CLADOPHORA INVESTIGATIONS

-1959-

A REPORT OF

OBSERVATION ON THE NATURE AND CONTROL OF EXCESSIVE GROWTH OF CLADOPHORA SP. IN LAKE ONTARIO

REPORT NUMBER 1

BY

THE
ONTARIO WATER RESOURCES
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This publication contains a record of research work carried out by the Ontario Water Resources Commission in the summer of 1959 on the nature and control of algae Cladophora growth. For many years this type of algae has caused widespread nuisances in the lakes and streams of the Province. It grows in great profusion under favorable conditions, and when wave action detaches it from the rocks it washes into shallow areas where decomposition sets in with resultant offensive odors.

This growth has been prevalent in many parts of Ontario, and is stimulated by a good environment which includes sunshine and presence of food in the form of fertilizer. Control of the environment is usually too difficult, thus making other measures necessary.

The studies noted in this report resulted from attempts to destroy algae in its early growth through chemical treatment of the water. A. number of methods were carried out, and encouraging results were obtained. However, the investigation is not yet completed, and more field work will be carried on before a full assessment can be made of the various measures.

It is gratifying to report that the results to date give promise of an effective attack against a long-standing nuisance problem.

Chairman

General Manager

ACKNOWLEDGEMENTS

The co-operation of the Geophysical Group of the Research Division of the Department of Lands and Forests is gratefully acknowledged. The exchange of information, personnel and equipment was most helpful. Most particularly, the services of Mr. David Whiteman and Mr. W.R. Franklin, captain of the tug "Plainsville", were appreciated.

Dr. Roger Dean and his assistants aided us materially by conducting diving operations to determine conditions prevailing on the lake bottom in the areas studied.

Technical officers of a number of chemical companies provided very appreciable aid through generous donations of time and materials. Special mention should be made of the Shell Oil Company of Canada, The Shell Chemical Corporation, Chipman Chemicals Limited and Rohm and Haas Company.

TABLE OF CONTENTS

SUMMARY and RECOMMENDATIONS

Summary

1. Cladophora is found growing along the northwesterly shores of Lake Ontario wherever a suitable rock bottom is found and in waters up to and slightly exceeding six feet in depth. In water approximately 10 feet in depth growth of the alga is negligible. In these areas, lack of water movement and limited aeration may be important in limiting or preventing growth.

2. Two main crops were observed in 1959. The first and most significant crop developed prior to August 1. A second, lesser crop began about August 1 and persisted for the balance of the season.

3. Major shoreline accumulations of disintegrating algae occur as a result of a crop, having matured and become free floating, being carried in and held on shore by suitable winds and currents.

4. Local shore improvements may lessen the tendency to retain the algal masses. If it remains and disintegrates odor control by chemical means is impractical. The algal crop should be destroyed before large masses of growth occur.

5. Under the conditions of these tests, copper sulphate proved to be of little value in controlling Cladophora. Tri-basic copper sulphate was somewhat more effective while sodium arsenite and Hyamine were comparable and more effective. None of these chemicals achieved the removal of the alga. Growth was merely retarded.

6. "Aqualin", at concentrations of 5 and 10 p.p.m. (parts per million), cleared the plots of Cladophora and they remained clear for four weeks during which observations were taken.

Recommendations

In view of the observations and results which have been recorded above, the following recommendations are made:

1. The investigation should continue in 1960. To gain a complete understanding, observations should be made in May, on a weekly basis. More intensive work would be required throughout the balance of the season.

2. Fundamental studies with respect to the organism and its growth requirements, upon

which any control program will ultimately depend, should continue.

3. The preliminary results obtained with algicides in 1959 must be checked and the studies enlarged upon with particular regard to:

   (a) the proper timing of the control effort to provide maximum control of growth and of shoreline accumulations;

   (b) the duration of the period of influence of any one treatment; and

   (c) the determination of a suitable recommendation for algal control bearing in mind its feasibility both from the standpoint of economics and from the point of view of the mechanics of operation.

4. Subsequent to the completion of the 1959 investigation, information has been received concerning two chemicals which are recommended for the control of Cladophora. Endothal and TD-47 Herbicide, supplied by Pennsault Chemicals, should be tested in 1960.

5. In view of the interest shown in this and similar problems in natural waters and of the consequent demand for the widespread application of algicidal, herbicidal and other chemicals, it is expected that suitable procedures for the certification of these chemicals for the regulation of their use will be devised by the Commission.

   In many instances, toxicity studies, beyond those conducted by industry, will be required.

INTRODUCTION

General Nature of the Problem

Fresh water species of the branching, filamentous, green alga Cladophora are of common occurrence in natural waters throughout Ontario and indeed throughout the world. The taxonomy of the genus is difficult and, at the moment, in need of clarification. Certain of the species are free floating but those with which this investigation is concerned grow attached to any available firm substratum.

Generally, the growth of this alga is not excessive, and its presence does not constitute a nuisance. Occasionally, however, in remote as well as in urbanized areas massive growths occur and subsequently accumulations of disintegrating, highly objectionable masses of organic matter result. Excessive growth of algae may occur in natural waters anywhere but the nuisance is greater where the concentration of mineral nutrients is increased by sewage effluents and by runoff waters from rich agricultural lands and other sources.

Nuisance conditions created by the decomposition of excessive growths of algae have occurred quite generally along the northern shores of Lake Erie for many years, and the related problems are familiar, particularly in the Crystal Beach area. In the past, certainly Cladophora has been encountered also in Lake Ontario but, in recent years nuisance conditions have not occurred. In the summers of 1957 and 1958, however, excessive growths did occur and the distressing results became the concern of a great number of property owners and municipal authorities along the lake front from Cobourg to Hamilton and beyond.

Conference on Problems Related to Cladophora in Lake Erie and Lake Ontario

On November 20, 1958, a conference was sponsored in Toronto by the Ontario Water Resources Commission to consider the conditions and problems associated with these objectionable growths of Cladophora in Lake Ontario particularly and in Lake Erie.

A panel composed of members of the Commission and others, chaired by Dr. A.E. Berry, heard reports from various interested parties and supplied information relative to various phases of the problem. The discussions have been abstracted, published and circulated by the Commission.

Organization and Purpose of the Investigation

In recognition of the magnitude and importance of the problems concerned, an investigation was undertaken for and by the OWRC of the conditions surrounding the excessive growths of Cladophora in Lake Ontario.

It was considered necessary and desirable to accumulate fundamental information concerning the alga and its basic growth requirements. Such studies would include the determination of species, the seasonal life-cycle fluctuations of the organisms concerned and its growth responses to temperature, light, aeration, nutritional elements and other chemical and physical environmental factors. In a similar manner, the actual lake conditions under which the alga grows were of interest. Information concerning wave action, currents, drifts, water temperature and turbidity, and concentrations and distribution of nutrient mineral elements was recorded. Of importance as well was a survey to determine the actual extent of the algal meadows taking into consideration the depth at which the alga can satisfactorily grow and the distance from shore to which the growth, consequently, may extend.

In view of the urgency of the problem, however, it was determined that an immediate effort should be made first of all to devise a means of limiting or controlling the excessive growths of Cladophora and perhaps of lessening the related nuisance problems. The fundamental investigations, some of which have been mentioned above, were considered, momentarily, as being of secondary importance.

Various natural biological means of controls were considered and discarded in favor of the use of various algicidal chemicals; it was believed that some of them might reduce and control the alga even under the conditions which a large lake provides in terms of volume, mixing and consequent dilution. Various methods of clipping and harvesting the alga by mechanical means were considered and some thought was given to possible uses.

On June 22, 1959, an investigation concerning the chemical eradication and control of Cladophora was undertaken. The objective was to devise a method that could be recommended to interested municipalities or individuals. It was further proposed that, insofar as possible, physical and chemical environmental factors would also be investigated and fundamental features relative to the alga itself considered.

METHODS, MATERIALS AND PROCEDURES

Experimental Plots and Sampling Stations

For purposes of convenience it was decided to select Oakville as the center of the field survey and to limit our attention to the Port Credit-Oakville-Bronte region.

For the testing of algicidal chemicals, experimental plots approximating one half acre (200 by 100 feet) were marked off with buoys. The areas varied in depth from one to six feet. These plots were located one mile east of Bronte near Coronation Park and approximately three miles west of Bronte beyond the Pig and Whistle property. Areas were selected which were supporting a uniformly heavy growth of Cladophora.

Chemical sampling stations were established off Port Credit, Oakville and Bronte extending from the harbor mouth to points two miles off shore. On occasion samples were taken in certain of the test plots as well.

Water samples were taken and submitted to the Commission laboratories for nitrogen and phosphorus determinations. Bacterial counts were also made.

In the selection of experimental areas consideration was given to control measures which were being attempted by an Oakville organization, The Farm & Forest Research Corporation, on the lakefront in the immediate vicinity of Oakville.

Selection and Application Chemicals

A survey of the literature relative to algal control measures and a canvass of the agricultural chemical divisions of local chemical firms yielded very little information concerning chemicals suitable for controlling Cladophora under lake conditions. Two chemicals, which had been considered, were withdrawn from the market just before our investigation began.

The program for testing algicidal efficiencies included copper sulphate, tri-basic copper sulphate and sodium arsenite. Supplies of these chemicals were made available by Chipman Chemicals Limited, Hamilton. A quarternary ammonium compound, supplied by Rohm & Haas Chemical Company under the trade name "Hyamine", was tested as an algicide and, to a limited extent, for odor control. Later, "Aqualin", an algicidal and herbicidal chemical, being developed by Shell Chemical Corporation, New York City, was obtained, supplied and applied by the Shell Oil Company of Canada.

Copper sulphate was applied in a crystalline form, using, a Cyclone Seeder, on the theory that the crystals would sink to the bottom and go into solution in close proximity to the algal growth. The crystals, on one occasion, were coated with a finely powdered commercial clay in an effort to delay dissolution of the crystals. In one additional test the copper sulphate was applied as a solution. The tri-basic copper compound was applied by towing a burlap "drag", containing the chemical, on a line behind the boat. The sodium arsenite and ""Hyamine" were applied with a hand sprayer while the "Aqualin" was applied by officers of the Shell Company using a suitable power sprayer.

Rates of Applications of Algicidal Chemicals

On July 28, 1959, three test plots in the vicinity of Coronation Park were treated with algicidal agents as follows:

Plot #1 - 3 p.p.m. copper sulphate crystals
#2 - 5 p.p.m. sodium arsenite under-water spray
#3 - 1½ p.p.m. tri-basic copper sulphate (equivalent of 3 p.p.m. copper sulphate)

The first crop of Cladophora to which these applications were made was nearing the end of its life and was dense with massive tangled plumes running up to three feet in length.

On August 13, 1959, six test plots in the Pig and Whistle area were treated as follows:

Plot #4 - 2 p.p.m. copper sulphate crystals
#5 - 4 p.p.m. copper sulphate crystals
#6 - 10 p.p.m. copper sulphate crystals
#7 - 10 p.p.m. tri-basic copper sulphate
#8 - 3 p.p.m. sodium arsenite solution
#9 - 6 p.p.m. sodium arsenite solution

On the same day a plot in the Coronation Park area was treated with 5 p.p.m. of copper sulphate supplied as a spray. At the time of application conditions were almost calm. The second growth Cladophora was six to eight inches in length.

On August 19, 1959, in co-operation with officials of the Shell Oil Company of Canada, "Aqualin", a Shell product, was applied as a spray to three plots in the vicinity of Coronation Park. By this time, of course, the initial crop had been replaced as in the above tests by a second crop of alga having filaments six to eight inches in length forming a solid cover over the rocky bottom.

Plot #10 - 10.5 p.p.m. "Aqualin"
#11 - 5.3 p.p.m. "Aqualin"
#12 - 2.7 p.p.m. "Aqualin"

At the time of application the lake was calm but a sub-surface drift in a southwesterly direction was noted which could account for a good deal of dilution of the chemical. The water temperature was 58°F and the pH 8.0.

This was the first application of "Aqualin" in Canada and the first application in open water to be made anywhere. On August 20 two plots in the vicinity of the Pig and Whistle property were treated with "Hyamine", a quarternary ammonium compound.

Plot #13 - 2½ p.p.m. Hyamine
#14 - 5 p.p.m. Hyamine

At the same time an application of this chemical was made to decomposing masses of Cladophora along the shore at the Pig and Whistle property.

Co-operation with the Geophysical Research Group

Through the co-operation of the Geophysical Research Group of the Research Division of the Department of Lands and Forests, arrangements were made for the use of a navy tug, the "Plainsville", which was obtained on July 14, and was subsequently berthed at Metro-Marine Basin in Bronte. In addition to serving as an operational base the to was used for off-shore sampling and the dinghy and outboard for shallow water operations.

During our investigations some observations on drifts, water temperature and turbidity were made and reported to the Geophysical group. As this investigation proceeds other physical and chemical observations made in Lake Ontario by the Geophysical group will be available for our use.

On September 1 and 2, 1959, Dr. R. Dean, Department of Geology, University of Toronto, carried out diving operations in the Bronte area, Detailed information concerning the condition of the lake bottom and the extent of algal growth up to one-half mile off shore in water up to 30 feet in depth was obtained.

RESULTS OF THE CLADOPHORA INVESTIGATIONS

The General Nature of the Alga

The genus Cladophora includes about 160 species which are not well defined. A great deal of taxonomic study is required to provide for the certain identification of species of the genus. Both fresh water and marine species occur and the genus is widely distributed.

A member of the green algae, Cladophora grows usually as a branched, attached, filamentous form. In addition to the upright portion, attached species produce a prostrate, rhizoidal, basal growth which is usually perennial and from which regrowth of the alga may rapidly occur.

In most species which have been carefully studied there is in the life cycle a definite alternation of sporophytic and gametophytic plants which are identical in gross morphology but distinct in terms of their cytological detail and reproductive processes.

In most instances reproduction is accomplished most extensively by the formation of zoospores, involving reduction division. These are widely dispersed and form, by direct germination, haploid gametophyte plants. These plants produce gametes which, following sexual fusion, form resting spores. The latter germinate at once to produce diploid sporophyte plants thus completing the sexual cycle.

As a consequence, there is a constant possibility of renewal of growth at any time throughout the season. In addition, new growth may readily arise from the prostrate, perennial, rhizoidal base.

Most species require good aeration which is afforded in rapids and in areas where wave action is marked. It should be understood however that some species are capable of existence in quiet bodies of deep water.

The Actual Extent and Nature of the Algal Growth in Lake Ontario

Although it was not possible to conduct exhaustive studies of the lake front in general, the basic features relating to the Cladophora growth, as it occurred in the vicinity of Oakville from late June to mid September, were observed and useful deductions may he drawn.

It is obvious that the species of Cladophora with which we are concerned, grow only in areas where a suitable, firm substratum is available for attachment. On bed rock, the alga is able to establish itself only in cracks and crevices where, presumably, the reproductive cells have an opportunity to settle. Similarly the protected edges of large rocks support dense growths and, consequently, the most dense meadows are found in locations possessing a shingle or cobble bottom. With respect to the universal distribution of this alga and the importance of a suitable attachment it may be noted that various artificial sub-strata, such as piers and bridgework, soon become coated with the alga in areas where growth is otherwise absent. Marker buoys, during this investigation, became coated with Cladophora. At Rondeau Park, a single Cladophora-infested post was observed with no other algal stands within miles along the sandy beach.

In the Oakville area Cladophora was observed growing heavily in suitable areas from the water line to points in excess of six feet of water. Dr. Dean's diving operations indicated that, in areas ranging from six to 12 feet in depth, the amount of attached, growing Cladophora decreased rapidly. At 12 feet and beyond no significant growth was observed although quantities of disintegrating, free-floating masses were observed. Although no quantitative observations were made it was noted that in water ranging from 10 to 30 feet in depth, light was reduced at the bottom and a marked drop in temperature was noted in the bottom sediments.

In accordance with this evidence, considering depths approaching 10 feet, very extensive meadows may be expected along the shallower stretches of the shoreline. Certainly some of the meadows extend out 1000 feet from shore. Considering also the linear extent of the shoreline involved and the productivity of the alga per square foot, some appreciation of the magnitude of the control problem is attained.

Relationship of the Algal Growth to Mineral Nutrients

The results of chemical analyses have been summarized in Tables I and II. For complete details, refer to tables included in the appendix. It must be noted that the analyses obtained from samples taken at the Port Credit stations are not typical of the general shoreline since local municipal and industrial contamination strongly influence the results.

TABLE I. Mean concentrations of nitrogen compounds, total phosphates, and coliform bacteria at stations in Lake Ontario between July 21 and September 21, 1959. Bacteria expressed as coliforms per 100 ml. All other data in parts per million. (See appendix for complete records).

Location and distance from shore	Nitrogen compounds as N NH_3	Total Kjeldahl	Total Phosphates as PO_4	Coliform Bacteria
Port Credit at 100 feet	.86	3.2	2.13	5,200,000
250 "	.28	2.5	.27	110,000
500 "	.12	1.4	.15	73,000
1000 "	.09	.91	.11	6,500
½ mile	.05	.81	.08	810
1 "	.04	.85	.08	290
1½ "	.07	.61	.08	57
2 "	.03	.59	.08	190
Oakville at				
100 feet	.07	.81	.12	1,800
250 "	.07	.78	.08	110
500 "	.06	1.1	.19	150
1000 "	.06	.38	.06	22
½ mile	.04	.45	.06	52
1 "	.05	.82	.08	180
1½ "	.04	.49	.05	1
2 "	.10	.87	.06	130
Bronte at 100 feet	.06	.94	.17	110
250 "	.04	.47	.10	2,600
500 "	.05	.52	.06	3,000
1000 "	.04	.54	.04	9,200
½ mile	.06	.40	.06	29
1 "	.06	.52	.06	14
1½ "	.04	.52	.05	15
2 "	.07	.45	.05	5

TABLE II. Maximum and minimum concentrations, summarized from Tables 1-3, of soluble phosphates and phenols at points in Lake Ontario from July 21 and September 21, 1959. (See appendix for complete results).

Location and distance from shore	Soluble Phosphates			Phenols		
	Number of samples	Maximum	Minimum	Number of Samples	Maximum	Minimum
Port Credit at						
100 feet	2	7.	.09	3	3	0
250 "	2	.09	.00	3	3	0
500 "	2	.09	.00	3	3	0
1000 "	2	.01	.00	3	3	0
½ mile	2	.01	.00	3	3	0
1 "	2	.01	.00	3	6	0
½ "	2	.01	.00	3	2	0
2 "	2	.01	.01	3	2	0
Oakville at						
100 feet	2	.03	.00	3	3	0
250 "	2	.05	.00	3	3	0
500 "	2	.00	.00	3	0	0
1000 "	2	.00	.00	3	2	0
½ mile	3	.00	.00	4	3	0
1 "	3	.00	.00	4	4	0
1½ "	3	.00	.00	4	2	0
2 "	3	.00	.00	4	0	0
Bronte at						
100 feet	3	.01	.00	4	0	0
250 "	3	.01	.00	4	0	0
500 "	3	.01	.00	4	0	0
1000 "	3	.01	.00	4	2	0
½ mile	3	.01	.00	4	3	0
1 "	3	.01	.00	4	3	0
1½ "	3	.01	.00	4	2	0
2 "	3	.01	.00	4	2	0

The mean concentrations of NH_3 at Port Credit show a steady decrease with increasing distance from shore. At Oakville a similar trend was noted but the mean concentration at the two-mile station was 0.1 p.p.m. as compared with 0.05 at 500 feet from shore. At Bronte there seemed to be no significant variation in mean concentrations at the stations studied.

Mean concentrations of total nitrogen at Port Credit show a decrease from 1.40 p.p.m. at 500 feet to 0.09 p.p.m. at the two-mile station. At Oakville stations no constant variation was observed and at Bronte only a slight tendency toward decrease in mean concentrations was observed with distance from shore. At the 100-foot station however a mean concentration of 0.04 p.p.m. was recorded while at two miles the mean was 0.45 p.p.m.

At Oakville and Bronte the mean concentrations of total phosphorus approximate 0.1 p.p.m. at the onshore stations. On these ranges, the phosphorus content was reduced to approximately 0.05 p.p.m. at two miles. At Port Credit, beyond 500 feet, a similar reduction of approximately 50% was noted in the phosphorus analyses at two miles.

With the exception of the onshore stations at Port Credit, no exceptionally high concentrations of these essential nutrient elements, nitrogen and phosphorus, were noted. It is significant however that the mean concentrations tend to decrease with increasing distance from shore. At the two-mile stations mean concentrations of one-half and one-quarter those recorded for near-shore locations may be observed in Table I.

Minute quantities of nutrient chemicals are sufficient for the support of normal plant growth. Slight increases in the nutrient elements present may cause very large increases in the crop supported. Certainly the excessive growths of Cladophora observed in Lake Ontario indicate that the chemical nutrients are present in at least very adequate amounts. There is evidence of added enrichment of the waters at the shoreline relative to the chemical composition of the lake in general as indicated by sampling at the two-mile stations. In our present state of knowledge, however, it would be difficult to say whether or not any measure of control might be expected from a lowering of the mineral content of the lake.

In view of the chemical uniformity of the lake in the area investigated it appears that the distribution of the growth is controlled mainly by physical factors related to the attachment of the organism.

<u>Relationship of Algal Growth to Physical Factors</u>

Throughout the period of the investigation temperature and current determinations were made from time to time. There are recorded in the following table. The current flow is indicated in feet per minute.

TABLE III.

Date	Port Credit			Oakville			Bronte		
	Sfc. Temp.	Current	Bot. Temp	Sfc. Temp.	Current	Bot. Temp.	Sfc. Temp.	Current	Bot. Temp
July									
14	--	--	--	60	--	--	60	--	--
16	--	--	--	--	--	--	67	--	--
20	--	--	--	--	--	--	66	--	--
29	70	--	--	66	--	--	65	--	--
Aug.									
4	60	SW-10	58*	62	Variable	60*	61	--	--
10	69	SE-15	64	68	SE-20	64	69	--	67
18	46	S-5	43*	49	W-WNW	48*	48	ESE-15	42*
19	--	--	--	--	10-25	--	--	--	--
19	--	--	--	--	--	--	58	--	--
24	67	calm	64	67	NE-1	65	67	NE-1	64
Sept.									
8	64	--	52	58	--	52	56	--	52
21	--	--	--	62	--	61	62	--	61

* Reading taken at 15 feet

The surface temperatures throughout the area were quite uniform during the period of investigation and approximated 60°F. As is shown by the records taken on August 18 and 19, however, marked and rapid fluctuations did occur and for the determination of rates of application of algicides, adjustments must be made according to the temperature prevailing at the time of treatment.

Some temperature gradient was noted in the lake but usually it amounted only to a few degrees.

Although temperature records are not presently available for the entire season, it is known that the alga undergoes appreciable growth in the early season and continues to thrive late in the fall. From December 28, 1959 to January 2, 1960, for example, the water intakes of the British American Oil Company were plugged by masses of Cladophora. It has been reported that these algal masses were healthy and fresh at that time and were carried in by a strong easterly wind.

The most extensive and rapid growth of Cladophora occurred in late June and during July. The more restricted growth, obtained in August and September, does not seem to be attributable to the water temperature. In view of its very universal distribution, the alga seems to be very tolerant of temperature conditions.

Water currents were studied mainly during reasonably calm periods. One set of records which were taken under storm conditions may be available at a later date. As is shown in Table III currents noted were either induced or influenced by the prevailing wind. Currents varying from zero to 25 feet per second (seven miles per day) were encountered.

In calm weather marked water currents were noted on the bottom when test plots were being observed. No measurements of these were made but such a phenomenon must be taken into account when determining the dilution factors relative to applications of algicidal chemicals. Such currents may also be important with respect to the agitation and aeration of the algal growth. In connection with the latter however wave action may be of greater importance.

Turbidity of the water might be a factor in limiting growth due to reduction of light intensity at lower levels. In general however a rock bottom which might be associated with low turbidity is essential for the establishment of attached species of Cladophora.

Seasonal Fluctuations in Growth of Cladophora

From observations elsewhere it is known that many algae including Cladophora, may be found growing at all seasons of the year. So far as this investigation is concerned observations were made only from late June to mid-September with some limited surveys in October.

When first observed at the end of June the Cladophora meadows were well developed. It is probable that considerable growth was attained in May although low water temperature may have retarded the rate of growth during the early part of the season.

Throughout July however the upright filamentous growth of Cladophora attained lengths of two to three feet and began to appear on the surface in suitably shallow water. Under the action of the water presumably, tangled plumes formed making the presence of the alga much more noticeable toward the end of July.

In general, during the early part of August, this first most massive crop of the season "matured" became free floating and disintegrated. As this massive growth of alga dispersed a second crop consisting of filaments one and two inches in length could be observed over the rock bottom. In subsequent weeks this crop never exhibited the vigor or extent of the earlier one. When last observed in detail on September 16 the growth in untreated areas had attained a maximum growth of approximately 12 inches.

Generally speaking, the significant growths of Cladophora and the subsequent nuisance conditions may be anticipated in July and early August. In the case of a particularly heavy infestation however distressing shore conditions may persist well into the fall. As has been mentioned above, accumulations of Cladophora plugged the water intakes at the British American Oil Company on January 1, 1960.

The Nature, Occurrence and Control of Shore Accumulations

Masses of algal material accumulated and disintegrating along the shore is of course, the very essence of this problem. In Lake Ontario there is no great reason for concern about the healthy growth of the alga excepting in connection with some isolated cases of recreational use. When the alga accumulates and breaks down at the water's edge, in a band that may be 30 to 50 feet in width and several feet in depth, a nuisance condition results which can neither be minimized or ignored.

On the basis of our observations it is apparent that the alga becomes free-floating at the end of a growth cycle. Contrary to popular assumptions heavy wave action is not capable, in itself, of breaking down health, vigorous growths although it may be by such means that mature" crops of Cladophora are cast up on the beaches. In general it would appear that this Cladophora thrives under violent physical action.

When the alga breaks away from its attachment it will remain healthy so long as it floats freely and does not stagnate in large masses. As a consequence, shore accumulations may occur for a limited time and be removed by appropriate wind and water action without ever developing any objectionable odor. Throughout the course of the investigation it was not uncommon to encounter large masses of Cladophora floating in the open lake. It is obvious that only a part of the algal mass arrives on shore and then only when suitable on-shore winds prevail.

If the alga is driven high on shore and is allowed to dry it forms a felt-like mass which is very resistant to break down, and of course free of odor. If it remains as a mass in contact with the water and is closely packed, it may form an artificial extension of the beach, dry and brown on top, black, oily and incredibly offensive beneath. Once established such an accumulation may persist for a considerable period of time. It is relatively inoffensive in dry weather but with rain, storms or even high humidity it again produces an odor problem.

One application of Hyamine to such an accumulation was made to control the odor. While some influence might be exerted the fact impresses that there is little possibility of preventing or even diminishing the odor from any such reasonably extensive mass of disintegrating organic matter. It would involve complete and continuous sterilization.

Control of the offensive conditions associated with shoreline accumulations must involve either their prevention or their physical removal. The latter would present very great difficulties.

Diving operations revealed large masses disintegrating on the lake bottom. In water ranging in depth from 12 to 30 feet black, gaseous masses with the characteristic offensive odor were encountered on the bottom during the late season (September 1). Apparently this represents the fraction which has remained in deep water and which has ultimately settled.

In the light of these comments it seems probable that really obnoxious accumulations are derived in the main from the first, massive algal crop. These may persist and recur until September and October although at this late season the odor problem does not seem to be as great. Lower temperatures perhaps influence the rate of decomposition.

According to the observations the second more limited crop did not become free floating as a whole within the period of investigation although it may have produced local minor accumulations.

Control of the Alga by Chemical Means

The first applications of algicidal chemicals were made on July 28, 1959, but since this coincided with the end of a growth cycle, it was not possible to interpret the results. Subsequently the observation of the plots was often rendered difficult by the large floating masses of Cladophora that tended to obscure the bottom.

No indication of any effect on the alga was evident on August 4, one week after treatment but extensive algal accumulations were observed along the shore. As time went on, the first crop in treated and non-treated areas alike, became detached and the lake bottom, so far as the algal growth was concerned, became uniform. Meanwhile the second crop consisting of short, young filaments was developing.

TABLE IV. Summary of results of applications of algicides in Lake Ontario for the control of *Cladophora* sp.

Date of Application	Test Plot		Application of Algicide		Results
	Reference Number	Location of Plot	Chemical Used *	Concentration in p.p.m.	
July 28	1	near Coronation Park	$CuSO_4.5H_2O$ crystals	3	no control
" "	2	" "	Na_2HAsO_3 solution	5	" "
" "		" "	$CuSO_4.3Cu\ (OH)_2$	1.5	" "
Aug.13	4	near Pig and Whistle Restaurant	$CuSO_4.5H_2O$ crystals	2	" "
" "	5	" "	"	4	slight, temporary inhibition
" "	6	" "	"	10	slight, inhibition of 30% of crop for 4 wk
Aug. 13	7	" "	$CuSO_4.3Cu(OH_4)_2$	10	eradication of 50% of the crop, remainder chlorotic and inhibited for 4 wk
" "	8	" "	$NA_2HA_5O_3$ solution		slight, inhibition of 100% of crop for 5 weeks
" "	9	" "	" "	6	moderate inhibition of 100% of crop for 5 wk
" "	9	" "	$CuSO_4.5H_2O$ solution	5	no control
Aug. 19	10	near Coronation Park	"Aqualin" solution	10.5	complete eradication of 100% of crop for 4 wk
" "	11	" "	" "	5.3	severe inhibition of 100% of crop for 4 wk
" "	12	" "	" "	2.7	moderate inhibition of 100% of crop for 4 wk
Aug, 20	13	near Pig and Whistle Restaurant	"Hyamine" Sol'n (Active ingredient)	2.5	Inhibition of 100% of crop for 4 wk
" "	14	" "	" "	5	" "
" "	15	shoreline near Pig and Whistle Restaurant	" "	Sprayed on shore accumulations for odor control the result could not be assessed.	

* In the case of copper sulphate, sodium arsenite and "Aqualin", calculations are in terms of the compound. "Hyamine" applications are calculated on the basis of the active component and tri-basic copper sulphate applications were expressed in terms of copper sulphate (copper equivalents).

The results obtained using various applications of algicidal chemicals are summarized in Table IV. A discussion of these results follows:

(a) Copper Sulphate Applications

Applied at the rate of two p.p.m. copper sulphate crystals had no influence at any time and after a period of four weeks the alga was normal and healthy.

Four p.p.m. of copper sulphate produced some scattered killing of branch systems, particularly at their tips. Chlorosis and killing was apparent during the first three weeks but by four weeks following treatment (September 8) the alga was showing signs of recovery. By September 16 the test plots appeared to be essentially normal.

Ten p.p.m. copper sulphate produced a terminal kill over approximately 30% of the area within seven days (August 20). The basal portion of the growth, however, maintained a healthy appearance and the killing effect was more extensive where the growth was sparse and less so in the more dense areas. Throughout the four week period that followed there seemed to be some recovery. Actually, it would seem that the chlorotic tips were removed and the more healthy basal growth reduced by this means to a length of two to three inches were exposed.

Five p.p.m. copper sulphate applied as a solution had no recognizable influence on the algal growth.

(b) Tri-basic Copper Sulphate

In general 10 p.p.m. of this chemical produced a more uniform chlorotic effect than copper sulphate crystals. Three weeks after treatment approximately 50% of the alga had been killed. The alga remaining was somewhat chlorotic and retarded in growth.

Tri -basic copper sulphate appeared to be slightly more effective than copper sulphate at the same copper concentration.

(c) Sodium Arsenite Solution

The influence of sodium arsenite was similar to that of tri-basic copper sulphate in that the chlorotic effect was uniform. At the close of one week a general chlorosis was apparent. The application of six p.p.m. was somewhat more effective than the three p.p.m. application. In subsequent weekly observations however the two test plots and the intervening check plots, apparently by diffusion, became uniform in appearance.

Five weeks after the treatment had been applied the growth in the arsenite treated areas was chlorotic and reduced to approximately two to three inches.

Although there was no eradication the growth of the alga was retarded more by sodium arsenite than by either of the copper compounds referred to above.

(d) Hyamine Solutions

In two adjoining plots treated with two and one-half and five p.p.m. of Hyamine, a quarternary ammonium compound, an effect similar to that induced by sodium arsenite above was produced. The chemical seemed to become uniformly distributed by diffusion and mixing. At the close of three weeks it was estimated that the crop had been reduced by 60 to 70%. After five weeks (September 16) the plots, similar to those treated with sodium arsenite, exhibited chlorotic growth which was reduced to two or three inches in length.

(e) "Aqualin" Applications

It is possibly significant that the influence of applications of "Aqualin" was apparent less than 24 hours after the applications were made.

Applied at the rate of 2.7 p.p.m., "Aqualin" destroyed a significant portion of the growth rather than merely producing a chlorotic condition. An actual dissolution of the plant material seemed to have taken place.

At this rate of application however re-growth was apparent throughout the third and fourth weeks after treatment.

"Aqualin" when applied at the rate of 5.3 p.p.m. removed a remarkable portion of the alga. Large areas of the bottom were completely cleared within one week and only a few scattered clumps of Cladophora persisted on the edges of rocks and in crevices.

"Aqualin" applied at the rate of 10.5 p.p.m. removed all but a few brownish remnants during the first week. Subsequently for an additional three weeks during which observations were made this treated area remained perfectly clear of all growth and stood out in remarkable contrast to the surrounding untreated plots. It is noteworthy that with "Aqualin", very little diffusion or mixing occurred. Apparently the killing action is rapid and the chemical is absorbed or dissociated before it has an opportunity to drift beyond the actual area of application.

DISCUSSION

The Occurrence and Distribution of Cladophora in Lake Ontario

It is evident that Cladophora is capable of growing anywhere in the portion of the lake studied where suitable attachment is afforded and where the depth and turbidity of the water is not too great. On a shore area with a uniform rock bottom Cladophora was found to decrease rapidly in areas covered by more than six feet of water and to be almost virtually lacking in ten feet of water. These limitations allow for the establishment of meadows extending 500 to 1,000 feet from shore in many of the areas studied.

On the basis of recorded monthly means, the maximum known variation in the water level in Lake Ontario is 6.2 feet. The water level during the summer of 1959 was 3.1 feet below the previous cyclic peak which was recorded in 1952. Extensive soundings were not undertaken during this investigation. It is obvious however that fluctuations in the water level would influence the lake area suitable for the growth of Cladophora. However it would seem the recent occurrence of excessive growths of Cladophora cannot be completely explained on this basis alone.

On the basis of surface and bottom lake temperatures recorded the water temperature does not seem to be a critical factor in the control of growth. With respect to the influence of water depth, lack of turbulence is probably more influential in limiting the growth of Cladophora than either temperature or light intensity.

The chemical analyses recorded in Tables I, II and III of the Appendix, do not indicate extremely high concentrations of nutrient elements at the on-shore stations. It is true however that the nutrient elements nitrogen and phosphorus are present at on-shore locations in amounts approximately double those found at the two-mile stations. This condition is undoubtedly due to rich run-off water along the shore and to the presence of municipal and industrial wastes.

For the growth of any plant, Cladophora included, the amount of essential elements required may be determined. Up to the point where a toxic condition results increases in available nutrients will induce increased growth. Accepting the fact that all other physical factors are suitable the degree of enrichment of the on-shore waters will have a direct effect upon the extent of algal growth.

The nutrient concentration is surely adequate for the support of excessive algal growth at the present time With increased urbanization expected, the nutrient salts available to the lake will probably not diminish in the future. From the point of view of nutrient elements Cladophora must be regarded as a continuing problem in Lake Ontario.

To explain the fluctuations which are known to have occurred in the past with reference to excessive growths of Cladophora at these locations reference can be made only to known fluctuations in the water level. While the water level might influence the extent of the growth it does not seem capable of explaining completely the presence or absence of nuisance conditions.

Our observations indicate that Cladophora produces at least two crops in any one growing season. The first crop was well established in mid-June and became free-floating around August 1st. The second crop, commencing in early August, remained healthy and attached at least until observations were discontinued in September. Subsequent information referred to above indicates the presence of nuisance accumulations of the alga as late as December and January.

During the period of investigation the first crop was much more extensive than the second. It is possible that water temperature may have an influence on the rate of growth.

The Importance of Shore Accumulations

In a location such as Lake Ontario the healthy growing Cladophora presents practically no problem, It is only when massive accumulations of free-floating alga becomes crowded in and disintegrates along the shore that a nuisance condition exists.

Kept moist nothing less than total sterilization will prevent the breakdown of this organic matter and the consequent distressing odor. Various odor control procedures have been suggested but it is unlikely that any will give success in actual practice.

In some areas these accumulating algae have been collected and removed mechanically. Even where this is attempted it is scarcely practical and in most areas along the shore conditions are such as to made these procedures quite impossible.

For practical results the prevention of these accumulations must be achieved. This will involve effective prevention or control of the growth of the alga before a large volume of growth has occurred. Otherwise an algicide, similar perhaps to "Aqualin", might be used in the killing of the alga bringing about its dissociation in situ and thereby obviating shore accumulations.

The observation that the alga breaks loose and becomes free floating as a result of the maturation of a crop rather than due to mechanical damage by storm is important in planning control measures. Most significant beach problems even those occurring in the fall, trace back and relate to the heavy first crop which occurs prior to August 1. In view of the fact that the second crop is by comparison not extensive, the control or destruction of the first crop might go a long way toward controlling the Cladophora problem in any one season.

The Effectiveness of Algicidal Chemicals

All of the available algicidal chemicals which were recommended for the control of Cladophora were tested. Most of these produced enough effect to warrant further study. None were investigated thoroughly enough to warrant their complete rejection.

Copper sulphate is well known tor its toxicity to plant materials but under the conditions prevailing in. Lake Ontario it has proven unsatisfactory in concentrations of two and four p.p.m. Plots treated with 10 p.p.m. showed apical killing of the filaments with a consequent reduction in growth. The alga was at no time removed and at the end of five weeks the growth was green and plentiful.

Tri-basic copper sulphate produced an effect on Cladophora which was limited but nonetheless more extensive than that induced by copper sulphate.

Sodium arsenite and "Hyamine", a quarternary ammonium compound, were both more effective than either of the copper compounds. The growth was uniformly influenced and distinctly reduced in each case. The proper timing of treatment of the first crop of the season with these two chemicals might well be investigated further. It is possible that the crop might be reduced and contained within limits which would prevent subsequent objectionable shore nuisances.

Applications of "Aqualin" proved to be most interesting. Only this chemical, of all those tested was capable of bringing about a total removal of visible growth. For a period of four weeks at least, plots treated with five and 10 p.p.m. remained virtually barren.

It is apparent that "Aqualin" kills quickly and in low dilution. Thus the dilution problem which is so important a factor in a large body of water is minimized. Moreover the chemical is rapidly absorbed by organic matter of any kind and its residual effect is reduced rapidly.

Although a Canadian price for this experimental chemical is still not available plans are being made to place it on the Canadian market at a competitive price. Moreover other related chemicals are being investigated with a view to improving the general effectiveness of the product. Further study of "Aqualin", from many points of view, is certainly desirable.

Comparative Cost of Control Measures

No consideration of this phase of the problem has been possible up to the present moment for aside from the actual costs of material, some of which are not yet available, many other factors upon which the final cost picture will ultimately depend have not been determined.

Of greatest importance with respect to the actual growth program of the alga and to the cost and general effectiveness of treatment is the timing of the control effort. In turn the optimum time for treatment will depend on a number of factors, the influence of which can only be determined by experimentation.

To control the first crop and to prevent subsequent shoreline accumulations of disintegrating algae, an early application of algicide might be most effective. Moreover, the less the amount of organic matter present the less algicidal chemical is required. On the other hand the lower lake temperature in the early season might reduce the effectiveness of the chemical to the point where the application of an effective treatment would be too expensive.

Probably of greater importance in determining the cost of treatment is the period of effectiveness of any one application of a particular algicide. If this period is long enough it will be practical to use the algicide even though the initial cost is high.

APPENDIX TABLE I

Concentrations of nutrient chemicals, phenols and coliform bacteria at Lake Ontario stations near Port Credit from July 21 to September 21, 1959. Concentrations of bacteria expressed as coliforms per 100 ml., phenols in parts per billion and all other data in parts per million.

Date	Distance from shore	Nitrogen Cpds as N		Phosphates as PO_4		Total Phenols	Coliform Bacteria
		NH_3 Test	Kjeldahl Test	Total	Soluble		
July 21	100 feet		2.1	0.26			
	250 "		1.8	0.26			
	500 "						
	1000 "		0	0.13			
	½ mile		1.2	0.08			
	1 "		2.1	0.04			
	1½ "		0.0	0.01			
	2 "		0.3	0.01			
July 29	100 feet	0.05	0.5				
	250 "	0.05	3.0				
	500 "	0.04	3.8				
	1000 "	0.03	1.7				
	½ mile	0.05	1.0				
	1 "	0.06	0.4				
	1½ "	0.19	0.4				
	2 "	0.02	<0.05				
Aug. 4	100 feet	0.08	1.1	0.29			17,000
	250 "	0.08	0.4	0.32			33,000
	500 "	0.06	0.2	0.32			60,000
	1000 "	0.05	<0.2	0.29			150
	½ mile	0.05	0.3	0.13			120
	1 "	0.04	1.2	0.09			0
	1½ "	0.04	0.2	0.13			0
	2 "	0.04	0.4	0.08			0
Aug.10	100 feet	0.03	0.4	0.08			9,000
	250 "	0.02	0.5	0.05			58,000
	500 "	0.04	0.6	0.05			160,000
	1000 "	0.04	0.8	0.05			29,000
	½ mile	0.02	1.6	0.05			4,000
	1 "	0.05	0.5	0.05			630
	1½ "	0.03	1.2	0.21			40
	2 "	0.03	<0.2	0.05			46
Aug.18	100 feet	2.1	9.4	±1.			0
	250 "	1.4	2.3	0.73			60
	500 "	0.40	1.2	0.15			70
	1000 "	0.20	1.5	0.10			4
	½ mile	0.08	1.0	0.02			0
	1 "	0.04	0.2	0.20			0
	1½ "	0.11	0.5	0.03			0
	2 "	0.03	1.3	0.18			0

APPENDIX TABLE I (Continued)

Date	Distance from shore	Nitrogen Cpds as N		Phosphates as PO_4		Total Phenols	Coliform Bacteria
		NH_3 Test	Kjeldahl Test	Total	Soluble		
Aug. 24	100 feet	0.03	0.8	0.00		3	400,000
	250 "	0.27	9.9	0.00		0	48,000
	500 "	0.03	1.3	0.00		3	89,000
	1000 "	0.06	1.7	0.00		3	67
	½ mile	0.05	0.5	0.12		3	15
	1 "	0.03	0.3	0.05		2	0
	1½ "	0.04	2.0	0.05		2	0
	2 "	0.04	0.8	0.18		2	2
Aug. 31	100 feet	0.22	2.0	0.26	0.09	0	11,000
	250 "	0.08	2.0	0.31	0.09	0	34,000
	500 "	0.21	2.2	0.26	0.09	0	17,000
	1000 "	0.18	1.3	0.10	0.01	0	0
	½ mile	0.05	0.6	0.10	0.01	0	0
	1 "	0.06	1.3	0.10	0.01	0	21
	1½ "	0.03	0.3	0.10	0.01	0	2
	2 "	0.05	0.6	0.05	0.01	0	0
Sept. 8	100 feet	3.5	8.9	13.	7.	0	31×10^6
	250 "	0.04	0.4	0.19	0.00	4	510,000
	500 "	0.04	0.2	0.09	0.00	0	110,000
	1000 "	0.04	0.1	0.08	0.00	2	10,000
	½ mile	0.06	0.3	0.04	0.00	2	700
	1 "	0.03	0.8	0.00	0.00	6	1,100
	1½ "	0.03	0.3	0.00	0.00	0	300
	2 "	0.02	1.2	0.01	0.00	0	1,100

APPENDIX TABLE II

Concentrations of nutrient chemicals, phenols and coliform bacteria at Lake Ontario stations near Oakville from July 21 to September 21, 1959. Concentrations of bacteria expressed as coliforms per 100 ml., phenols in parts per billion and all other data in parts per million.

Date	Distance from shore	Nitrogen Cpds as N		Phosphates as PO_4		Total Phenols	Coliform Bacteria
		NH_3 Test	Kjeldahl Test	Total	Soluble		
July 21	100 feet		0.3	0.01			
	250 "		1.5	0.05			
	500 “						
	1000 "		0.6	0.06			
	½ mile		0.6	0.06			
	1 "		2.7	0.36			
	1½ "		0.0	0.08			
	2 "		2.1	0.01			
July 29	100 feet	0.05	1.7				
	250 "	0.06	1.0				
	500 “	0.06	3.2				
	1000 "	0.06	0.9				
	½ mile	0.05	<0.05				
	1 "	0.06	0.8				
	1½ "	0.06	<0.05				
	2 "	0.06	1.3				
Aug. 4	100 feet	0.24	0.7	0.19			1,000
	250 "	0.07	0.3	0.11			350
	500 “	0.20	0.4	0.16			700
	1000 "	0.16	<0.2	0.11			31
	½ mile	0.10	<0.2	0.08			50
	1 "	0.10	<0.2	0.08			18
	1½ "	0.05	0.8	0.09			0
	2 "	0.27	0.4	0.05			0
Aug. 10	100 feet	0.04	0.3	0.05			9,300
	250 "	0.04	0.4	0.08			60
	500 “	0.02	0.9	0.05			10
	1000 "	0.03	<0.2	0.08			38
	½ mile	0.03	<0.2	0.04			110
	1 "	0.04	0.6	0.04			46
	1½ "	0.02	1.1	0.04			7
	2 "	0.02	0.8	0.04			17
Aug. 18	100 feet	0.05	0.8	0.26			2
	250 "	0.04	1.2	0.04			0
	500 “	0.03	0.2	0.62			0
	1000 "	0.03	0.2	0.03			7
	½ mile	0.03	0.3	0.15			0
	1 "	0.06	0.2	0.03			0
	1½ "	0.05	0.2	0.03			0
	2 "	0.05	0.6	0.20			0

APPENDIX TABLE II (Continued)

Date	Distance from shore	Nitrogen Cpds as N: NH_3 Test	Nitrogen Cpds as N: Kjeldahl Test	Phosphates as PO_4: Total	Phosphates as PO_4: Soluble	Total Phenols	Coliform Bacteria
Aug. 24	100 feet	0.04	0.8	0.06		3	0
	250 "	0.04	0.6	0.05		3	0
	500 "	0.04	1.4	0.05		0	9
	1000 "	0.03	0.7	0.05		2	1
	½ mile	0.04	0.7	0.05		3	0
	1 "	0.03	1.3	0.05		3	5
	1½ "	0.04	0.1	0.12		2	0
	2 "	0.16	0.5	0.02		0	4
Aug. 31	½ mile	0.05	0.7	0.01	0.00	0	4
	1 "	0.05	0.5	0.01	0.00	0	15
	1½ "	0.03	0.9	0.01	0.00	0	2
	2 "	0.05	0.8	0.01	0.00	0	0
Sept. 8	100 feet	0.02	1.7	0.03	0.00	0	300
	250 "	0.02	0.6	0.00	0.00	0	53
	500 "	0.03	1.2	0.00	0.00	0	200
	1000 "	0.06	0.3	0.04	0.00	0	55
	½ mile	0.02	1.4	0.07	0.00	0	200
	1 "	0.03	1.1	0.04	0.00	0	1,200
	1½ "	0.02	0.7	0.00	0.00	0	0
	2 "	0.20	1.3	0.04	0.00	0	900
Sept. 21	100 feet	0.06	0.2	0.21	0.03	0	0
	250 "	0.22	0.6	0.21	0.05	0	0
	500 "	0.03	0.06	0.26	0.00	0	0
	1000 "	0.02	0.03	0.08	0.00	0	0
	½ mile	0.02	0.06	0.05	0.00	2	0
	1 "	0.03	0.06	0.05	0.00	4	0
	1½ "	0.02	0.6	0.03	0.00	0	0
	2 "	0.02	0.03	0.08	0.00	0	0

APPENDIX TABLE III

Concentrations of nutrient chemicals, phenols and coliform bacteria at Lake Ontario stations near Bronte from July 21 to September 21, 1959. Concentrations of bacteria expressed as coliforms per 100 ml., phenols in parts per billion and all other data in parts per million.

Date	Distance from shore	Nitrogen Cpds as N		Phosphates as PO_4		Total Phenols	Coliform Bacteria
		NH_3 Test	Kjeldahl Test	Total	Soluble		
July 21	100 feet		0.3	0.10			
	250 "		0.3	0.31			
	500 "						
	1000 "		1.2	0.05			
	½ mile		0.0	0.03			
	1 "		1.6	0.18			
	1½ "		0.9	0.08			
	2 "		0.3	0.21			
July 29	100 feet	0.03	<0.05				
	250 "	0.03	<0.05				
	500 "	0.05	0.7				
	1000 "	0.03	<0.05				
	½ mile	0.06	0.8				
	1 "	0.09	0.4				
	1½ "	0.04	0.5				
	2 "	0.04	0.2				
Aug. 4	100 feet	0.07	1.9	0.13			200
	250 "	0.10	0.6	0.07			470
	500 "	0.07	0.5	0.08			190
	1000 "	0.08	0.4	0.08			54
	½ mile	0.07	0.6	0.11			0
	1 "	0.14	0.2	0.11			0
	1½ "	0.04	0.2	0.07			0
	2 "	0.2	0.6	0.05			0
Aug. 10	100 feet	0.07	1.4	0.40			160
	250 "	0.06	0.9	0.32			2,500
	500 "	0.06	0.8	0.09			2,500
	1000 "	0.03	0.7	0.09			59
	½ mile	0.02	0.5	0.16			89
	1 "	0.04	< 0.2	0.05			3
	1½ "	0.04	1.4	0.05			16
	2 "	0.02	0.3	0.05			20
Aug. 18	100 feet	0.06	0.4	0.03			7,400
	250 "	0.03	0.3	0.03			14,000
	500 "	0.07	0.4	0.16			15,000
	1000 "	0.07	0.2	0.05			88
	½ mile	0.06	0.3	0.03			12
	1 "	U.04	0.3	0.04			31
	1½ "	0.07	0.3	0.02			1
	2 "	0.08	0.3	0.05			2

APPENDIX TABLE III (Continued)

Date	Distance from shore	Nitrogen Cpds as N		Phosphates as PO_4		Total Phenols	Coliform Bacteria
		NH_3 Test	Kjeldahl Test	Total	Soluble		
Aug. 24	100 feet	0.03	0.9	0.52		0	1
	250 "	0.03	0.6	0.00		0	0
	500 "	0.03	0.7	0.00		0	0
	1000 "	0.05	0.7	0.00		0	0
	½ mile	0.02	0.6	0.00		3	0
	1 "	0.02	0.6	0.00		3	0
	1½ "	0.03	0.5	0.00		2	1
	2 "	0.02	0.7	0.00		2	3
Aug. 31	100 feet	0.03	1.2	0.01	0.01	0	2
	250 "	0.04	0.6	0.01	0.01	0	1
	500 "	0.03	0.7	0.01	0.01	0	2
	1000 "	0.03	1.2	0.03	0.01	0	64,000
	½ mile	0.03	0.4	0.03	0.01	0	0
	1 "	0.04	0.3	0.05	0.01	0	16
	1½ "	0.03	0.6	0.01	0.01	0	90
	2 "	0.11	0.4	0.01	0.01	0	6
Sept. 8	100 feet	0.08	1.7	0.03	0.00	0	30
	250 "	0.03	0.7	0.03	0.00	0	1,000
	500 "	0.04	0.3	0.03	0.00	0	3,000
	1000 "	0.03	0.4	0.00	0.00	2	100
	½ mile	0.20	0.3	0.05	0.00	0	100
	1 "	0.10	1.1	0.00	0.00	0	46
	1½ "	0.03	0.1	0.08	0.00	2	0
	2 "	0.03	1.2	0.01	0.00	0	0
Sept. 21	100 feet	0.12	0.65	0.05	0.00	0	2
	250 "	0.03	0.2	0.05	0.00	0	0
	500 "	0.03	0.06	0.05	0.00	0	0
	1000 "	0.03	0.1	0.05	0.00	0	0
	½ mile	0.03	0.06	0.05	0.00	0	0
	1 "	0.03	0.06	0.05	0.00	0	0
	1½ "	0.03	0.2	0.05	0.00	0	0
	2 "	0.03	0.06	0.05	0.00	0	1

APPENDIX TABLE IV

Concentrations of nitrogen and phosphorus nutrient compounds in various algicidal test plots.

Date	Location		TREATMENT AREAS				
			Nitrogen as N			Phosphates as PO_4	
			NH_3	NO_3	Total Kjeldahl	Total	Ortho
July 21	Test area	1			1.0	0.05	
		2			2.4	0.16	
		3			0.3	0.06	
July 29	Test area	1	0.09		0.8		
		2	0.04		3.0		
		3	0.06		0.9		
Aug. 4	Test area	1	0.06		0.9	0.11	
		2	0.24		0.5	0.07	
		3	0.18		0.5	0.07	
Aug. 10	Test area	1	0.9		<0.05	0.05	
		2	0.8		0.05	0.05	
		3	0.5		<0.05	0.05	
Aug. 18	New plots W. Bronte						
		4	0.03		1.2	0.05	
		5	0.03		0.3	0.10	
		6	0.05		1.8	0.08	
		7	0.03		0.3	0.05	
		8	0.03		0.8	0.16	
		9	0.03		0.8	0.08	

APPENDIX TABLE V

Concentrations of nitrogen compounds, total phosphates, phenols and coliform bacteria at miscellaneous stations in Lake Ontario, between July 21 and September 8, 1959. Concentrations of bacteria expressed as coliforms per 100 ml., phenols in parts per billion, all other data in parts per million.

Date	Location of Station			Nitrogen Compounds as N		Total Phosphates as PO_4	Phenols	Coliform Bacteria
				NH_3 Test	Kjeldahl Test			
July 21	Mouth of		Credit River		1.3			
	"	"	Oakville Creek		1.2	0.21		
	"	"	Bronte Creek		2.1	0.10		
Aug. 4	Mouth of		Credit River					1,000
	"	"	Oakville Creek					300
	"	"	Bronte Creek					110
Aug. 10	Mouth of		Credit River					2,600
	"	"	Oakville Creek					12,000
	"	"	Bronte Creek					94
Aug. 18	Mouth of		Credit River	0.2	0.7	0.91		
	"	"	Oakville Creek	1.0	1.5	0.65		22,000
Aug. 24	Mouth of		Credit River	0.03	0.1	0.12	3	150
	"	"	Oakville Creek	0.30	1.9	0.31	3	710
	"	"	Bronte Creek	0.05	0.2	0.05	3	20
Aug. 31	Mouth of		Oakville Creek					400
	"	"	Bronte Creek					3
Sept. 8	Mouth of		Credit River					1,800
	"	"	Oakville Creek					8,600
	"	"	Bronte Creek					3