BIOLOGICAL AND LIMNOLOGICAL ASPECTS OF WATER SUPPLY

Ontario

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TABLE OF CONTENTS

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INTRODUCTION

The accelerated enrichment of our lakes and streams is viewed with increasing concern because of induced changes in fish populations, interference with water oriented recreational activities and impairment of the aesthetic quality of water. In addition, and of major interest to waterworks personnel, are its effects on the economic provision of suitable water for municipal and industrial use. This presentation will outline the concepts of eutrophication as related to Ontario; describe some of the more important limnological and biological phenomena, particularly as they relate to problems of water treatment and supply; and indicate the value of maintaining long-term biological records.

CONCEPTS OF EUTROPHICATION

In general limnologists are in agreement that all lakes, even the largest and deepest and those entirely unaffected by man's activities are transitory bodies of water and are continually undergoing a gradual process of change from oligotrophy to mesotrophy to eutrophy. Progressing even further, death of a lake can be equated to the onset of a "swamp" or "marsh" condition. In small shallow lakes this entire process may have occurred in some cases within a single century following the glacial retreat; in other instances, the process is well advanced, and still going on, and in many larger deeper lakes remote from human influences, significant changes can only be measured on a geologic time scale (i.e. thousands of millions of years).

The changes are associated with sedimentation and increases in the dissolved mineral content of a lake - specifically substances such as phosphates, nitrates, carbonates and numerous other mineral salts and trace elements - increases which occur as a result of rainfall, land runoff and percolation of soil-water to the lake. Higher concentrations of these dissolved materials cause the water to become progressively more fertile and productive, stimulating the development of free-floating microscopic plants called phytoplankton, generally referred to as algae.

It should be clarified that algae are normal inhabitants of virtually all surface waters and fulfill an essential role in maintaining a balanced condition in the aquatic environment. They not only provide the entire nutritional base for a complex aquatic food web which includes the production of game and commercial fish species, but produce and release oxygen to the water which is essential to the metabolism of fish and all other forms of aquatic life. The natural development of algae is regulated not only by nutritional factors, as previously mentioned, but by environmental factors such as temperature, the intensity and duration of illumination, and by physical factors such as size, depth and shape of the lake basin. Thus, the corresponding rates of eutrophication in different lakes are determined by varying combinations of extrinsic and intrinsic features.

Oligotrophic lakes such as those situated in Ontario's pre-Cambrian Shield are characterized by low rates of algal production and consequently age less rapidly than lakes surrounded by the deeper, richer soils of Southern Ontario. These lakes (Figure 1) of moderate to extreme depths, generally support a relatively low production of cold-water fish species such as lake trout, whitefish and herring. They are characteristically clear and well suited to water-oriented recreational activities. Also, the deeper waters of many of the larger lakes are well supplied with oxygen (Figure 2) throughout the year. This latter condition relates to the low algal production and concomitant lack of any significant oxygen depletion associated with the decomposition of algae at the lake bottom.

As mentioned earlier, all lakes are subject to natural inputs of algal-stimulating nutrients from the atmosphere, ground-water, runoff from the surrounding land and forest and nutrient exchange from lake sediments. However, artificial fertilizing inputs associated with increasing urbanization and industrial development, which parallels the increase of Ontario's population, have aggravated the problem of aquatic enrichment. Affected lakes are characterized by increased phytoplankton levels, the development of high numbers of blue-green algae in late summer (Figure 1) and reduced pH and dissolved oxygen *Rhodomonas* species have comprised about 30% of the total phytoplankton cell volume. Other taxa consistently reported in the results of the eastern basin studies include spring and fall pulses by *Stephanodiscus tenuis* and *S. niagarae* and *Peridinium aciculiferum* (Lemm.) Lemm. (mainly in the spring) and occasional abundance of the prymnesiophyte *Chrysochromulina parva* Lackey.

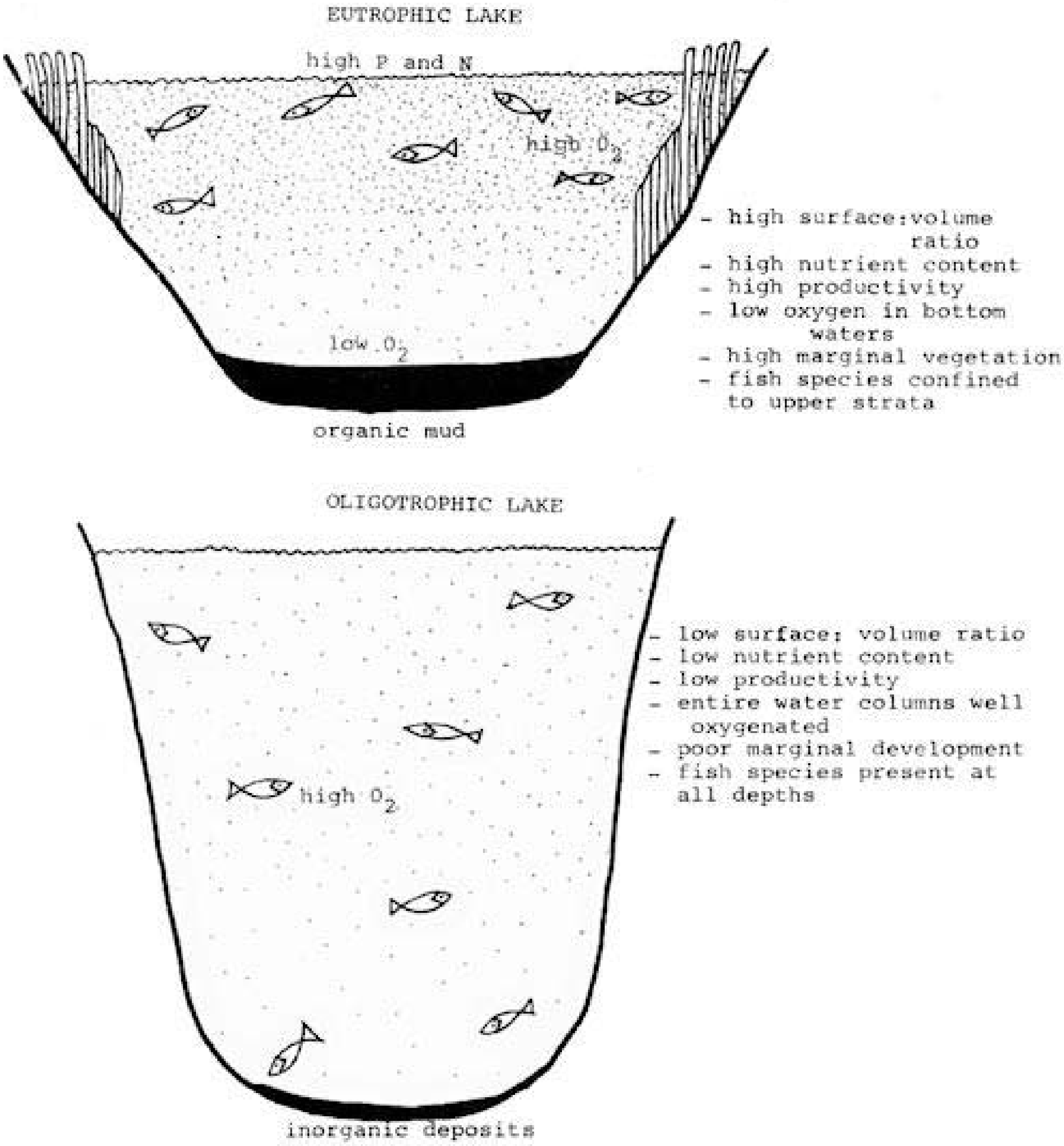

Figure 1. Two principal lake types in stylized cross sections.

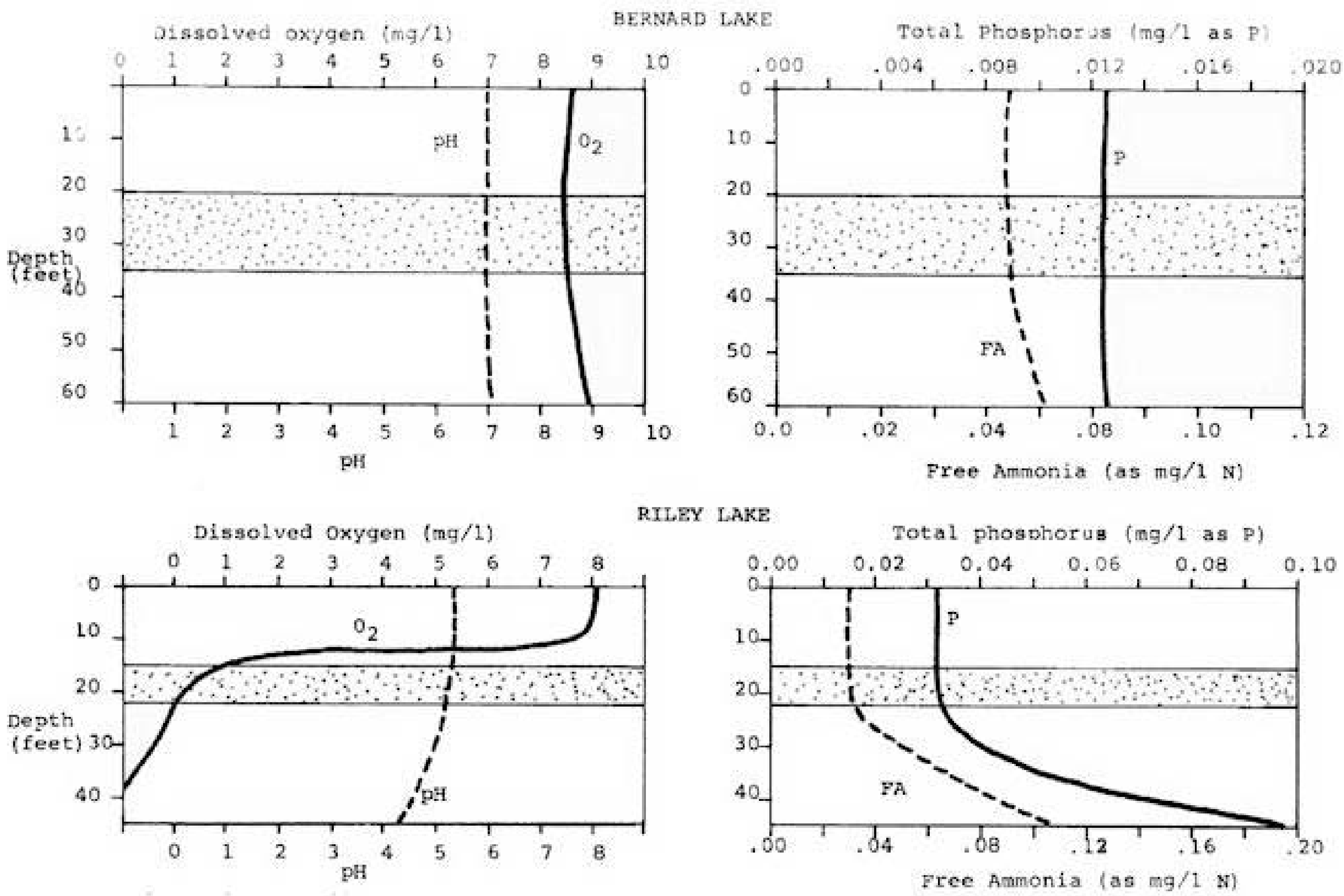

Figure 2. Profiles of pH, oxygen, phosphorus and free ammonia in eutrophic Riley Lake and oligotrophic Bernard Lake during the summer stagnation period of 1969. Shaded areas approximate the position of the thermocline.

Evidence for recent changes in the phytoplankton of the eastern basin cannot be obtained from the data available with the possible exception of the Dunnville water intake data (Fig. 8). Samples of raw water from the intake located 6 m deep and 0.5 km offshore have been collected weekly or bi-weekly since 1967. There was an apparent increase during the 1973-76 period which resulted in a doubling of average annual biomass in relation to the values from the late 1960's and early 1970's. More recently, algal densities in the Dunnville intake samples returned to levels more typical of the earlier years (Fig. 8). This long term trend in phytoplankton densities may be related to nutrient loading from the adjacent Grand River.

Flow data from the Grand River (Fish. & Envir. Canada, 1969-1978) show a trend which generally parallels the trends in algal density in the Dunnville intake except for a period of several months during 1975 (Fig. 9). A preliminary evaluation of available total phosphorus data for the lower Grand River (Min. Envir. 1973-1978) suggests that trends in phosphorus loading from the Grand River probably parallel the flow data closely since there has been little year-to-year change in P concentrations between 1972 and 1977. Furthermore, there is evidence from river plume tracking using specific conductance measurements (Ross & Hamdy 1980) that the Grand River discharge often impinges directly on the north shore water mass serving the Dunnville intake.

It is clear that nutrient concentrations in the Grand River mouth are sufficient to support algal densities which are several times higher than those found farther offshore (Fig.10). It is likely, therefore, that trends observed in the Dunnville intake data are the result of local river influences and may not be typical of a very extensive portion of the nearshore zone in the eastern basin of the lake.

SIGNIFICANCE OF ENVIRONMENTAL ASPECTS OF ALGAL PRODUCTION

Effects of thermal stratification on lakes

The upper layer of a stratified small lake or reservoir is characterized by warm good light conditions, the abundance of available oxygen and relatively small quantities of reduced elements (i.e. iron, manganese). Under these conditions, the algae multiply, occasionally to the extent that some may die through exhaustion of nutrients, others from parasites and yet others from the grazing activity of the zooplankton. The dead cells, as well as some live ones, sink into the depths. In the hypolimnion, decay of the dead algae and organic matter occurs. As a result, the available oxygen supply is depleted until at the mud-water interface, all of the free oxygen may be used up.

An important consequence of this microbial decay is that nutrients (particularly phosphorus) are regenerated but are confined to the hypolimnion because of the barrier presented by the thermocline. Brydges (1970) stressed that the decomposition and release of an iron-phosphorus complex from the lake sediments under reducing conditions is a major factor in controlling phosphorus concentrations in lake water. The accumulated nutrients below the thermocline are prevented from re-entering epilimnetic waters and the trophogenic zone as long as thermal stratification persists. Algae in the upper hypolimnion(and correspondingly in the lower extreme of the euphotic zone) of a lake may utilize solubilized nutrients originating from either decomposition of organic material formed during the present year or from previous years sedimented organic material. However, once the water is mixed either by strong winds or by the fall overturn these substances are dispersed throughout the entire water mass.

In lakes and reservoirs where stratification periods are extensive, it would, therefore, be undesirable to depend on intakes located near the surface or too close to the bottom. An intake located in the euphotic zone would draw water containing tremendous quantities of algae, while a supply pipe located in the hypolimnion would contain undesirable sulphides, ferrous iron, manganous manganese, ammonia and a variety of odour producing organic compounds. It would be more sensible in some instances, to take water from a depth near the lowest part of the epilimnion or in the thermocline zone. In shallow, fertile lakes with no stratification, consistently high algal populations may prevail. Lakes of this type are seldom suitable as sources of water supply.

The spring and fall algal pulse

Most inland lakes in Ontario as well as Lake's Ontario, Huron and Superior are characterized by a bimodal pattern of phytoplankton development. Pennak (1946) described the pattern as having a "....large spring pulse, a decreased population during the summer, a second, less pronounced, pulse in the autumn, and a very small population during the winter." Following the disruption of the thermocline during the late tall and winter months, an enriching of the surface waters with nutrients occurs, so that in the spring, concentrations of reactive phosphorus and nitrogen in the superficial layers are higher than at any other time of the year (Figure 3).

When solar energy rises to an appropriate level, a pulse of algae dominated mainly by diatoms occurs. Although a complex series of light and temperature effects are involved, the spring diatom pulse only begins when the compensation level for the specific diatoms involved extends to a depth sufficient to involve a "critical volume" of lake water in order that an exponential growth rate materializes. Depletion of the lake's inorganic nutrient reservoir occurs as the nutrients are incorporated into cellular organic material.

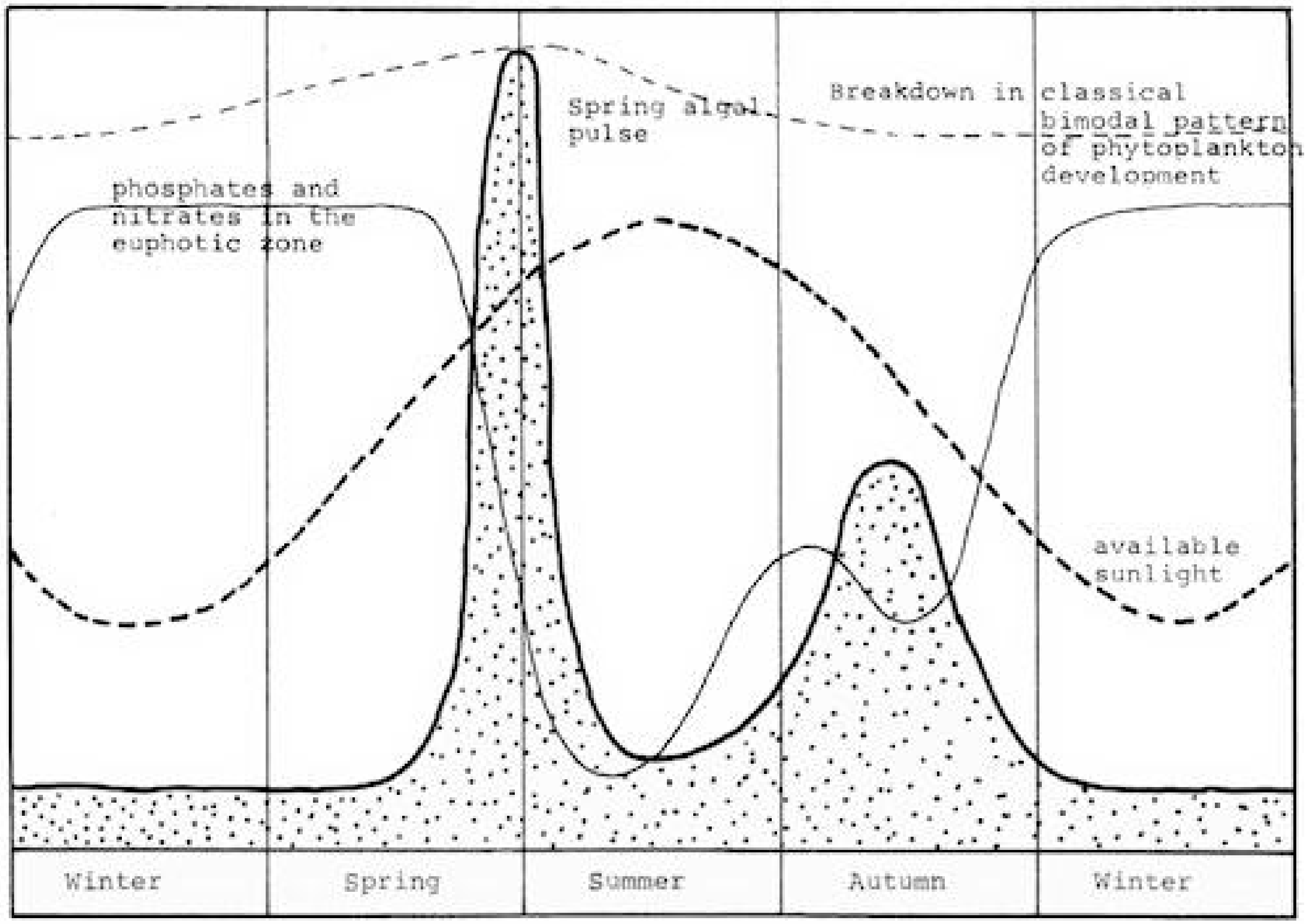

Figure 3. The spring algal increase and other seasonal features of primary production in Ontario lakes. A breakdown in the pattern of phytoplankton development similar to that observed in Lake Erie is indicated. Figure adopted from Russell-Hunter, 1970.

Generally, algal productivity in a large lake remains at a low level throughout the summer. However, Davis (1964) and Michalski (1968) have provided evidence that an increase in the intensity and duration of the spring and fall maximum, as well as a failure of the summer and winter minima to materialize, were indications of the rapid enrichment of Lake Erie at Cleveland, Ohio and at the Union Water Treatment Plant located on the northern shoreline of the Western Basin of the Lake, respectively (Figure 3). The development of an autumnal pulse is not as universal as the early spring diatom maximum. The fall increase occurs largely in those regions where decreasing surface water temperatures cause a breakdown in the thermal regime and where a concomitant replenishment of nutrients from the lower strata to the surface layers occurs.

For example, a breakdown of the thermocline, as well as an extended period of relatively warm, calm, sunny weather were instrumental in recently promoting a dense "water-bloom" of blue-green algae in Kempenfelt Bay and over most of Lake Simcoe. During the winter period reduced illumination and lower water temperatures generally result in minimum algal growths while the continued mixing of the deeper waters with those of the surface strata restores the nutrient concentrations in the upper waters to their high winter levels. This winter-long breakdown of the thermocline has been compared to the ploughing of agricultural land in preparation for the growing season of green plants.

Effect of light on algal productivity

It is obvious that any factor which limits light penetration in a lake would inhibit photosynthesis. McCombie (1953) reported that turbidity affects phytoplankton production by reducing the quantity and quality of light which is available for photosynthesis. Schenk and Thompson (1965) reported that phytoplankton levels at the Toronto Island Filtration Plant were lower than at the R.C. Harris Plant, located some 10 miles east of the former location, although water entering the R.C. Harris Plant was more typical of the general water quality throughout Lake Ontario and was characterized by higher concentrations of plant stimulating nutrients than water entering the Toronto Island Plant. The authors reported that the high turbidity levels had a strong impact in limiting phytoplankton production in the vicinity of the Island Filtration Plant intake.

Effects of the internal seiche

One potential difficulty which influences the quality of the raw water entering an intake is the matter of the internal seiche. The internal seiche is a swinging, see-saw motion of the thermocline which occurs after the wind has blown strongly in one direction. Figure 4 illustrates the effects of the wind on a stratified body of water. When the wind blows from the west to the east, the warm epilimnetic waters move towards the east side of the lake. There is a piling up of the warmer upper waters on the windward side of the lake. The thermocline is depressed on the windward side of the lake and correspondingly elevated on the upwind side.

If the wind is strong, a breakdown of the stratified layers on the eastern side of the lake occurs. With a stop in the wind, the regular stratification layers are restored but the thermocline continues to swing back and forth with corresponding shifts of the water in the epilimnion and hypolimnion.

Consider the example where an intake extends into the thermocline from either the eastern or western shoreline. With a drop in wind velocity, the type of water reaching the supply pipe will differ from time to time according to the regular periodical pattern established by the motion of the thermocline.

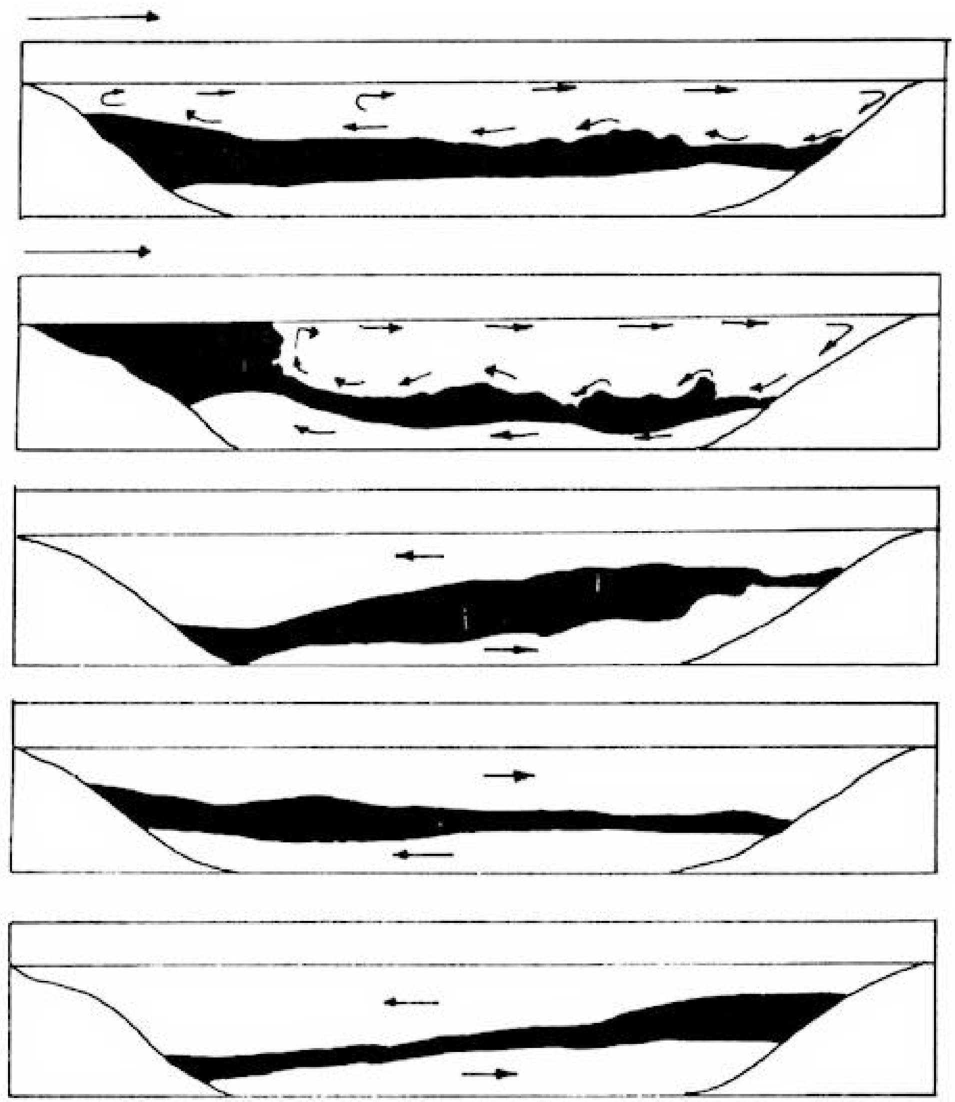

Figure 4. Diagrammatic representation of an internal seiche. Flow of direction is indicated by arrows (reproduced from. Lund, 1967).

In a highly eutrophic body of water, an internal seiche could mean that for a period of time, water containing tremendous growths of algae in the epilimnion would enter the water treatment plant; later in the day, water from the hypolimnion containing the decaying remains of algae, reduced metallic ions (i.e. iron and manganese), ammonia, undesirable organic compounds, sulphides and possibly even hydrogen sulphide would enter the intake.

To exemplify the effect of the internal seiche, consider a series of algae counts and corresponding water temperature data acquired five days per week between July 10 and December 13, 1968 (Figure 5). As indicated increases in levels of algae and changes in species composition coincided with rises in water temperature. For instance, samples collected from September 30 to October 9 were characterized by low numbers of algae (35-190 areal standard units per millilitre). The dominating algae were *Tabellaria fenestrata, Oedogonium* sp., *Chlamydomonas* spp. and *Stephanodiscus* spp. Between October 9 and 17, the water temperature Increased from 5.5 to 16.5 ^{0}C and phytoplankton levels increased correspondingly (233 - 1,865 a.s.u. per ml). *Cryptomonas* spp. replaced the aforementioned algae as the dominant form. It is logical to conclude that highest numbers of algae occurred when the thermocline moved below the intake so that waters of epilimnetic origin entered the treatment plant. The low standing stocks of algae corresponded to periods when hypolimnetic waters entered the intake. It goes without saying that such rapid changes in water quality often cause a good many problems to water treatment and supply operations. Additionally, Michalski (1969) pointed out that, "Water entering treatment plants, having pipes located below the thermocline (and generally below the euphotic zone) or subjected too frequently to influences of hypolimnetic water should be avoided for monitoring standing stocks as an index of increasing eutrophication."

In large lakes such as the St. Lawrence Great Lakes, interrupted periods of summer stratification may drastically affect the distribution of polluted water entering

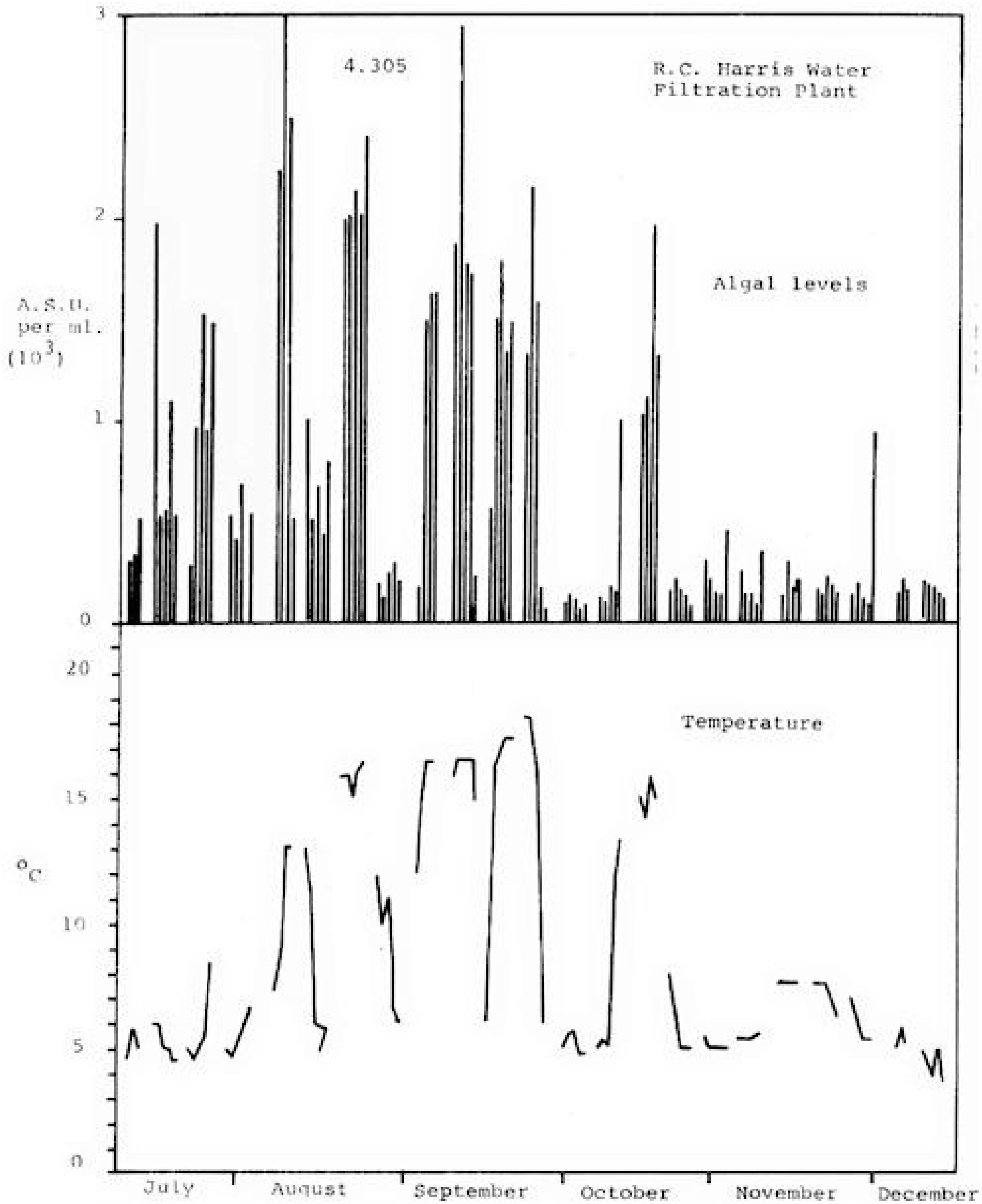

Figure 5. Phytoplankton levels at the R.C. Harris Filtration Plant during the period July 10 -December 13.1968. Daily fluctuations at the water treatment plant are also indicated.

a lake. In most instances, the temperature of the in-flowing polluted water is higher than that of lake water and tends to remain at or near the surface of the lake. If the thermocline is present the polluted water enters and mixes with' the upper, warmer epilimnetic waters. If, however, the epilimnion has been displaced by colder upwellings of the hypolimnion, the warm polluted water remains almost as a film on the lake surface. Indeed, pools of polluted waters have been reported (Matheson 1963) lying immediately over an intake while the deeper, colder hypolimnetic waters were observed entering the water supply intake below.

In the absence of a thermal barrier (such as during periods of wind stress in the summer months and throughout the major portions of the autumn, winter and spring seasons), the polluted inflowing water disperses throughout all depths of the receiving water. If, for example, the polluted waters were to contain high levels of ammonia, the water treatment plant operator would have to contend with high chlorine demands and possibly the odours of nitrogen trichloride.

It should be apparent from the aforementioned that many variable factors interact to regulate the degree and extent of algal growth in a lake. In addition, zooplanktonic predation, continuous artificial inputs of fertilizing elements and fluctuating water levels all have a significant role in controlling biological production. Thus, any attempt to correlate changes in phytoplankton levels with a single physical-environmental factor is unjustifiable.

SIGNIFICANCE OF INCREASED PRODUCTION OF ALGAE AND AQUATIC VEGETATION IN WATER SUPPLIES

The main problems associated with algae in water supplies are their ability to produce tastes and odours and to clog sand filters. Additionally, algae and aquatic vegetation may effect changes in pH, alkalinity and dissolved oxygen of the raw water.

Increases in pH and low water temperatures may inhibit proper floc formation, while variations in total organic content, stemming from changing phytoplanktonic conditions, may necessitate close control of dosages of chlorine in order to maintain constant results.

Certain industries in Ontario have been troubled by algae affecting the quality or quantity of production. Examples of this have been defects in high grade photographic papers because of the presence of phytoplankton in process waters and clogging of small bore heat exchange tubes by the filamentous green algae *Cladophora* at the Lakeview Generating Plant of Ontario Hydro.

Here in Ontario, the areal standard unit method has been used to enumerate phytoplankton in water supply studies. This standardized technique involves the establishment of areal values for different genera of algae by means of a micrometer disc in the eyepiece of a microscope. One areal standard unit (a.s.u.) is the equivalent of an areal value of 400 square microns (Whipple 1914).The method has been widely adopted in the waterworks field because of interest in the relationship between density of phytoplankton and filter clogging, which is most reasonably defined in areal terms. A test that has been used a great deal in the investigation of taste and odour problems is the threshold odour test. The threshold odour number (T.O.N.) represents the number of times an odour-bearing water must be diluted in order to reduce the odour to the threshold point, or to a concentration at which the odour is just barely perceptible.

Filter clogging and algae

In all instances where algae are a nuisance to water treatment plant operators, problems stem from an overabundance of algae; however the numbers required to create difficulties will vary from species to species and from one specific problem to the other. It is a well recognized fact that diatom levels are related to reduced filter runs where pre-filtration facilities are inadequate. The rigid cell wall of the diatoms are silicified and are not subject to decomposition. Therefore, even though the diatoms may die-off rapidly on the surface of the filter, their silica walls remain to plug pores in the sand.

Published information and experience has indicated that the most serious offenders are *Fragilaria, Melosira, Stephanodiscus, Asterionella, Tabellaria* and *Synedra.* It is difficult to make conclusive statements concerning the relationship between algae populations and filter clogging or taste and odour production, due to the inconstancy of variable factors which are present in different situations. Nonetheless, some generalizations may be made. If pre-treatment measures are not adequate to prevent a large percentage of the algae from gaining access to the filters, definite impairment of filtering efficiency may be anticipated when levels of diatoms from 1,500 to 2,000 a.s.u. per ml. are reached.

The problem would become increasingly severe with higher levels of diatoms and would be compounded by the presence of supplementary populations of blue-green algae or green algae. It should be emphasized that in certain instances lower levels of diatoms can create serious reductions in filter runs. For example, during the months of January and February 1967 at the Kingston Water Treatment Plant, diatom levels ranged between 793 a.s.u. per ml and 1,425 a.s.u. per ml and lengths of filter runs were substantially reduced. Data on weather conditions in the Kingston area indicated that a mid-winter thaw occurred during the latter part of January and the first two weeks in February.

During this period, agricultural and municipal runoff (containing essential plant nutrients) together with the warm, sunny weather undoubtedly contributed to the development of uncommonly high algal levels. Owing to the clear, cold nature of the water, floc formation and sedimentation were reduced. The algae; therefore, would "carry over to the filter beds and reduce lengths of filter runs. From the aforementioned, it is clear that reduced filter runs are not entirely dependent upon total numbers of algae in the raw water supply, and when pin-pointing causes of reduced filter runs, water treatment plant operators should place due emphasis on local environmental factors as well as considering the implications of biological, chemical and physical aspects on respective water supply systems.

Levels of blue-green algae in the range of 2,000 to 3,000 a.s.u. per ml would similarly cause problems with filter clogging. Planktonic green algae rarely constitutes any hazard as far as filter clogging is concerned.

Taste and Odours and algae

The production, nature and intensity of algal-caused tastes and odours is determined by the type and number of algae that are present. The flagellate *Synura* may make its "cucumber-like" presence known when only a few colonies per millilitre are involved, while the diatom *Asterionella* does not become objectionable until 2,000 to 3,000 a.s.u. per ml are present. A few diatoms such as *Asterionella* and *Tabellaria* may produce geranium-type odours at lower levels which change to fishy or musty-like, as the populations of algae increase. Based on past experiences in various areas of the Province, levels of blue-green algae in excess of 500 to 1,000 a.s.u. per ml in water have caused consumer complaints owing to grassy flavours which are imparted to the water by the algae.

With counts in excess of 2,000 a.s.u. per ml consumer complaints become more objectionable, especially with normal characteriological doses of chlorine which tend to release distasteful oils from the algae. Depending on the state of decomposition or relative good health of the algae, vile septic or pigpen tastes and odours may be produced at such elevated levels.

Evidence and effects of eutrophication in Ontario

A number of studies and investigations relating to water supply conditions and problems have been undertaken in the past 15 years which reflect the artificial enrichment of waters throughout the Province.

Consider for example, a breakdown of phytoplanktonic conditions from several municipalities located on the Great Lakes (Table 1). The data (from Veal and Michalski 1971) are based on samples collected between May and September 1969, except for the Georgian Bay information collected near Collingwood, data were obtained during the ice-free period of 1968; phytoplanktonic conditions in 1969 are assumed similar to those of 1968.(It should be emphasized that water from the Collingwood and. Grand Bend areas is likely more typical of the general water quality throughout Georgian Bay and Lake Huron, respectively. Phytoplankton levels from the Penetanguishene - Waubaushene area (i.e. Penetang, Midland and Hogg Bays),are higher than those reported from Collingwood and Grand Bend indicating that the entire Penetang - Midland - Port McNicoll area is decidedly more productive than the open waters of Georgian Bay and Lake Huron.

Additionally standing stocks of algae within the Penetanguishene - Waubashene area, except for those within Penetang Harbour, were higher than those of Hamilton and Cornwall, municipalities located on the shorelines of oligotrophic to mesotrophic waters, yet significantly lower than those recorded for the Union Water Treatment Plant on the northern shoreline of the enriched Western Basin of Lake Erie.

Table 1. Summary of phytoplanktonic data collected from various sources during the summer of 1969, except for the Collingwood information which was obtained during the ice-free period of 1968. All results are expressed as areal standard units per millilitre.

Municipality	Source	Sampling Received	Number of Samples	Areal Standard Units per ml. Maximum	Minimum	Mean
Penetanguishene	Penetang Bay	May 13- Oct.22	36	9,577	281	2,510
Midland - Port McNicoll	Midland Bay Port McNicoll	May 13- Oct.22	72	2,655	181	687
" "	Hogg Bay	May 13- Oct.22	12	1,102	134	392
Collingwood	Georgian Bay	Apr. 2- Dec.4	207	782	7	226
Grand Bend	Lake Huron	Apr. 2- Sept.25	25	559	23	155
Union	Lake Erie Western Basin	May 8- Sept.29	26	7,147	1,022	3,190
Hamilton	Lake Ontario	May 5- Sept.25	26	1,313	128	276
Cornwall	St. Lawrence River	May 7- Sept.24	11	854	111	438

The fact that phytoplankton populations in Penetang Bay were of the same order of magnitude as those recorded from the Union Plant provides conclusive evidence that conditions of accelerated eutrophy are undermining water use potential in relatively small isolated bays of the Upper Great Lakes.

That the productive capacity of Lake Erie is increasing rapidly is exemplified by phytoplankton records maintained at the Division Avenue Filtration Plant in the City of Cleveland. Davis (1964) summarized these records and demonstrated a consistent increase in the average quantity of phytoplankton between 1919 and 1963. This is suggested also by data accumulated over the past few years at the Union Water Treatment Plant (Table 2). As indicated standing stocks of phytoplankton were consistently higher at the Union Plant than at water works along Lakes Ontario or Huron.

Comparisons of standing crops of phytoplankton in the major basins of the lower Great Lakes with those in the Bay of Quinte are even more striking. Belleville obtains its water from this shallow bay which was studied as early as 1948 because of its outstanding plankton production (Tucker, 1948). Generally, algae counts in excess of 8,000 a.s.u. per ml prevail throughout the bay for more than half of each year. The advanced eutrophication of the Bay of Quinte is reflected not only by its generous production of phytoplankton, but also by prolific growths of submergent vegetation throughout a large portion of the bay. This high productivity of the bay may be largely accounted for by its shallow nature and input of water from the Trent River system. Since it drains a relatively productive region characterized by deep loam and clay soils, the Trent River contributes an abundance of soluble nutrient substances. Use of agricultural fertilizers, as well as urbanization and economic development along the Trent system and the Bay of Quinte have undoubtedly augmented the problem of enrichment.

Table 2. Summary of phytoplantonic conditions at six municipalities located on the Great Lakes. All results are expressed as areal standard units per millilitre.

Year >	1966			1967			1968			1969			1970		
Municipality	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Goderich	387.9	131	1,170	3,095	0	761	7,718	42	793	2,253	40	746	17,097	31	329
Sarnia	2,235	24	542	1,164	33	590	742	211	534	1,506	161	645	1,645	221	695
Union	4,174	881	2,114	9,631	1,554	5,430	8,724	1,273	4,776	8,594	710	4,496	1,472	54	4,426
Dunnville	2,143	54	548	1,606	179	669	1,595	83	601	2,947	118	781	1,186	23	562
Hamilton	912	64	433	2,108	37	450	886	17	165	1,313	13	268	1,106	86	251
Cornwall	2896	34	533	1,267	120	424	919	111	425	1,063	94	403	1,357	39	439

Production of high numbers of phytoplankton in the Great Lakes has sometimes reduced the efficiency of filtration at water treatment plants, especially during periods following the spring freshet. High numbers of diatoms, especially, may reduce the length of filter runs to as low as two to four hours. Copious production of the diatom *Melosira* in November of 1962 temporarily affected nearly all water works between Hamilton and Kingston and the plant at Scarborough was removed from service entirely for several days.

Filterability would be seriously affected each spring at the Union Water Treatment Plant, situated on the Western Basin of Lake Erie, as well as at a number of other water works, were it not for the presence of micro-strainers which remove the majority of the diatoms prior to sedimentation and/or filtration. As mentioned earlier, several species of diatoms can cause serious tastes and odours because of their soluble excretory products and this condition is usually experienced at the Union Plant during these peak periods of phytoplankton production. In fact, when phytoplankton stocks begin to increase in the early spring at Union, feeding of activated carbon is used routinely to control tastes and odours.

Belleville could not possibly utilize water from the Bay of Quinte to meet its requirements if microstrainers were not a component part of its water treatment facility. Chronic taste and odour problems result from the high level or organic production in the Bay of Quinte. It is difficult to isolate causative factors where phytoplankton, submergent aquatic vegetation and probably actinomycetes are all influencing the palatability of the raw water supply. Not only does aquatic vegetation produce metabolic waste products but odouriferous compounds are released as it decomposes following the termination of the growing season. Production of actinomycetes is known to increase as degradation of blue-green algae occurs, (Silvey 1963) and these micro-organisms may compound the problem following peak levels of blue-greens such as *Anabaena* and *Aphanizomenon*. On particular occasions at

Belleville, taste and odour production has related clearly to the presence of specific types of algae. For example, extremely unpalatable waters owing to the presence of 300-350 a.s.u. per ml of the flagellated algae *Dinobryon* and *Synura* have been characterized by Threshold Odour Numbers between 25 and 50.

In addition to problems on the Great Lakes and in the Bay of Quinte, production of troublesome levels of phytoplankton and submergent vegetation have led to a number of evaluations of smaller lakes, rivers and reservoirs throughout the Province. Lakes such as Sturgeon, Pigeon and Rice which form part of the Trent canal system. Specifically, personnel of our Biology Branch were recently requested to comment on the suitability of Sturgeon Lake as a potential source of potable water for a new sub-division. Utilizing biological, chemical and physical data collected over the past summer, it was pointed out that the lake was extremely productive and consumer complaints would certainly materialize if adequate algal removal and taste and odour control facilities were not included in the proposed plant. Additionally, waters of all depths were extremely warm during June, July and August; as such it is extremely doubtful whether such warm waters would conform to the OWRC's (1970) "Desirable Criteria" for municipal drinking supplies described as "pleasant tasting".

A recent investigation of tastes and odours in the water supply at Alexandria, south of Ottawa, revealed that both algae and vascular aquatic vegetation along the Garry River system were responsible for the problem. Threshold odour numbers at the time of the investigation ranged from 12 to 24. Fish odours resulting from over 12,000 areal units per ml. of the blue-green alga *Lyngbya* in a naturally eutrophic lake at the source of the Garry River were accentuated by passage of the river through a series of swampy areas before reaching a small lake providing water for the town.

Lakes need not be grossly enriched either naturally or artificially to create taste and odour problems, although this is often the case. It has been observed that several small northern Ontario lakes support one or more species of flagellated algae, usually during the spring or fall, which have the capacity to produce tastes and odours at extremely low numbers. Apsey Lake near Espanola, Clarke Lake near Bancroft, Turner Lake near Cache Bay, Gull Lake near the town of Kirkland Lake and Ruhl Lake near Hanover do not appear to be eutrophic either on the basis of their chemical and physical attributes or their level of primary production. Nonetheless, water in all of these lakes have been rendered periodically unpalatable because of the presence of small numbers of one or more species of odour producing flagellates including *Synura, Trachelomonas* and *Dinobryon*. The problem in many of these lakes is further complicated. Chlorination which is usually the only treatment has been known to change and intensify the nature of the odour imparted by species such as *Synura* or *Dinobryon*.

Recurring taste and odour problems in Apsey Lake prompted a six day survey in 1970.Chemical and biological data secured provided evidence that the lake was mesotrophic in nature (Figures 6 and 7). Additionally, water entering the intake was drawn from the mid-thermocline stratum - the zone of water where maximum algal populations developed. Certainly, hypolimnetic water would be an improvement over that taken from the mid-thermocline zone. However, owing to the current mesotrophic nature of the lake, it is questionable whether consistently superior water could be supplied by extending the intake into a deeper stratum. Consulting engineers have been retained to prepare plans which would include treatment facilities for algal removal and taste and odour control.

It has become more and more apparent that solutions to problems of biological origin are extremely difficult and costly to remedy where water treatment plants are well established. One of the best methods of providing good quality water for municipal use is to select the best possible source of supply. As much as is possible, lakes, rivers and reservoirs offering potential as a source of municipal supply are being assessed by means of chemical and biological analyses for at least one year prior to the installation of any waterworks facilities. Such studies would allow treatment plant facilities to be considered at an early design stage. To date, studies have been carried out for Sundridge (Bernard Lake), Barry's Bay (Barry's Bay) and Ameliasburgh (Roblin Lake).With specific reference to Roblin Lake, a small (0.35 square mile) , shallow (mean depth - 10 feet) lake in Prince Edward County which is being considered as a water supply source for a population approximating 150-200, it was apparent that poor water quality would be frequently experienced by domestic users unless treatment facilities for algal removal and taste and odour control were included in the plant design. It was cautioned (Michalski and Hopkins 1971) that the expense of such facilities might not be justified in view of the-small population to be serviced, the enriched nature of the lake and the marginal status of resource capabilities provided by the lake and its drainage basin.

Ramsay Lake at Sudbury is situated adjacent to a city having a population of 80,000. Inadequate sewage disposal in the past and admission of storm water and surface runoff from the urbanised area have led to artificial enrichment of this source of water supply for the city. Unbelievable number of the diatom *Navicula* developed in May of 1963 when counts up to 134,000 a.s.u. were recorded. Serious conditions developed again in the fall of 1965 when the blue-green alga *Aphanizomenon* exploded in numbers and created. threshold odour levels which ultimately exceeded 200.

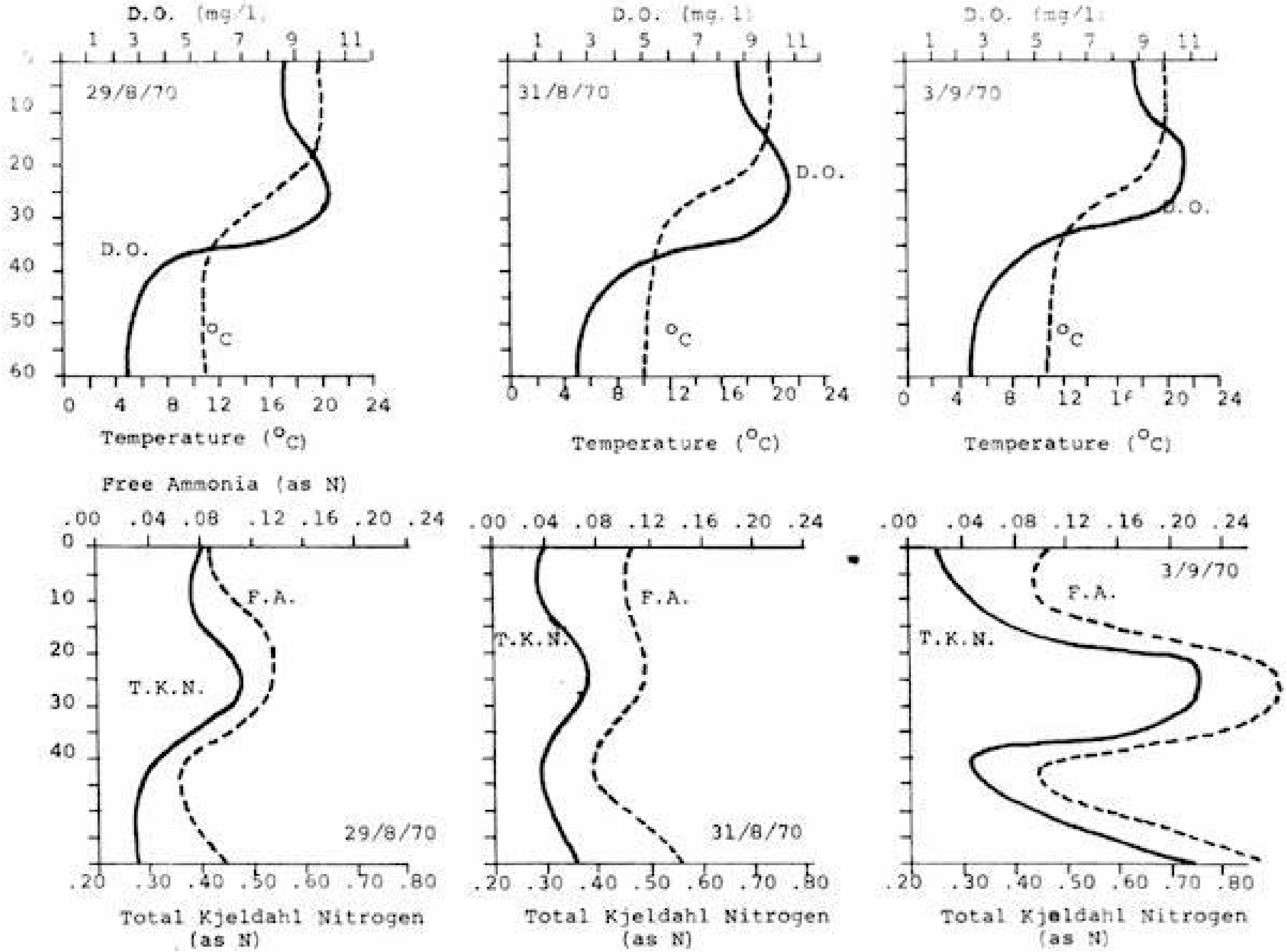

Figure 6. Profiles of dissolved oxygen, temperature, free ammonia and total Kjeldahl nitrogen on three dates in 1970. Water treatment plant intake located at 27 feet of depth.

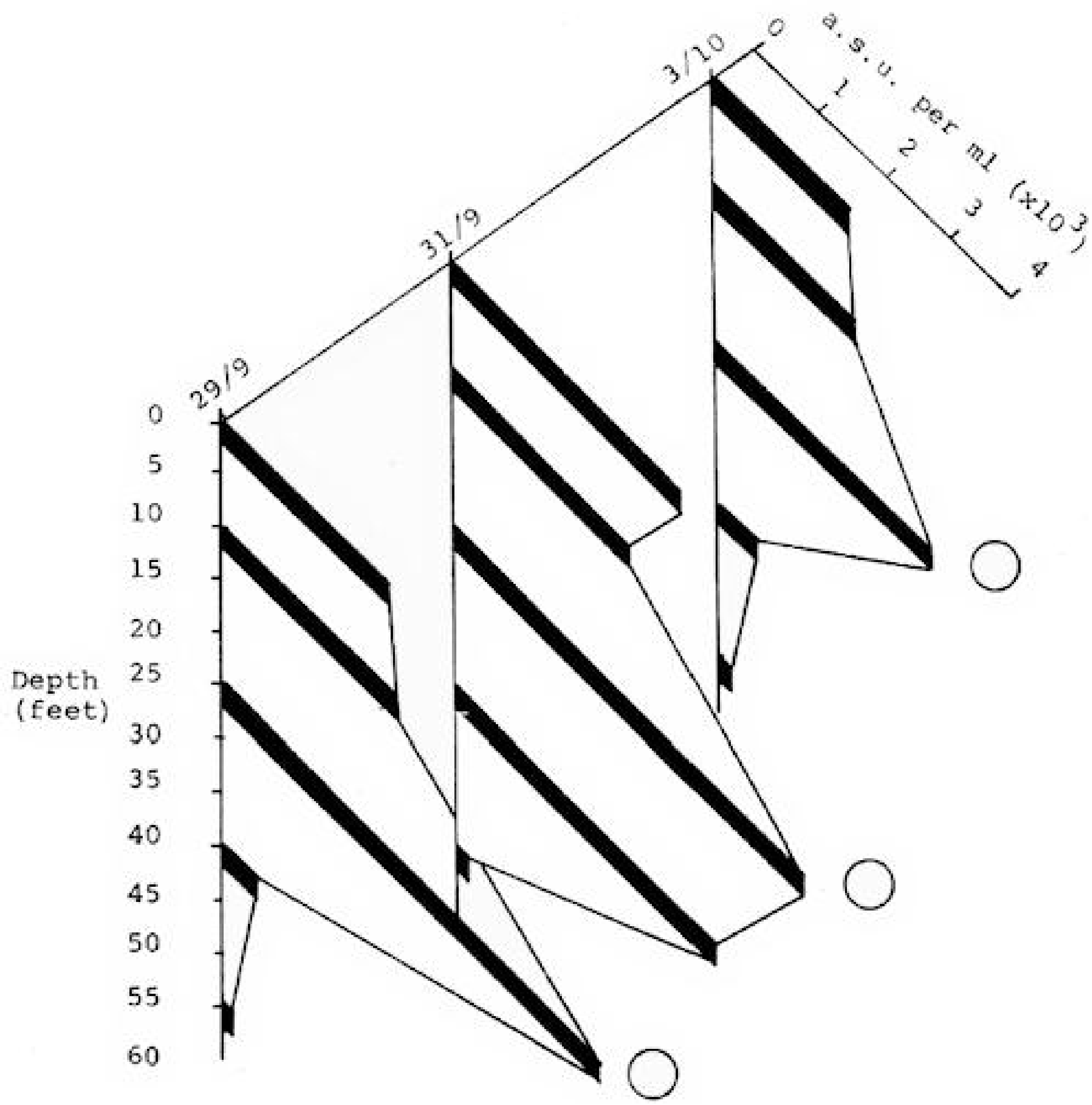

Figure 7. Standing stocks of total phytoplankton in Apsey Lake on three days in 1970. All results are expressed in areal standard units per millilitre. Position of intake is indicated (27 feet).

PHYTOPLANKTON MONITORING IN ONTARIO

In 1964, the scope of the Commission's programme related to phytoplankton studies was expanded to include 4n Algae Identification and, Enumeration Course and, a Phytoplankton Inventory Programme. The algae counting course is offered annually to water treatment plant operators. To date a total of 15 operators identify and enumerate algae on a regular weekly basis (Table 3). Staff of our Biology Branch complement these data by completing analyses from an additional nine municipalities (Table 3).

In order to maintain and stimulate interest, personnel of the Branch visit each of the participants at least once per year to discuss problems associated with the programme. At least once-per-year, an informal bulletin entitled "Algae Counters' Review" is prepared and distributed. By means of this bulletin a liaison can be maintained between Commission staff and participating water treatment plant operators. Additionally, the "Review" provides a means of informing co-operating municipalities of the results of investigations undertaken by OWRC personnel, and of the success of any corrective measures employed to offset accompanying troublesome algal.

In addition to documenting information on the biological quality of the water at a number of municipalities along the Great Lakes and from various inland waters, the data generated by the aforementioned on-going studies have been utilized as part of public relations programmes by various water treatment plant personnel. Illustrated representations have been extremely popular and helpful in promoting a better understanding of algae, their growth patterns and related water treatment plant problems to the public in general.

Table 3. Municipalities currently participating in Phytoplankton Inventory Programme.

Municipality	Source	Analyst: Municipal Operator	Analyst: Biology Branch Technician
Goderich	Lake Huron	X	
Grand Bend	Lake Huron	X	
Sarnia	Lake Huron	X	
Windsor	Lake Erie	X	
Union (Kingsville)	Lake Erie	X	
Wheatley	Lake Erie		X
Cedar Springs	Lake Erie		X
Port Dover	Lake Erie		X
Dunnville	Lake Erie	X	
Bertie Township	Lake Erie		X
Grimsby	Lake Ontario		X
Hamilton	Lake Ontario	X	
South Peel	Lake Ontario		X
Oshawa	Lake Ontario		X
Cobourg	Lake Ontario		X
Brockville	Lake Ontario		X
Cornwall	Lake Ontario	X	
Sudbury	Ramsay Lake	X	
"	Bethel Lake	X	
"	Laurentian Lake	X	
"	Minnow Lake	X	
"	Mud Lake	X	
"	Nepahwin Lake	X	
"	Wahnapitae Lake	X	
"	Wahnapitae River	X	
Peterborough	Otonabee River	X	
Smith Falls	Rideau River	X	
Lindsay	Scugog River	X	
Ottawa	Ottawa River	X	
Belleville	Bay of Quinte	X	

The need for adequate nutrient controls was a major requirement in the report to the International Joint Commission, "Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River". Implementation of phosphorus removal facilities which will eventually embrace most municipalities. throughout the Province will undoubtedly be one of the major water pollution control programmes of this decade. The importance and significance of long-term "before-hand" phytoplankton data compiled by participants of our Phytoplankton Inventory Programme cannot be overemphasized in providing an evaluation of the effectiveness of nutrient removal facilities.

APPENDIX A

INTERFERENCE ORGANISMS IN WATER SUPPLIES

While problems of biological organisms in water supplies have ranged from isolated once-in-a-lifetime to widespread experiences affecting several water supply systems, there have been no indications that the organisms have been injurious to health. The greatest objections to interference organisms relate to effects on plant operational procedures and consumer complaints - especially in relation to the palatability and for aesthetics of the treated water.

One hundred and eighty two reports pertaining to interference organisms in water have been filed with our Biology Branch over the past seventeen years. One hundred and five municipalities have requested assistance in identifying the causative organism. In all, a total of seventy-five organisms have been incriminated in biologically induced problems. Table 1 provides a documentation of the organisms encountered while Table 2 provides a summary of the problems.

Organisms reported from water supply systems

Algae have been by far the most important organisms creating nuisance conditions in a water supply system. Over the past seventeen years a total of sixty-two cases involving algae have been documented. The flagellated algae *Synura, Dinobryon, Ceratium* and *Chlamydomonas* have been associated with the most intensive taste and odour problems. *Synura*, alone has caused fourteen separate problems - all owing to the presence of a cucumber-like odour. The blue-green algae *Aphanizomenon, Anabaena, Oscillatoria* and *Lyngbya* and the diatoms *Asterionella, Melosira* and *Synedra* are types frequently implicated in taste and odour production.

Table 1. Organisms found in Municipal Water Supplies Reported only once if no number follows name of the organism.

Algae		**Animal**	
Blue-greens		Protozoa	6
		Hydra	2
Unidentified	9	Porifera-sponge	2
Anabaena	2	Bryozoa	5
Anacystis			
Gloeotrichia		Oligochaeta	2
Lyngbya		Lumbricus - earth worm	2
Microcystis		Tubificidae -Aeolosoma	
Oscillatoria	3	Naidium	2
Scytonema	2	Chaetogaster	
Total	20	Hirudinea-Leech	4
		Gordian worm	4
Greens		zooplankton	5
		Cladocera	2
Unidentified	2	Copepoda	2
Chara	2	Isopoda	
Cladophora	8	Amphipoda	
Dictyosphaerium		Hyalella	
Spirogyra		Collembola	4
Total	12		
		Diptera	2
Flagellates		Chironomidae	4
Unidentified	3	Chaoborus	3
Ceratium		Plectoptera	
Chlamydomonas		Corixidae	
Dinobryon	10	Hydrocarina	
Synura	14	Physidae-snails	
Total	27	Sow Bug	
Diatoms		Millipede	
Unidentified	10	Total	62
Asterionella	3		
Cyclotella			
Fragilaria			
Gomphonema			
Melosira	17		
Navicula			
Synedra	4		
Tabellaria			
Total	43		
Unspecified algae	37		
Total	139		

Table 1. Continued

Bacteria		Miscellaneous	
Bacterial slime	5	Aquatic weeds	5
Iron bacteria	7	Air bubbles from humic acid	
Leptothrix		Duckweed	
Crenothrix	2	Horse hair	
Gallionella		Oil	
Sphaerotilus	5	Organic detritus	5
Sulphur bacteria	2	Ozonation	
Fungal growth	2	Phenols	3
		Precipitated iron	6
		Stagnant water	
		Unidentified	4
Total	25	Total	29

Table 2. Biological Problems associated with Water Supplies.

1.	Tastes and Odours		
	a)	caused by algae	62*
	b)	caused by aquatic weeds	2
	c)	caused by iron bacteria	7
	d)	caused by organic detritus	1
	e)	caused by phenolic compounds	1
2.	Slime or Algal Growths in the System		2
3.	Animal Organisms in the System		53
4.	Operational Problems		
	a)	Clogged intake screens	10
	b)	clogged microstrainers	3
	c)	Alterations in various chemical feeds to control organism or problem caused by organism, i.e. tastes and odours	
	d)	problems in the system ahead of the filters - wet well mixing chamber, flocculation chamber, settling basin, etc.	11
	e)	problems after the filters -clear well, storage reservoir, elevated tanks and distribution system	8
5.	Assessing the Biological Quality of a Surface Water Supply		
6.	Location of the Intake to minimize biological problems		
7.	In-plant design to exclude the transmission of biological organisms through a water treatment system.		

* Numbers refer to cases sited in this report.

Cladophora, a filamentous green alga which grows in abundance in the littoral zone of the lower Great Lakes has been a frequent cause of plugged intake screens. In the ten instances reported, the problem was severe enough to curtail the flow through the intake or to the low lift well.

The diatoms *Gomphonema, Melosira, Navicula* and *Synedra*; the green algae *Cladophora, Chara* and *Chlorella;* the blue green forms *Anabaena, Aphanizomenon, Gloeotrichia, Oscillatoria* and *Scytonema* have interfered or altered the normal operation of mixing chambers, flocculators; sedimentation basins or other pre-filtration facilities.

Filter beds have become plugged owing to the development of tremendous numbers of *Melosira, Navicula, Synedra* and *Tabellaria* and the green algae *Chlorella* and *Spirogyra.*

Finally, algal forms (*Anabaena, Aphanizomenon, Microcystis, Oscillatoria, Scytonema, Chlamydomonas, Chara, Cladophora Dinobryon, Synura, Asterionella, Melosira, Synedra* and *Cyclotella*) in clear wells, storage reservoirs and distribution systems have accounted for problems in many situations. For example, *Scytonema,* a filamentous blue-green alga which produces an abundant sheath and matrix restricted the flow to a mere trickle to several consumers in one system.

Animal organisms and water supply

Twenty-eight (28) animal organisms (Table 1) were responsible for sixty (60) sample submissions requiring identification. *Collembola* (springtails) were found in the low lift well, reservoir, filter effluent and in the distribution system at four supply systems. Bryozoa (moss animalcules) and Porifera (freshwater sponges) have on five occasions blocked intake screens and microstrainers. Diptera larvae, *Chaoborus* larvae (Phantom midge) and Chironomid larvae (blood worms) have been reported from reservoirs from intake screens, filter beds and from household taps.

Zooplankton organisms, including Amphipods (scuds), Isopods (aquatic sow bugs), Copepods (*Cyclops*) and Cladocera (*Daphnia*) have plugged intake screens and micro-strainers and infested sedimentation tanks, filter beds, clear wells, storage reservoirs and distribution systems. These organisms which are just visible to the naked eye may frequently be missed in examining the water. *Hydra,* (small Coelenterates) have been found in low-lift wells and on the filter beds of two water treatment plants. Members of the Oligochaeta, the tiny segmented aquatic earth-worms have been reported on six occasions. On one occasion, the terrestrial earth worm *Lumbricus terrestris* was found at two locations in the same distribution system.

Nematomorpha, (Horsehair or Gordian worms) have been reported (in the distribution system) on four occasions. These worms are 2-3 inches in length and $^{1}/_{16}$ - $^{1}/_{8}$ inch in diameter making them readily visible. Hirundinea (leeches) emerging from a tap can probably do an efficient job of shaking the consumer's confidence in the quality of his water supply, and correspondingly, in the competence of the individual water treatment plant operator. Four such incidences are recorded in our files. Millipedes, terrestrial sow bugs, insect larvae, Corixidae (water boatmen), Hydrocarina (water mites) and snails have been reported occasionally from distribution systems.

Bacteria and water supplies

Bacterial problems are normally directed to our Bacteriology Branch. However, on twenty-five (25) occasions samples submitted to our Biology Branch have been characterized by bacterial growths such as slimes, iron and sulphur bacteria and *Sphaerotilus. Leptothrix, Crenothrix* and *Gallionella*, all iron bacteria, were mistaken for algal growths or were present in samples containing algae and collected from distribution systems. These samples were nearly all associated with taste and odours in the treated supply. *Sphaerotilus*, commonly called sewage fungus, is actually a filamentous bacterial slime. While it is normally associated with gross pollution it is a facultative organism and can thrive under certain clean water conditions. *Sphaerotilus* was present in the distribution system in a number of instances.

Miscellaneous problems

Rooted aquatic plants, organic detritus and stagnant water have occasionally produced odours and plugged intake screens. Other problems have, been attributed to Duckweed, protozoa, precipitated iron, oil, air bubbles, ozonation, and last but not least horse-hairs.

Methods of entry

The method of entry into a water supply system often remains a mystery though in many cases it is thought that the minute eggs pass through the filtration beds and develop subsequently in the distribution system. This problem is not more widespread because the inside of a water main is relatively clean so that food is available only in very limited quantities. In some cases the life cycle cannot be completed entirely under water so that insects such as blood worms cannot reproduce in the water main. Some animals such as snails and worms gain access to open-air reservoirs and hence into the distribution system. Birds and ducks often transport small aquatic insects and deposit them into reservoirs and in some instances aquatic earth worms gain entrance into open pipes during construction processes.

Control of infestations

Many of the cases described above were isolated and required no remedial action. Others were detected and corrected by the plant operating staff before they reached the consumer. Excessive algal growths in the raw water supply were treated with copper sulphate at Sudbury and Hanover.

As most of the organisms that inhabit water mains are resistant to normal water works sterilization procedures and as no chemicals are suitable for adding to water to control this type of nuisance organism, good housekeeping is the only effective control. As much as possible of the organic material should be kept from the water mains. This is best accomplished through chemical precipitation and sand filtration. In laying water mains, low flow areas should be eliminated as much as possible, as they provide a refuge. Where dead ends occur in the system, they should be flushed routinely.

In this way, it will be possible to maintain the confidence of the consumer in the products that are delivered. Suggestions on changes in operational procedures have usually been referred to our Division of Research, Technical Advisory Services Branch, while distribution system problems have been referred to our Division of Sanitary Engineering.

APPENDIX 'B'

PROBLEMS ASSOCIATED WITH MUNICIPAL WATER SUPPLIES IN ONTARIO

(Information from files of OWRC, Biology Branch 1954-1971)

Municipality	Problem Location	Nature of Problem	Cause of Problem	Date
1a. Alexandria	Loch Garry raw water	Taste and odours	Aquatic weeds and algae.	July/54
1b. Alexandria	Loch Garry raw water.	Taste and odours, including evaluation of supply	Aquatic weeds and algae, and Lyngbya	June-Aug. 1965
2. Alfred	Reservoir and lowlift well.	Infestation	Collembolla - Springtails	Sept/70
3. Allenburg (Thorold)	Distribution system.	?	Algae - Chlamydomonas	-
4. Alliston	Distribution system.	Worm	Gordian or Horsehair worm	Sept/67
5. Aurora	Distribution system - tap.	Worms	Naidium	Aug/71
6a. Bancroft	Clarke Lake raw water & Distribution system	Tastes and odours cucumber-fishy.	Algae-Synura	Oct/66
6b. Bancroft	Clarke Lake raw water & distribution system	Taste and odours cucumber -fishy.	Algae -Synura	May/68
7a. Belleville	Microstrainers	blocked	slime growths	Jan/59
7b. Belleville	Distribution system - taps.	Organisms in taps	Diptera Hyallela astrea Isopoda Physidae-Snails Crustaceans.	Dec/59
7c. Belleville	Top of filter beds	Organisms	Chaoborus - phantom midge	Jan/61
7d. Belleville	Distribution system - taps.	Organisms in taps.	Protozoa Bacteria (iron) Gallionella Crenothrix	Nov/63
7e. Belleville	Raw water and treated water.	Tastes &Odours	Algae - Dinobryon Synura and Chlorophyta	Feb/64

Municipality		Problem Location	Nature of Problem	Cause of Problem	Date
7f.	i Belleville ii " iii "	Bay of Quinte Raw Water at plant. Treated " " "	T.O.N. max 200 T.O.N. max 140 T.O.N. max 70		Oct/65Oct /65Oct/65
7g.	"	Treated water	Tastes and odours	Algae and ozonation	Feb/69
7h.	"	Filter beds	Foaming	Air bubbles from humic acid.	Apr/70
7i.	Trenton Water Service Area	L. Ontario	proposed regional supply. Request information on algal populations for public hearing.		July/70
7j	"	L. Ontario	Request information on diatom levels to advise plant consultant of in-plant design.		May/71
8a.	Bertie Twp.	Intake opening	Blocked	Cladophora	July/52
8b.	Bertie Twp.	Microstrainers	Identification of organisms,	Various micro and invertebrates & Cladophora	Feb/64
8c.	Bertie Twp.	Screens in low lift well.	Blocked	Cladophora	July/66
9.	Blenheim	Wells and distribution system	Growth	Protozoa & slime bacteria.	June/53
10.	Blind River	Raw water and distribution system (mains)	Taste and odour	Iron bacteria and precipitate.	Nov/67
11.	Bobcaygeon	Sturgeon Lake raw water.	Biological evaluation of potential sources of supply.	algae - blue- greens.	1964
12.	Bondhead	Distribution system	Taste and odour.	?	Sept/70
13.	Bracebridge	L. Muskoka	Biological evaluation of potential source of supply.	-	1965
14.	Brantford	Intake screens.	Blocked	Diptera larvae	May/59
15a.	Brockville	Distribution system - taps.	Algae	Unidentified	Dec/55
15b.	Brockville	Distribution system - taps.	Algae	Diatoms	Dec/59

Municipality	Problem Location	Nature of problem	Cause of Problem	Date
15c. Brockville	Distribution system - taps.	Wigglers?	?	Sept/61
15d. Brockville	Distribution system - (mains)	Taste &odour	Organic debris and algae.	Oct/61
15e. Brockville	Low liftwell	Oily Scum	Zooplankton	July/67
16. Burlington	Filter beds	Blocked	Algae - Melosira	Oct/62
17. Cache Bay	Tanner Lake	Biological evaluation of water supply, taste and odour present.	Dinobryon, Synura	Aug/64
18. Caramet	Raw water - lake depth is 30'	Taste and odour	Algae and organic debris	Aug/70
19a. Campbellford	Trent River	Taste and odour	Synura	March/61
19b. Campbellford	Trent River	Taste and odour.	Synura	Oct/61
20. Carlton Place	Distribution system - tap	Organisms in tap.	2 leeches	Sept/61
21. Chapleau	Distribution system.	Sediment	Diatoms, Sphaerotilus, gelatinous material	Feb/67
22a. Cobourg	Distribution system - tap	Algae filaments	Cladophora	July/66
22b. Cobourg	L. Ontario	Biological evaluation of new intake location.	Algae	1969-70
23. Cochrane	Filter beds	Growth on walls	Blue-green algae - Gloeotrichia	Oct/62
24. Cornwall	St. Lawrence Sanitorium W.W. intake screen.	Blocked	Sphaerotilus	Feb/70
25a. Delhi	Distribution system.	Taste & odour	Chara in open reservoir.	
25b. Delhi	Raw Water	Taste & odour	Algae	Aug/67
26a.Desoronto	Bay of Quinte	Algae	Blue-greens	July/54
26b.Desoronto	Raw Water	Algae	Melosira & Anabaena	Aug/55
26c.Desoronto	Distribution system.	Taste & odour	Algae, Protozoa, crustaceans	Feb/62

Municipality	Problem Location	Nature of problem	Cause of Problem	Date
26d.Desoronto	Filtered water and Raw water	Check on removal of taste & odour, 97-99% removal.	blue-greens and Flagellates	July/ Oct/68
27. Dorset	Distribution system.	Sediment in taps	Cyclotella & other diatoms.	Aug/71
28. Douglas	Raw Water	insects	Collembolla - springtails	Jan/62
29a Dryden	Raw Water	Taste & odour	Synura	Jan/68
30.Elliot Lake	Raw water	Taste & odour	Dictyosphaerium & Dinobryon	Nov/62
31a. Espanola	Apsey Lake & distribution system.	Taste & odour	Dinobryon	June- Sept 63
31b. Espanola	Treated water - distribution system	Taste & odour	Synura	May-June/ 1964
31c. Espanola	Wet Well	Sediments	Organic debris algae & protozoa	1965
31d. Espanola	Raw Water	Taste & odour	Synura	Mar/66
31e. Espanola	Distribution system - toilet tank.	Scum	Blue-greens	Feb/70
31f. Espanola	Apsey Lake	Biological evaluation of existing intake location and potential new position.	Blue-green algae. Aphanizomenon	Sept/70
31g. Espanola	Apsey Lake	Algal scum on shoreline	Oscillatoria	April-May 1971
32a. Fort William	Intake strainer Loch Lomond	Blocked	Bryozoa - Fresh Water Sponges	1960
32b. Fort William	Filter beds	organisms present	Hydra	1963
33a. Georgetown	Reservoir & distribution system.	Worms & Algae	Chironomid larvae	Oct/62
33b.Georgetown	Distribution system - tap	Worm	Lumbricus terrestris - earthworm	Dec/70
34a.Geraldton	Raw Water	precipitate	Iron Dinobryon - present	Oct/62

Municipality	Problem Location	Nature of Problem	Cause of Problem	Date
34b. Geraldton	Raw Water	Worm	Gordian worm-horsehair worm	June/64
35. Goderich	Filter beds	short runs	algae/temp.	June/67
36. Grand Bend	" "		" "	
37a. Grimsby	Filter beds	blocked	Melosira	Oct/62
37b. "	Flocculation chambers & settling basin	floating sludge	Filamentous growth	July/66
37c. "	Dist. system	organism present	Leech	June/69
38. Haileybury	Raw Water	Biological evaluation of a new water supply		1967
39a. Hamilton	2 1/2" plastic pipe to marina on dist. system	Growth in pipe	Blue-green algae & precipitated iron	Sept/64
39b. Hamilton	Sedimentation chambers and filter beds	poor floc	algae and zooplankton	Sept/68
40. Hanover	Raw Water & Dist. system	Taste & Odours	Ceratium & Dinobryon	Nov/66
41a. Hastings	Raw Water	Taste & Odours	Algae	Nov/66
41b. "	" "	Biological evaluation of water supply	Algae	Jan/67
42a. Ingersoll	Watermains - Dist. System	organism present	Tubificids- sludge worms	Aug/68
42b. "	reservoir screens	organisms present	snails	Aug/68
43a. Kenora	Raw Water	Algae	blue-green bloom	Oct/53
43b. "	Dist. system	Organism present	Chironomid larvae-blood worm	Nov/53
44a. Kingston	Filter beds	Reduced filter runs	Melosira	1955-59
44b. Kingston	Filter beds	Reduced Filter runs	Melosira	Nov/62
44c. "	"	"		Feb/67
44d. "	Raw Water	Biological Evaluation of proposed new intake extension		1967
45a. Kirkland Lake	Gull Lake	Tastes & Odour-fishy	Probably Synura	1959

Municipality	Problem Location	Nature of problem	Cause of Problem	Date
45b. Kirkland Lake	Dist. System	Organism present	Midge fly Larvae	1960
45c. "	Dist. System	Taste & Odour	Algae- Melosira, Asterionella	1961
45d. " Twp. of Peck	Gull Lake	Taste & Odour	Synura	1962
45e. Kirkland Lake	"	" "	Dinobryon	1965
46a. Lindsay	Filter effluent	Organism present	Collembola- springtails	Jan/62
46b. "	Dist. system-taps	" "	Chaetogaster Naidium-aquatic earth worms	June/71
47a. London City System	Reservoirs -Fanshawe L., Springbank Park & Dist. System	Tastes & odours	Weeds & Algae Anabaena, Microcystis Synedra	1955-57
47b. London	Reservoir	Organisms present	Copepods	Aug/70
47c. "	Reservoir screen	" "	snails	Sept/70
47d. "	Dist. system	" "	Gordian worm	June/71
48a. Manitouwadge	Dist. system	Infestation	Fungus	June/63
48b. "	" "	" "	Iron bacteria fungus & Leptothrix and Sphaerotilus	Sept/67
49 Markham Twp.	Dist. System	Organisms present	Oligochaeta- aquatic earth worm	July/58
50a. Mary Lake Monastery	Dist. System	Taste & odour	Algae- Oscillatoria	Apr/70
50b. " "	Raw Water	"	"	July/70
51. Massey	Dist. System	Taste & odour	Algae	1961
52. Meaford	Infiltration System	Red colour	Iron bacteria Crenothrix	July/55
53. Merriton	Settling basin	Taste & odour	Algae & Miscrocrustaceans	July/54
54. Mitchell	Dist. System-Mains	Growth in System	Iron and sulphur bacteria	Aug/54
55a. Napanee	Dist. System	Taste & odour	Algae	Sept/55
55b "	Filters-backwash water	Reduced filter runs	Organic Detritus	Feb/69

Municipality	Problem Location	Nature of problem	Cause of Problem	Date
56. New Hamburg	Reservoir	Weed infestation	Chara	June/61
57. New Liskeard	Dist. System	Swampy Taste & Odour	Decomposed Organic Matter	Nov/62
58. Niagara-on-the Lake	Dist. System	Taste & odour	Winter thaw	Jan/69
59. Niagara Falls	Dist. System	Taste &	Algae-diatoms	Aug/70
60a. North Bay	Dist. System	Odour Infestation	Coliform organisms and Diatoms	1960 Summer
60b. " "	L. Nipissing	Biological evaluation of potential new source of supply	Dinobryon	Dec/64
61. Oakville	Filter Beds	blocked	Melosira	Nov/62
62. Ont. Fire College Gravenhurst	Dist. System	Taste & odour	Iron and or algae	July/64
63. Orillia	L. Couchiching Raw Water	Taste & dour	Dinobryon	1965
63b. "	"	"	Asterionella, Dinobryon	Dec/69
64a. Ottawa	Mixing chambers	sediment	Algae-Chlorella Diatoms	1961
64b. "	Wash water troughs of filters	Growth	Diatom-Navicula & blue-green Oscillatoria	1963
64c. "	Dist. System	Organism present	Cyclops	1963
64d. "	Mixing tank and settling basin	Insects present	Corixidae water boatmen	June/71
65. Parmour	Intake	Infestation	Daphnia	Jan/64
66a. Parry Sound	Raw Water	Taste &Odour	Algae	1960
66b. " "	Treated water and Dist. System	Sediment	Iron precipitate, Diatom shells & Zooplankton	Aug/66
67a. Pelham- Fonthill	Dist. System-taps	Plugged	Blue-green algae Scytonema	Apr/70
67b. "	" " " (open reservoir)	"	mirabile	Mar/71
68. Perth	Dist. System	Infestation	Chironomid larvae	Oct/56
69a. Peterborough	Dist. System	Taste & Odour	Algae	Spring/63

Municipality	Problem Location	Nature of problem	Cause of Problem	Date
69c. Peterborough	Dist. System-tap	Infestation	Algae	Sept/70
70a. Picton	On filters	Insects	Hydracarina - water mite	June/65
70b. "	Intake screens	Blocked	Algae & aquatic plants	June/67
71. Port Arthur	Microstrainers	Blocked	Slime growth	1959
72. Port Credit	Flocculent accelerator	Possible Oil Contamination	Bunker 'C' Oil	Dec/66
73. Port Dover	Dist. System	Taste & Odour	Algae ?	June/59
74a. Port Hope	Raw Water	Algae	Cladophora	Nov/57
74b. " "	"	"	"	Jan/61
75. Prescott	Intake screens	Blocked	Spirogyra & Cladophora	Aug/66
76. Sault Ste. Marie	Raw Water	Taste & odour	Phenols ? Diatom Indicators Present	1966-68
77. Sharon	Raw Water	Infestation	Midge larvae & protozoa	Jan/62
78a. Simcoe	Settling basin	Wood fibres ?	Slime Growth- Sphaerotilus Protozoa	July/63 &
78b. Simcoe	Infiltration supply gallery	organism - present	Millipede	Dec/64
79a. Smiths Falls	Dist. System-tap	Worm	Gordian worm- horsehair worm	June/55
79b. " "	" " "	Insect	Stonefly nymph Plectoptera	Apr/56
79c. " "	" " "	"	Sow bug	Sept/68
80. St. Catharines	Clear well	Organisms Present	Daphnia	June/60
81. St. Marys	Dist. System	Taste & odour	Iron and Sulphur bacteria	Oct/57
82a. St. Thomas	Raw Water	Taste & odour	Phenols ? Synedra & Synura	Dec/61
82b. "		"	Sphaerotilus	Mar/62
83. Stouffville	Dist. System-tap	Insect	Chironomid Larvae	June/65

Municipality	Problem Location	Nature of	Cause of Problem	Date
84a. Streetsville	Dist. System-tap	Hair	Horsehair	Dec/63
84b. "	Intake Screens	Blocked	Freshwater Sponges Duckweed, aquatic plants silt	Aug/66
85a. Sudbury	Dist. System	Taste & odour	?	1959
85b. "	Raw Water & Dist. System	"	Aphanizomenon	Oct/65
86a. Sutton	Raw Water	Filters blocked	Melosira	Dec/61
86b. "	" "	Filters blocked & Taste & Odour	Melosira	Nov/63
86c. "	" "	Algae & particulate matter	Melosira & Cyclops	Mar/69
87. Swastika	" "	Taste & odour	Synura	Jan/63
88. Thornbury	Main Supply	Sediments	Iron, Bacterial Slime, diatoms	Dec/63
89. Thornhill	Dist. System-tap	Insect.	Collembola-springtail	Oct/71
90. Thorold	Reservoir	Taste & odour	Algae	May/53
91. Thunder Bay	Dist. System -tap	Sediments	Iron precipitate Oscillatoria, Diatoms	Nov/71
92. Tilbury	Dist. System and intake Channel	Taste & odour	Algae & Stagnant water	June/66
93. Timmins	Raw Water	Biological evaluation for potential ? source of supply		1969
94. Toronto (Metro)	Filter Beds	Blocked	Melosira	Nov/62
95. Toronto Twp. (South Peel System)	Filter Beds	Blocked	Melosira	Nov/62
96. Township of Rayside	Whitewater Lake	Biological evaluation of potential source of supply		June-Dec/ 66
97. Trenton	Raw Water	Taste & Odour	Melosira, Anacystis & Phenols	Aug/63
98. Welland	Coagulation basin	Odour & buildup in settling basin	Algae	May/67
98b. "	Mixing chamber	Stringy floc	Slime Growth	July/71
99a. Whitby	Filters	Blocked	Melosira	Nov./62

Municipality	Problem Location	Nature of problem	Cause of Problem	Date
99c. Whitby	Storage reservoir	Blocked	Melosira	Nov/62
99d. "	Dist. System-tap	Infestation	Blue-green Oscillatoria	Mar/69
100a. Windsor	Filters	Blocked	Diatom- Synedra	1963-64
100b. "	Intake screen	Blocked	Diatom- Gomphonema	Mar/69
101. Woodbridge	Dist. System-tap	White Worms	Aeolosoma	Aug/67

APPENDIX 'C'

REFERENCES on BIOLOGICAL PROBLEMS ASSOCIATED WITH WATER SUPPLIES

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