TABLE 5. COMPARATIVE EFFECTIVENESS OF VARIED RATES OF APPLICATION ACCORDING TO HOURS OF APPLICATION AND STREAM LENGTH

Concentration applied in ppm

Hours of Application	10 or less		11 to 20		21 to 30		31 to 40		41 and over		Total	
	No**	%	No.	%	No.	%	No.	%	No.	%	No.	%
Stream lengths 0 to 400 feet												
4 to 8	—	—	1/3	33	5/5	100	2/4	50	2/3	67	10/15	67
9 to 16	1/1	100	—	—	—	—	—	—	—	—	1/1	100
17 to 24	0/2	0	—	—	—	—	1/1	100	—	—	1/3	33
Stream lengths 0 to 1100 feet												
4 to 8	0/1	0	2/3	67	3/5	60	2/2	100	2/2	100	9/13	69
9 to 16	2/2	100	—	—	1/1	100	1/3	33	1/1	100	5/7	71
17 to 24	0/2	0	2/2	100	1/1	100	—	—	—	—	3/5	60
Stream lengths 0 to 3700 feet												
4 to 8	—	—		—	—	—	1/1	100	—	—	1/1	100
9 to 16	1/4	25	—	—	0/3	0	0/1	0	—	—	1/8	12
17 to 24	0/1	0	0/2	0	—	—	—	—	—	—	0/3	0

* Effectiveness is reduction in snail population of 90 per cent or more through the 2 month post-treatment period.

** Number of successful treatments x 100:
―――――――――――― = per cent of effective treatment.
Total number of streams.

Bold type indicates application by briquette method, all others were applied by the drip method.

TABLE 6. THE EFFECTS OF ONE TREATMENT OF SODIUM PENTACHLOROPHENATE ON AUSTRALORBIS GLABRATUS IN STREAM 0-39

Area in stream *	Pre-treatment survey	Post-treatment surveys					
		7th day		1st month		3rd month	
	No. alive	No. alive	% dead **	No. alive	% dead **	No. alive	% dead **
0 to 900 ft.	120	0	100	0	100	1	99
900 to 2000 ft.	191	0	100	0	100	0	100
2000 to 3500 ft.	1291	12	99	196	85	594	54
Total	1602	12	99	196	85	595	63

* Feet from origin of stream.

** Percentages are based on number of snails found in pre-treatment survey.

Earlier in this report, it was demonstrated that the actual observed concentration of sodium pentachlorophenate at points below the site of application in streams was usually considerably lower and of longer duration than at the rate at which it was applied (Table 2).

It may be of interest to show what effects the mean concentrations as determined from samples of water taken at selected points from the streams, had on the snails. The comparative molluscacidal effects of the mean concentrations of the chemical at 48 of the points (areas) in streams are shown in Table 7. Regardless of the method of application, concentrations over 10 ppm gave somewhat better results. It is noteworthy that the chemical was effective in 9 out of 10 sites where concentrations of 2 to 5 ppm were maintained over 20 hours. However, it must be pointed out that in all these instances the compound was applied at much higher rates than at the concentrations observed here. In the groups above 5 ppm there were no significant differences obtained in the results which could be correlated with the length of time the concentrations of sodium pentachlorophenate were maintained.

In some streams and in parts of others, as in 0-39 (Table 6), a 90 per cent or better reduction in the snail population was observed up to 12 months after the experiments were started. An indication of the effectiveness of the sodium pentachlorophenate during a five-month period of time can be obtained from examination of the mean of the per cent reductions in the snail populations of all the streams examined on each survey (Figure 6). These results were also plotted to show the effects of distance from the site of application. Not included are the results from seven streams in which the initial ineffectiveness was definitely known to be due to unsatisfactory dispersion of the chemical and therefore these results are based on data from 28 out of 35 streams that were treated with this compound. The initial effectiveness after application of the compound is clearly shown by the 100 per cent mortality of snails in one half or more of the streams from 0 to 3000 feet below the site of application. Beginning with the first month there was a gradual and progressive increase in the snail population and at the third and fourth month, control of the snails in the first 1000 feet of one half of the streams examined was 90 per cent.

The snail population increased most rapidly in the most remote parts of the longer streams (Figure 6). This appears to be due to the character of the typical stream of this area which is rather slow flowing and has many pools. The greatest dilution of sodium pentachlorophenate occurred two to three thousand feet below the place where the chemical was applied (Figure 1). In the lower levels of the stream, the chemical was also the least effective in destroying snails; hence, it was to be expected that the increase in the snail populations would be more rapid in the lower parts of streams because of the survival and propagation of more snails in these areas (Figure 6). These data again indicate that better results may be expected if the chemical is

TABLE 7. COMPARATIVE EFFECTIVENESS* OF DIFFERENT DETERMINED MEAN CONCENTRATIONS OF THE CHEMICAL IN POINTS OF STREAMS TREATED BY "BRIQUETTE" AND "DRIP" METHODS

Mean concentration observed ppm	Drip method						Briquette method								All							
	Hours						Hours								Hours							
	11 to 20		21 to 30		Total		4 to 10		11 to 20		21 to 30		Total		4 to 10		11 to 20		21 to 30		Total	
	Number of Areas Treated																					
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
2 to 5	0/1**	0	4/5	80	4/6	67	0/3	0	2/3	67	3/4	75	5/10	50	0/3	0	2/4	50	7/9	80	9/13	69
6 to 10	1/4	25	0/5	0	1/9	11	5/8	62	—	—	—	—	5/8	62	5/8	62	1/4	25	0/5	0	6/17	35
11 to 20	1/1	100	1/3	33	2/4	50	4/6	67	3/3	100	1/1	100	8/10	80	4/6	67	4/4	100	2/4	50	10/14	71
21 to 45	1/2	50	1/1	100	2/3	67	1/1	100	—	—	—	—	1/1	100	1/1	100	1/2	50	1/1	100	3/4	75
Total	3/8	37	6/14	43	9/22	41	10/18	55	5/6	83	4/5	80	19/29	65	10/18	55	8/14	57	10/19	52	28/48	58

* Here effectiveness is defined as a reduction in the snail population of 90 per cent or more through a period of 2 months.

** $\frac{\text{Areas effectively treated} \times 100}{\text{Total areas treated}}$ = per cent of areas effectively treated.

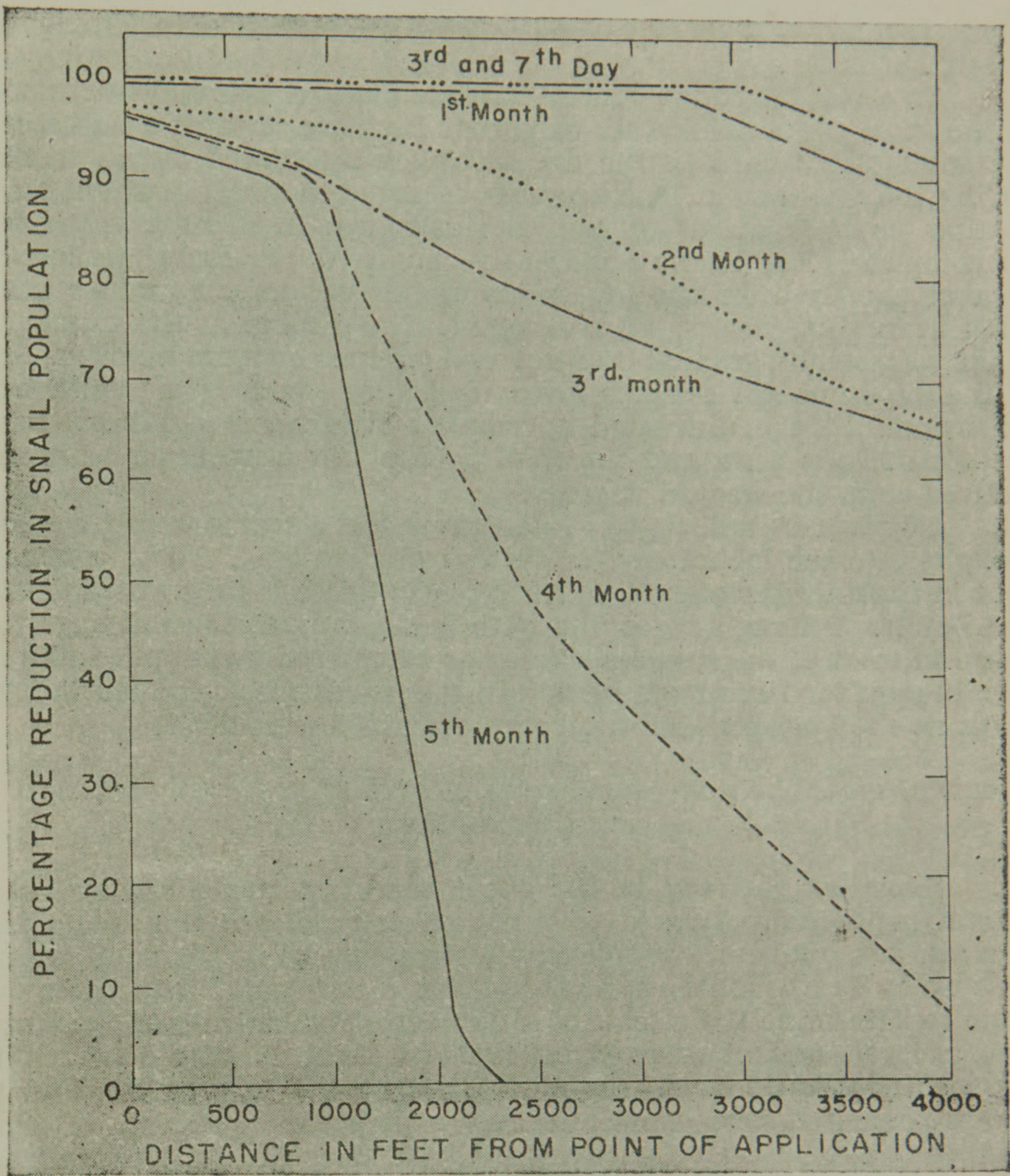

Figure 6. The mean rate of the reduction of the snail populations in streams examined on each survey, at different distances below sites of application.

applied in the average stream of this area at spaced intervals of about 1000 feet.

The data from experiments with *Australorbis glabratus* and *Tropicorbis* species were combined in preparing this report. The results of application of the compound in three of 10 streams harboring *Australorbis* and 12 of 22 streams harboring *Tropicorbis* were satisfactory over a two-month period. However, this difference in the results is hardly significant, since five of the field trials with *Australorbis* were made in the type of habitats where tests with *Tropicorbis* were also unsatisfactory, and more experiments were conducted in *Tropicorbis*-infested streams.

In a few untreated control streams marked seasonal fluctuations in the snail populations were observed. In these streams a decrease in the snail populations in the dry season was followed by an increase during the wet season. The decrease occurred in streams which ceased to flow as they dried up or nearly dried up. In streams which dried up completely the snails apparently survived extreme desiccation because shortly after the first rains of the wet season mature snails, often in large numbers, were observed. The decline in the number of snails was usually gradual over a period of three or more months. None of the experimental streams dried up before the fourth month after treatment. In the untreated permanent streams, fluctuations rarely exceeded 25 per cent, and the snail populations were never as greatly reduced as in the treated streams.

Clusters of snail eggs collected from test streams were frequently brought into the laboratory for further observations. These eggs were kept in fresh pond water up to three weeks to see if they would develop and hatch. Although no counts were made, only dead snail eggs were found in most of the streams where the compound was applied at rates over 10 ppm for 10 or more hours. In the places where the mortality of snails was 100 per cent, all snail eggs examined were dead.

Effects of more than one application of sodium pentachlorophenate on snail populations

Since, as observed in the above report, a single application of sodium pentachlorophenate did not often eradicate the snails from streams, but frequently produced effective control of the snail populations up to 3 to 5 months after treatment, a number of field trials were made to determine the effects of a number of treatments of streams at various levels and at selected intervals of time. It should be pointed out that additional experiments of this type are in progress, and the results presented here constitute only a preliminary report. Because these tests were initiated only a short time after the early experiments with single applications were started, it was not possible to take into consideration all the factors discussed above as influential in producing variation in efficacy of the compound.

Attempts to eradicate snails by more than one application of sodium pentachlorophenate were made in four streams and their tributaries. In making these treatments, the chemical was also applied to the drainage ditches, ponds, and springs connected with each stream. At the same time sodium pentachlorophenate was applied to the banks of most waters. The powdered sodium pentachlorophenate mixed with talcum or wheat flour was applied to the banks of some waters with mechanical dusters, and the moist sawdust preparation was applied to others. Snail surveys were made once a month or more frequently.

Results obtained from treatment of a stream harboring *Tropicorbis centimetralis* are illustrated in Table 8. This stream, 5000 feet long and its 7 tributaries ranging in length from 300 to 1100 feet were given four treatments during a period of 12 months. Sodium pentachlorophenate briquettes in muslin bags were applied in the stream at 1000-foot intervals. The calculated rate of application of each treatment was 10 ppm for 10 hours. The observed concentrations in samples taken at the different levels of the stream were 5 or more parts per million for 6 to 12 hours.

To kill the eggs and snails which may survive one application of the chemical, a second treatment was made two weeks after the first. The first two treatments were made at the beginning of the rainy season, the third during, and the fourth near the end of the rainy season. In making the fifth treatment, the chemical was not applied in the main stream but in its tributaries and drainage ditches. This method of treatment was unsatisfactory because only low or sub-lethal concentrations of the chemical entered the main stream, and few snails were destroyed in the lower levels.

In the main stream, a marked reduction in the snail population was observed for two or more months after each application of the chemical. A decided increase in the snail population occurred in the lower areas of the stream by the third month after the fourth treatment. Most of these snails were not fully grown. However, in most of the areas there was a negligible or no increase in the number of snails. Increase in snails usually occurred near drainage ditches or springs which were inadequately treated. Living snails were occasionally found in some ditches which dried up completely between showers during the rainy season. Eradication of the snails in these ditches was not always successful. It is noteworthy that after the first treatment no living snails were found in three of six tributaries of this stream.

Six applications of briquettes failed to eradicate the snails from a flowing spring on a tributary of the main stream. Snails coming from a spring appeared to account for the increase in snails in the 0 to 500 foot area at the head of the stream. In this and other streams adult snails usually were not found until after a heavy rain indicating that some snails were not in the streams at the time of treatment.

The decrease in the snail population following the December 4th treatment of the ditches and branches of the main stream may have been due to the unusually severe drought. Most of the ditches and all tributaries dried up completely. On the last survey early in the following March, there was no current, and isolated pools of standing water were found. At this time a decrease in the snail population was observed in some non-treated streams. Results similar to the above were observed in the other *Tropicorbis* infested streams in which sodium pentachlorophenate was applied more than one time. Although the snails were not eradicated, the control was satisfactory.

Only one attempt was made to eradicate *Australorbis glabratus* from an area. This area consisted of a stream 1800 feet long and 5

TABLE 8. RESULTS IN AN ATTEMPT TO CONTROL TROPICORBIS CENTIMETRALIS IN A STREAM BY TREATMENT WITH SODIUM PENTACHLOROPHENATE

		Area in stream: 0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500	4500-5000	Total	Percentage* reduction
Pre-treatment survey	Snails Alive	0	20	202	245	152	92	260	233	346	448	1998	
	Snails Dead	0	0	17	21	20	8	17	23	15	23	144	
Number of living snails found: After 1st treatment March 13, 1952	11 days	0	1	3	5	3	5	3	6	8	10	44	97.7
After 2nd treatment March 27, 1952	11 days	0	0	0	0	0	0	2	0	0	0	2	99.9
	18 days	0	0	1	0	0	0	1	0	0	0	2	99.9
	34 days	0	0	0	3	0	0	52	0	0	3	58	97.0
	62 days	0	0	4	1	3	0	14	33	9	4	68	96.5
After 3rd treatment June 4, 1952	14 days	8	0	0	0	0	0	1	0	0	0	9	99.5
	60 days	1	0	0	1	0	0	1	0	0	0	3	99.8
After 4th treatment August 19, 1952	7 days	20	0	0	0	0	1	0	0	0	0	21	98.9
	30 days	2	0	0	0	0	0	0	0	0	0	2	99.8
	58 days	1	0	0	0	1	0	3	0	0	0	5	99.7
	99 days	4	0	0	0	77	0	26	0	0	228	335	83.2
After treatment of ditches December 4, 1952	13 days	95	0	0	0	0	0	0	0	0	228	383	81.8
	41 days	15	0	0	0	0	0	0	7	0	146	168	91.5
	91 days	5	0	0	0	5	0	10	12	3	33	68	96.5

* Percentages based on fisrt pre-treatment snail counts.

TABLE 9. RESULTS OF ATTEMPTS TO CONTROL AUSTRALORBIS GLABRATUS IN FLOWING WATERS WITH SIX APPLICATIONS OF SODIUM PENTACHLOROPHENATE

				Stream	Ditches	Total	Percentage reduction*
	Pre-treatment survey		Alive	593	206	799	
			Dead	23	1	24	
Number of living snails found	After 1st treatment July 6, 1952	3rd day	Alive	57	0	57	93
		7th day	Alive	45	0	45	94
		23rd day	Alive	19	2	21	97
		56th day	Alive	85	11	97	88
	After 2nd treatment August 30, 1952	3rd day	Alive	0	0	0	100
		13th day	Alive	2	0	2	99.7
		28th day	Alive	3	0	3	99.6
	After 3rd treatment October 1, 1952	3rd day	Alive	0	0	0	100
		21st day	Alive	3	0	3	99.6
	After 4th treatment October 22, 1952	19th day	Alive	0	0	0	100
		50th day	Alive	24	0	24	96.9
		64th day	Alive	131	0	131	83.6
	After 5th treatment December 30, 1952	9th day	Alive	1	0	1	99.9
		21st day	Alive	0	0	0	100
	After 6th treatment January 9, 1953	43rd day	Alive	0	0	0	100
		60th day	Alive	1	0	1	99.8

* Percentages based on first pre-treatment snail counts.

ditches totalling 1800 feet in length. Six treatments (Table 9) were made during an observation period of 9 months. The stream dried up completely in March 1953. The first treatment was made by the drip method at a rate calculated to give a concentration of 5 parts per million for 24 hours. All subsequent treatments were made with briquettes applied at a rate of 20 ppm for 5 hours.

A marked reduction in the snail population was maintained (Table 9). Except in a small area, no living snails were found in the main stream or ditches after the second application of the chemical. This small area which illustrates one of the difficulties encountered in attempting to eradicate snails consisted of a group of small springs and seepage waters.

Results with experiments conducted to date illustrate that effective control of snails can be attained by repeated applications of sodium pentachlorophenate at spaced intervals of time. However, due to the ability of the snails to survive in the habitats mentioned, eradication of snails in all areas cannot be accomplished in one year.

DISCUSSION

Obviously, decrease in chemical concentration in relation to distance of application point must be attributable to more factors than simple dilution of the material. An analysis of these factors on the basis of these field studies is hardly possible because the streams tested were very varied in type of bottoms, vegetation, and so forth. However, it will be profitable to present here some discussion of the conditions which may effect dispersion and persistence of the molluscacide.

Downstream, the dilution of the chemical varied with the distance from the point where it was applied and the velocity of the streams (Figure 1). In order to compensate for the decrease in the concentration at lower levels, the dosage applied could be increased or the chemical could be applied at spaced intervals along the course of the stream. Frequently, lethal concentrations (2 ppm or more) of the compound were maintained in the water for a longer period than the time of application (Table 2). To some extent this compensated for the decrease in the concentration as far as molluscacidal effect was concerned.

Pools or impounded waters along the course not only retarded the passage and greatly diluted the chemical downstream but also caused the area to be exposed to the chemical for longer periods. Small pools, unless numerous, did not require separate treatment. The stream J-2 (Table 1) had 29 small artificial or natural pools. It took nine hours for the chemical to cover the distance from the zero to the 3500 foot level. Results indicate that all comparatively large pools and inlets require special treatment. These pools can be treated as still water projects or the chemical can be applied in the stream above the intake. In the pools examined, a good distribution of the chemical was obtained by both methods. Vaughn et al. (in press) obtained good results in treating pools by applying sodium pentachlorophenate at the intake.

The effects of soils on dilute solutions of sodium pentachlorophenate under laboratory conditions were reported by Dobrovolny and Haskins (1953). While making field trials in still waters the effect of mud and muddy waters was also observed. The problem is important where herds of animals frequent the waters and when streams remain muddy for several days following heavy rains.

Under the different conditions the compound was applied, variable results were to be expected. Compared to results reported elsewhere, the data presented here indicate that the technique of application of molluscacides may require considerable variation from one geographical area to another, depending on the ecological conditions of the snails. Primarily the results bring out some of the problems encountered and suggest the need for further experiments in the solution of these problems.

A marked reduction, frequently 100 per cent, of snail populations in streams was observed following a single application of sodium pentachlorophenate. No living snails were found in 11 of 35 streams examined during the first month after treatment. Additional evidence of the effectiveness of this compound may be found from examination of results from the upper parts of the streams. The percentage of upper parts where no living snails were found in post-treatment surveys through the sixth month were: third day and seventh day, 60 per cent; first month, 41 per cent; second month, 30 per cent; and third month, 17 per cent; and fourth to sixth month, 12 per cent. Most of the streams and parts of them from which the snails appeared to have been eradicated were repopulated by the second to fourth months after treatment. Since many of the snails found in the streams were mature and large enough to indicate that they were alive before the date of treatment, they either survived the action of the chemical and were not discovered during the early post-treatment surveys or they were not in the waters while the chemical was being applied. The latter way of escaping treatment was the more likely in view of the significant number of streams involved and the comparative ease of detecting mature snails in surveys when present in large numbers. It is possible for waters that were freed of snails by the action of a molluscacide to become repopulated. A number of ways by which reinfestation of streams appeared to have occurred, or could occur, can be mentioned.

In shaded habitats where the ground is always wet or moist, specimens of *Australorbis* and *Tropicorbis* were found well above the water level on the banks of streams where they apparently migrated in search of food. On wet banks snails were also found under dead leaves, between loosely packed stones, on the sides of fallen banana trunks, and under other objects. Following treatment of the stream, these snails could easily migrate back into the water. No areas of this type have been successfully treated and the kill has always been less than 100 per cent (examples in Table 2, 0-32 to 38, J-2 and J-3). For some experiments in this type of habitat, the banks were raked free of vegetation several days before the chemical was applied. Then at the same time the streams were treated the banks were dusted with sodium pentachlorophenate or treated with moist sawdust which was soaked in an aqueous solution of the compound. The results were only slightly better for many snails on the banks were apparently unaffected by the chemical. Wet sprays applied to the banks with hand powered pumps seemed to give somewhat better results.* Perhaps the use of more effective methods of application might result in greater destruction of snails on the banks. It is also possible that more concentrated solutions of sodium pentachlorophenate would have been of greater efficacy in such applications, or that other molluscacides such as the insoluble copper salt of pentachlorophenate would have produced a better kill of the extra-aquatic snails.

In a number of streams, it was observed that snails were left stranded on the banks when high waters recede. In some places, once or twice a year, snails were deposited on the banks by man in the process of clearing the dense vegetation from streams and ditches. The cleaning was accomplished by raking the vegetation, including some snails, from the water up onto the banks. During rains following treatment some of these snails probably migrate or are washed back into the streams. Moreover, Barbosa and Dobbin (1952) and Olivier (personal communication) have shown that many of these snails survive out of water for the five months of the dry season. It is doubtful if any of the known molluscacides will kill snails in estivation on dry soil. Perhaps if the chemical were applied when the waters were high, the results would be better. A few experiments were made after heavy rains, and the wet banks were treated with sodium pentachlorophenate at the same time. However, the results were inconclusive and more experiments along this line need to be made.

As already stated snails in springs, inlets, and bogs along the course of a stream, unless given special treatment, can reinfest the stream. Destruction of snails in flowing springs presents a special problem, for it is difficult to apply the chemical in a way to make adequate contact with the animals. Extermination of snails in some types of swamps or bogs often cannot be accomplished with one application of chemical. One bog along the course of a stream was treated five times in five months before a 100 per cent mortality was observed.

It has not been definitely established as has been suggested that during treatment *Australorbis* and *Tropicorbis* burrow into the mud to escape from sodium pentachlorophenate and that some snails normally living deep below the surface of the mud may emerge to reinfest the water after the chemical has disappeared. Observations and

(*) In experiments in progress wet sprays of sodium pentaclorophenate applied to the banks and still waters of streams with gasoline motor powered pumps resulted in effective control for three months in places where other methods of treatment were not sucessfull.

experiments should be made to determine if this is an important factor in snail control.

In a few streams where all adult snails were apparently killed, the new population of snails may have come entirely from eggs which survived the action of the chemical. More complete studies of this type should be made. Under field conditions, egg laying appears to be seasonal as few eggs were found during the dry season, and they were most abundant at the end of the rainy season.

As far as was determined, plants did not decrease the efficacy of the molluscacide, for both good and unsatisfactory results were obtained in areas covered with dense vegetation. However, a dense growth of grass does reduce the velocity of the current and may in some instances prevent adequate dispersion of compounds. Where still water areas or the banks of a stream are treated, vegetation may prevent the dust and liquid compounds from being properly dispersed. McMullen *et al*. (1951) and Hunter *et al*. (1952) cut the grass to about the water level in areas to be treated. In the experiments conducted here, neither the manpower nor funds were available to have the grass cut. A thick layer of brown algae frequently covered the vegetation and bed in many of the streams, and it was suggested that this may account for some of the less satisfactory results. However, laboratory tests show that this alga does not reduce the concentration of dilute solutions of sodium pentachlorophenate. It appeared, on the other hand, that the snail mortality was lower in streams having muddy waters (Dobrovolny and Haskins (1953). More chemical needs to be applied when the waters are muddy.

Very effective control of snail populations was accomplished by retreatment of streams at various levels and at various intervals of time. In some parts of these streams no living snails were recovered over a 12-month period of observation. It appears that adequate snail control but not eradication can be obtained by treatments at intervals of 3 to 4 months, but more data are needed and experiments now in progress may provide the solution of this and other problems as they relate to snail abatement with molluscacides.

SUMMARY AND CONCLUSIONS

1. Studies designed to determine the efficacy of sodium pentachlorophenate applied in flowing waters were made in northeast Brazil.

2. A single application of sodium pentachlorophenate did not eradicate entire snail populations from all streams, but a 100 per cent reduction in the snail population was noted in some streams for periods up to 12 months where the chemical was applied in the more effective ways. For a 4-month period following treatment, a snail reduction of 90 per cent or more was noted in about 40 per cent of the streams examined on each survey. In some entire streams and parts of other streams effective control of the snails was observed for more than 12 months after application of the compound.

3. Control of snail population was successful in streams where

the chemical was applied at selected intervals of time over periods up to one year. It would appear that in this locality some streams may require 3 or more treatments each at spaced intervals of 3 to 4 months.

4. Usually the chemical was most effective in the stream where the largest dosage was applied for the longest period of hours. However, it was observed that concentrations as low as 2 ppm maintained for 40 hours were frequently as effective as high concentrations for shorter periods.

5. Streams in which no living snails were found for months after treatment often became repopulated. These snail-free waters may become reinfested in a number of ways. In moist shaded habitats snails often migrate from the water on to the banks of streams, and following treatment some return to the stream. Snails left stranded on the banks of streams following high water and snails raked on to the banks of streams with vegetation when streams are cleaned go into estivation. During rains they migrate or are washed back into the snail-free waters.

6. To determine the efficacy of dispersion of sodium pentachlorophenate in flowing water tests for the chemical were determined from samples of water taken at selected points in streams below the sites where the chemical was applied. These tests for the chemical show that in most streams the concentrations observed were considerably lower than the rate at which the chemical was applied. In one half of the areas observed and with the different methods of application, the mean decrease was over 50 per cent greater than expected. As could be expected, there was a progressive decline in the amounts of the chemical below the site of application in the streams.

7. Some factors which may account for reduction in the concentrations of sodium pentachlorophenate applied in streams are: velocity of the current, large pools or impounded waters in the course of the stream, composition of the soil in the stream bed, turbidity of the water, and vegetation in the streams.

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EXPERIÊNCIA DE CAMPO SÔBRE A ATIVIDADE MOLUSCACIDA DO PENTACLOROFENATO DE SÓDIO EM ÁGUAS CORRENTES DO BRASIL

SUMÁRIO

Experiências de campo foram conduzidas a fim de estimar a atividade moluscacida do pentaclorofenato de sódio quando aplicado em águas correntes no Estado de Pernambuco.

Como se sabe a esquistossomose é endêmica em várias regiões do Brasil, e, nesta parte do país, são os planorbídeos *T. centimetralis* e *A. glabratus* seus hospedeiros intermediários.

Para melhor apreciar a ação do moluscacida, foi o composto aplicado em riachos apresentando condições diversas e em situações consideradas relativamente desvantajosas.

Êste trabalho descreve os problemas surgidos durante a condução das pesquisas e espera-se que possa oferecer algumas sugestões aplicáveis, no futuro, ao emprêgo rotineiro do moluscacida.

O pentaclorofenato de sódio, contendo 75 a 79 % de ingrediente ativo, foi usado em pó e em *tabletes* de uma onça. Vários métodos de aplicação são descritos.

A diminuição na concentração do pentaclorofenato observada em relação à distância do ponto de aplicação, deve ser atribuída a outros fatôres além da simples diluição do material. Uma análise dêstes fatôres, considerando êstes estudos de campo, é quase impossível porque os riachos trabalhados apresentavam condições diversas. Entretanto, será proveitoso apresentar, em primeiro lugar, os resultados relativos à persistência e a distribuição do moluscacida.

A diluição do pentaclorofenato, riacho abaixo, variava com a distância do ponto onde o mesmo havia sido aplicado e a velocidade da corrente (Figura 1). A fim de compensar a diminuição da concentração dos níveis mais baixos, a dosagem podia ser aumentada ou o pentaclorofenato ser aplicado em intervalos mais ou menos espaçados ao longo do riacho. Freqüentemente, concentrações letais (2 ppm ou mais) eram mantidas na água por um período maior do que o tempo de aplicação (Quadro 2). De certo modo, isso compensava a diminuição da concentração em relação ao efeito do moluscacida.

Alagados ou águas estagnadas ao longo dos riachos retardavam a passagem e diluiam grandemente o pentaclorofenato, mas também sujeitavam a área ao contato mais prolongado do composto.

Os resultados indicam que todos os alagadiços relativamente grandes e suas comunicações requerem tratamento especial.

Os efeitos do solo sôbre a solução diluída do pentaclorofenato de

sódio, no laboratório, foram relatados por Dobrovolny e Haskins (1953). Em experiências de campo, não sòmente em riachos como em águas paradas, ficou demonstrado que a lama e as águas lamacentas reduzem a ação do moluscacida. O problema é importante onde animais freqüentam as águas e quando os riachos permanecem lamacentos durante muitos dias após as chuvas. Nestas condições o pentaclorofenato de sódio deve ser aplicado em maior concentração.

Os dados apresentados indicam que a técnica de aplicação do moluscacida pode requerer variação considerável de uma área geográfica para outra, dependendo das condições ecológicas.

Uma única aplicação do pentaclorofenato de sódio não erradicou completamente os caramujos em todos os riachos. Foi porém observada redução de 100 %, em alguns cursos d'água, por período superior a 5 meses quando o moluscacida foi aplicado de maneira mais eficiente. Durante o período de 4 meses após o tratamento, redução de 90 % ou mais foi verificada em cêrca de 40 % das águas trabalhadas. Em algumas destas áreas verificou-se, total ou parcialmente, contrôle eficiente dos planorbídeos após 12 meses.

Em alguns lugares houve necessidade de aplicar o planorbicida em vários intervalos de tempo durante um ano, sugerindo assim que, para estas localidades, certos riachos requerem tratamento espaçados cada 3 ou 4 meses, a fim de que resultados satisfatórios pudessem ser obtidos.

Embora a eficiência do moluscacida dependa, usualmente, de dois fatôres — concentração elevada e maior tempo de contato — foi observado que 2 ppm mantidas durante 40 horas eram freqüentemente tão eficientes quanto altas concentrações por períodos mais curtos.

Em habitats que ficam na sombra onde o solo está sempre molhado ou úmido, exemplares de *A. glabratus* foram encontrados muito acima do nível das águas sôbre as margens dos riachos para onde, aparentemente, haviam migrado. Nas margens úmidas os caramujos também foram encontrados debaixo de fôlhas mortas, entre amontoados de pedras sôltas, ao lado de troncos de bananeiras e de outros objetos. Após o tratamento, êstes caramujos poderiam ter fàcilmente migrado de volta às águas. Nenhuma área dêste tipo foi tratada com êxito e a mortalidade tem sido sempre menor do que 100 % (Quadro 2, 0-32 a 38, J-2 e J-3). Em algumas experiências, neste tipo de habitats, as margens foram limpas dias antes da aplicação do pentaclorofenato e pulverizadas com o moluscacida. Os resultados foram apenas um pouco melhores porque, provàvelmente, muitos caramujos que se encontravam fora d'água, não foram atingidos pelo produto químico. Borrifações úmidas aplicadas sôbre as margens com uma bomba manual deram, de algum modo, melhores resultados (*).

(*) Em experiências que estão em andamento o pentaclorofenato de sódio foi aplicado sôbre as margens e águas paradas ao lado dos riachos com bombas de gasolina poderosas. Com êste processo foi obtido contrôle efetivo durante três meses em lugares onde outros métodos de tratamento haviam falhado.

Também foi observado que caramujos eram depositados sôbre as margens quando as águas baixavam. Em alguns lugares, uma ou duas vezes no ano, caramujos eram depositados nas ribanceiras pelos homens quando limpavam a vegetação densa dos riachos e valas. Durante as chuvas que se seguiram ao tratamento, êstes caramujos provàvelmente migraram ou foram carregados de volta para dentro dos riachos. Barbosa e Dobbin (1952) e Olivier (comunicação pessoal) demonstraram que muitos dêstes moluscos sobrevivem em extrema dessecação durante o verão. É duvidoso que algum moluscacida conhecido possa matar os caramujos durante o estio sôbre o solo.

Tanto quanto se pode determinar, as plantas não diminuem a eficiência do moluscacida, porque tanto resultados bons, como não satisfatórios, foram obtidos em áreas cobertas por densa vegetação. Entretanto, o capinzal reduz a velocidade da corrente e pode, em alguns casos, impedir a distribuição adequada do composto químico. Também a vegetação pode interferir quando o pentaclorofenato, em pó ou líquido, é aplicado em águas paradas e nas margens dos riachos.

Contrôle muito eficiente da população dos caramujos foi conseguido, tratando-se os riachos repetidamente em vários trechos. Em algumas partes dêstes riachos nenhum caramujo foi encontrado em período superior a 12 meses de observação. Parece que contrôle adequado dos caramujos, mas não sua erradicação, pode ser alcançado com tratamentos em intervalos de 3 a 4 meses. Faz-se necessário, no entanto, maior número de dados a êste respeito e experiências em andamento podem solucionar não sòmente êste como outros problemas relativos à exterminação dos caramujos.