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REPORT ON

CLADOPHORA INVESTIGATIONS

OBSERVATIONS ON THE NATURE AND CONTROL OF EXCESSIVE GROWTH OF *CLADOPHORA* SP. IN LAKE ONTARIO AND LAKE ERIE

BY

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A Report of

Observations on the Nature and Control of Excessive Growth of *Cladophora* sp. in Lake Ontario and Lake Erie

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The
Ontario Water Resources Commission

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This project was carried out by the Ontario Water Resources Commission under the direction of John B. Neil, Supervisor, Biology Branch of the Commission's Division of Laboratories. Dr. Duncan A. McLarty, Department of Botany, University of Western Ontario, was in charge of the field work.

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SUMMARY AND RECOMMENDATIONS

Summary

1. The period and extent of growth in Lake Ontario in 1960 was similar to that observed in 1959. *Cladophora* was first observed arising from a prostrate, perennial, basal structure on the rocky substratum on May 25. Subsequently, a uniform growth was produced in suitable areas bearing up to approximately six feet of water. The first crop matured and floated free late in July and was replaced by a second crop which persisted beyond the period of observation in the fall.

2. The degree of growth was much less in 1960. In most areas the filaments did not exceed six inches in length at any time. Shore-line accumulations were minimized but not eliminated by virtue of the large area of growth involved and by the drifting together of material from distant points.

3. It is difficult to explain the marked reduction in growth in 1960. It was observed, however, that the lake was very turbid throughout the season; radiation was much reduced in 1960 while rainfall Was more abundant. The latter feature may, in terms of dilution of nutrient minerals in water along the shore, be related to the lower nitrogen and phosphorus content of the shore-line samples taken in 1960.

4. In Lake Erie, *Cladophora* was found only on suitable exposed rocky reefs which were somewhat removed from shore. Although the water was clear in these areas, the *Cladophora* appeared no more green and healthy than in the turbid waters of Lake Ontario and the extent of growth was similar to that in Lake Ontario. The ability of this alga to eventually contaminate shore-lines which are obviously far removed from the source was clearly demonstrated.

5. Applications of Aqualin were made at the rate of 3,6 and 9 ppm in Lake Ontario. Although much killing occurred in the test areas, the individual plots were not clearly recognizable as they were in 1959 under similar conditions. Diffusion or current action obviously had distributed the algicide over a considerable area. Observation of the Plots was difficult due to persistent rough weather and to conditions of high turbidity.

In Lake Erie, applications of Aqualin at rates of and 6 ppm had no significant influence. It is presumed that wave action on the very exposed site diluted the chemical below its effective level of concentration.

6. In Lake Erie, copper sulphate, sodium arsenite and Endothol were applied with no significant result. TD-47, however, applied at the rate of 0.5 ppm, achieved complete control on one acre of *Cladophora*.

RECOMMENDATIONS

In view of the results obtained and reported, the following recommendations are made.

1. This investigation should be continued in order to capitalize upon results already obtained. The factors contributing to and controlling the growth of *Cladophora* under conditions found in large bodies of water are almost virtually unknown aside from our own observations. Seasonal variations in physical and chemical environmental factors may only be determined by and evaluated, in terms of algal production, on the basis of observations taken over a period of years.

2. For the testing of algicidal chemicals, representative areas which are capable, nonetheless, of some confinement and control must be sought otherwise, in open water locations in the Great Lakes, larger test areas must be employed to minimize the dilution factor which is introduced by diffusion, currents and wave action.

3. Laboratory and field experiments, designed to provide concrete fundamental knowledge concerning the biology of *Cladophora*, upon which its growth and the ultimate intelligent control of its growth will depend, must be undertaken. Such information is almost totally lacking at the present time.

4. In the course of such controlled experimentation, approaches to control measures, other than by classical chemical means, should be considered. Biological means of control, for example, should not be disregarded.

5. In conjunction with these studies, information concerning the general properties and characteristics of algicidal and herbicidal chemicals, currently being produced and promoted for use in natural waters, should be determined to enable the Commission to certify these chemicals and regulate their future use.

INTRODUCTION

During the summers of 1957 and l958, excessive growths of *Cladophora* occurred on rocky out-crops along the north-westerly shores of Lake Ontario. When the crop matured and floated free, large masses of disintegrating alga material accumulated along the shoreline. As a result, the lake front was rendered almost uninhabitable for a period of time and the resultant odor was apparent for as much as one mile inland. Lake shore municipalities and private owners were concerned and their problem was brought to the attention of the Ontario Water Resources Commission. Field studies which were conducted under the direction of the Commission in 1959, have been reported and the studies have been continued in 1960.

Initially it was proposed to test all available algicidal chemicals with respect to their effectiveness in the control of *Cladophora* production and with regard to the dangers and problems associated with their use. The primary purpose of the investigation was to select, if possible, a compound which might be safely recommended for use by interested municipalities or individuals.

Moreover, the investigations conducted in 1959 demonstrated the need for fundamental information concerning the biology of the organism itself and of the chemical and physical features of the lake environment upon which excessive growths may depend.

Accordingly, preparations were made for intensive studies of the growth and accumulation of Cladophora in the immediate vicinity of Oakville and Bronte and of chemical means of control. Subsequently, the studies were extended to include investigations at various points in Lake Erie.

METHODS, MATERIALS AND PROCEDURES

Basic Equipment

Sampling stations were marked by anchored wooden spars. Test plots, for application of algicidal chemicals, were measured and buoyed in areas bearing one to six feet of water. Fish net floats were used as markers for the plots which were one-half of one acre in extent.

A 16-foot aluminum boat, powered by a 18 horse power outboard motor, was used for all water sampling and spray applications. This boat, which was provided by the Commission, was equipped with a trailer to permit its use in many locations.

A gasoline-powered centrifugal pump was prepared for the 5 application of chemicals in solution. The pump was equipped with a dual intake and attached to a fourteen foot boom. The boom was mounted on the stern of the boat and supplies with four submerged nozzles. Concentrated solutions were metered in on the suction side of the pump, diluted with a large volume of lake water and applied to the lake bottom over a sixteen foot strip. By this means applications were made uniformally and with reasonable rapidity.

Applications of crystalline materials were made using a Cyclone Seeder.

Water samples were taken at various distances from shore to be analysed in the laboratories of the Ontario Water Resources Commission.

Algicidal Chemicals Tested

It is probably significant that, in areas where aquatic weed and algal control programs have been carried out for more than a quarter of a century, the classical compounds, copper sulphate and sodium arsenite are still used almost exclusively for routine, extensive control operations. In a compilation of information derived from recent research on aquatic weed and algal control in the United States, Mr. Kenneth

M. Mackenthun reports,[1] in addition to results on more recently developed compounds the continued reliance upon these copper and arsenic compounds in control measures applied in the state of Wisconsin.

The toxicity of copper in respect to plants generally is well known and applications of copper sulphate, particularly as a control for planktonic algae, have been made for many years.

Arsenic Trioxide (sodium arsenite) has been applied widely in the control of rooted aquatics and, in some instances, for the control of certain green filamentous algae.

Chemicals of more recent origin are available for use as herbicides and algicides. In many cases, however, their effectiveness under various specific conditions is not known and their toxicity to fish and other wildlife is often only partially determined. In most cases the cost relationships are such that, for general application, they will be able to compete economically with the classical compounds only if they prove to be much more efficient.

Endothol, prepared and supplied by the Pennsalt Chemicals Corporation, is the disodium salt of 3,6 endoxohexahydrophthalic acid. Used as an herbicide originally, it has been suggested for the control of aquatic growths since 1956. It is available in liquid and granular formulations and has been reported as effective against algae and aquatic weeds in concentrations ranging from 1-3 ppm.

TD-47 herbicide is another derivative of the endoxohexahydrophthalic acid which available for experimental use only. Produced originally as a pre-emergent herbicide, it is suggested as an aquatic herbicide to be used at concentrations ranging from 0.25 to 1.0 ppm.

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1 Mackenthun, Kenneth M. 1959. Summary of Aquatic Weed and Algae Control Research and Related Activities in the United States. Wisconsin Committee on Water Pollution.

Aqualin, a solution containing 85% acrolein, has been prepared and promoted by the Shell Oil Company. Although its properties require special care in handling and its toxicity is such that universal application may not be possible, the effectiveness of this chemical in the control of aquatic growths, both rooted and algal, is most encouraging.

For the adequate and economic control of aquatic weeds and algae in large systems, such as Lake Ontario, an exceedingly effective, quick acting chemical with low toxicity to wild life is required to overcome the massive dilution effects of wave and current action.

Experimental Plots and Sampling Stations.

In Lake Ontario, algicide testing plots were selected in the area between Coronation Park and Bronte. Arrangements were made with a local commercial applicator that no operations would be carried on in this vicinity which would in any way influence the testing procedures of the Commission. One half acre plots were used in this case.

In Lake Erie, plots were selected on the southerly side of Mohawk Island where, on extensive rocky ledges two miles from the main shore, uniform beds of *Cladophora* were observed. On the southerly side of Stoney Island, located about one mile from shore, other plots were established. In each case, one acre plots were used.

Chemical samples were taken at shore line stations either side of Bronte. One station was located fifty feet from shore one mile west of the Pig and Whistle Restaurant in an area used for algicidal chemical tests in 1959. A second station was located fifty feet from shore half way between. Bronte and Coronation Park. At the westerly boundary of Coronation Park sampling stations were established 100, 250, 500 and 1000 feet from shore with additional stations one-half and one mile from shore.

Applications of Algicidal Chemicals

On June 7, 1960, three test plots were treated in the vicinity of Coronation Park with the co-operation of members of the Shell Oil Company of Canada.

Plot #1- 3.0 ppm. "Aqualin"
Plot #2 - 6.0 ppm. "Aqualin"
Plot #3 - 9.0 ppm. "Aqualin"

At the time of application the lake was clear and calm. The water temperature was 57°F, and the rocky bottom was covered by a uniform growth of *Cladophora* approximately four inches in length.

On August 11, 1960 in co-operation with members of the Shell Oil Company of Canada, applications were made on one acre plots off Mohawk Island in Lake Ontario.

Plot #4 - 2.0 ppm. "Aqualin"
Plot #5 - 6.0 ppm. "Aqualin"

At the time of application the water temperature in the plots was 71°F and the water was crystal clear. The rocky bottom was covered with a uniform, continuous growth of *Cladophora* approximately six inches in length. Excepting when occurring at the water line on large, emergent rocks, the alga appeared pale and did not display the deep green colour usually associated with the alga.

During the period of application a stiff southwesterly breeze got up for a time and rough water over the ledge almost forced the discontinuance of operations.

On August 18, 1960, applications of algicidal chemicals were made at Stoney Island.

Plot #6 - 10.0 ppm. copper sulphate crystals
Plot #7 - 10.0 ppm. sodium arsenite solution

The water temperature in the plots was 73°F and the bottom was covered by a dense growth of *Cladophora* which was four to six inches in length. The pale, yellowish condition of the alga persisted. The lake was calm.

On August 24, 1960, applications of Endothol and a liquid preparation of TD-47 were made on one acre plots off Mohawk Island. Of these chemicals supplied by Pennsalt Chemicals Corporation, the latter is a recently developed compound which is available only in limited amounts for experimental purposes.

Plot #8 - 2.0 ppm. Endothol
Plot #9 - 0.5 ppm. TD-47 solution

At the time of application the water temperature was 70°F and the lake was calm. The *Cladophora* growth was dense and uniform throughout the plots. It approximated six inches in length and showed the yellowish colour which characterized the growth as it was observed in 1960.

Observations on Algal Growth and Shore Accumulation

From mid-May to early September the condition and growth of *Cladophora* in Lake Ontario was observed. Shore conditions were noted periodically from Port Credit to Burlington and, in relation to reports of commercial control procedures, detailed observations were made of shore line accumulations of *Cladophora* on July 15 and August 26.

Periodically throughout the summer observations were made on south shore of Lake Ontario near Stoney Creek with reference to *Cladophora* production.

On July 26, 1960 observations were made of the Lake Erie shore line, and of the lake from Cedar Crest, west of Port Colborne to Humberstone Community Beach. Throughout August and in early September observations and tests were made on Lake Erie in the vicinity of Lowbanks, a small community west of Port Colborne.

RESULTS OF THE *CLADOPHORA* INVESTIGATIONS

Observations of Lake Conditions

In Lake Ontario, in the Oakville-Bronte area at least, high turbidity persisted throughout the season. To some extent, at points east of Bronte this condition might be attributed to heavily silted waters observed flowing into the lake at Bronte and being carried eastward in the prevailing drift. It should be recorded, however, that west of Bronte in the vicinity of Burlington and east of Oakville conditions were not significantly different. For the most part the bottom was quite invisible in areas with more than even one foot of water.

On a few occasions the water was clear and the bottom conditions readily discernible. The growth of *Cladophora* was uniform but never extensive in length and usually heavily silted. This condition undoubtedly contributed to the pale, yellowish appearance which characterized the algal growth in 1960.

In the course of the summer, *Cladophora* filaments did not attain a growth of more than a few inches in any of the areas under observation. The initial growth in early June was rapid and widespread but the total production in 1960 was far below that experienced in 1959. Difficulties associated with the observation and assessment of plots before and after chemical treatment and the almost static condition of the algal growth, combined to create a situation in Lake Ontario which was very unfavourable for algal control investigations.

In Lake Erie the circumstances associated with *Cladophora* production differ in one significant way from those prevalent in Lake Ontario. The shore line in the Port Colborne district, for example, consists of bays with sandy, silted bottoms in which various rooted aquatics are established but where no *Cladophora* occurs. Between the bays, however, rocky points extend out into the lake, sometimes a great distance, on which the beds of *Cladophora* are found. At Mohawk Island such a series of rocky ledges extends several miles from the island in a southeasterly direction. In a similar fashion shoals occur in the vicinity of Stoney Island which create large areas suitable for *Cladophora* production.

These areas, remote from shore, were not subject to silting, as has been described for Lake Ontario locations. The algal growths, however, appeared pale and yellowish and were limited in linear development as has already been described for Lake Ontario growths in 1960.

Bearing in mind that only a fraction of the *Cladophora* crop is required to create a problem along the shore, these remote, extensive beds may represent a serious source of trouble even when the growth is actually minimal. Moreover, in these exposed positions, rough water often occurs which stimulates *Cladophora* production but which makes the chemical control of the alga very difficult by promoting a rapid dilution of the algicide.

Throughout the period of investigation in 1959 the surface temperature of Lake Ontario fluctuated around 65°F and, at times late in the season, dropped to as low as 48°F.

TABLE I. Meteorological Data taken at Toronto Ontario.

		May	June	July	Aug.	Sept.
Mean Air Temperature						
°F	1959	58	68	73	74	66
	1960	56	65	69	69	65
	Normal	55.2	65.6	70.7	68.8	61.2
Total Precipitation	1959	1.19	1.14	1.23	1.35	3.79
	1960	5.29	2.43	4.38	1.23	0.31
	Normal	2.65	2.70	3.23	2.39	2.67
Bright Sunshine						
hours	1959	247.8	252.5	298.1	251.3	222.4
	1960	144.0	265.1	307.1	291.2	181.1
	Normal	222.8	265.3	289.4	260.8	194.0
Radiation, B.T.U./ft^2						
	1959	58287	61510	66037	53888	41605
	1960	44007	60771	62871	57312	38979
	Normal	38088	51097	59911	57821	51999

Observations Concerning General Meteorological Conditions

As shown in Table I the hours of bright sunlight, recorded for Toronto, were greater in June, July and August, 1960, than in the corresponding months in 1959. It may be noted that in May, 1960, the hours of bright sunlight were less than normal and much less than those recorded for May, 1959. The total radiation recorded for May to September in 1960 was uniformly less than in 1959 excepting for August. During this month the radiation was less than normal but greater than the radiation recorded in August 1959. Associated with these records are the mean air temperatures which, in 1960, were uniformly less than corresponding air temperatures recorded for 1959.

These data, when considered along with the conditions of high turbidity which were experienced in Lake Ontario in 1960, suggest that a reduction in solar radiation may explain, in part, the general reduction in growth of Cladophora in Lake Ontario during 1960.

The meteorological records show, in addition, that precipitation was generally higher than normal in May, June, and July, 1960, and much higher than in the corresponding period in 1959. In August and September, however, the rainfall was less in 1960 than in 1959. The heavier precipitation early in the growth period, and the consequent dilution of the lake water along the shore particularly, may be associated with the generally reduced chemical nutrient content of lake samples taken from these locations in 1960.

Algal Growth and Shore Line Accumulations

The first filamentous growths of *Cladophora* were observed arising from the yellowish, squamous, perennial base on May 25, 1960. At that time the filaments consisted of less than a dozen cells. In the subsequent two week period, up to June 7, 1960, when first applications of algicidal chemical were made, the alga attained a length of four to six inches. Subsequently, however, it made very little growth and appeared to be essentially quiescent. The total algae production in 1960 was significantly less than in 1959.

As a consequence, the algal accumulations along the shore, creating nuisance conditions, were at a minimum in 1960. No massive accumulations were observed. Minor washings were observed on June 20. These were comprised of very short fragments of *Cladophora*. Observations, along the shore from near Port Credit to near Burlington on July 15 and August 26, 1960, which were made with reference to reports in the press by a local commercial applicator, provided useful information.

While no large accumulations were observed on July 15, conditions seemed to be slightly better in the Oakville area where control measures had been commercially applied. On August 26, however, the situation was quite reversed. The position of the accumulations indicated that wind direction, currents, and natural and artificial obstructions along the shore determine the location of accumulations of algae. As in Lake Erie, the algal material may be carried some distances from point of origin.

On July 26, local accumulations were observed along the shore of Lake Erie in the vicinity of Port Colborne. At two locations mechanical removal had been attempted but it was found to be quite impractical because the algal material continued to accumulate under the influence of on-shore winds. At Cedar Bay, Silver Beach and Humberstone Community Beach, where commercial control measures were said to have been applied, varying conditions existed which were in no way different from those observed in untreated areas west of Port Colborne.

On August 25, shore line accumulations were reported to have occurred during the previous two week period on the south shore of Lake Ontario in the vicinity of Stoney Creek. The area was quite clear at the time and no further information was available.

TABLE II. Summary of results of applications of algicides for the control of *Cladophora* sp.

Date of Appli-cation	Test Plot		Application of Algicide		Result
	Number	Location of Plot	Chemical Used *	Concentration in ppm	
June 7	1	Near Coronation Park	Aqualin	3	Complete eradication in irregular areas.
June 7	2		Aqualin	6	Individual plots not discernible Buoys removed by storm
June 7	3	"	Aqualin	9	Turbidity difficulties.
Aug. 11	4	Mohawk Island	Aqualin	2	No control
Aug.11	5		Aqualin	6	No control
Aug. 18	6	Stoney Island	$CuSO_4 \cdot 5H_2O$ crystals	10	Terminal burning on 50% of crop. Mainly recovered in three weeks.
Aug. 18	7		NA_2HAsO_3	10	Temporary burning Complete recovery in three weeks.
Aug. 24	8	Mohawk Island	Endothol	2	No control
	9	“	TD-47	0.5	90% eradication after two wk

* In the case of copper sulphate and "Aqualin concentrations are calculated in terms of the compound.
Sodium arsenite, Endothol and TD-47 are calculated in terms of the active component.

Control of the Alga by Chemical Means

The results of applications of algicidal chemicals are summarized in Table I.

Due to high turbidity and storms it was not possible to observe the plots for two weeks following applications of Aqualin on June 7. When observed on June 20, the markers had been carried away and the plots were not discernible. The alga, however, had been eradicated over a considerable area in the vicinity of the plots. It was apparent that a good deal of diffusion of the chemical had occurred.

Applications on plots 4 and 5 at Mohawk Island produced no significant result. It should be noted, however, that, due to difficulties with respect to calibration of the pumps, slightly less that 2.0 ppm. was applied on plot 4 and a result was not anticipated. Rough lake conditions, which developed during the application, may well have diluted the chemical severely before any influence on the growth was possible.

Copper sulphate and sodium arsenite, applied at the rate of 10 ppm., had very little significant and permanent effect. Killing was confined to the terminal branches of approximately 50% of the growth. After three weeks, the green, unaltered basal growth was again exposed by the sloughing off of the dead, terminal filaments.

Endothol, applied at the rate of 2.0 ppm had only a temporary influence on the *Cladophora* but TD-47 produced a 90% kill when applied at the rate of 0.5 ppm.

It should be emphasized that all of the experimental plots in Lake Erie were in very exposed locations which are subjected to great mixing when even moderate wave action occurs. The positive action of TD-47 in this type of location is suggestive of very great efficiency.

EXPERIMENTS INVOLVING ARTIFICIAL FERTILIZATION OF NATURAL WATERS

With respect to excessive algal growths it is often assumed that increased mineralization of streams and lakes, by runoff waters from rich agricultural land and by the discharge of domestic and industrial sewage effluents, is the determining factor. In the absence of proof, however, this remains purely an assumption.

If, in a barren area otherwise suitable for *Cladophora* production, applications of various fertilizer salts would induce the growth of the alga, evidence of the importance of increased concentrations of nutrient salts would be obtained. Consequently, some experiments were undertaken by Mr. Neil in suitable locations in Georgian Bay.

In the vicinity of Methodists Point$_s$ a rocky area was selected where no *Cladophora* was observed. The alga was observed, however, at various locations remote from the test area. Stations were established at points about one-half mile apart in water approximately two feet in depth. Applications of nutrient elements were made on June 26, by anchoring bags of commercial fertilizer at various stations, as listed below, and allowing the salts to dissolve over a period of time.

1. Aeroprills (Cyanamid of Canada Ltd.) - 33.5% Nitrogen
2. Super phosphate (Canadian Industries Ltd.) - 20% active
3. Turf Special (Canada Packers Ltd.) -10-6-4 analysis
4. Milorganite - 5.5-4-0 analysis

When examined on July 29, all of the chemicals, with the exception of some super phosphate, had dissolved. Additional applications were made in the same manner as described above.

Cladophora was not induced to become established in any of the areas to which fertilizer were added. With the exception of the appearance of a growth of an unspecified green alga in the vicinity of the super phosphate station, the applications of nutrient elements produced no apparent result.

In such an experiment, of course, only a positive result would be significant. The absence of any result whatever may depend upon one or several of many possible factors. For example, the concentration of the nutrient elements attained may not have been high enough to be significant or other environmental factors may have been limiting. Reproductive units of *Cladophora* may have been carried into the area from the distant growths or additions of these nutrients may not be a determining factor in the establishment of growths of *Cladophora*. It should be recalled, however, that artificial fertilization is practised to increase the productivity of fish ponds by stimulation of planktonic growth.

It is possible that similar experiments, conducted under different circumstances, might yield interesting results concerning the relationship between levels of concentration of nutrient salts and excessive algal growth.

Chemical Analyses of Lake Samples

The results of chemical analyses and bacteriological counts, made on water samples taken from Lake Ontario in 1960, are recorded in Tables I to VI of the appendix. Averages, maximum and minimum and median values are recorded for each individual station and average concentrations and counts for each sampling period throughout the season are included.

The nitrogen and phosphorus concentrations, with the exception of ammonia tend to decrease throughout the season (Table III). More significantly, perhaps, ammonia and total nitrogen concentrations decrease from June 22 to July 20, attain a second maximum early in August and then decline again to the end of the sampling period. Total and soluble phosphorus concentrations show a similar pattern, but the second maximum concentration occurs earlier, on July 27. These patterns may be related to the crop cycle noted for *Cladophora*.

When the mean concentrations of nitrogen and phosphorus compounds, at all stations within 100 feet of shore, are compared with the mean concentrations in all off-shore samples, some evidence of shoreline accumulations of nutrient elements is obtained. In Table III these calculations are summarized along with early season and late season average means.

TABLE III. Variation in average mean concentrations of nutrient elements with reference to the season and in respect to distance from shore expressed in ppm.

	Early Season	Late Season	0n-Shore	Off-Shore
Ammonia	0.17	0.18	0.22	0.10
Total Nitrogen	0.44	0.37	0.41	0.35
Total Phosphorus	0.11	0.07	0.08	0.06
Soluble Phosphorus	0.05	0.03	0.04	0.03

From the results of another research project carried out by the Commission it was found that the average result of total phosphorus determinations from open water areas of Lake Ontario was 0.057 ppm as compared with the mean of the shore samples taken of 0.074 ppm. The mean of samples taken from the open water areas of Lake Erie was 0.073.

DISCUSSION

Algal Production

The most outstanding feature of the 1960 survey was the marked reduction in the growth of *Cladophora*, which was observed at all locations studied in both Lake Ontario and Lake Erie. In 1959 the first crop attained growths up to three feet and the second crop was approximately one foot in length. For the most part the growth was deep green in color. In 1960 the free filamentous growth was never greater than approximately six inches in length and excepting for growths observed at the water-line on rocky outcrops, the alga appeared generally chlorotic.

For Lake Ontario, the very turbid condition of the water which prevailed throughout the season might be considered as a factor contributing to the reduced algal growth. In the *Cladophora* -bearing areas in Lake Erie the water was very clear. The appearance and extent of the algal growth, however, was not unlike that in Lake Ontario.

As presented in Table I, records compiled for the Toronto area show that radiation was high both in 1959 and in 1960 in comparison to average values. In 1959, however, radiation was particularly high and associated air temperatures in 1959 exceeded those recorded during a similar period in 1960. These figures may be considered significant for the Bronte area and, in-so-far as they reflect meteorological conditions which prevailed generally in southwestern 0ntario, they may be applied, to some extent, to Lake Erie locations. Reduced radiation during the growing period, may have contributed to the generally reduced algal growth observed in both lakes in 1960.

TABLE IV. Average mean concentrations of nutrient elements contained in shore and lake samples taken in Lake Ontario in 1959 and 1960 expressed in ppm and compared with seasonal average concentrations recorded for Sturgeon Lake during 1952-55.

Element	1959		1960		Sturgeon Lake	
Ammonia	* Shore -	0.06	Shore -	0.22	** Station #7-	0.05
	Lake -	0.05	Lake-	0.10	Station #3-	0.65
Total	Shore -	0.94	Shore -	0.41	Station #7-	2.12
Nitrogen	Lake-	0.49	Lake-	0.35	Station #3-	5.24
Total	Shore -	0.17	Shore -	0.08	Station #7-	0.147
Phosphorus	Lake-	0.06	Lake-	0.06	Station #3-	0.966
Soluble	***Shore -	0.01	Shore -	0.04	Station #7-	0.02
Phosphorus	Lake-	0.01	Lake-	0.03	Station #3-	0.59

* Shore Stations within 100 feet of Shore.

** Station #7 was representative of lake conditions and Station #3 represented the Scugog River 0.6 miles below a sewage out fall.

*** Based on 3 samples only.

As shown in Table IV, total nitrogen and total phosphorus concentrations at shore stations in Lake Ontario were approximately twice as great in 1959, when excessive *Cladophora* production occurred, as in 1960 when less algal production was observed. This reduction in concentrations may be related to the diluting effect of the much heavier rainfall which occurred in the Toronto area in 1960 (Table I). With respect to total phosphorus content, which is considered very significant with regard to the productivity of lakes, concentrations in Lake Ontario 1959 approximated those recorded for Sturgeon Lake samples during the survey there. Under these conditions, both lakes were highly productive.

Reduction in total phosphorus by one half in Lake Ontario in 1960 may be highly significant in explaining the sharp reduction in productivity. The similarity between total phosphorus concentrations determined in 1960 for shore stations in Lake Ontario and lake stations in Lake Erie, which represent the areas of *Cladophora* growth in the two lakes, adds emphasis to the importance of total phosphorus concentrations.

Laboratory experiments demonstrate the importance of nitrogen concentrations in determining algal growth and a reduction by one half in total nitrogen content in 1960 may be very significant, particularly at this level of concentration. In Sturgeon Lake, by comparison, total nitrogen concentration approximated 2.12 ppm (Table 1V).

Ammonia and soluble phosphorus, which have not been considered directly indicative of lake productivity, were present in somewhat higher concentrations **in** 1960 than in 1959.

The figures recorded in Table IV for Station #3 are of interest for purposes of comparison. This station was known to be influenced by the effluent from a sewage disposal system.

On the basis of information provided by this survey, reduction in *Cladophora* production in Lake Ontario may be related to a reduction in radiation reaching the plants and to a reduction in fertility as indicated by smaller amounts of total nitrogen and phosphorus in the lake water.

Algal Accumulations

Although the total production of *Cladophora* was much reduced in 1960, shore line accumulations were not eliminated. It has already been noted that the acreage involved in *Cladophora* production is very great in both Lake Ontario and in Lake Erie. Moreover, when the crop becomes free floating a large percentage of it may float freely and remain healthy for an extended period in free water. These masses may be carried for appreciable distances to accumulate on the shore when prevailing winds are suitable.

Even when growth is at a minimum, massive accumulations of algal material may occur. It is obvious that, to control the nuisance conditions related to *Cladophora* growth, the alga must be eliminated almost completely over large areas. Local control will be of no practical significance.

Mechanical Control of Nuisance Conditions

In some localities beach conditions may allow the consideration of various physical means of removal of the algal material. In other localities such methods would not be possible. At the best, this type of procedure is difficult and expensive, the masses involved may be large and, depending upon the wind direction, the material may accumulate more rapidly than it is removed.

The removal of obstructions at the water's edge, when possible, may aid in preventing accumulations at a particular point and by allowing the area to be cleared by natural means if an accumulation has occurred.

Chemical Control of *Cladophora*

Growth conditions during the 1960 season were not conductive to the testing of algicidal chemicals. In general the alga appeared unhealthy and in Lake Ontario the turbidity of the water made the observation of growth and the evaluation of results of applications of chemicals difficult, and, at times, impossible.

No conclusive results were obtained with Aqualin in 1960. One series of applications, made in June in Lake Ontario, were subject to a great deal of dilution by diffusion and current action. Although eradication of the alga occurred in the vicinity, the plots were not clearly discernible and the very positive result, obtained in the same area in 1959, was not duplicated.

Later applications of Aqualin in Lake Erie were not effective. In one case, due to faulty calibration of the equipment, an ineffective concentration was applied. On another plot, 6 ppm was applied but strong wave action occurred during and after the application and it is probable that the chemical was diluted below its effective concentration.

An application of TD-47 was applied on a similar location on an exposed, rocky reef in Lake Erie. At a concentration of 0.5 ppm. almost complete eradication of the alga was achieved. On the basis of one application only in a very exposed and difficult location, this compound appears to be remarkably effective in the control of *Cladophora*. As in the case of Aqualin, however) TD-47 may be excluded from certain areas due to its toxicity to fish.

Applications of copper sulphate, sodium arsenite and Endothol were made without significant result. It was difficult to appreciate any result with Endothol. As in 1959, however, concentrations of 10.0 to 15.0 ppm. of copper sulphate and sodium arsenite did have a killing effect over a short period of time. The terminal portions of the filaments were killed on varying portions of the total stand. Eradication was not achieved, however, and after three to four weeks, the necrotic terminal growth sloughed off and the crop remained, apparently healthy, and only somewhat reduced.

On the basis of this study, the control of *Cladophora* is not to be anticipated by the application of even high concentrations (10.0 ppm.) of copper or arsenic compounds. Aqualin and TD-47, however, show promise.

Other Considerations Concerning Algal Control

Cladophora, as it occurs in Lake Ontario, presents a rather unique problem. It is practically a pure stand existing in almost total isolation so far as other obvious living organisms are concerned. More particularly, it occurs here in a very large body of water where, for testing purposes, it is impossible to control the dilution factors. If satisfactory progress is to be made in the assessment of various algicidal chemicals, more control must be obtained over the test plots. On the basis of past experience, it will be difficult to find suitably confined areas which will be, at the same time, representative of lake conditions. The enclosing of plots with plastic sheeting is possible in small bodies but quite impractical so far as this lake is concerned. To minimize the dilution effect and to allow for valid interpretations of experiments, an effort must be made therefore, to apply tests over large areas.

In support of this point of view, it is pertinent to point out that, in other studies related to the control of rooted aquatics, when plots were treated in small bodies of water and when the test areas comprised a considerable percentage of the total area involved, satisfactory results were often obtained. Similar procedures, carried out in large bodies of water, failed to produce reliable results.

By virtue of its isolation, the control of *Cladophora* in Lake Ontario by chemical means may be possible and practical. In general, however, in an aquatic situation chemical control procedures may disrupt the ecology of the environment in such a way as to produce even greater problems. Chemical means of control quite possible, should be regarded as temporary expedients to be applied only until more natural means of control, based on the biological features of the organism concerned, are available.

Consequently, subsequent studies of the *Cladophora* problem must include controlled laboratory experiments designed to determine specifically the growth requirements of the alga and, possibly, to investigate the actual biological effectiveness of various algicidal chemicals and other more natural means of control. In the field, intensive investigations of all pertinent physical and chemical environmental growth factors interpreted in the light of laboratory findings, are required. Testing of algicidal chemicals must be done on a scale large enough to yield reliable results.

APPENDIX

TABLE I. Concentrations of ammonia nitrogen in samples taken at Lake Ontario stations in the vicinity of Bronte from June 22 to September 8, 1960, expressed in parts per million.

		June 22	June 29	July 7	July 13	July 20	July 27	Aug. 2	Aug. 29	Sept. 8	Total	Aver-*age*	Max.	Min.,	Median
Bronte East		0.26	0.05	030	0.09	0.21	0.28	0.26	0.18	0.22	1.85	0.21	0.30	0.05	0.22
Bronte West		0.35	0.40	0.40	0.21	0.09	0.15	0.49	0.38	0.11	2.58	0.29	0.49	0.09	0.35
“	100 ft	0.25	0.05	0.09	0.05	0.04	0.09	0.19	0.28	0.18	1.22	0.14	0.28	0.04	0.09
“	250 ft	0.21	0.05	0.21	0.05	0.05	0.05	0.49	0.09	0.06	1.26	0.14	0.49	0.05	0.06
“	500 ft	0.25	0.05	trace	0.07	0.18	0.18	0.26	0.09	0.09	1.17	0.13	0.26	0.0	0.09
"	1000 ft	0.35	0.05	0	0.34	0.05	0.07	0.39	0.28	0.15	1.68	0.19	0.39	0.0	0.15
"	½ mile	0.28	0.05	0.07	0.09	0.03	0.15	0.22	0.48	0.04	1.41	0.16	0.48	0.03	0.09
"	1 mile	0.21	0.05	0.39	0.04	0.13	0.07	0.06	0.38	0.31	1.64	0.18	0.39	0.04	0.13
TOTAL		2.16	0.75	1.46	0.494	0.78	1.04	2.36	2.16	1.16					
Average		0.27	0.09	0.18	0.12	0.09	0.13	0.29	0.27	0.14					

TABLE II. Concentrations of total (Kjeldahl) nitrogen in samples taken at Lake Ontario stations in the vicinity of Bronte from June 22 to September 8, 1960, expressed in parts per million.

		June 22	June 29	July 7	July 11	July 20	July 27	Aug. 2	Aug. 29	Sept. 8	Total	Aver-age	Max.	Min.	Median
Bronte East		0.70	0.50	0.39	0.32	0.29	0.48	0.29	0.50	0.43	3.90	0.43	0.70	0.29	0.43
Bronte West		0.70	0.70	0.45	0.32	0.29	0.48	0.49	0.68	0.30	4.41	0.49	0.70	0.29	0.48
"	100 ft	0.70	0.40	0.25	0.32	0.29	0.38	0.20	0.44	0.32	3.30	0.37	0.70	0.20	0.32
"	250 ft	0.21	0.40	0.48	0.18	0.40	0.40	0.53	0.31	0.22	3.13	0.35	0.53	0.18	0.40
"	500 ft	0.70	0.90	trace	0.32	0.28	0.28	0.73	0.31	0.31	3.83	0.43	0.90	trace	0.31
"	1000 ft	0.54	0.50	trace	0.51	0.15	0.28	0.75	0.31	0.22	3.26	0.36	0.75	trace	0.31
"	½ mile	0.38	0.40	0.20	0.32	0.15	0.28	0.73	0.55	0.16	3.17	0.35	0.73	0.15	0.32
"	1 mile	0.60	0.40	0.60	0.70	0.15	0.32	no sample	0.44	0.32	3.53	0.44	0.70	0.15	0.42
TOTAL		4.53	4.20	2.37	2.99	2.00	2.90	3.72	3.54	2.28					
Average		0.57	0.53	0.30	0.37	0.25	0.36	0.53	0.44	0.28					

TABLE III. Concentrations of total Phosphorus in samples taken at Lake Ontario stations in the vicinity of Bronte from June 9 to September 8, 1960, expressed in parts per million.

		June 2	June 22	June 29	July 7	July 13	July 20	July 27	Aug. 2	Aug. 22	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East		0.105	0.095	0.075	0.063	0.045	0.060	0.350	0.032	0.065	0.040	0.930	0.093	0.350	0.032	0.064
Bronte West		0.128	0.075	0.110	0.051	0.035	0.044	0.195	0.096	0.077	0.02	0.831	0.083	0.195	0.02	0.076
“	100 ft	0.175	0.410	0.100	0.085	0.110	0.040	0.155	0.040	0.052	0.02	1.187	0.119	0.410	0.02	0.093
“	250 ft	0.047	0.105	0.076	0.036	0.045	0.047	0.185	0.054	0.035	0.02	0.650	0.065	0.185	0.02	0.047
“	500 ft	0.040	0.060	0.066	0.062	0.047	0.105	0.065	0.059	0.022	0.02	0.539	0.054	0.105	0.02	0.060
"	1000 ft	0.052	0.048	0.093	0.057	0.047	0.043	0.070	0.054	0.023	0.02	0.507	0.051	0.093	0.02	0.050
"	½ mile		0.120	0.046	0.070	0.050	0.045	0.095	0.054	0.028	0.02	0.528	0.059	0.120	0.02	0.050
"	1 mile		0.270	0.098	0.155	0.050	0.080	0.092	0.054	0.065	0.02	0.884	0.098	0.270	0.02	0.092
TOTAL		0.547	1.183	0.664	0.579	0.429	0.464	1.207	0.443	0.358	0.18					
Average		0.091	0.148	0.083	0.072	0.054	0.058	0.151	0.055	0.046	0.023					

TABLE IV. Concentrations of Soluble Phosphorus in samples taken at Lake Ontario stations in the vicinity of Bronte from June 9 to September 8, 1960, expressed in parts per million.

		June 2	June 22	June 29	July 7	July 12	July 20	July 27	Aug. 3	Aug 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East		0.034	0.036	0.055	0.049	0.028	0.043	0.073	0.014	0.015	0.02	0.367	0.037	0.073	0.014	0.035
Bronte West		0.046	0.036	0.023	0.051	0.030	0.020	0.040	0.034	0.022	0.02	0.322	0.032	0.051	0.020	0.032
“	100 ft	0.050	0.305	0.045	0.045	0.032	0.032	0.052	0.027	0.018	0.02	0.626	0.063	0.305	0.018	0.038
“	250 ft	0.033	0.027	0.030	0.040	0.031	0.031	0.048	0.022	0.024	0.02	0.306	0.031	0.048	0.020	0.031
“	500 ft	0.037	0.050	0.042	0.041	0.036	0.020	0.023	0.024	0.014	0.02	0.307	0.031	0.050	0.014	0.030
"	1000 ft	0.036	0.046	0.048	0.032	0.039	0.040	0.042	0.025	0.020	0.02	0.348	0.035	0.048	0.020	0.037
"	½ mile		0.050	0.030	0.050	0.037	0.030	0.057	0.018	0.024	0.02	0.316	0.035	0.057	0.018	0.030
"	1 mile		0.103	0.029	0.037	0.040	0.073	0.046	0.019	0.026	0.02	0.393	0.044	0.103	0.019	0.037
TOTAL		0.236	0.653	0.302	0.345	0.273	0.289	0.381	0.183	0.163	0.16					
Average		0.039	0.082	0.038	0.043	0.034	0.036	0.048	0.023	0.020	0.02					

TABLE V. Bacterial counts taken from samples obtained at Lake Ontario stations in the vicinity of Bronte from June 22 to September 8, 1960, expressed as coliforms per 100 ml.

	June 22	June 29	July 7	July 13	July 20	July 27	Aug. 3	Aug. 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East	274		7	100	1	6	13	76	48	525	65.6	274	1	30.5
Bronte West	169		1	2	0		54	30	1500	1756	250.8	1500	0	30.
“ 100 ft	3		5	15	2	6	18	86	24400	24535	3066.8	24400	2	10.5
“ 250 ft	6		19	5	0	8	16	38	4600	4692	586.5	4600	0	12.
“ 500 ft	54		200	0	0	5	11	28	13800	14098	1762.2	13800	0	19.5
" 1000 ft			9	1	0	38	21	47	1500	1616	230.8	1800	0	21.
" ½ mile	3		0	0	0	8	15	32	800	858	107.2	800	0	5.5
" 1 mile			0	0		3	19	45	1	68	11.3	48	0	2.
TOTAL	509		241	123	3	74	167	382	46649					
Average	84.8		30.1	15.4	0.4	10.6	20.9	47.8	5831.1					

TABLE VI. Concentrations of phenolic compounds in samples taken at Lake Ontario stations in the vicinity of Bronte from June 22 to September 8, 1960, expressed in parts per billion.

		June 22	June 29	July 7	July 13	July 20	July 27	Aug. 3	Aug. 29	Sept. 8	Total	Average	Max.	Min.	Median
Bronte East		30.	0.	35.	9.	32.	6.	0.	0.	0.	112.0	12.4	35.0	0.0	6.0
Bronte West		8.	0.	15.	37.	0.	5.	0.	0.	0.	65.0	7.2	37.0	0.0	0.0
"	100 ft	70.	5.	4.	0.	6.	0.	0.	0.	0.	85.0	9.4	70.0	0.0	0.0
"	250 ft	12.	8.	12.	0.	3.	0.	40.	0.	0.	75.0	8.3	40.0	0.0	3.0
"	500 ft	25.	0.	7.	5.	18.	17.	0.	0.	0.	72.0	8.0	25.0	0.0	5.0
"	1000 ft	35.	0.	0.	12.	8.	3.	0.	0.	0.	58.0	6.4	35.0	0.0	0.0
"	½ mile	25.	10.	3.	3	3	6.	0.	25.	0.	75.0	8.3	25.0	0.0	3.0
"	1 mile	12.	3.	4.	0.	6.	23.	0.	20.	8.	76.0	8.4	23.0	0.0	6.0
TOTAL		217.	26.	80.	66.	76.	60.	40.	45.	8.					
Average		27.1	3.2	10.0	8.2	9.5	7.5	5.0	5.6	1.					