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by

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ABSTRACT

The literature was reviewed with respect to naturally occurring organic compounds. Their identity and effects on life forms are listed in tabular form.

Methods of separation and identification of trace organics in aquatic systems are discussed and applied to a reservoir. Six organic compounds (acetaldehyde, methanol, ethanol, propanal, acetone, and 2-propanol) were identified and monitored in the reservoir from September 1974 to April 1975. Algal populations were simultaneously observed and bioassays were performed on some of these populations to determine the effects of the compounds. No effects of the compounds on the algae were observed at the concentration levels found in the reservoir.

Possible sources of these compounds were discussed and it was observed that *Chlamydomonas reinhardi* (axenic culture) did produce ethanol, propanal, and acetone, thus suggesting possible alga sources of the compounds observed. In the fall of the year, high concentrations of methanol, ethanol, and acetone are the result of bacterial action on dying mats of *Aphanizomenon.*

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INTRODUCTION

Control of Algal Dynamics

The concept of control as applied to aquatic ecosystems is not a recent concept. Control concepts originally arose from consideration of energy flow where sunlight was the driving force behind biological energy flow and there were feedback loops arising from overpopulation or from the limit of environmental carrying capacity as modified by grazing and/or predation. Another important control concept in water pollution management is that of a limiting factor or toxin controlling populations and communities.

Relationships between productivity or toxicity and how aquatic community succession and diversity develop have been related to information transfer and to control of specific populations. For example, the limitation of inorganic nitrogen concentrations in marine algal assemblages has been postulated as controlling succession (references 27.85 and 39.77); the means for controlling succession of phytoplankton have been postulated based on relative growth rates and nitrogen saturation coefficients. (The numbering system chosen for this report facilitates alphabetizing the reference list and represents a modified Dewey Decimal System.)

In the complexities of community development many factors operate, and although at this stage in our knowledge about species dynamics in specific trophic levels, cause and effect (i.e. control) are not readily definable, it is possible that benchmarks can be determined for defining when succession of algae will occur.

Organic Compound Dynamics

All aquatic organisms release organic compounds into their surroundings. The release of organics by algae is well known (references 21.8, 32.1, 33.5, 70.3, 71.5, 74, 117). They sometimes release as much as 40 percent of the total carbon fixed as organic carbon (references 8.5, 32, 61.8). It may be a complex toxin, a waste product, an internally used compound that leaks out of the cell, or the loss of cell coatings or other extracellular compounds. These organic compounds may affect ecosystem function, community composition or succession, and may at times make an entire lake useless for many beneficial uses of society.

Algae might use released organic compounds to gain dominance in a lake along with changes in environmental factors, light, temperature, nutrient levels. Sometimes these changes affect man's use of the lake especially when the population of algae reaches bloom conditions and the water develops taste, odor, or recreational use problems.

Some possible ecosystem roles and interactions of organic compounds as influenced by or in controlling populations of microorganisms are shown in Figure 1. It can be noted from Figure 1 that organic compounds might affect organisms by inhibiting or stimulating growth, by acting as a toxin, vitamin, food source, or transporting chelator. The three groups, bacteria, algae, and higher life forms, act as sources of organic compounds and all interact with one another. For example toxins of the blue-green algae have been known to cause the death of higher life forms including fish, birds, cattle, and sheep (references 16, 29, 39, 45, 49, 86, 98). Algae not only affect higher life forms but also simpler forms, such as bacteria, by producing antibiotic substances (references 50.5, 76.5, 85, 114.2, 114.3).

Objectives of Study

With these considerations in mind a study of naturally occurring low molecular weight organic compounds was initiated in a eutrophic lake to determine:

1. The identity of organic compounds present in the lake and their possible sources.
2. The changes in concentrations of the organics with time.
3. Specific effects of the certain organic compounds on certain organisms (elucidation of Figure 1).

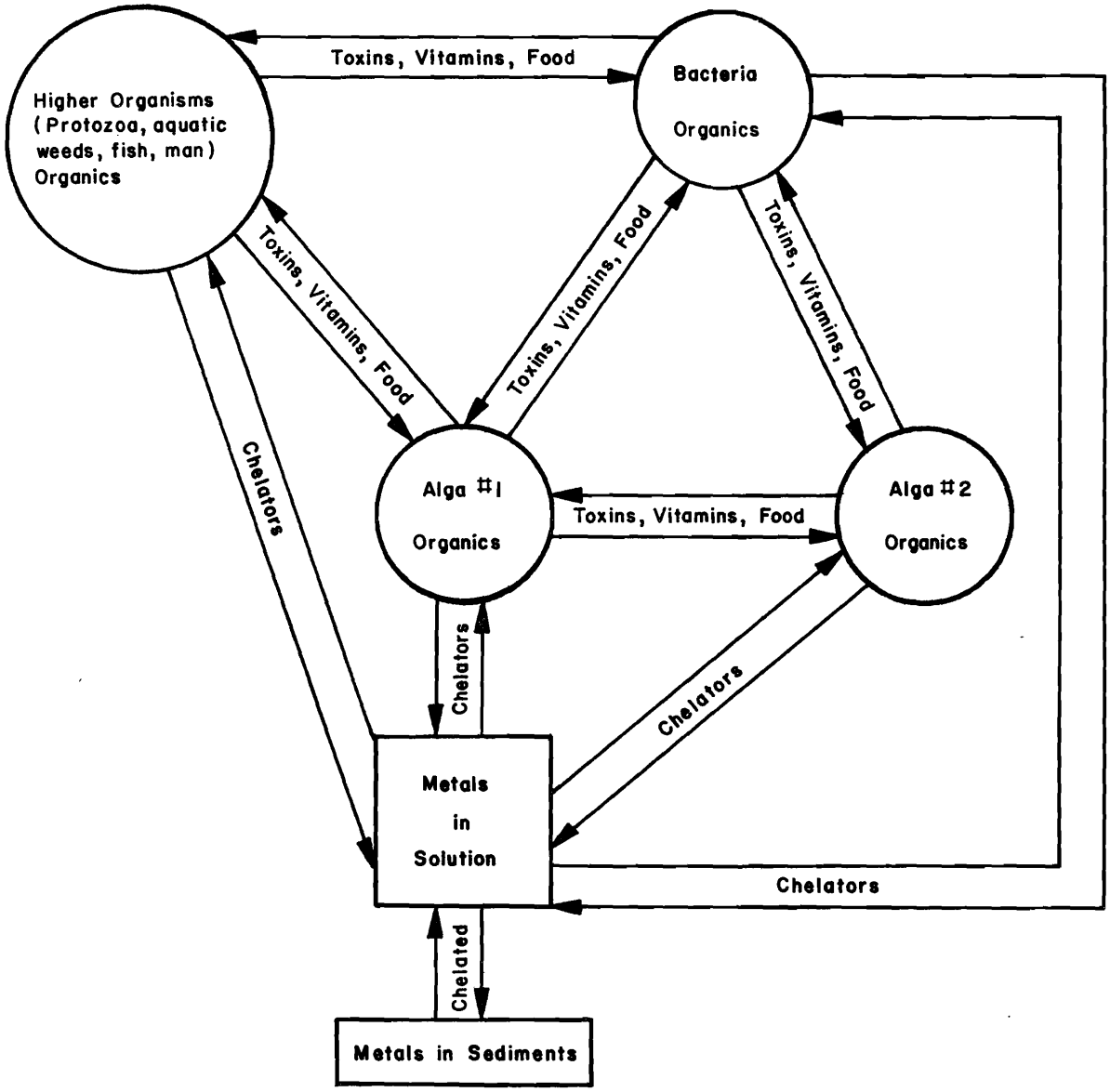

Figure 1. Organic compounds serve as toxins, vitamins, food sources, or chelators either transporting needed metals into the cells or lowering metals in their concentrations around the organism to a non-lethal level. These organic compounds may inhibit or stimulate growth or attract or repel other organisms as interchange arrows indicate.

LITERATURE REVIEW

To identify some of the important specific organic compounds involved in natural systems and to elucidate the exact nature of the interchanges listed in Figure 1, seven tables and one appendix have been prepared from recent literature. They are:

Table 1. Naturally occurring *organics* and their effects
Table 2. *Organisms* observed to have produced organics and organisms affected by known organic compounds
Table 3. *Algae* known to be capable of utilizing organic substances for energy or growth
Table 4. *Vitamin* requirements of algae
Table 5. Incidence of *growth-factor* requirements in algae
Table 6. *Growth-factor* requirements of algae
Table 7. *Algae* affecting other *algal* grown
Appendix A. Compounds affecting algae

Natural Occurring Small Molecular Weight Organic Compounds in Natural Water Systems

To meet the first objective of the study (to identify the organics present) the literature was reviewed for methods of identification and to determine all the natural organics so far observed in natural water systems.

In the past little emphasis has been placed upon individual components of the organic phases of an aquatic community other than pesticide analysis. These organic phases have been measured semi-quantitatively using parameters such as total organic carbon (TOC) (10.5), chemical oxygen demand (COD) (10.5), biochemical oxygen demand (BOD) (10.5), gross elemental analysis (39.8, 93.1), adsorption (10.5), and size distribution (36.8, 25.08). As instrumental analysis techniques are being developed to measure microquantities of organic compounds, more and more emphasis is being placed upon the isolation and identification of these individual organic compounds. Their interaction and effects on organisms and communities of organisms in an aquatic ecosystem are of great importance to an effective understanding of the organic material requirements and their regulatory capacities within an ecosystem.

Since numerous reports, publications, and reviews on the advances in isolation, instrumentation, and identification of organic substances in natural waters have been prepared, this material will be discussed herein only when appropriate to the experimental work; the reviews are as follows: 8.6, 11.2, 11.15, 11.17, 12.3, 18.65, 28.4, 28.8, 28.9, 36.9, 36.91, 44.3, 70.55.

The more than 300 natural occurring organic compounds have been identified from natural water systems including antibiotics, common metabolites, and cellular compounds (Table 1). The compound is listed in the first column of Table 1 and the second column cites the reference(s) that has shown the compound to be present in natural waters.

Effects of Organics

Listed in the third column of Table 1 are the references to studies showing the effect of the compound listed in column one on certain biota, thus helping to achieve the third objective of the study (effects of the organics). For example from Table 1, references 22.5 and 23 report the observation of acetaldehyde in natural waters which references 36.1, 36.3, and 96 describe studies of the effects of acetaldehyde on different life forms. Table 1 is a complete survey (with unknown exceptions) of organic compounds in fresh water systems.

Results for those organic compounds which were bioassayed in detail are summarized in Appendix A; compounds are divided into five general classes (antibiotics, carbohydrates, fatty acids, organic acids, and phenol-like compounds) and their specific effects on certain organisms are listed along with the experimental conditions. For example if one were interested in citric acid (or its salt, citrate), one could find in Table 1 an observation of the salt (citrate) observed in nature (21.8) and studies showing the effects of citrate (or citric acid) on different organisms (40.2, 69, 93, 96), or Appendix A can be used. Looking in Appendix A under the class of compounds, organic acids, we find listed under citric acid that *Haematococcus pluvialis* yields only 59 percent of its normal growth (by cell count) in four days, in liquid cultures (125 ml Erlenmeyer flask) at 21° C, pH of 5, 3,000 lux (continuous), and at a

Table 1. Natural occurring organic compounds found in water systems and their effects. A list of natural occurring organic compounds (column one) found in water systems (column two) and studies showing the effects of these compounds (column three) on different life forms.

Compound	Studies Showing the Natural Observance of the Compound	Studies Showing the Effect of the Compounds on Certain Biota
Acachidic acid	110	
Acetaldehyde	23, 22.5	36.1, 36.3, 96
Acetamide		86.6, 96
Acetate	124, 125	18, 26, 27.1, 36.1, 36.3, 40.1, 48.2, 63.1, 63.4, 63.5, 63.6, 73.82, 73.83, 86.5, 86.6, 86.7, 87, 94.5, 96, 104, 115.5
Acetic Acid	65, 73.8, 104, 110	69, 81, 93
Acetoacetic Acid	65	
Acetone	23	
Aconitate		27.1, 96
Aconitic Acid		69
Actedione	120	46,81,128
Acrylic Acid	110,39.9	
Adenine	110	20,21,101
Adipic Acid	69	5,11.2,36.1,36.3,40.1,48.2,60.02,96
Aerosporin		18, 33, 36, 46, 81
Aesculin		75
Alanine	12, 28, 43, 110, 114, 116, 117, 123	5, 11.2, 36.1, 36.3, 40.1, 48.2, 60.02, 96
Allantoin	110	
Altafur		18
p-Aminobenzoic Acid	110	
α-Aminobutyric Acid	110	
Amphotericin		18, 46
Aniline		30
Anisomycin		46
Aphanicin	110	
Aphanin	110	
Aphanizophyll	110	
L-Arabinose	14, 43, 66, 70.3, 71, 110, 112, 122	11.25, 18, 96
Arachidic Acid	2, 110	
Arginine	12, 28, 43, 82, 110, 116	11.25, 96
Asparagine		6, 36.1, 36.3, 40.1, 63.1, 86.6, 96, 129
Aspartate		11.2, 96, 115.5
L-Aspartic Acid	12, 28, 43, 110, 114, 116, 123	60.02
Astacene	110	
Atabrine		30
Aurcomycin	28.3	18, 33
Azaguanine		1
Azaleucine		1
Azathymine		1
Azauracil		1
Bacitracin		18, 33, 36, 46
Behenic Acid	110	
Benzene Polycarboxylic Acid	22	
Benzimidazole		36
Benzoic Acid		69
Biotin	47, 48, 78, 110	52, 78, 88, 96
5-Bromo 3, 4 dehydroxybenzaldehyde		70

Table 1. Continued.

Compound	Studies Showing the Natural Observance of the Compound	Studies Showing the Effect of the Compounds on Certain Biota
n-Butyric Acid		69
Butyrate		27.1, 36.1, 36.3, 40.1, 48.2, 63.4, 73.82, 86.5, 86.7, 96, 104, 115.5
Butyric Acid	110	
Caffeine		1
Caproate		63.4, 96
n-Caproic		69
Capronic	110	86, 96, 115.5
Caprylic	110	96, 115.5
Captan		36
Carbomycin		18
λ-Carboxylic Acid	110	
alpha-carotene	110	
beta-carotene	2, 110	
Catechin		22
Catechol	22	30
Cellalose	110	
Cellobiose		75, 96
Cerotic Acid	110	
Cetyl-Alcohel	110	
Chloramphenicol	28.3	18
Chlorellin	84	84
Chloromycetin	28.3	18, 33, 36
Chlorophyllide	50.5	
Cholesterol	2, 110	
Choline	110, 123	
Chrysene	110	
Citrate	21.8	40.2, 96
Citric Acid		69, 93
Cobalamin	110	88, 96
Colistin Sulfate		18
Creatinine	110	
Cresotic Acid	110	
α-Crotonic Acid	110	
Cupriethylenediamine	17	
Curcumin	22	
Cyanwric Acid	110	
Cycloheximide	72	
Cycloserine		18
Cysteine	116	61
Cystine	82, 110	11.25, 96, 115.5
Cytosine	110	
Decanoic Acid		87.5
Declomycin		18
Desoxysantalin	22	
Demethylchlortetracyeline		18
Dehydroascorbic Acid	110	
Dextrin		40.2, 96
2, 3-dibromo 4,5 dihydroxybenzylalcohol		70
Dihydrostreptomycin		18
3,4 dihydroxyphenylethylamine		70
3,5-dihydroxybenzyoic Acid	22	

Table 1. Continued.

Compound	Studies Showing the Natural Observance of the Compound	Studies Showing the Effect of the Compounds on Certain Biota
Dioxyacetone		86.5, 86.7, 96
Dithane		36
Erythritol		96, 115.5
Erythromycin		18
Ethanol		48.2, 96, 129
Ethionine		1, 52.5
Ethyl-acetate		86.5, 96
2-Exo-Hydroxy-2 Methylbornane		70.28
Flavacin	110	
Flavan-3,4 dial unit	22	
Flavonol Unit	22	
Flavorbodin	110	
Fluorophenylalanine		1
Formaldehyde	22.5	
Formate		104
Formic Acid	65, 73.8, 110	93
Fructose	110, 112, 122	18, 18.6, 61.7, 63.1, 75, 96, 104.6, 115.5
Fucose	70.3, 71, 110	
Fucoxanthin	110	
Fumarate		27.1, 96
Fumaric Acid		69, 93
Furacin		18
Furadanthin		18
Furaltadone		18
Furfuraldehyde	23	
Furoxone		18
D-Galactose	14, 66, 70.3, 71, 110, 122	11.25, 18.6, 36.3, 40.2, 63.1, 75, 96, 104.6, 115.5
Galacturonic Acid	110	
Gelatine		11.5, 15.1, 63.1, 96
Geosmin	94,36.36	
Glatamic	123	
Glatamine	123	
Gliotoxin		33
Glucosamine		86.7, 96
Glucose	12, 17, 66, 70.3, 110, 112, 122, 124, 125	11.25, 15.1, 18.6, 18.61, 25.01, 27.1, 36.2, 36.3, 40.2, 44, 61.7, 63.1, 73.81, 73.84, 75, 96, 104.6, 115.5, 118.5, 129
Glucuronic Acid	71, 110	
Glutamine	117	11.25, 48.2, 86.6, 96
L(+) Glutamic Acid	12, 28, 43, 110, 114, 116	61
Glutamine		7, 94.5, 96
Glutaric Acid		69
Glyceraldehyde		86.5
Glycerate	21.8	
Glycerol	12, 32, 43, 110	18.6, 61.7, 96, 129
Glycine	110, 114, 116, 118	11.25,36.1,36.3,40.1,48.2,63.1,96,115.5
Glycocoll	28	3,4
Glycollate	21.8, 117	
Glycollic Acid	8.5, 12, 65, 70.3, 106, 117.5	26, 63, 69, 93
Glyoxylic Acid	65	69
Gramicidin	42.01	36
Guanine	110	

Table 1. Continued.

Compound	Studies Showing the Natural Observance of the Compound	Studies Showing the Effect of the Compounds on Certain Biota
Guaiaylpropane Unit	22	
Hentriacontane	110	
Heptacosanoic	110	
Heptacosanol	110	
n-Heptanal	23	
Heptonic	110	
Histidine	82, 110, 116	20,21,60.02,88,96
Humolimnic Acid	97	
Hydroquinone		30
Hydroxylamine	86	
p-Hydroxybenzaldehyde	22	
m-Hydroxybenzoic Acid	22	
Hydroxyproline	110, 114	
p-Hydroxyphenylpropane	22	
8-Hydroxyquinoline		30, 36
Hypoxanthine	110	
Inositol	110	11.25, 52, 96
Insulin		11.25, 40.2, 96
Isocitric lactone	21.8	
Isoleucine	110	
Iso-Nicotinic Acid Hydrazide		18
Isocitric lactone	21.8	
Kanamycin		18
α-Ketoglutarate		27.1, 96
α-Ketoglutaric Acid	65	69
Lactate		27.1, 40.1, 86.5, 86.7, 96, 115.5, 129
Lactic Acid	65, 73.8	69, 93
Lactose		11.25, 18.6, 40.2, 75, 96
Lauric Acid		87.5, 96, 115.5
Leprotene	110	
Leucines	28, 43, 110, 114, 116	11.25, 36.1, 36.3, 40.1, 96, 115.5
Levulose		11.25, 96
Linoleic Acid		87.5
Lysine	12, 43, 110, 114, 116	61
Lysozyme		24
Lutein	110	
Madribon		18
Magnamycin		18
Malate	21.8	27.1, 40.2, 86.5, 96
Maleic Acid	70.3	69
Malic Acid		69, 93
Malonic Acid		69
Maltose	110, 122	11.25, 15.1, 18.6, 96
Mannitol	12, 32, 43, 110	96, 115.5
Mannose		18.6, 36.3, 63.1, 96, 104.6
Melezitose		11.25,96
Methenamine Mandelate		18
Methionine	12, 110, 116	61
Methionine Sulphoxide	110	
Methylamine·HCl		30
Methyl β-D-Glycoside		75, 96
Methyl Ethyl Ketone	22.5	

Table 1. Continued.

Compound	Studies Showing the Natural Observance of the Compound	Studies Showing the Effect of the Compounds on Certain Biota
Methylglyoxal	110	
Methoxyphenyl		36
Monotanic Acid	110	
Monomethylamine	110	
Monostearin	2	
Myristic Acid		87.5, 96, 115.5
Myxoxanthin	110	
Myxoxanthophyll	110	
Naphthol		30
Neomycin		18, 33
Nicotinic Acid	32	
Niacin	48, 110	52
Nitrofurantoin		18
Nitrofuranzone		18
Nonanoic Acid		87.5
Nonylic		96, 115.5
Novobiocin		18
Nystatin		18,46
Oenanthic Acid		96, 115.5
Oleandomycin		18
Oleic Acid		87.5
Oxalic Acid	8.5, 70.3, 110	
Pandorinine	96	
Pantothenic Acid		52
Palmitic Acid		87.5, 96, 115.5
Para Amino Salicylic Acid		18
Paromomycin		18
Penicillin	28.3	18, 33, 36, 81
Pentatriacontane	110	
Peptone		11.25, 25.01, 40.2, 63.1, 63.4, 63.6, 73.81, 86.6, 96
Peridinin	110	
Perylene	78.1	
Petaloxanthin	110	
Phenylalanine	28, 110, 114, 116	11.25, 40.1, 52.5, 61, 96
Phenethicillin		18
Phospholipase (Lecithinase c)		10
Phytin	110	
α-Picoline	110	
Phenanthraquinone		30
Phenol		36
Phenolic Acids	54, 68	54, 68
Phenylthiourea		30
Phormidine	96	
Phroracemic		96
Phthalic Acid		69
Picric Acid		81
Pimelic Acid		69
Pinosylvia	22	
Polymyxin B	13, 28.3, 102	18, 36, 46, 81
Polysaccharides	61.8, 71, 105, 117	
Proline	12, 28, 32, 43, 110, 114, 116	

Table 1. Continued

Compound	Studies Showing the Natural Observance of the Compound	Studies Showing the Effect of the Compounds on Certain Biota
Proprionate		27.1, 86, 96, 104, 115.5
Propionic Acid	73.8, 104	69
Propylaldehyde		36.1
Protocatechnic Acid	22	
Pyridoxine	110	8, 52, 96
Pyroracemic Acid		115.5
Pyruvate		18,27.1,63.5,86.5,96
Pyruvic Acid	65, 73.8	69, 93
Quercetin	22	
Quinone		30
Raffinose		11.25, 96, 115.5
Resveratrole	22	
Rhamnose	14, 66, 70.3, 71, 110	11.25, 96
Rhodopurpurin	110	
Rhodoviolascin	110	
Riboflavin	110	20, 52
Ribose	66, 70.3, 71, 110, 112, 122	18
Ristocetin		18
Salicylic Aldehyde	110	
Scenedesmine	96	
Serine	110, 114, 116, 117, 123	11.25,60.02,86.6,96
β-Sitosterol	110	
Spiramycin		18
Starch		11.25, 15.1, 40.2, 96, 129
Staphcillin		18
Stearic Acid	2	87.5, 96, 115.5
Streptomycin	28.3	33, 36, 81, 102
Streptothricin		102
Succinamide		6
Succinate		27.1, 40.1, 48.2, 86.5, 86.6, 86.7, 96, 129
Succinic Acid	110	69, 93
Sucrose	12, 106, 110, 112, 122	11.25, 15.1, 18.6, 18.61, 59, 60, 63.1, 96, 115.5
Suleatoxanthin	110	
Sulfathiazole		18
Syncillin		18
Syringaldehyde	22	
Syringylpropane	22	
Tartaric Acid	21.8	69
Taurine	118	
Terramycin	28.3	18, 33, 36, 81
Tetracosane	2	
Tetracycline	28.3	18, 36
Thiamine (Vitamin B_1)	47, 78, 110	52, 78, 88, 96, 96.5
Thiourea		36
Threonine	110, 116, 123	
Thrimethylamine	110	
Trehalose		11.25,96
Triburon		18
Thicosane	2	
Tripalmitin	2	
Triple Sulfa		18

Table 1. Continued.

Compound	Studies Showing the Natural Observance of the Compound	Studies Showing the Effect of the Compounds on Certain Biota
Tris (Hydroxymethyl) Amino Methane	67	
Tristearin	2	
Trithiobenzaldehyde	110	
Tritriacoptane	110	
Tryptophane	82, 110	11.25, 52.5, 96, 115.5
Tyrosine	28, 82, 110, 116, 123	11.2, 40.1, 52.5, 96
Undecylic		96, 115.5
Uracil	110	88, 96
Urea		14, 89, 96.5
Urease	14	14
Valeraldehyde	23	36.1, 36.3, 96
Valerate		36.1, 36.3, 86.5, 96, 104, 115.5
n-Valeric Acid		69
Valine	12, 28, 43, 110, 114, 116, 117, 123	11.25, 40.1, 96
Vanillin	22, 110	81
Vancomycin		18
Viomycin		18
Vitamin A	2, 110	
Vitamine B_1		96
Vitamine B_6 (Pyridoxin)		96
Vitamine B_{12} (Cobalamin)	78, 110	78, 96, 96.5
Vitamine D	110	
Vitamine H (Biotin)		96
Xanthine	110	
Xylose	14, 66, 71, 110, 112, 122	11.25, 18, 42, 96, 115.5
Xylulose		126
Zeaxanthin	110	

concentration of citric acid of 5.0 mg/l. This outline would be followed to see how a compound (like citric acid) controlled an alga like *Haematococcus pluvialis.*

If one were interested in knowing compounds which control specific algae, Table 2 would be used. For instance, for the green alga *Haematococcus pluvialis,* the references (3.5, 6, 69, 87.5, 97, 104) in column 3, Table 2, show that alanine, aspargine, glycollic, malonic, succinic, fumaric, maleic, tartaric, malic, lactic, acetic, propionic, n-butyric, nonanoic, decanoic, lauric, myristic, palmitic, linoleic, and citric acids all affect the growth of *Haematococcus pluvialis.* Further information about the compounds and their effects indicate that growth of *Haematococcus pluvialis* can be completely stopped by glutamic and pimelic acids (Appendix A).

Producers of Organic Compounds (Sources of Energy and Vitamin Compounds)

Some organisms are known to produce organic compounds and references for these organisms are listed in Column 2 of Table 2. The organics produced can have far reaching effects as mentioned previously (Figure 1). Specific examples were compiled by Saunders (Table 3). These results show algae that would be capable of utilizing certain organic substances for energy or growth (food source) and thus could survive and grow rapidly at low light levels. For example, such algae could be productive during winter ice formation (11.23) while using the organics produced by other algae that grow at low light intensities or organics in sewage oxidation ponds.

Table 2. Organisms known to produce organic compounds and that are affected by known organic compounds.

Organism	Studies Showing Organic Production from the Organism	Studies Showing Certain Organics That Affect the Organism
BACTERIA		
Archromobacter		36
Bacillus polymyxa	13	52
Bacillus subtiles		85
Chlostridium welchii		102
Diplococcus pneumoniae Type I		102
Eberthella typhosa		102
Erysipelothrix rhusiopathiae		102
Escherichia coli		1, 102
Flavobacterium sp.		
Lactobacillus arabinosus		1
Lactobacillus mesenteroides		1
Pseudomonas aeruginosa	15	102
Pseudomonas sp.		36
Salmonella schottmuelleri		102
Salmonella typhimurium		
Shigella dysenteriae		102
Staphyloccus aureus		85, 102
Streptococcus, gp A, Strain C203		102
Streptococcus, gp B		102
Streptococcus, gp D		102
VIRUSES		
Influenza B		1
Influenza PR8		1
Poliomyelitis (lansing)		1
CYANOPHYTA		
Anabaena cylindrica		1, 46, 128
Anabaena flos-aquae	71.5	
Anabaena valiabilis		36
Anacystis nidulans		87.5
Aphanocapsa sp.		128
Calothrix sp.		33
Coelosphaerium küetzingianum		128
Cyanidium caldarium	12.4	24
Cylindrospermum sp.		118.5
Fremyella diplosiphon		24, 46
Gloeotrichia echinulata		128
Gloeothece rupestris		128
Lyngbya sp.		128
Microcystis aeruginosa	16	30, 128
Microcystis sp.		33
Nostoc sp.		33, 46
Nostoc pruntiforme		40.2
Oscillatoria formosa		24
Oscillatoria tenuis		24, 128
Phormidium luridum		14, 24
Phormidium foveolarum		128
Phormidium sp.		33, 46
Plectonema calothricoides		14, 24
Porphyridium aerugineum		14
Porphyridium cruentum		14
Symploca muscorum	94	
Symploca sp.		33

Table 2. Continued.

Organism	Studies Showing Organic Production from the Organism	Studies Showing Certain Organics That Affect the Organism
Synechococcus cedrorum		1
Synechococcus lividus		14, 24
Tolypothrix sp.		128
Tolypothrix tenuis		128
FUNGI		
Aspergillus niger		1
Aspergillus sydowii		36
Saccharomyces carlsbergensis		1
Saccharomyces cerevisiae		1
Torula monosa		1
Torula utilis		1
CHLOROPHYTA		
Ankistrodesmus braunii	21.8	
Ankistrodesmus falcatus		3, 5, 6, 46, 128
Chlamydomonas agloeoformis		40.1, 46, 63.5, 128
Chlamydomonas angulosa	70.3	
Chlamydomonas chlamydogarna	70.3	
Chlamydomonas debaryana	21.8	
Chlamydomonas dorsoventralis		63.01
Chlamydomonas globosa	22.5	
Chlamydomonas monoica		63.01
Chlamydomonas pseudococcum		63.01
Chlamydomonas pseudogloc		63.01
Chlamydomonas pulchra		63.01
Chlamydomonas subglobosa		63.01
Chlamydomonas reinhardii	87.5	87.5, 93.5, 104
Chlamydomonas sp.	32, 70.3	33
Chlorella ellipsoidea	70.3	115
Chlorella miniata	70.3	
Chlorella protothecoides		3, 5, 6
Chlorella pyrenoidosa	12, 65, 70.3	36,36.1,36.2, 36.3, 42, 46, 73.835, 107.5, 128
Chlorella variegata		11.25
Chlorella viscosa		11.25
Chlorella sp.		3, 5, 85
Chlorella vulgaris	65, 70.3	11.25, 15.1, 27.1, 73.81, 73.835, 73.84
Chlorella vulgaris B		6, 36
Chlorella vulgaris M		3, 4, 5, 6, 87.5
Chlorococcum aplanosporum		18
Chlorococcum diplobionticum		18
Chlorococcum echinozygotum		18, 126
Chlorococcum ellipsoideum		18
Chlorococcum humicola		11.25
Chlorococcum hypnosporum		18
Chlorococcum intermedium		18
Chlorococcum macrostigmaticum		18
Chlorococcum minutum		18, 46, 128
Chlorococcum multinucleatum		18
Chlorococcum oleofaciens		18
Chlorococcum perforatum		18
Chlorococcum pinguideum		18
Chlorococcum punctatum		18
Chlorococcum scabellum		18

Table 2. Continued.

Organism	Studies Showing Organic Production from the Organism	Studies Showing Certain Organics That Affect the Organism
Chlorococcum tetrasporum		18
Chlorococcum vacuolatum		18
Chlorococcum wimmeri		18
Chlorogonium elengatum		87
Chlorogonium elongatum		11.25
Chlorogonium euchlorium		40.1, 63.1, 86, 86.5
Coccomyxa elongata		46, 128
Coelastrum proboscideum		2.5
Haematococcus lacustris		46, 128
Haematococcus pluvialis		3, 5, 6, 69, 87.5, 97, 104
Hormidium sp. 1		3, 6
Hormidium sp. 2		3, 5, 6, 46
Hormidium subtile		128
Oocystis sp.		33
Polytoma unvella		86.7
Raphidonema longiseta		128
Scenedesmus acuminatus		3, 5, 6
Scenedesmus acutiformis		3, 5, 6
Scenedesmus actus		25.01
Scenedesmus basiliensis		36.1
Scenedesmus bÿugata	70.3	
Scenedesmus costulatus var chlorelloides		18.6, 18.61
Scenedesmus dimorphus		3, 5, 6
Scenedesmus obliquus	70.3	4.1, 5, 6, 7, 8, 36, 46, 128
Scenedesmus quadricauda		6, 87.5, 97, 104.6
Stichococcus bacillaris		3, 5, 6, 36.1, 46, 128
Zygnema sp.		3, 5, 6
CHRYSOPHYTA		
Gomphoenema sp.		33
Navicula minima		61.7, 128
Navicula pelliculosa		46, 61.7, 87.5
Nitzschia sp.		33
Ochromonas danica		1, 1.1
Ochromonas malhamensis		1.1
Stephanodiscus hantzschii	117	
Synura petersenii	23	
Synedra acus	117	
Tribonema aequale		128
EUGLENOPHYTA		
Euglena gracilis		1, 1.1, 27.01, 46, 48.2, 73.82, 86.5, 86.6, 87
Euglena gracilis var. bacillaris		40.1, 48.2, 63.4
Euglena stellata		40.1
PYRRHOPHYTA		
Amphidinium carteri	114.9	
PHAEOPHYTA		
Fuais vesiculosus	23.8	
Prototheca zopfii		20, 21

Table 3. Algae capable of utilizing organic substances for energy or growth (from Saunders, 96).

Chlamydomonas	
agloeformis	40.1, 63.5
dorsoventralis	63.01
monoica	63.01
pseudococcum	63.01
pseudogloe	63.01
pulchra	63.01
reinhardi	93.5
subglobosa	63.01
Chlorella	
ellipsoidea	115
pyrenoidosa	36.1, 36.2, 36.3, 73.835, 107.5
variegata	11.2
viscosa	11.2
vulgaris	11.2, 15.1, 27.1, 73.81, 73.835, 73.84
Chlorococcum	
humicola	11.2
Chlorogonium	
elongatum	11.2
euchlorium	40.1, 63.1, 86, 86.5
Coelastrum	
Proboscideum	2.5
Cylindrospermum sp.	118.5
Cystococcus sp.	18.6, 18.61
Euglena	
gracilis	27.01,48.2,73.82,86.5,86.6
gracilis var. *bacillaris*	40.1, 48.2, 63.4
stellata	40.1
Mannochloris	
bacillaris	11.2
Navicula	
minima	61.7
pelliculosa	61.7
Nostoc	
punctiforme	40.2
Polytoma	
uvella	86.7
Scenedesmus	
acutus	25.01
basiliensis	36.1
costulatus var. *chlorelloides*	18.6, 18.61
quadricauda	104.6
Stichococcus	
bacillaris	36.1

Required Organic Compounds

Some algae require vitamins for growth (Tables 4, 5, 6). Knowing that a certain alga requires vitamins can be the first step in understanding factors that control or limit the growth of a specific alga (Tables 4 and 5). For example, *Synura petersenii* (a plankton member of the *Chrysophyta*) is known to produce taste and odor problems in water supplies possibly by production of furfuraldehyde, acetaldehyde, acetone, valeraldehyde and n-heptanal (23). Since *Synura petersenii* requires vitamin B_{12} (Table 4), *Synura petersenii* could be controlled by limiting the availability and/or input of this vitamin and thus the water supply be improved. Table 1 lists natural sources of vitamin B_{12} (78,110); thus control methods for *Synura petersenii* might be based on this information. Ohwada and Taga (78) and Valentine (110) have indicated that vitamin B_{12} concentration may be a limiting growth factor in lakes.

Algae Interacting with Algae

The inhibition or stimulation of certain algae by other algae is well known (Table 7). Although the degree of reaction may vary with temperature, light, pH, and size of inoculum, the general trends can still be noted and controlling factors suggested. For example, *Scenedesmus obliquus* or *Scenedesmus quadricauda* inhibits the growth of *Ankistrodesmus arcutus* (Table 7).

Table 4. Vitamin requirements of specific algae. (Taken from Provasoli, 87.9; references in Provasoli).

Species	B_{12}^{m}	Thiamine	Biotin
CHLOROPHYCEAE			
Astrephoneme gubernaculifera[a]	O	R(?)	O
Brachiomonas submarina	O	O	O
Chlamydomonas aglöeformis	O	O	O
Chlamydomonas chlamydogamma[b]	R	O	O
Chlamydomonas moewusii	O	O	O
Chlamydomonas reinhardii	O	O	O
Chlorella vulgaris	O	O	O
Chlorogonium elongatum	O	O	O
Chlorogonium euchlorum	O	O	O
Coelastrum morus (?)	O	R	O
Dunaliella salina	O	O	O
Dunaliella primolecta	O	O	O
Dunaliella viridis	O	O	O
Gonium pectorale	R	O	O
Haematococcus pluvialis	O	O	O
Lobomonas pyriformis	O	O	O
Lobomonas rostrata	R	O	O
Nannochloris atomus	O	O	O
Nannochloris oculata	O	O	O
Pilinia sp.	O	O	O
Platymonas sp.	O	O	O
Polytoma caudatum[c]	O	R	O
Polytoma obtusum[c]	O	O	O
Polytoma ocellatum[c]	O	R	O
Polytoma uvella[c]	O	O	O

Table 4. Continued.

Species	B_{12} [m]	Thiamine	Biotin
Polytomella caeca[c]	O	R	O
Prasiola stipitata	O	O	O
Prototheca zopfii[c]	O	R	O
Pyramimonas inconstans	R	R	O
Selenastrum minutum (Cambridge Culture Collection)	O	O	O
Selenastrum minutum	O	R	O
Stephanoptera gracilis	O	O	O
Scenedesmus obliquus	O	O	O
Stichococcus cylindricus (?)	O	O	O
Stichococcus cylindricus (?)	R	O	O
Stichococcus sp.	O	O	O
Volvulina steinii[a]	O	R(?)	O
EUGLENINEAE			
Astasis longa[c] *(=A. klebsii,* VonDach)	R	R	O
Euglena gracilis var.: typica, bacillaris, urophora	R	R	O
Euglena gracilis[c] permanently bleached[d]	R	R	O
Euglena pisciformis	O	R	O
Euglena stellata	R	R	O
Euglena viridis	R	R	O
Peranema trichophorum[c,e]	R	R	O
Phacus pyrum	R	R	O
Trachelomonas abrupta[f]	R	S	O
Trachelomonas pertyi[f]	R	S	O
CRYPTOPHYCEAE			
Chilomonas paramoecium[c]	O	R	O
Cryptomonas ovata (var. palustris)	R	O	O
Cyanophora paradoza	R	O	O
Hemiselmis virescens[g]	R	R	O
Rhodomonas lens[h]	S	R	O
Rhodomonas sp. (6 strains)	R	R	O
DINOPHYCEAE			
Amphidinium klebsii (?)	R	R	R
Amphidinium rhynchocephalum (?)	R	R	R
Exuviaella cassubica	R	O	O
Glenodinium foliaceum	R	O	O
Gonyaulax polyedra[i]	R	O	O
Gymnodinium breves[j]	R	R	R
Gymnodinium splendens	R	O	O
Gyrodinium californicum (Gyrodinium sp.)	R	O	O
Gyrodinium cohnii[k]	O	S-R	R
Gyrodinium resplendens	R	O	O
Gyrodinium uncatenum	R	O	O
Peridinium balticum	R	O	O
Peridinium chattoni	R	O	O
Peridinium trochoideum	R	O	O
Woloszynskia limnetica (Peridinium sp.)	R	O	O

Table 4. Continued.

Species	B_{12}	Thiamine	Biotin
CHRYSOPHYCEAE			
Hymenomonas (Syracosphaera) *carterae*	R	O	O
Hymenomonas (Syracosphaera) *elongata*	R	R	O
Isochrysis galbana	R	R	O
Microglena arenicola	R	R	O
Monochrysis lutherii	R	R	O
Ochromonas danica	O	R	R
Ochromonas malhamensis	R	R	R
Pleurochrysis scherffelii[l]	O	R	O
Poteriochromonas stipitata	R	R	R
Prymnesium parvum	R	R	O
Stichochrysis immobilis	O	O	O
Synura caroliniana	R	O	(?)
Synura petersenii	R	O	O
BACILLARIOPHYCEAE			
Asterionella formosa	O	O	O
Amphora perpusilla	R	O	O
Fragilaria capucina	O	O	O
Navicula pelliculosa	O	O	O
Nitzschia putrida[c]	O	O	O
Phaeodactylum tricornutum (N. closterium v. minutissima)	O	O	O
Skeletonema costatum	R	O	O
Stephanopyxis turris	R	O	O
Tabellaria flocculosa	O	O	O

[a] May use para-aminobenzoic acid.

[b] Requires histidine.

[c] Colorless species.

[d] Streptomycin-bleached.

[e] Also needs riboflavin. May need other vitamins.

[f] Thiamine not indispensable; necessary for prolonged good growth.

[g] Glycine is required.

[h] The addition of B_{12} allows optimal growth.

[i] May need other vitamins.

[j] Other unknown requirements. Other vitamins in media not determined as essential.

[k] G. cohnii has been carried through 20 transfers in biotin alone, but growth reaches only 60,000 cells/ml., while in biotin plus thiamine it reaches 500,000 cells/ml. Histidine is necessary, but it can grow without histidine after adaption.

[l] Another chrysomonad with filamentous stages and coccolithophorid zoospores needs only thiamine.

[m] B_{12}: organisms responding to cyanocobalamin (i.e., "true" B_{12} = antipernicious anemia factor).

R = required; S = stimulatory; O = not needed; S-R = borderline case, see footnote k; (?) = unconfirmed data.

Table 5. Incidence of growth-factor requirements in algae. (Table taken from Provasoli and Pintner, 88; see references in 88.)

Species	Vitamins Needed	Thiamine	Cobalamin	Other
CHLOROPHYTA				
Chlamydomonas agloëformis	0			
Chlamydomonas chlamydogama	+		+	Histidine
Chlamydomonas moewusii	0			
Chlamydomonas sp. ("marine")	0			
Chlorogonium elongatum	0			
Chlorogonium euchlorum	0			
Coelastrum (morus ?)	+	+		
Haematococcus pluvialis	0			
Lobomonas pyriformis	0			
Lobomonas rostrata	+		+	
Polytoma caudatum	+	+		
Polytoma obtusum	0			
Polytoma ocellatum	+	+		
Polytoma uvella	0			
Polytomella caeca	+	+		
Prototheca zopfii	+	+		
Selenastrum minutum (E. A. George strains)	0			
Selenastrum (minutum ?)	+	+		
CHRYSOPHYTA				
Amphora perpusilla	+		+	Uracil ?
Nitzschia closterium f. minutissima	0			
Nitzschia putrida	0			
Ochromonas malhamensis (3 strains)	+	+	+	Biotin + histidine
Poteriochromonas stipitata	+	+	+	Biotin + histidine
Synura sp.	+	?	+	?
Syracosphaera carterae	+	?	?	?
EUGLENOPHYTA				
Euglena gracilis vars. typica, bacillaris, urophora	+	+	+	
Astasia longa (= klebsii VonDach*)*	+	+	+	
E. gracilis, streptomycin-bleached	+	+	+	
E. pisciformis	+	+	+	
E. viridis, E. stellata	+	+	+	

Table 6. Growth-factor requirements of algae. (Table taken from Saunders, 96; references in Saunders.)

Species	B_1	B_6	B_{12}	Biotin	Histidine	Uracil	Reduced Sulfur Cmpd.	Unknown Org. Fact.
CHLOROPHYTA								
Chlamydomonas chlamydogama			R		R			
Chlamydomonas sp.			R					
Chlorella sp.								S
Lobomonas rostrata			R					
Coelastrum morus ?	R							
Scenedesmus obliquus		S						
Scenedesmus quadricauda								S
Selenastrum minutum	R							
Stichococcus sp.			R					
EUGLENOPHYTA								
Euglena gracilis			R					
var. typica	R		R					
var. bacillaris	R		R					
var. urophora	R		R					
pisciformis	R							
viridis	R		R					
stellata	R		R					
CHRYSOPHYTA								
Achnanthes microcephala								S
Amphora perspusilla		S	R			S		
Ditylum brightwellii						R		
Monochrysis lutheri	S		R					
Navicula pelliculosa							R	
Nitzschia acicularis								S
Nitzschia palea ?								S
Prymnesium parvum	S		R					
Skeletonema costatum			R					
Syracosphaera carterae								R
Syracosphaera elongata	S		R					
Porteriochromonas stipitata	R		R	R	R			
PYRROPHYTA								
Cryptomonas ovata var. palustris			R					
Cyanophora paradoxa			R					
Gymnodinium splendens			R					
Gymnodinium sp.			R					
Ochromonas malhamensis	R		R	R	R			
Paridinium sp.	R		R					
Synura sp.			R					

R = required.
S = stimulates.

Table 7. Algae affecting other algae. Interactions between algae growth products show inhibition (I), stimulation (S), or no effects (N). Occasionally autoinhibition (A) is indicated.[a]

Reacting Organism / Culture Filtrate from:	*Achnanthes microcephala*	*Ankistrodesmus arcuatus*	*Chlamydomonas*			*Chlorella*					*Cosmarium*			
			globosa	*moewusii*	*reinhardi*	*ellipsoidea*	*pyrenoidosa*	*terricola*	*vulgaris*	*sp.*	*botryis*	*lundellii*	*ochthodes*	*sp.*
Anacystis nidulans					[0%] *(87.5)				[5%] *(87.5)					
Ankistrodesmus arcuatus						I*(61.1)		I*(61.1)	I*(61.1)					
Chlamydomonas chlamydogama														
Chlamydomonas reinhardi									[75%] *(87.5)					
Chlamydomonas sp.										S(8.45)				
Chlorella ellipsoidea			I**(55)											
Chlorella terricola														
Chlorella pyrenoidosa														
Chlorella vulgaris					[25%] *(87.5)				A(85.1)					
									S,low conc. (83)					
Endorina california														
Endorina cylindrica														
Endorina elegans														
Endorina illinoisensis														
Gonium pectorale														
Haematococcus pluvialis									I(87.4)					
Mesotaenium caldariorum													N(60.2)	
Microcystis aeruginosa				I*(113.2)										
Nitzschia palea							S(50.4)					I(60.2)		
Nostoc sp.									S(113.9)					
Nostoc punctiforme														
Raphidonema sempervirens														
Scenedesmus oahurensis	I(60.1)	I*(60.1)												
Scenedesmus obliquus		I*(61.1)				I*(61.1)		I*(61.1)	I*(61.1)					
Scenedesmus quadricauda		I*(61.1)			[87%] *(87.5)	I*(61.1)	I(50.4)	I*(61.1)	I*(61.1)		I(60.05)	I(60.05)	I(60.05)	
Skeletonema costatum														
Pandarina charkowiensis														
Pandarina morum	I(60.1)											I(60.1)	I(60.1)	I(60.1)
Phormidium uncinatum	I(60.1)													
	S, young culture (60.2)													
Platudorina caudata														
Volvox teruis														
Volvox globator														
Volvulina pringsheimii														

[a]Those marked with * were algae grown together while those marked with ** were grown together but species were mechanically kept apart. Percent values indicate relative growth compared to control. Numbers in parentheses are references of approximate study.

I = inhibition of normal growth, A = autoinhibition, N = no inhibition, and S = stimulates growth.

Table 7. Continued.

Reacting Organism / Culture Filtrate from:	*Endorina*				*Euglena descs*	*Gonium pectorale*	*Haematococcus*		*Mesotaenium caldoriorum*	*Micrasterias spp.*	*Naviculla pelliculosa*	*Nitzschia frustulum*	*Nitzschia polea*	*Nostoc*	
	californica	*cylindrica*	*elegans*	*illinoisensis*			*lacustria*	*pluvialis*						*sp.*	*punctiforme*
Anacystis nidulans								[0] *(87.5)							
Ankistrodesmus arcuatus								[0] *(89.5)							
Chlamydomonas chlamydogama								S,I(70.25)							
Chlamydomonas reinhardi								[0%] *(87.5)							
Chlamydomonas sp.															
Chlorella ellipsoidea															
Chlorella terricola															
Chlorella pyrenoidosa					I*(60.05)								I(50.4)		
Chlorella vulgaris								[20%] *(87.5)				I*(90.5)		I(113.9)	
Endorina californa	N(41)	I(41)	I(41)												
Endorina cylindrica		N(41)		I(41)											
Endorina elegans			N(41)			I(41)									
Endorina illinoisensis		I(41)	I(41)	N(41)											
Gonium pectorale						N(41)									
Haematococcus pluvialis															
Mesotaenium caldariorum															
Microcystis aeruginosa							I**(113.2)				I**(113.2)				
Nitzschia palea													A(25.05)		
Nostoc sp.															
Nostoc punctiforme															A(40.2)
Raphidonema sempervirens															
Scenedesmus oahurensis															
Scenedesmus obliquus															
Scenedesmus quadricauda								[29%] *(87.5)	I(60.1)				I(50.4)		
Skeletonema costatum															
Pandarina charkowiensis			I(41)												
Pandarina morum		I(41)	I(41)	I(41)		I(41)			N(60.1)	I(60.1)					
Phormidium uncinatum															
Platydorina caudata															
Volvox teruis				I(41)											
Volvox globator			I(41)	I(41)											
Volvulina pringsheimii			I(41)			I(41)									

[a]Those marked with * were algae grown together while those marked with ** were grown together but species were mechanically kept apart. Percent values indicate relative growth compared to control. Numbers in parentheses are references of approximate study.

I = inhibition of normal growth, A = autoinhibition, N = no inhibition, and S = stimulates growth.

Table 7. Continued.

Culture Filtrate from: / Reacting Organism	*Raphidonema sempervirens*	*Scenedesmus*			*Skeletonema costatum*	*Pandorina*		*Pediastrum*		*Phormidium uncinatum*	*Platydorina caudata*	*Volvox*		*Volvulina pringsheimii*
		oahuensis	*ovalternus*	*quadricauda*		*charkowiensis*	*morum*	*boryanum*	*duplex*			*tertius*	*globator*	
Anacystis nidulans				[10%] *(87.5)										
Ankistrodesmus arcuatus	I*(61.1)													
Chlamydomonas chlamydogama														
Chlamydomonas reinhardi				[12%] *(87.5)										
Chlamydomonas sp.														
Chlorella ellipsoidea	I*(61.1)													
Chlorella terricola	I*(61.1)													
Chlorella pyrenoidosa				S(50.4)					I*(60.05)					
Chlorella vulgaris	I*(61.1)			[25%] *(87.5)										
Endorina california						I(41)	I(41)					I(41)	I(41)	I(41)
Endorina cylindrica						I(41)	I(41)					I(41)	I(41)	I(41)
Endorina elegans						I(41)	I(41)						I(41)	I(41)
Endorina illinoisensis						I(41)	I(41)					I(41)	I(41)	
Gonium pectorale						I(41)					I(41)	I(41)	I(41)	I(41)
Haematococcus pluvialis				[38%] *(87.5)										
Mesotaenium caldariorum		N(60.2)		N(60.2)						N(60.2)				
Microcystis aeruginosa														
Nitzschia palea				S(50.4),I(60.2)				I(60.2)		I(60.2)				
Nostoc sp.														
Nostoc punctiforme														
Raphidonema sempervirens														
Scenedesmus oahurensis														
Scenedesmus obliquus	I*(61.1)													
Scenedesmus quadricauda	I*(61.1)	I(60.1)		A(50.4)				I(60.05)		S, young culture (50.4) I, old culture (50.4), (60.2)				
Skeletonema costatum					A(61.6)									
Pandarina charkowiensis						N(41)	I(41)							I(41)
Pandarina morum		I(60.1)	S(60.1)			I(41)	N(41)	N(60.1)		I(60.1)	I(41)	I(41)	I(41)	I(41)
Phormidium uncinatum		I(60.2)		I(60.05),(60.1)				I(60.2)						
Platydorina caudata						I(41)					A(41)	I(41)	I(41)	I(41)
Volvox teruis												N(41)		I(41)
Volvox globator						I(41)	I(41)						N(41)	I(41)
Volvulina pringsheimii						I(41)	I(41)				I(41)	I(41)	I(41)	A(41)

[a]Those marked with * were algae grown together while those marked with ** were grown together but species were mechanically kept apart. Percent values indicate relative growth compared to control. Numbers in parentheses are references of approximate study.

I = inhibition of normal growth, A = autoinhibition, N = no inhibition, and S = stimulates growth.

MATERIALS AND METHODS

Review of Techniques for Isolation and Identification of Lake Organic Compounds

Several methods of extracting and identifying the organic compounds were used. They were:

Concentration or Extraction Methods

1. Liquid-Liquid Extraction
2. Liquid-Solid Extraction
3. Freeze-Concentration
4. Distillation
5. Carbon Adsorption
6. Freeze-Drying
7. Co-precipitation

Identification Techniques

1. Infrared Spectroscopy
2. Thin-layer Chromatography (TLC)
3. Gas Chromatography (GC)
4. Gas Chromatography-Mass Spectrometry

These techniques are described in general terms as they were applied to the study. The methods finally selected for the study will be discussed in detail later in this chapter.

Liquid-liquid extraction

A widely employed method of separating organic compounds from mixtures in which they are found or produced is that of liquid-liquid extraction. This technique is based upon the principle of phase distribution. It states that a substance in contact with two immiscible liquid layers will be distributed or partitioned between the two immiscible liquids such that the ratio of the concentration in one solvent to the concentration in the second solvent remains constant at a constant temperature. This does not hold true if the substance ionizes or reacts in some way with one of the immiscible solvents.

C_{A_1} = concentration of A in S_1
C_{A_2} = concentration of A in S_2

$$K = \text{Constant} = \frac{C_{A_1}}{C_{A_2}} \quad \ldots\ldots (1)$$

The constant K is termed the distribution or partition coefficient. Theoretically, the distribution coefficient is equal to the ratio of the individual solubilities of substance A in pure solvent S_1 and pure solvent S_2. However, solvent characteristics sometimes slightly affect the value of K since no two liquids are completely immiscible.

In order to secure the best possible extraction, the practical performance of extraction on the distribution law must be determined. For a given total volume of solvent S_1 to be used to separate a substance A from its solution in S_2, it can be shown that several successive extractions with portions of that volume is more efficient than one extraction with the full volume of solvent. The advantage gained from several successive extractions falls off rapidly. Dividing a given volume of solvent into more than three portions is of little avail. The larger the distribution coefficient (K), the fewer the number of repetitive extractions necessary to separate the solute effectively. It is important to have a low boiling extraction solvent and to keep the volume to a minimum because of the time and other factors involved in evaporation or distillation of the solvent to recover the extracted material.

The simple extraction process is usually carried out in a separatory funnel using several successive, small extraction volumes rather than one large volume. This can be shown to be most effective by the following equation:

Let the volume, V ml, of an aqueous solution containing W_o grams of the dissolved compound be repeatedly extracted with fresh portions of S ml of an organic solvent, which is immiscible with water:

$$\frac{W_1/V}{\frac{(W_o - W_1)}{S}} = K$$

$$\frac{SW_1}{V(W_o - W_1)} = K$$

$$SW_1 = KVW_o - KVW_1$$

$$SW_1 + KVW_1 = KVW_o$$

$$W_1 (S + KV) = KVW_o$$

$$W_1 = \frac{KVW_o}{S+KV}$$

This can be shown to be most effective by Equation 2 where a volume V ml of an aqueous solution contains W_o grams of the solute and is repeatedly extracted with S ml of the organic solvent, which is immiscible with the aqueous phase. Then one obtains:

$$W_n = W_o \left(\frac{KV}{KV+S}\right)^n \quad \ldots\ldots (2)$$

in which W_n gives the grams of solute remaining in the aqueous phase after the n^{th} extraction (Equation 2 can be easily derived from the distribution coefficient Equation 1). As can be seen from Equation 2, for W_n to be as small as possible for a given amount of solvent, n should be large and S small.

Frequently, when isolating material from natural sources, the desired compound must be extracted from a very large volume of aqueous solution in which the compound is in very small concentration. The partition coefficient may also be small, i.e., more favorable toward water. In such cases, very large quantities of organic solvent must be employed in order to obtain even a moderate extraction. Further problems include the need to shake manually large volumes in a separatory funnel.

For continuous liquid-liquid extractions the solvent (being vaporized and then condensed) is made to pass either up or down, depending on relative densities, through the aqueous solution containing the desired material. By means of specialized apparatus, the solution of extracting solvent and solute is continuously separated into a boiling flask from the mixture being extracted. The solution is subjected to continuous distillation and the condensed distillate returned as fresh extracting solvent to the extraction boiling flask and reused. In the process, the extracted material is increasing in concentration (provided that it is rather nonvolatile) in the boiling flask; i.e., as the dilute solution is continuously coming into the flask, the solvent is being distilled away. After a period of time (a few hours to several days), the nonvolatile extractable material becomes concentrated. The solvent can be dried using a solid drying agent then filtered and concentrated to a few milliliters by roto-evaporation or distillation. Various analytical methods may then be used for identification.

Liquid-solid extraction

For the continuous extraction of a solid by a solvent, the soxhlet extraction is used. The extraction is similar to the liquid-liquid extraction except the solid material is placed in a porous thimble in a chamber with the extracting solvent in a boiling flask below. The solvent is boiled gently; the vapor passes up through a tube, is condensed and the condensed solvent falls into the thimble and slowly fills the chamber of the soxhlet. When the solvent reaches the point of siphoning (soxhlet design) it siphons over into the boiling flask and carries with it that portion of the substance which has been extracted. This process is continued for as long as necessary for effective removal of the desired material. The nonvolatile extracted material may then be isolated from the solvent by any of the usual methods and identified.

Freeze concentration

Freeze concentration offers a means of concentrating trace organics in aqueous solution at low temperature which is less likely to alter their chemical composition. Partial freezing of aqueous-organic solutions is expected to produce relatively pure ice crystals with the organic material concentrated in the unfrozen liquid.

At a given temperature, the coefficient k_o is a measure of the distribution of a solute between the solid or ice phase and the liquid or aqueous phase.

$$k_o = C_I/C_L \quad \ldots\ldots\ldots (3)$$

in which

- C_I is the concentration of the solute in the ice phase
- C_L is the concentration of the solute in the aqueous phase

When the solute concentration is very low, k_o approaches a constant as the equilibrium temperature approaches the melting point of pure ice. If the solute transfer by diffusion across the interface between phases is sufficient to keep the solute ahead of the ice front and no reverse diffusion occurs, solute concentration in the liquid will increase as the freeze rotation process progresses. If a concentration gradient is created by too rapid freezing, solute entrapment in the ice will tend to occur. The extent of entrapment will determine the deviation of the actual or effective coefficient, k, from the distribution coefficient, k_o. This is an idealized treatment since many factors (electro-, chemical, and mechanical forces) affect or modify the probability of solid inclusion. Thus the theoretical mathematical treatment of the solute movement process inadequately describes the actual process. Too little is known about the effects in real systems with no clear understanding of the chemical and physical principles involved.

Concentration can be accomplished in a 2 liter, round-bottom flask containing 500 ml of aqueous solution rotated while submersed in a mixture of crushed ice and salt ($\approx$ -12° C). Precooled aqueous solutions and seeded flasks prevent flash freezing. During the rotation process the round-bottom flask is held at $\approx$ 45° angle during the freezing process. The freeze rotation continues until a predetermined volume has been frozen (usually concentrates 10:1). When the desired volume has been frozen (when the 500 ml of liquid has been frozen to the point where $\approx$ 40 ml of liquid remains as determined by elapsed time and judgment), the rotation is stopped and the flask removed. The contents are poured into a graduated cylinder and the ice is washed with sufficient liquid to bring the concentrated volume to 50 ml (10:1 concentration). Analysis of the concentrated liquid can then be made.

To achieve higher organic content in the concentrated liquid, a cascade freezing technique can be performed using freeze rotation. For example, if ten 500 ml samples are reduced to 50 ml each and then composited and again concentrated (500 ml composite sample to 50 ml), a concentration of 100:1 can be obtained. It appears that even greater concentration ratios could be achieved by expanding the cascade sequence. In doing so, extreme care must be used not to introduce carbonaceous impurities which will be concentrated during the cascade sequence.

Distillation

The aim of distillation is the separation and purification of a volatile liquid from a non-volatile substance, or, more usually, the separation of two or more liquids of different boiling points. This process consists of vaporizing the liquid by heating and then condensing the vapor in a separate receiver to yield a distillate. There are various methods of distillation depending upon the impurities present and the stability of the material being purified. The simple distillation involves non-volatile impurities which remain in the distillation residue. If volatile impurities are present, a fractional distillation is necessary. The theoretical treatment of fractional distillation requires a knowledge of the relation between the boiling points, or vapor pressures of the mixtures of the volatile liquids and their composition.

For a binary ideal solution (for simplicity) of two volatile components A and B obeying Raoult's Law a rationale for fractional distillation can be developed. Raoult's Law states that

$$P_A = P_A^o X_A$$

i.e., the vapor pressure of a component of a solution at a given temperature is equal to the vapor pressure of the pure substance (P_A^o) multiplied by its mole fraction (X_A) in the solution.

Considering an ideal mixture of A and B and applying Raoult's Law to the two volatile components, we have:

$$P_A = P_A^o X_A \text{ and } P_B = P_B^o X_B$$

The total pressure P will be:

$$P = P_A + P_B = P_A^o X_A + P_B^o X_B$$

The vapor pressures are proportional to the mole fractions in the vapor phase and their composition is given by:

$$X_A^{vap} = \frac{P_A}{P_A + P_B} \text{ and } X_B^{vap} = \frac{P_B}{P_A + P_B}$$

The relative concentrations of constituent B in the vapor phase and the liquid phases will be:

$$\frac{X_B^{vap}}{X_B} = \frac{\frac{P_B}{P_A + P_B}}{\frac{P_B}{P_B^o}} = \frac{P_B}{P_A + P_B} \cdot \frac{P_B^o}{P_B}$$

or

$$\frac{X_B^{vap}}{X_B} = \frac{1}{X_B + \frac{P_A^o}{P_B^o} \cdot X_A} \quad \ldots\ldots (4)$$

Now if $P_A^o = P_B^o$, X_B^{vap}/X_B is unity, since in the liquid phase $X_A + X_B = 1$. If $P_B^o > P_A^o$, the concentration of B will be greater in the vapor phase and if $P_B^o < P_A^o$, it will be less. For the case where $P_B^o > P_A^o$, the first few drops of distillate would contain a very high concentration of B. This collected fraction could then be (theoretically but impractically) redistilled several times to obtain a pure substance B. Similarly, by collecting the last fraction of each distillation and redistilling in the same stepwise manner, one could obtain a small amount of pure A.

This laborious process of repeated distillations can be eliminated with proper apparatus (fractional distillation column) to accomplish the fractional separation virtually automatically. A fractional distillation apparatus consists of a boiling flask, a fractionating column, a still head (containing

thermometer), a condenser and receiver. A quantity of liquid is placed in the boiling flask containing some porous boiling chips and heated. Under ideal conditions at the top of the fractionating column, the vapor phase consists almost entirely of the more volatile component and the liquid phase at the bottom being less rich in the volatile component. If various requirements are met (intimate and extensive contact between the liquid and vapor phases in the column; maintenance of the proper temperature gradient along the column; sufficient column length; and sufficient boiling point differences), the components of the mixture can be separated and purified.

Some mixtures do not behave ideally, and the resultant deviations from Raoult's Law result in a two component system acting similar to the three component system, i.e., the "third component" has a constant boiling point because the vapor in equilibrium with the liquid has the same composition as the liquid itself. This mixture is called an azeotropic mixture. Fractional distillation of such mixtures will not yield both of the components in pure form but only the azeotropic mixture and the component present in excess of the azeotropic composition (numerous alcohols, acetates, acids, and hydrocarbons can form azeotropes with water).

In considering extremely dilute solutions (volatile solute in mg/l or μg/l in aqueous solvent) the ideal situation is not expected. The first few milliliters fractionally distilled will contain a higher concentration of the volatile substances (either fractionated or azeotroped) with additional distillation being only that of the aqueous phase. Thus, for a 500 ml sample 25-50 ml are collected. Additional aqueous collection will only dilute the volatile compounds distilled initially. This initial sample can then be analyzed by gas chromatography or by gas chromatography/mass spectrometry If the volatile organics are less than 100 μg/l in the sample collected, cascade distillation may be necessary depending on the gas chromatography response factor of the volatile organic compound in question.

Carbon adsorption

The carbon adsorption method has been used as a standard procedure for the determination of non-volatile organic contaminants in water. It consists of passing a known volume of water (a few gallons to several thousands) through an activated carbon column, removing and drying the carbon, and eluting the organics from the carbon by sequential extraction with the appropriate solvents. Carbon adsorption has been widely used in the United States. Although the method allows the sampling of large quantities of water with the recovery of workable quantities of organic material, some concern has been expressed that the sorption and desorption is not complete and composition of organic compounds may be altered while they are adsorbed on the carbon. This particular method was not shown to be effective for volatile organic material.

Freeze-drying

Freeze-drying is based upon the theory of sublimation. Sublimation is the process by which a substance which is a solid under ordinary conditions can be volatilized (without melting) at a certain temperature depending upon the pressure. Usually in the laboratory, purification by sublimation involves vaporizing a solid sample by heating at a temperature below the melting point after which the vapor is condensed (crystallized) directly to the solid state on a cold surface (no intermediate liquid state in either process).

To obtain a better understanding of sublimation it is necessary to look at a typical phase diagram (Figure 2) relating the solid, liquid, and vapor states of a substance with pressure and temperature. The various equilibrium curves are represented by B-D liquid-vapor; B-C solid-liquid; and B-A solid-vapor. Point B is known as the triple point where solid, liquid, and vapor co-exist. It is the equilibrium curve B-A between solid and vapor which is of importance for sublimation.

It is clear that if the vapor at a pressure below the triple point is reduced sufficiently in temperature, it will condense directly to the solid form. In order that a solid may pass directly into vapor (without

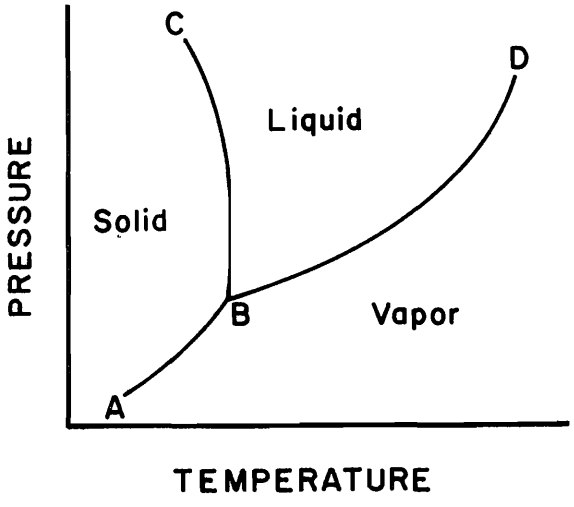

Figure 2. Solid-liquid-vapor phase diagram.

liquid formation) the pressure of the vapor must not be allowed to exceed that of the triple point.

For aqueous samples these conditions can be usually met by the use of a freeze-drying apparatus. The aqueous sample is quickly frozen (commercial freezer) and placed in the freeze-dryer. The condensing chamber is at about -55° C and a vacuum of < 10 μ of Hg is applied. The frozen solution is sublimed (solid-vapor-solid) leaving a residue in the beaker. This residue can then be analyzed and/or extracted according to appropriate analytical procedures. Note: This method of concentration of aqueous samples applies only to components which are relatively non-volatile.

Co-precipitation

Many metal ions can be precipitated out of solution as their hydroxides. Magnesium, calcium, and iron ions can all be removed in this fashion. The floc that forms may also physically enmesh organic compounds in them as it settles. Some ionic organic forms will chelate with heavy metals and precipitate out of solution (104.2) (see Figure 3).

Two methods were tried in the removal of organics from water: (1) making the solution basic (pH ~ 13) and (2) adding $FeCl_3$ to the solution (final concentration about 0.1 M and at pH 8.8) to form organic removing flocs. The first method is reported to concentrate organics by a factor of 2,000, the second method by a factor of 10,000 (50). (Most assuredly the concentration factors depend upon the type and concentration of the cation used for floculation.)

These methods were tried since Hyrum Reservoir is a hard water lake high in Mg^{+2}, Ca^{+2}, and $CO_3^{=}$. Furthermore the concentration of these salts

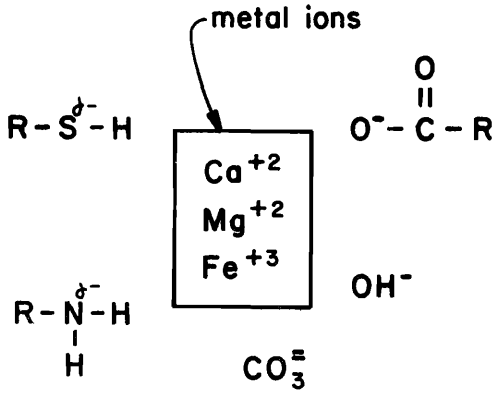

Figure 3. Metal ions interacting with organics and $CO_3^{=}$ and OH^- ions.

was increased by a factor of 7, using freeze rotation, making the solution ideal for floc formation. The floc is then separated, made acidic, and extracted with an appropriate solvent for organic compound recovery.

Infrared spectroscopy

The spectrum that is usually most easily obtained and that which gives the most information about an organic compound is its infrared spectrum. The interaction of infrared light (5,000 to 500 cm^{-1} reciprocal centimeters or wave numbers; wave length μ (cm) is also used where μ = 10,000/frequency, cm^{-1}) with an organic molecule can be explained by the infrared radiation interacting with the constant vibration of the bonds of the organic molecule. These stretch (and contract) and bend with respect to each other. The frequencies of the various vibrations of the molecule correspond to those of infrared radiation; thus absorption of the radiation occurs, producing an increase in the amplitude of the molecular vibrational modes. This energy gained by the molecule in the form of light is soon lost in the form of heat. Thus by plotting the percent transmittance, vs the frequency of the radiation (wave length, cm^{-1} or wave number, μ), an infrared spectrum is obtained.

Absorption between 5,000 cm^{-1} and 1250 cm^{-1} involves vibrational excitation of particular functional groups (i.e., -OH of alcohols 3,200 - 3,600 cm^{-1}; the C=O group of ketones 1,710 cm^{-1}; -C≡N group, at 2,250 cm^{-1}; the $-CH_3$ group at 1,450 and 1,375 cm^{-1}) present in the molecule. This region of the infrared spectrum thus provides much information of the presence or absence of a number of functional groups. The absorption region between 1,250 and 500 cm^{-1} (fingerprint region) cannot usually be associated with any particular functional group but is representative of the entire molecule.

In using infrared spectra for identification of organic compounds, characteristic functional group frequencies have been assigned following the examination of many compounds containing that particular group. The ranges have been quite well defined but the precise frequency of the group depends upon its environment within the molecule and on its physical state. Thus, a comprehensive examination of an infrared spectrum can give information as to the presence or absence of characteristic group absorption bands but complementary instrumental analysis is usually necessary for complete compound identification. The sample size required for IR analysis (and complementary instrumentation) is considerable and is of definite concern when only small amounts of the organic compound are available.

Thin-layer chromatography (TLC)

Chromatography is based upon the selective adsorption of the components of a solution on the active surface of certain finely divided solids. The types of interactions causing adsorption are the same as those that cause attractions between any molecules, i.e., electrostatic attraction, complexation, hydrogen bonding, van der Waal's forces, etc. Thin-layer chromatography involves solid-liquid adsorption chromatography where the solid adsorbent is spread as a thin layer (0.25 mm to 2 mm) on a piece of glass, rigid plastic or aluminum. A small drop of solution is placed on one edge and the plate is placed in a developing chamber containing enough eluting solvent to come to a level just below the spot. The eluting solvent migrates up the plate carrying with it at different rates the components of the mixture. Ideal results give a series of detectable, well separated spots on the plate. Detection of the spots on the thin-layer plate for colored compounds is easy. Other detection methods are ultraviolet light, fluorescent reagents, sulfuric acid followed by charring, iodine, etc., depending on the molecular properties of the spots. Numerous solid adsorbents (silica gel, alumina) and eluting solvents are available to accomplish TLC separations. The more strongly adsorbed the components are on the solid adsorbent the more polar the eluting solvent must be.

Given a set of conditions (adsorbent, solvent, layer thickness, and homogeneity) the retention front, R_f, (distance traveled by a substance from a starting line to the front (top) of the spot divided by the distance traveled by the solvent) can be determined. The R_f value (under the specified conditions) is an important property of the compound and may be used to identify it.

This method requires small quantities of sample, is quite rapid, and can be used to determine elutant solvents and adsorbent solids for column chromatography. Larger samples can also be used (preparative thin-layer), then after separation the "spot" can be scraped off the glass plate, extracted from the solid support, and analyzed using analytical instrumentation.

Gas chromatography

Basic principles of gas chromatography are the same as extraction techniques and column and thin-layer chromatography, i.e. partitioning. A mixture of volatile components to be separated is vaporized and is carried along a column packed with some adsorbent (i.e., a finely divided substance with a liquid of low volatility adsorbed on the surface or a porous polymer type material) by a stream of inert carrier gas (usually helium or nitrogen), and then eluted and measured on a detector. The gaseous mixture is called the mobile phase whereas the adsorbent is called the stationary phase. Due to selective phase distribution of the volatile components between the mobile and stationary phases, these components may move through the column at different rates and thus be separated. The physical process in which the distribution of the volatile components between the eluting inert gas and the stationary phase is called partitioning and is analogous to liquid-liquid extraction partition coefficients. The properties of the component mixture and the column packing are important factors affecting the rate at which a compound will move through a column. In general, highly volatile compounds (i.e., low boiling, high vapor pressure, and low molecular weight) will move through the column at a faster rate than one of low volatility. Other interactions are also involved (solubility, hydrogen bonding, electrostatic, etc.).

The time necessary for a given component to pass through the gas chromatograph (injector port to detector) is called the retention time. This retention time is dependent upon: 1) The nature of the column packing; 2) the length of the column; 3) the temperature of the column; 4) the carrier gas flow rate; and is relatively independent of the nature and concentration of other components that may or may not be contained in the mixture. For a given set of conditions (1 through 4), the retention time is a property of the compound that may be used to tentatively identify it. As the nature of the column is of major importance, considerable effort is given to the proper selection of the packing material for the column. It is desirable to use a column which gives good separation with well defined peaks (good resolution) and preferably, peak responses which are non-overlapping, reasonably short retention times, and relatively sharp. Extensive research has been done on column packings and many excellent packings are available from gas chromatography supply houses.

Analytically three kinds of information can be obtained from a chromatogram (detector tracing of peak responses). The simplest is whether the material being tested is pure or a mixture of components. If the chromatogram contains more than one peak, the sample is a mixture of components. Single peak chromatograms should be looked at carefully to insure that the column was capable of separating a possible mixture of different components as it passes through the column.

The second use of the chromatogram is to be able to identify qualitatively the components of the mixture. This can be done by the use of retention indices of the components. As the retention time of the components is a function of the many variables of

column, flow and temperature operation, they should be checked with known standards. It is also sometimes necessary to use other means of identification in conjunction with gas chromatography (possibly another column, infrared spectrophotometry, mass spectrometry, etc.) to verify the results.

The third kind of information which can be obtained from the chromatogram is a quantitative analysis of the mixture (provided by the detector rather than the column). If the flow rate remains constant, the peak response of the detector is proportional to the concentration of the component (area under the peak). The peak response is related to an internal or external known standard and thus concentration can be determined.

To help with column selection for good resolution plus short retention times, some retention index systems have been published (Kovats, 52.9; Rohrschneider, 93.2, 93.3; McReynolds, 70.2; Dave, 25.03; Supina, 104.3, 104.4; and Littlewood, 62.8). As each system differs in their methods of column classification, each system will be only briefly described.

The Kovats indices are based by definition on normal paraffins. The value given for each carbon atom in the paraffin is 100, i.e., hexane is equal to 600. This definition applies regardless of the column used, the temperature, or any condition, and is the basis for the entire retention index system. For all other compounds it is extremely important that the conditions (i.e., stationary phase, concentration, support temperature) be specified. The retention time of a compound in question can be determined by running at least three normal paraffins which elute before and after the compound on a particular column with the above conditions specified. More information on retention index determination and greater details of the system are available (Ettre, 27.9; Kovats, 52.9; Supina, 104.4; Littlewood, 62.8).

Rohrshneider constants for column classification are based upon the fact that the polarity of a column depends not only on the column, but also on the substance being analyzed (Rohrschneider, 93.2, 93.3; Supina and Rose, 104.25). The measure of the polarity of a column and a compound is based on a comparison with a nonpolar column (squalene is considered the most nonpolar column available):

$$\Delta I = I_{polar} - I_{nonpolar\ (squalene)} = ax$$

in which

ΔI	=	a measure of the polarity of a column and a compound
a	=	a constant
x	=	"column polarity"

This equation thus gives a comparison of the retention index of a compound on a "polar" column to the retention index of the same compound on a nonpolar (squalene column). To better characterize a column (with more than one compound), Rohrschneider (93.2, 93.3) selected benzene, ethanol, methylethylketone, nitromethane, and pyridine and redefined the ΔI equation to:

$$\Delta I = ax + by + cz + du + es$$

By definition, x is equal to the polarity of the columns as far as benzene is concerned, i.e., $x = \Delta I/100$ for benzene where a is defined as 100 and similarly for y, z, u, and s being equal to $\Delta I/100$ for the other individual compounds selected.

The column can thus be characterized by determining the retention indices for the five standard compounds and subtracting them from the retention indices of the five standard compounds as determined on a squalene column. The constants must be determined under identical conditions. The constants can then be used to select and classify stationary phases on the basis of column and compound polarity. The interrelation and uses of the x, y, z, u, and s terms and mathematical derivations are described in greater detail by Rohrschneider (93.2, 93.3), Brown (18.63), Supina and Rose (104.25), Cram and Juvet (23.9).

McReynolds (70.2) greatly increased the utility of the Rohrschneider system by characterizing 25 columns using 68 different compounds. He then selected ten compounds which were found to be most representative for classification of the columns. They are: Benzene (x'), n-butanol (y'), 2-penthanone (z'), nitropropane (u'), pyridine (s'), 2-methyl-2-pentanol (H), 1-iodobutane (J), 2-octyne (K), 1,4-dioxane (L), and cis-hydrindane (M) with the letter (constant) as assigned by McReynolds to each. McReynolds presented his data as ΔI values (when divided by 100, they are similar to Rohrschneider constants). These data are of great value in selecting columns for specific separations, i.e., class separations, such as alcohols from ethers, esters from acids, etc. The columns are not designed for separation according to boiling point or within a class of compounds such as a homologous series. For example, if a column is needed which retards ketones with respect to aromatic or olefinic compounds, then what is needed is a high z' for a given x' value (not necessarily the highest z' but, a rather high z' with respect to x'). The McReynolds constant tables can be used to find the best relative difference of $z' > x'$. Once this is accomplished, and column selection has been narrowed to two or three columns, other factors such as column stability can then be assessed and a column prepared and tried.

In summary, the Rohrschneider and McReynolds data have been compared in depth (51.7, 104.4) and it is the consensus of most workers that these constants provide a useful tool for the selection of columns. However, considerable work is needed for better refinement of predicting retention indices.

As our interests involved small molecular weight organic compounds in dilute concentrations (ppm → ppb) which may affect algal dynamics, a column was needed to separate small molecular weight, natural aqueous phase organic compounds produced and utilized within a eutrophic reservoir. With the recent development and advancement of porous polymers (Porapak and Chromosorb Century Series) and their aqueous compatibility, they appeared to be an excellent starting point. The porous polymers also looked attractive because no messy liquid coating would be necessary and thus column bleed problems could be alleviated (note: porous polymers may initially show some column bleed but this can be essentially eliminated by proper column conditioning). From the literature (25.03, 50.2, 104.25) Chromosorb 101, Chromosorb 103, and/or Porapak R or Porapak S appeared to be good columns for use.

Chromosorb 101 is considered a general solid-adsorbent useful in separating short chain hydrocarbons, alcohols, fatty acids, esters, aldehydes, ketones, ethers, and glycols. Chromosorb 103 is a polyaromatic porous polymer material developed specifically for separation of amines and other basic compounds. Porapak R and S are porous polymer beads giving sharp, symmetrical peaks with low retention volumes for water, short chain alcohols, ketones, glycols, hydrocarbons, acids, and esters.

All the column materials and analyses were performed on a Model 5750 Hewlett-Packard research chromatograph equipped with both flame ionization and thermal conductivity detectors. The columns used were 6 ft by 1/8 in O.D. stainless steel and 4 ft x 4 mm I.D. glass coils. All columns were packed by inserting a glass wool plug (treated or untreated, depending on column packing material) in one end of the column, applying vacuum to that end, and adding the packing material to the other end of the column with continual vibration (where possible) of the column to facilitate uniform packing. Each column was conditioned at 25 °C below the maximum recommended temperature for 12 hours with a flow of 30 ml helium/min (effluent end not connected to detector while conditioning). After conditioning, the column (detector end) was repacked (vacuum and vibration) and reconditioned a second time if necessary.

The various operating conditions of the gas chromatograph can be found listed in Table 8.

Gas chromatography-mass spectrometry

Recent progress has been made toward a simple and fast method of analysis of an unaltered water sample. A study of direct aqueous injection into a gas chromatograph-mass spectrometry system is currently underway (EPA, Finnigan Corp., personal communication). This method involves gas chromatography coupled with a mass spectrometer as detector and a computer system for analysis of output data.

A mass spectrometer bombards a substance with an energetic electron beam which ionizes and breaks up the substance into fragments. Each kind of ion has a particular ratio of mass to charge, or M/e value (most ions have a charge of 1 so the M/e is simply the mass of the ion). A signal is obtained for each value of M/e which represents the relative abundance of the ion producing the response (signal intensity). The largest peak (base peak) is considered to be 100 and all other peaks are expressed relative to it. A plot (relative intensity vs. M/e) showing the various values is called a mass spectrum and is highly characteristic of a particular compound. The mass spectrum helps to establish the structure of an unknown compound by: (1) Giving the exact molecular weight (molecular ion, only one electron removed from parent molecule), (2) giving a molecular formula (or the choice of a few), and (3) indicating some specific molecular structural units.

If an unknown compound is subjected to mass spectral analysis and is found to be identical to a spectrum of a previously reported known compound, then it can be concluded that the two compounds are identical.

Analyzing a mass spectrum can be tedious and difficult. Computer program capabilities have been expanded to analyze the various M/e values and their relative abundances and compare them to knowns in their storage banks. This field of computer data handling is rapidly expanding and has certainly increased the ease of interpretation of mass spectral results.

Routine direct aqueous GC/MS/computer analysis of organic components offers instant analysis. Since laborious and time consuming pretreatment and concentration is not required, a relatively large number of samples can be processed in a short amount of time and at a relatively low unit cost. However compounds must be suitable for gas chromatographic analysis; most low molecular weight compounds are suitable. As our facility does not have one of these instruments (high initial cost of $100,000) samples have been sent to other laboratories for analysis (Appendix B and C).

Sampling

Water samples were collected from a eutrophic reservoir subject to agricultural and cattle feedlot runoffs but not subjected to industrial wastes. The reservoir was Hyrum Reservoir, Hyrum, Utah, located about 12 miles from the Utah Water Research Laboratory. The water samples were collected in 9 liter glass bottles which had been acid (HCl) washed, rinsed in deionized, distilled water, and rinsed again at the sampling site with the water to be collected; the jugs were capped with a rubber stopper covered with aluminum foil. The bottles were used only for this purpose to avoid possible laboratory contamination with other organic compounds.

The samples were taken from the surface off a small dock located at the boat launching ramps of the Hyrum State Park at the reservoir; during the winter, holes were cut in the ice with an ax but the same sample site was used. The influent (Little Bear River) was also sampled to assure the organics were produced in the lake and not added to it. The samples were immediately (25 minutes) brought back to the laboratory for processing.

Sample Processing

The water samples were filtered to remove particulate matter and thus, principally, dissolved organic matter was studied. The filters were glass fiber (Whatman GF/C) which had been prewashed with hot and then cold water and then prerinsed with the sample water before use in accordance with Cahn (18.9) to remove detergents. Distilled, deionized water was used with all processes to serve as a control to insure that all compounds isolated were not a product of the laboratory equipment or processes used.

Then, as shown in Figure 4, a sample of the filtered water was frozen and freeze dried; this fraction was called Group I. Another sample of the filtered water was taken and concentrated about 7 to 1 by freeze rotation, made basic (pH $\sim$ 13, with NaOH pellets) and the precipitate collected (Group II). To the filtrate was added an equal volume of 0.2 M $FeCl_3$, the pH was adjusted to 8.8 with HCl for maximum $Fe(OH)_3$ formation and the precipitate was collected (Group III). The filtrate was frozen and then freeze dried; the powder collected was called Group IV. Group II was also formed by adding NaOH pellets to filtered unconcentrated Hyrum water and Group III was also formed by adding $FeCl_3$ (saturation) to both unconcentrated and concentrated Hyrum water.

The percent organic carbon in each group was determined by standard methods using combustion-infrared and by chemical oxygen demand (COD) measurements. These four groups were treated separately using liquid extraction to extract their organic compounds, the solvent was evaporated (totally or in part) and the solution or residue was subjected to analysis (gas chromatography, mass spectroscopy, infrared, thin layer or column chromatography).

Some methods (18.4) of rudimentary organic separation were also tried on water from Hyrum Reservoir. By using various solvents and pH's five general groups of organic compounds were separated (basics, amphoterics, neutrals, phenolics, and acids). These grouped organics were then applied to *Selenastrum capricornutum* to study these effects (see Figure 4). Small quantities of crystals were formed in all five groups using water from Hyrum Reservoir in the late spring (May 1974) however within two weeks the compounds were no longer present in large enough quantities to handle in this manner and the method was terminated. No effects of the compounds (groups) was observed on the growth of *Selenastrum capricornutum* in the small amounts applied.

Liquid-solid extraction was also tried, extracting mud from the bottom of Hyrum Reservoir with benzene. Some yellow color was imparted in the benzene from the mud; however, the experiment was terminated in favor of following more active reservoir compounds instead of the sediment compounds which would have less interaction with the phytoplankton.

Besides trying to: (1) Bind or precipitate the organics out of solution (co-precipitation or carbon adsorption), (2) to partition the organic in some organic solvent (extraction), or (3) to remove the water (freeze drying or freeze concentrating), we also tried distillation of the organics. It was found that by using cascade freeze concentration followed by cascade distillation, the organics could be concentrated sufficiently for identification by gas chromatography and GC/MS. Identification with standards using the gas chromatograph alone was more time consuming than using the GC/MS/computer system for identification.

In sample handling, sample concentration and sample storage, numerous problems were encountered. Due to the volatility of the components being measured and the possibility of them being degraded, it was necessary to proceed with analysis immediately after bringing the samples to the laboratory.

This is a special problem when algal blooms occur and a new compound is observed. The

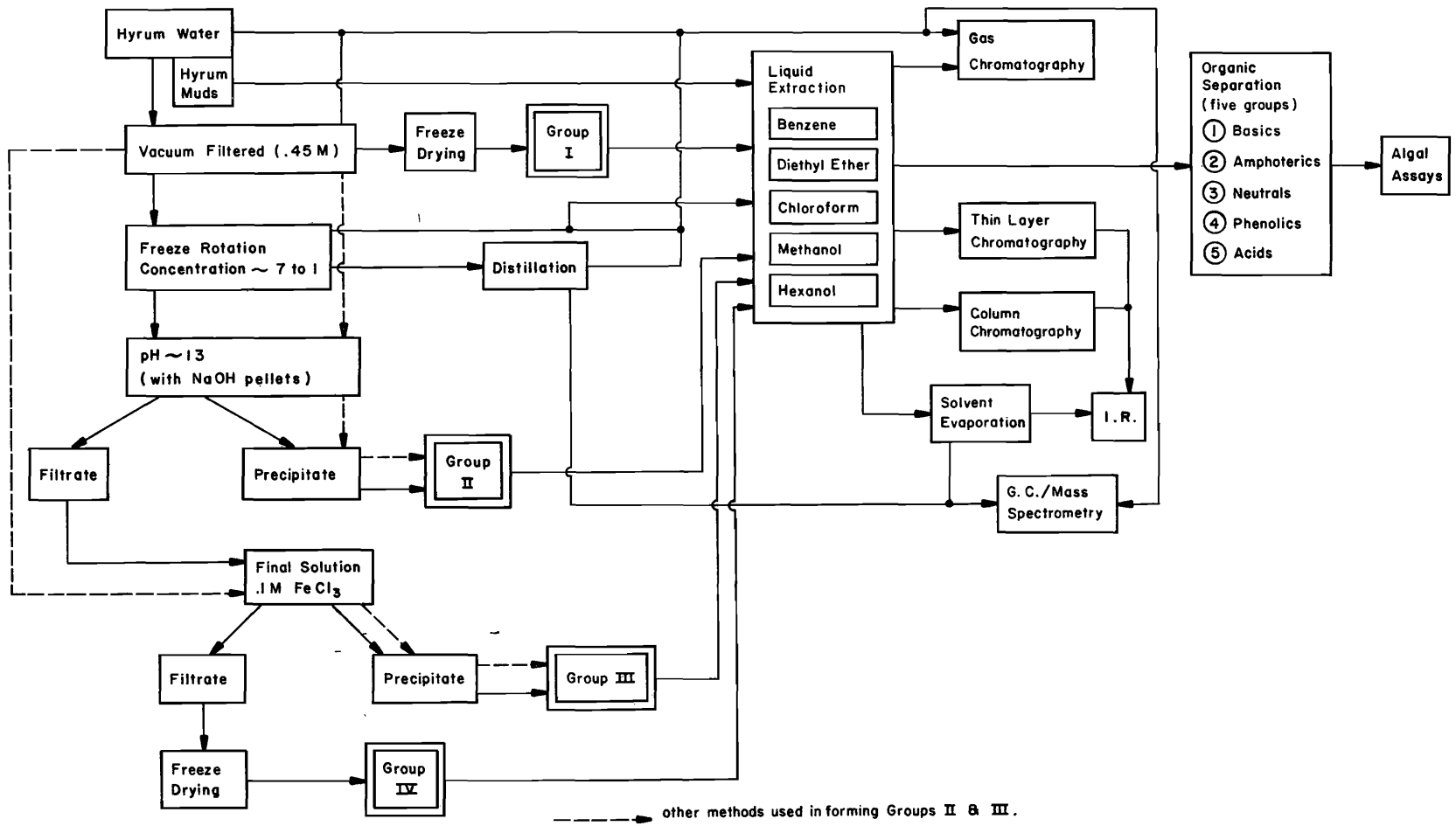

Figure 4. Processing of Hyrum water for the separation and identification of organic compounds found there.

identification procedure must be completed quickly because the compound may not survive storage and may not appear until the next year when the bloom occurs again. Even with refrigerated storage at 4° C, specific compounds can change or be lost or degraded over a short period of time.

Sample degradation also likely occurred when samples were sent to outside laboratories for analysis. Thus, compounds identified by the GC/MS were confirmed as present in Hyrum Reservoir only when immediate analysis on the Utah Water Research Laboratory gas chromatograph confirmed their presence.

Bioassay Material

Six low molecular weight compounds were identified to be present at Hyrum Reservoir (acetaldehyde, methanol, ethanol, 2-propanol, acetone, and propanal). Using redistilled reagent grade reagents, five of the six compounds were administered at varying concentrations and under conditions in accordance with EPA's Algal Assay Procedures/Bottle Test (27.8). Acetaldehyde was omitted because it only appeared once in the reservoir and then only in a trace amount (less than 0.1 ppm). The algae used were: (1) *Selenastrum capricornutum* (EPA), (2) *Chlamydomonas reinhardi* and *Navicula pelliculosa* (Indiana University Culture Collection), and (3) *Nitzchia sp.*, and *Scenedesmus sp.*, mixed culture, (4) *Chlorella sp.* and (5) *Kuchneriella sp.* (3, 4, and 5 were isolated from Hyrum Reservoir). Growth response was measured with cell counts or on a Bausch and Lomb Spectronic 70, at 750 nm wave length and using 1 cm cells.

The bioassays were conducted using test algae grown in Bristols solution (except *Selenastrum capricornutum* which was grown in NAAM) and parameters of response were, μ, specific growth rate, batch, and, X, cell population in optimal density units for a 1 cm cell at 750 nm (measured at a specific time, t). The specific growth rate was determined as the maximum measured growth rate during the growth curve where

$$\mu = \frac{1}{\Delta t} \ln \left(\frac{X_n}{X_{n-1}} \right)$$

Under the bioassay conditions growth had usually ceased by the 10th to 14th day.

RESULTS AND DISCUSSION

Algal Dynamics at Hyrum Reservoir

The algal community at Hyrum Reservoir was observed over a period of three years. Twenty-nine genera of algae were identified and counted in numbers throughout the water column for the first two years (May 1972 - May 1974; see Drury et al., 27.002). During the last year (September 1974 through April 1975) chlorophyll *a* was determined (36.4) and algal population observations were made but no counts were made.

During all three years, some regular cycles were noted as follows: (1) The appearance of a heavy blue-green *(Aphanizomenon)* bloom in the late summer, (2) an increase in the population of *Stephanodiscus* (large sp.) following the decline of the blue-green bloom, (3) a heavy winter population of *Stephanodiscus* (small sp.) terminating with spring turnover.

Some genera, such as *Chlamydomonas,* appeared all year (Figure 5), only changing in their number from season to season. Figure 6 shows that the *Aphanizomenon sp.* bloom of 1973 was about 10 times the bloom of 1972; notice also the changes in the populations of *Chlamydomonas* (Figure 5) and the two species of *Stephanodiscus sp.* from 1972 to 1973.

During 1973 when the *Aphanizomenon* bloom increased, there was a decrease in the population of *Chlamydomonas* and the winter species of *Stephanodiscus* (small sp.); the population of the large *Stephanodiscus sp.* increased. It was further observed that at the times of the *Aphanizomenon* blooms, other genera (greens and diatoms) decreased in population, some to undetectable numbers.

It was noteworthy that on August 14, 1972, no *Kirchneriella* were observed in the water column (1 through 19 meters); however, 16 days later the population was at 12,300 cell/ml, in the top meter of water and 14 days later, again, no *Kirchneriella* was observed in the water column nor did it reappear.

Since organic compounds may play a role in the changing algal population, organic compounds in Hyrum Reservoir were identified and their concentrations monitored as the algal population changed during the year 1974.

Identification and Separations of Hyrum Reservoir Organics

Gas chromatography

The most successful method of identification and monitoring organics at Hyrum was the use of gas chromatography. Upon initial gas chromatography work (direct aqueous injection onto a 6 ft x 1/8 in Porapak S stainless steel column), it was necessary to identify at least one peak in the chromatogram to obtain data sufficient to identify the other peaks present (using retention indices). A sample was run on a Hewlett-Packard GC(7620)/MS(5930A)/Data System(5933A) (Material Science Department, University of Utah, Salt Lake City) and a Finnigan 3300 GC/MS with a 6100 data system (Finnigan Corp., Sunnyvale, California) but the concentration was insufficient for any peak identification.

Distillation and freeze rotation techniques were used to concentrate (by 100 to 200 times) the sample and then the sample was analyzed again. The most concentrated peak (largest peak area, 45 mm from injection) was identified as acetone according to the computer search of the mass spectral data system (see Appendices B and C). From Dave's (25.03) work, acetone has a retention index of 475 on Porapak S (80/100 mesh at 225°C, 4 ft by 3 mm ID glass column). By selecting compounds with retention indices sufficiently different than acetone (both more than and less than), the retention indices of other peaks in the chromatogram could be quantified.

For example, Figure 7 shows a chromatogram of seven peaks with the largest peak at 45 mm from injection (chart speed at 0.25 in/min) being identified as acetone. Since methanol has the lowest retention index (345) on Porapak S (25.03), an aqueous sample of methanol ($\approx$ 5 μl MeOH/l H_2O) was analyzed on the same column. The aqueous methanol peak appeared at 17 mm from injection and appeared to be the same as the initial organic peak observed in Figure 7. This "tentative" peak identification was then confirmed by analysis of the same sample on a different column under different conditions. The second analysis also gave additional information about the peak between the methanol peak and the acetone peak. The peak between the two appeared 34 mm after injection. Thus an approximate retention index was calculated.

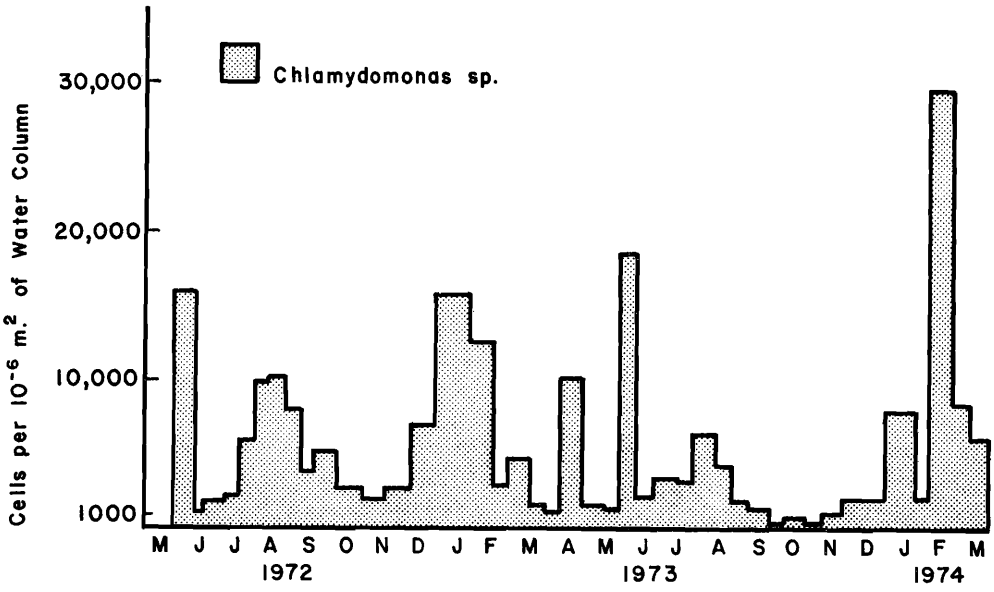

Figure 5. Non-cycling (always present) genera of algae at Hyrum Reservoir.

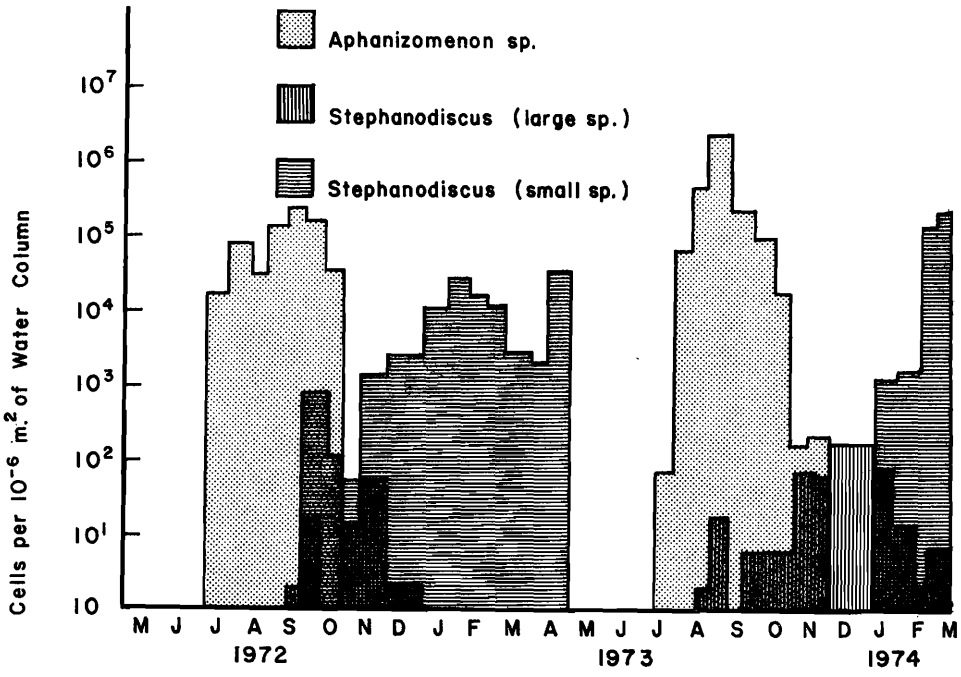

Figure 6. Regular cycling of algae at Hyrum Reservoir.

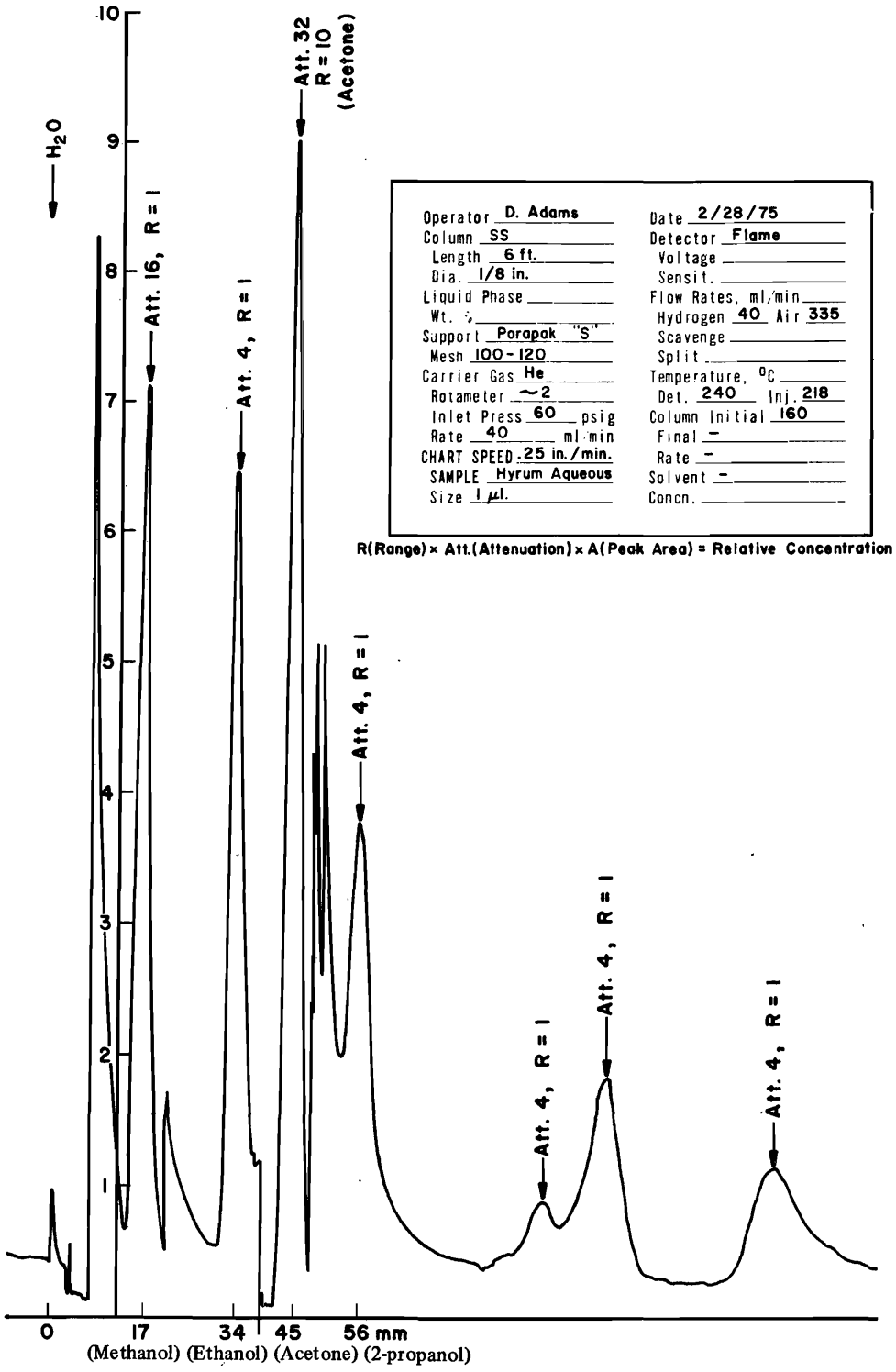

Figure 7. Typical gas chromatogram (concentrated sample) of volatile organic compounds found in Hyrum Reservoir.

Acetone	45 mm	475
Unknown	34 mm	?
Methanol	17 mm	345

Acetone	45	Acetone	475
Methanol	-17 mm	Methanol	-345
	28 mm		130

or 130 units/28 mm = 4.64 units/mm
The unknown was 11 mm less than acetone thus the approximate retention index was:

475 - 11 mm x 4.64 units/mm = 475 - 51 = 424

Using Dave's table (25.03), the following compounds were seen to have similar retention indices:

Ethanol	415
Acetaldehyde	375
Acetonitrile	465
Nitromethane	420

Ethanol and nitromethane were the closest to the approximate calculated value. Then pure compounds were run in aqueous solution under the same conditions to identify the peak. Acetaldehyde appeared almost identical to the methanol peak and nitromethane had a larger retention time than acetone. Acetonitrile gave a peak at 40 mm after injection with ethanol appearing at 34 mm as did the unknown peak. It was then necessary to confirm this on another column.

This is basically the method used for peak identification and also the use of GC/MS identification when practical. Thus, the compounds identified in Table 8 were verified on two or three columns under different conditions using redistilled organic knowns in aqueous solution at approximately the same concentrations as seen in Hyrum Reservoir.

Rotational freeze concentrating

Figure 8a shows a gas chromatograph of a synthetic water-volatile organic compound mixture (the mixture contained 10 μ l/l of each of the 5 organic compounds) before freeze concentration and Figure 8b shows the concentrations of the organics in the ice residue (the remainder of the organics are contained in the unfrozen water). The recovery of the organics by rotational freeze concentrating ranged between 82 and 99 percent (Table 9), as analyzed by gas chromatography.

Distillation

Another successful method of concentrating the organics is by distillation of the filtered water (Figure 9). Thus, 99.9 percent of the organics studied could be recovered by distilling 13 percent of the original volume of sample. This yields a concentration factor of seven; however, by using several large volumes (cascade distillation), concentration factors of 100 to 1000 were achieved as determined by gas chromatography.

Freeze drying, thin layer chromatography, and infrared spectroscopy

Although the best results were achieved by rotational freezing and distillation some success was achieved through the use of freeze drying and preparative thin layer chromatography.

On July 8, 1974, a heavy *Asterionella sp.* population was observed and 10.9 liters of Hyrum water were collected, filtered, and rotational freeze concentrated to 1.3 liters. The pH was adjusted to 13 with NaOH pellets and the precipitate (1.22 grams) was collected (Group II in Figure 3). The precipitate was determined to be 0.35 percent organic carbon (by combustion-infrared analysis); 0.5929 grams of the precipitate was taken and added to 20 ml of 5 percent HCl. This solution was extracted (liquid-liquid) with 1.5 liters of hexanol (redistilled) for three days.

The 1.5 liters of hexanol were evaporated in a hood down to 10 ml. This was applied to the base of a preparative thin layer chromatography plate (Al_2O_3). The plate was developed with a 1:1 methanol, benzene and observed with UV light to have five bands. The third band (most intense) was removed from the plate and extracted with hexanol. The hexanol was evaporated and the residue was placed in a desiccator for further drying. The residue was a tacky liquid-like substance, yellow-green in color and with a characteristic odor. The infrared spectrum (using NaCl plates) of the "unknown liquid" indicated -OH or -NH stretching absorption at 3350 cm^{-1}, and a broad band at 1080 cm^{-1} (characteristic of an alcohol), -C-H stretching absorption at 2855 cm^{-1} and 2910 cm^{-1} (methyl-methylene groups) and -C-H bending vibrations at 1450 cm^{-1} and 1370 cm^{-1} (Figure 10). The compound isolated had the infrared characteristics of a primary alcohol, but insufficient information could be described from the spectrum to identify the compound. Further identity was not achieved.

To the filtrate of the solution which formed Group II above, an equal volume of 0.2 M $FeCl_3$ was added, and the resulting precipitate was collected (Group III). Some of the material from Group III (0.5847 grams) was taken and added to 20 ml of 5 percent HCl and the solution extracted for five days with 1.5 liters of chloroform. Then the chloroform was evaporated in a hood down to 10 ml. This was spotted on an Al_2O_3 neutral preparative thin layer plate and using a developed using glacial acetic acid. Three bands were observed under UV light. The top

Table 8. Compound identification and verification of methanol, acetaldehyde, ethanol, 2-propanol, acetone, and propanal from aqueous Hyrum Reservoir samples.

Compounds Identified	Column 1 & Conditions	Relative Retention (mm)[a]	Column 2 & Conditions	Relative Retention (mm)[a]	Column 3 & Conditions	Relative Retention (mm)[a]	GC/MS
Methanol	Porapak S Isothermal 160°C	17.0	Porapak S Temperature Programmed 88°C - 128°C @ 6°/min	58.0	4% FFAP on Chromosorb WHP 40°C	34.0	-
Acetaldehyde	Porapak S Isothermal 160°C	17.2	Porapak S Temperature Programmed 88°C - 128°C @ 6°/min	53.0	4% FFAP on Chromosorb WHP 40°C	6.0	-
Ethanol	Porapak S Isothermal	34.0			4% FFAP on Chromosorb WHP 40°C	39.0	App. B
Propanal	Porapak S Isothermal 160°C	40.6	Porapak R Isothermal 160°C	51.0	Chromosorb 103 Temperature Programmed 90° - 135°C @ 6°C/min	41.5	-
Acetone	Porapak S Isothermal 160°C	45.0	Porapak R Isothermal 160°C	57.0	Chromosorb 101 Temperature Programmed 90° - 140°C @ 6°C/min	41.5	App. B & C
2-propanol	Porapak S Isothermal 160°C	57.0			Chromosorb 103 Temperature Programmed 100 - 140°C @ 4°C/min	60.0	-

[a]Measured from injection with chart speed of 0.25 in/min with a carrier flow of 30 ml/min helium, using Hamilton syringes for 1 µl injections. The flame detector gases were set at 40 ml/min and 335 ml/min for hydrogen and air, respectively.

Table 9. Percent organics recovered by rotational freeze concentrating.

Concentration Factor	% Recovered				
	Methanol	Ethanol	Acetone	Propanal	2-Propanol
1/22	87	92	82	92	87
1/17	90	97	91	96	96
1/11	93	99	92	95	99

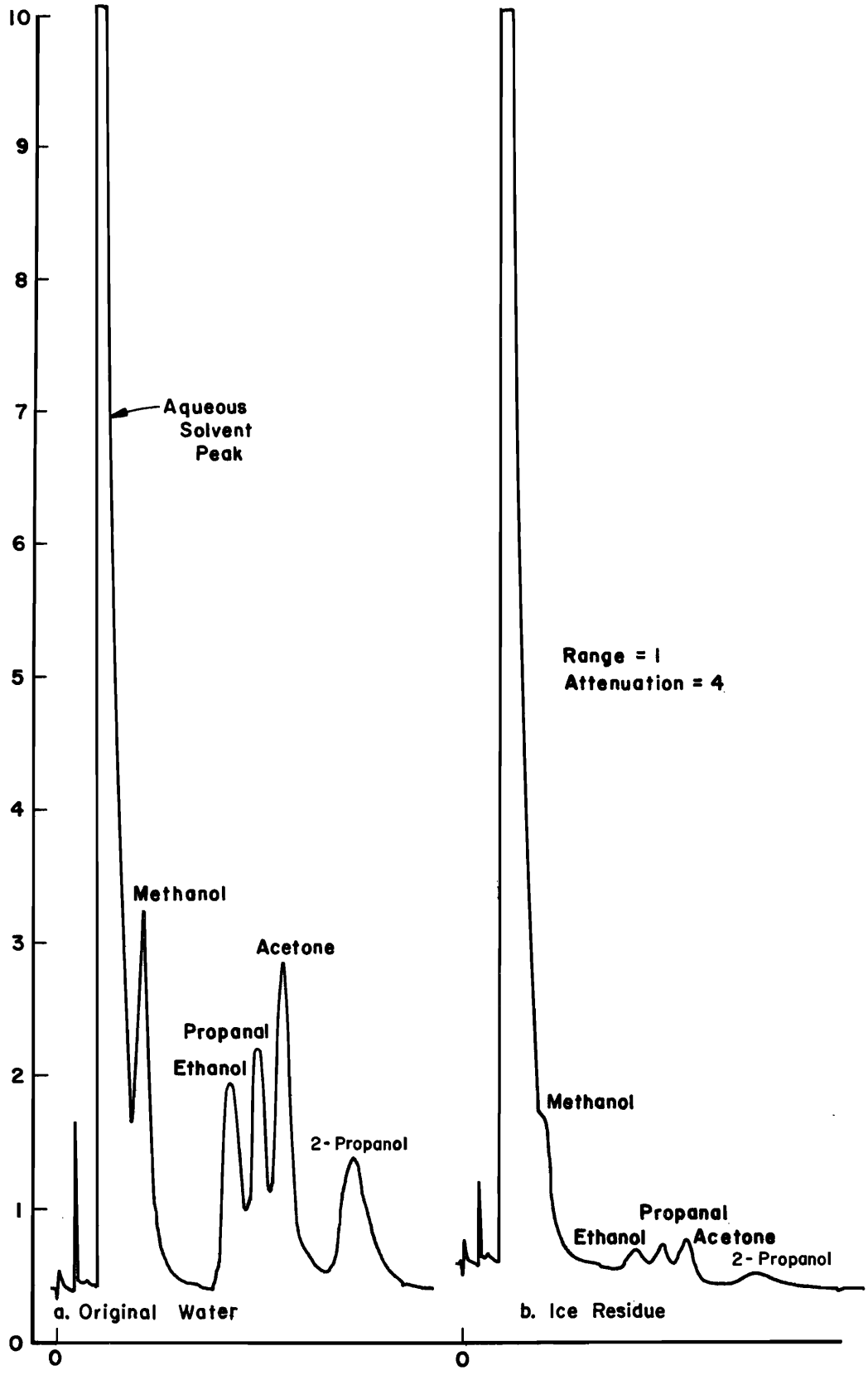

Figure 8. a) Concentration of organics before rotational freeze concentrating and b) Organics left in the ice after freeze concentrating

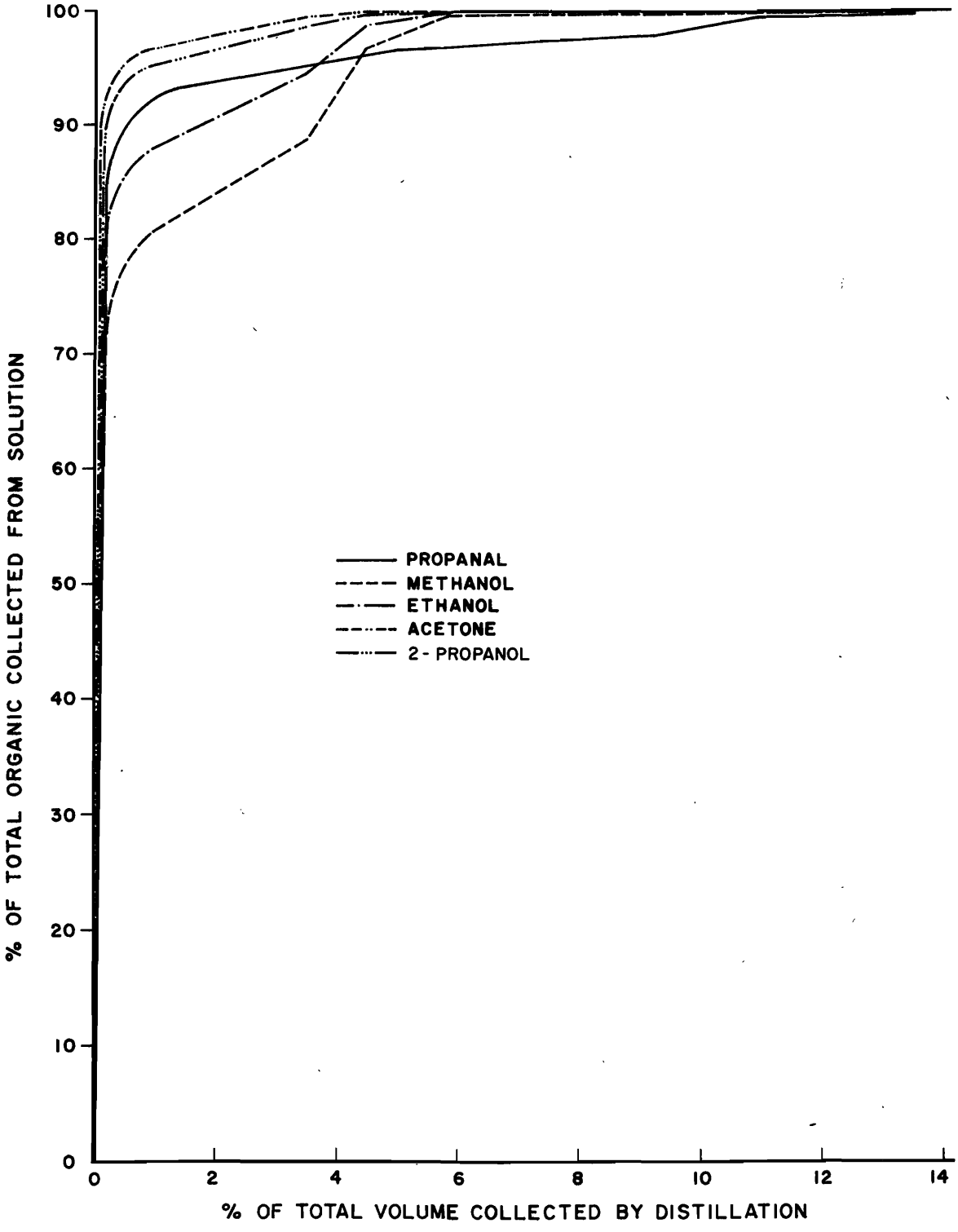

Figure 9. Percent recovery of organic compounds concentrating by distillation.

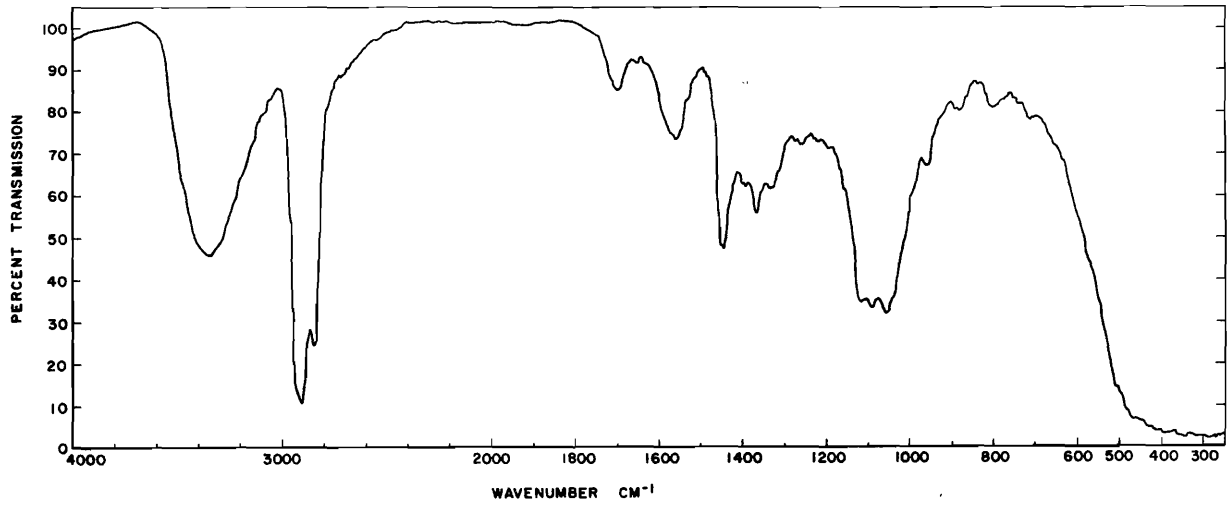

Figure 10. Infrared spectrum of an unknown from Group II separation (see Figure 3 for group identification).

band was collected and placed on a chromatographic column 9 mm in diameter and 23 cm long, containing Al_2O_3 (neutral) powder. Benzene was run through the column and collected (two 50 ml proportions). Then two proportions of ethanol were run through and collected. The second fraction of ethanol was evaporated and the residue placed in a desiccator. The residue was a tacky liquid-like, yellowish compound with a characteristic odor.

The infrared spectrum (using NaCl plates) of the unknown compound indicated a methyl-methylene type of absorption (infrared absorption at 2820 cm^{-1}, 2880 cm^{-1}, 2910 cm^{-1}, and 1425 cm^{-1}; Figure 11). The band at 1700 cm^{-1} would usually indicate carbonyl absorption but it was not particularly strong. Since there was no characteristic absorption for an aldehyde $-\overset{O}{\overset{\|}{C}}-H$ at ≈ 2700 cm^{-1}, a ketone carbonyl was a possible choice. Considering the relative intensities of the absorption bands and the absence of aromatic, nitrile, sulfur, and amine type absorption bands, the compound (from the IR spectrum alone) would appear to be a moderately sized ketone. Further information from other methods of analysis would be necessary to establish the chemical structure. Infrared spectra were obtained for all groups (I - IV) having been extracted by benzene, diethyl ether, chloroform, methanol, and hexanol (see Figure 4). Figures 10 and 11 report the best spectra obtained.

All liquid reagents used were distilled; distilled water was used as a control blank which was carried through the entire process from extraction to the running of the IR. These results showed that the compounds identified were not derived from laboratory contamination but were, in fact, from the waters of Hyrum Reservoir.

Temporal Variations in Organics at Hyrum

Using both rotational freeze concentrating and micro-distillation for separation and concentration and then analyzing the known organics using a gas chromatograph, the substances, methanol, ethanol, propanal, acetone, and 2-propanol were monitored at Hyrum Reservoir (Figure 12 and listed in Table 10). The highest concentrations of organic compounds were measured on September 4 and September 19, 1974. During this period the methanol concentration decreased and the acetone and ethanol increased. The values for those dates are high (order of magnitude) in comparison with total organic carbon measurements made in previous years. It was also noted that ethanol increases before the heavy populations of *Stephanodiscus* (large sp.), *Asterionella sp.*, and *Stephanodiscus* (small sp.) (Figures 12 and 13) were observed. This highest concentration of organics seemed to coincide with the *Aphanizomenon sp.* bloom and to slightly precede the development of high concentration of *Stephanodiscus sp.* (large).

There is little question that such factors as light, temperature, pH, nutrients, and seasonal variations play important roles in the succession of algae at Hyrum. However, organic compounds appear to be

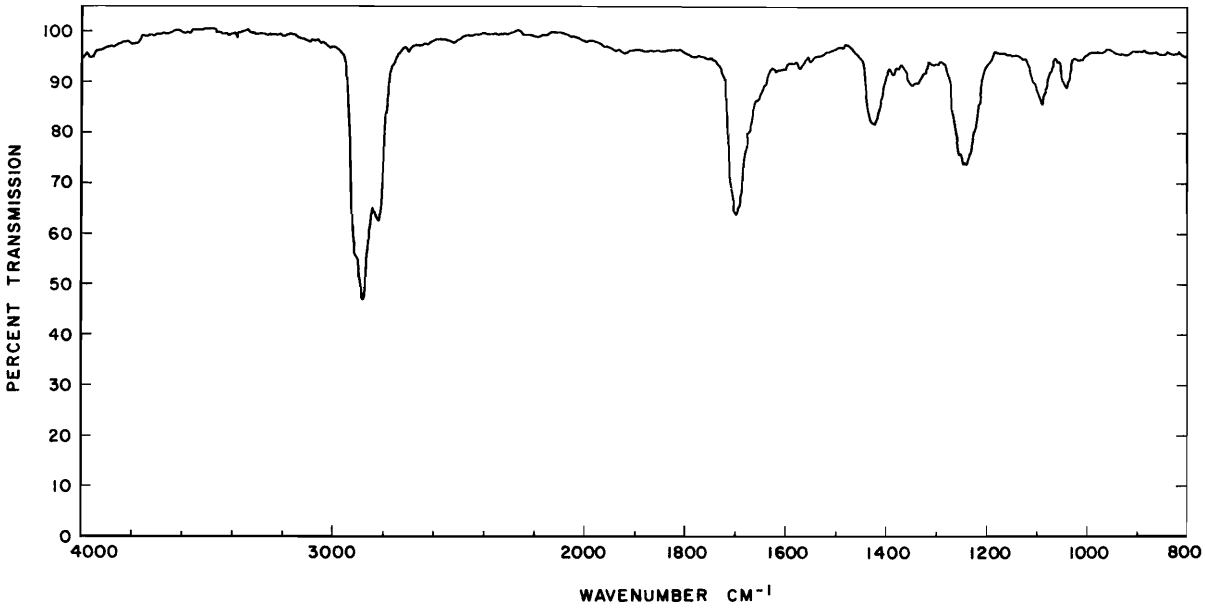

Figure 11. Infrared spectrum of unknown compound from Group III separation (see Figure 3 for group identification).

Table 10. Organic compounds (mg/l) found at Hyrum Reservoir. X = trace amount present.

	Methanol	Ethanol	Propanal	Acetone	2-propanol	Acetaldehyde
Sept. 4	38.5	0.8	1.3	6.1	X	
Sept. 19	6.1	22.2	X	34.5		X
Oct. 1	X	0.6	0.5	0.8		
Oct. 11	X	0.2	X	1.3		
Oct. 24	X	3.2	0.5	2.2		
Oct. 31		1.1	X	1.0		
Nov. 7		X	X	0.3		
Nov. 13		0.5		0.8		
Nov. 16	0.1	X	X	1.0	X	
Nov. 23	0.9	X	0.6	3.1	X	
Nov. 29	X		1.0	1.8		
Dec. 12	X		1.0	0.8		
Dec. 23			0.5	0.8		
Dec. 30			X	0.8		
Jan. 9				0.7		
Jan. 16	0.3	X	0.3	0.3		
Jan. 30	0.2	X	X	0.3		
Feb. 12	0.2	0.2	0.2	0.2		
Feb. 22	0.3	0.5	0.3	0.8		
Mar. 1	X	X	X	0.08		
Mar. 11	X		0.2	0.07		
Apr. 2	X		0.1	0.04		

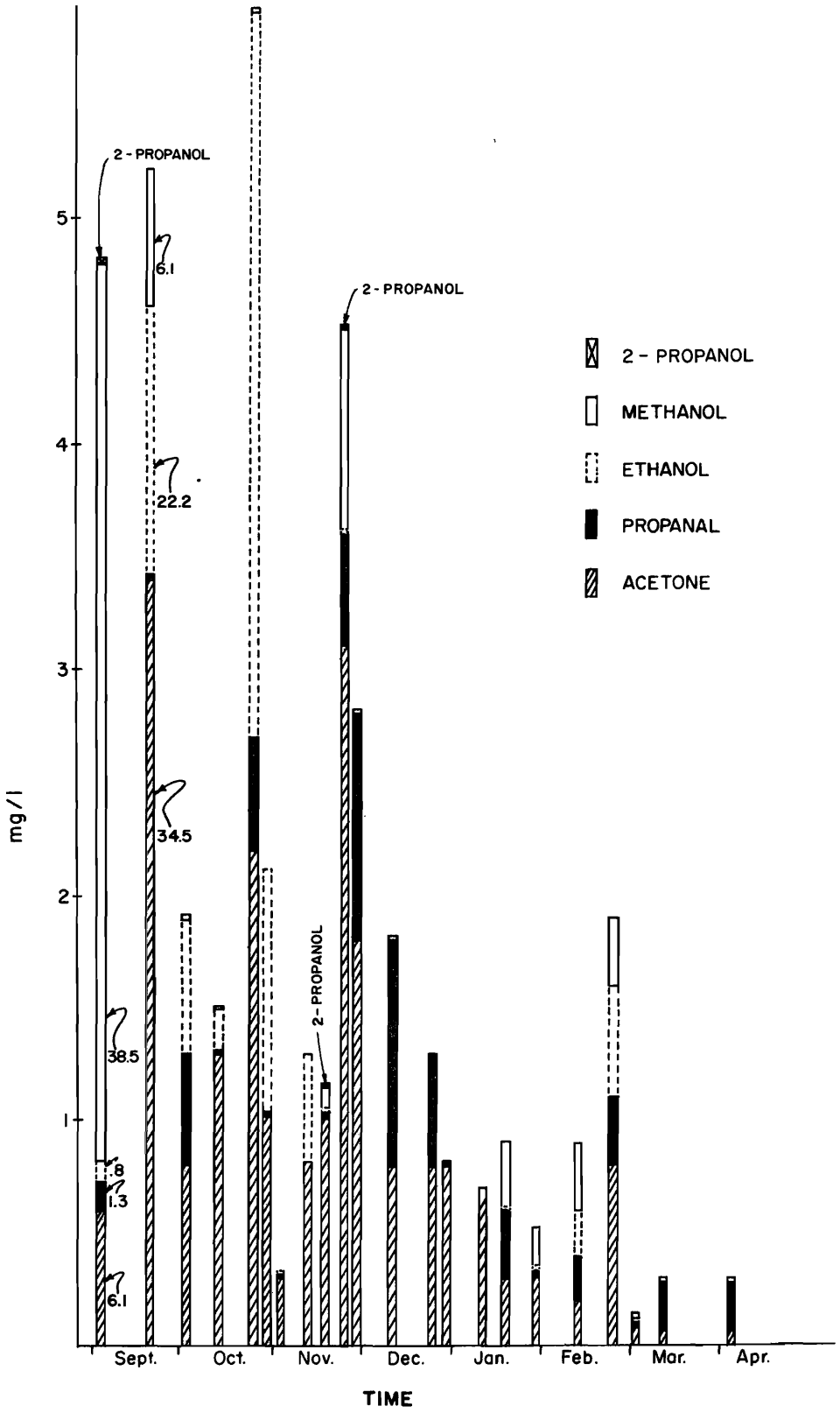

Figure 12. Concentrations of organic compounds found in Hyrum Reservoir between September 4, 1974 and April 2, 1975.

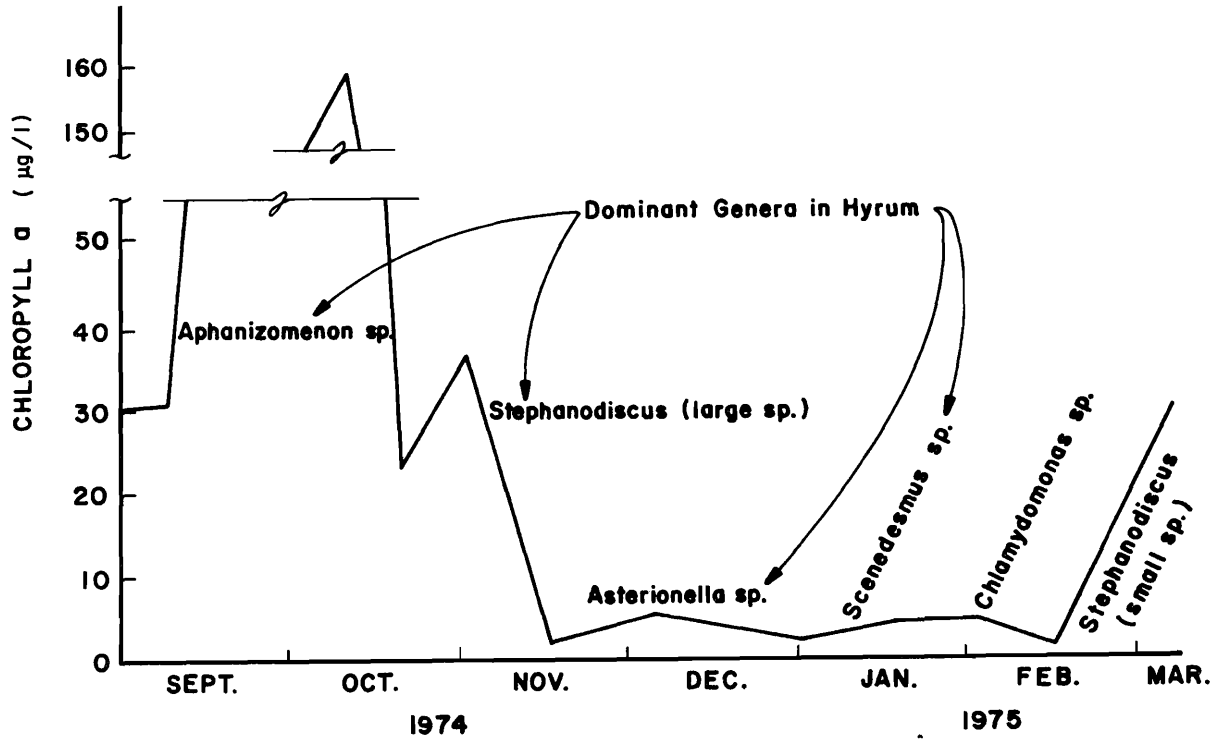

Figure 13. Dominant algal populations observed at Hyrum Reservoir, September 1974 through March 1975.

associated with blooms and undoubtedly play some role and from a control point of view, perhaps, a very important role. A possible example of organic interactions was noted in early 1975 at Hyrum Reservoir. From Figure 13, in late January and early February an increase in the population of *Chlamydomonas sp.* was observed. From Table 7 (algae affecting other algae) it was noted that *Chlamydomonas reinhardi* strongly inhibited the growth of *Scenedesmus quadricauda.* Since *Scenedesmus sp.* was observed in heavy numbers in January, it was predicted that this population would decrease as the *Chlamydomonas sp.* increased; indeed this was the observation (Figure 13). Further it was observed at this time (February 1975) that the concentrations of ethanol, propanal, and acetone increased in the reservoir. Since the population of *Chlamydomonas sp.* was also increasing at this time (Figure 10), it was suspected that *Chlamydomonas sp.* was the source of these compounds (Table 6).

Bioassays on Hyrum Reservoir Organics (Effect of Organic Compounds)

Five of the six organic compounds found to be present at Hyrum Reservoir were applied to different algae to study their effects. All algae tested were found to be native to Hyrum Reservoir except for *Selenastrum capricornutum.* This is the standard test alga for EPA's bottle test (27.8). Acetaldehyde was only found once in Hyrum at very low (trace) concentrations and was not bioassayed.

The effects of ethanol

Ethanol stopped the growth of *Selenastrum capricornutum* at high levels (75 to 7,500 mg/l) (Table 11); ethanol increased the growth rate and net growth of *Chlamydomonas reinhardi* (Table 12); ethanol decreased the growth rate of *Chlorella sp.* while increasing its net growth (Table 13); thus ethanol apparently created conditions where the alga *(Chlorella sp.)* grew slower but for a longer growth period. Ethanol increased the growth rate and net growth of *Navicula pelliculla.*

The effects of methanol

Methanol prevented the growth of *Selenastrum capricornutum* (Table 11) at 7,900 mg/l, while the growth rate and the net growth of *Chlorella sp.* (Table 13) increased in the concentration range from 0.8 to 80 mg/l. The growth rate of *Kircheriella sp.* was decreased at 80 mg/l (Table 14).

Table 11. **Effects of methanol, ethanol, and acetone on the growth *Selenastrum capricornutum* (NAAM medium).**

Organism Tested: *Selenastrum capricornutum*

Experiment Number:		1			2			3			4		
Initial Concentration (mg/l)		μ, days^{-1}	$X_{10.9}$ days	$X_{12.08}$ days	μ, days^{-1}	$X_{10.9}$ days	$X_{16.5}$ days	μ, days^{-1}	$X_{10.9}$ days	$X_{16.5}$ days	μ, days^{-1}	$X_{10.9}$ days	$X_{16.5}$ days
Controls	I	0.68	0.230	0.272	0.90	0.426	0.470						
	II	1.25	0.310	0.323	1.04	0.416	0.481						
	III				1.08	0.389	0.499	(# served as control)			(# served as control)		
	IV				1.21	0.416	0.465						
	V				1.25	0.388	0.460						
Methanol	.08	1.02	0.190	0.185	1.13	0.382	0.431	0.99	0.410	0.494	1.02	0.402	0.462
	.8	1.18	0.300	0.345	1.04	0.400	0.468	1.10	0.407	0.480	1.13	0.417	0.480
	8	1.24	0.215	0.241	1.15	0.395	0.450	0.99	0.397	0.450	1.18	0.417	0.474
	80	0.80	0.175	0.178	1.01	0.384	0.455	1.11	0.384	0.439	1.18	0.420	0.472
	800				1.16	0.417	0.471	1.10	0.422	0.480	1.08	0.412	0.465
	4,000				1.02	0.389	0.443	1.25	0.389	0.442	1.14	0.365	0.416
	7,900	N	N	N									
Ethanol	.08	1.02	0.250	0.288	0.65	0.406	0.481	0.81	0.408	0.490	1.40	0.414	0.471
	.8	1.05	0.260	0.282	1.61	0.417	0.478	0.95	0.407	0.467	1.03	0.395	0.450
	8	0.97	0.200	0.215	1.11	0.415	0.450	1.36	0.405	0.472	1.41	0.414	0.456
	75	N	N	N	1.13	0.426	0.488	1.03	0.442	0.486	1.03	0.427	0.475
	7,500	N	N	N									
Acetone	.08	0.94	0.235	0.272	0.83	0.419	0.469	0.76	0.409	0.469	0.89	0.398	0.460
	.8	1.33	0.330	0.352	0.61	0.402	0.470	0.81	0.426	0.493	0.85	0.412	0.470
	8	1.14	0.275	0.285	0.89	0.422	0.491	0.93	0.413	0.480	0.86	0.422	0.487
	79	1.19	0.252	0.272	0.65	0.411	0.469	0.86	0.424	0.469	0.82	0.413	0.485
	7,900	0.91	0.105	0.142	0.70	0.348	0.412	0.67	0.318	0.380	0.49	0.318	0.381
	40,000				N	N	N	N	N	N	N	N	N

μ = specific growth rate
X = cell population in optimal density units (1 cm cell at 750 nm)

Table 12. Growth of *Chlamydomonas reinhardi* subject to varying organic compounds and concentrations (Bristols Medium).

Organism Tested: *Chlamydomonas reinhardi*

Experiment Number:		5			6		7	
Initial Concentration (mg/l)		μ, days^{-1}	$X_{10.9}$ days	$X_{17.6}$ days	μ, days^{-1}	$X_{10.9}$ days	μ, days^{-1}	$X_{10.9}$ days
Control	I	0.55	0.360	0.505	0.30	0.413	0.67	0.418
	II	0.37	0.445	0.585	0.31	0.400	0.96	0.393
Methanol	.08	0.47	0.380	0.505				
	.8	0.34	0.380	0.590				
	8	0.50	0.410	0.590				
	80	0.26	0.325	0.519				
Ethanol	.08	0.72	0.330	0.608				
	.8	0.65	0.330	0.525				
	8	0.41	0.370	0.522				
	40	0.30	0.370	0.505				
Propanal	.8				0.27	0.358	0.89	0.395
	8				0.39	0.387	0.97	0.488
	80				0.05	0.023	1.57	0.030
Acetone	.08	0.43	0.400	0.500				
	.8	0.70	0.460	0.625				
	8	0.46	0.390	0.555				
	79	0.74	0.510	0.705				
2-propanol	.8				0.28	0.450	0.44	0.375
	8				0.32	0.428	0.65	0.404
	79				0.26	0.475	0.54	0.370

μ = specific growth rate
X = cell population in optimal density units (1 cm cell at 750 nm)

Table 13. Growth of *Chlorella sp.* subject to varying organic compounds and concentrations (Bristols Medium).

Organism Tested: *Chlorella sp.*									
Experiment Number:	8			9		10		11	
Initial Concentration (mg/l)	μ, days^{-1}	$X_{10.9}$ days	$X_{20.5}$ days	μ, days^{-1}	$X_{10.9}$ days	μ, days^{-1}	$X_{10.9}$ days	μ, days^{-1}	$X_{10.9}$ days
Control I	0.53	0.099	0.450	0.66	0.318	0.53	0.135	0.38	0.164
II	0.33	0.063	0.447	0.54	0.373	0.47	0.140		
Methanol .08									
.8	0.39	0.092	0.475						
8	0.54	0.072	0.550						
80	0.68	0.195	0.715						
Ethanol .08									
.8	0.61	0.041	0.362						
8	0.45	0.105	0.538						
40	0.33	0.125	0.760						
75									
Propanal .8				0.61	0.393	0.89	0.162		
8				0.67	0.400	1.15	0.103		
80				0.83	0.263	0.27	0.049		
Acetone .08									
.8	0.21	0.103	0.275						
8	0.48	0.076	0.538						
79	0.58	0.115	0.690						
2-propanol									
.8								0.46	0.136
8								0.56	0.158
79								0.55	0.140

μ = specific growth rate
X = cell population in optimal density units (1 cm cell at 750 nm)

Table 14. Growth of algal bioassays for specific organic compounds (Bristols Medium).

Organism Tested:	*Scenedesmus sp.* & *Nitzschia sp.* mixed					*Navicula pellicula*			*Kirchneriella sp.*		
Experiment Number:	12			13		14			15		
Initial Concentration (mg/l)	μ, days^{-1}	$X_{10.9}$ days	$X_{13.9}$ days	μ, days^{-1}	$X_{10.9}$ days	μ, days^{-1}	$X_{10.9}$ days	$X_{18.4}$ days	μ, days^{-1}	$X_{10.9}$ days	$X_{13.9}$ days
Control I	1.04	0.255	0.310	0.50	0.178	0.40	0.109	0.161	1.02	0.180	0.231
II	0.96	0.235	0.292	0.65	0.140	0.42	-	0.160			
III				0.37	0.103						
Methanol .08	1.02	0.250	0.218						1.05	0.260	0.318
.8	1.00	0.230	0.272			0.48	0.081	0.164	1.28	0.240	0.338
8	0.83	0.235	0.268			0.84	0.065	0.144	1.17	0.325	0.343
80	0.36	0.078	0.110			0.52	0.310	0.318	0.45	0.190	0.252
800											
Ethanol .08	0.79	0.215	0.283						1.16	0.162	0.212
.8	1.20	0.240	0.285	0.38	0.136	0.45	0.069	0.126	1.11	0.240	0.331
8	0.82	0.215	0.242	0.31	0.142	0.47	0.068	0.113	1.39	0.290	0.357
40	1.72	0.105	0.168			0.52	0.128	0.198	0.80	0.165	0.235
79				0.30	0.316						
Propanal .8				0.57	0.190						
8				0.42	0.196						
80				0.86	0.030						
Acetone .08	1.03	0.215	0.272						1.34	0.250	0.318
.8	1.10	0.225	0.285			0.44	0.065	0.113	1.41	0.205	0.325
8	0.96	0.370	0.369			0.56	0.103	0.193	1.11	0.235	0.332
79	1.16	0.240	0.285			0.68	0.208	0.256	2.23	0.390	0.368
7,900											
2-propanol .08				0.52	0.140						
8				0.45	0.140						
79				0.46	0.270						

μ = specific growth rate
X = cell population in optimal density units (1 cm cell at 750 nm)

Table 15. Generalized responses of algae to organic compounds.

Organism	Parameter Measured	Methanol (0.1, 1, 10, 100, 1,000, 10,000, 50,000)	Ethanol (0.1, 1, 10, 100, 1,000, 10,000, 50,000)	Propanal (0.1, 1, 10, 100)	Acetone (0.1, 1, 10, 100, 1,000, 10,000, 50,000)	2-propanol (0.1, 1, 10, 100)
Selenastrum capricornutum	μ	N N D	N N D		N N D	
	X	N N D	N N D		N N D	
Chlamydomonas reinhardi	μ	N	I N D	N N D	N N	N
	X	N	N	N N D	N N	N
Chlorella sp.	μ	I	I N	I D	N I	N
	X	I	D I	I D	N I	N
Navicula pellicula	μ	N I	N		I	
	X	N I	N		I	
Kirchneriella sp.	μ	N I D	I D		I	
	X	I	N I N		I	
Scenedesmus sp. *Nitzschia sp.* (mixed)	μ	N D	N I	N I	N	N
	X	N D	N D	N D	N	N I

I = increase over control
D = decrease over control
N = no change over control
μ = growth rate (days^{-1})
X = cell population (O.D.)

The effects of acetone

Acetone inhibited the growth of *S. capricornutum* at 40,000 mg/l and increased the growth rate and net growth at 79 mg/l for *Chlorella sp. Chlorella* had a decreased growth rate and net growth at 0.8 mg/l. *Navicula pelliculla* and *Kirchneriella sp.* both showed increased growth rates and net growths for acetone concentrations up to 79 mg/l.

The effects of propanal

Propanal inhibited the normal growth of *Chlamydomonas reinhardi, Chlorella sp.*, and a mixed culture of *Scenedesmus sp.*, and *Nitzschia sp.* all at 80 mg/l.

The effects of 2-propanol

2-propanol showed no effect at the levels tested (0.8 - 79 mg/l) and on the algae considered *(Chlamydomonas reinhardi, Chlorella sp.*, and a mixed culture of *Scenedesmus sp.* and *Nitzschia sp).*

Natural Sources of the Observed Compounds

Bacteria free cultures (grown in the laboratory) of *Chlamydomonas reinhardi* were shown to produce ethanol, propanal, and acetone; therefore *Chlamydomonas sp.* is one suspected source at Hyrum for the production of these compounds. Several species of *Chlamydomonas* are known to produce organic compounds (glycollic, oxalic, and keto acids, also a polysaccharide, reference 8.5).

Acetone and acetaldehyde have been mentioned early as being produced internally by *Synura petersenii,* a taste and odor producing alga (23). Acetone, ethanol, and 2-propanal are all products of fermentation but the exact sources of the compounds at Hyrum is still pending further study; methanol is of special interest because it is not apparently a common natural product.

Methanol and ethanol have been observed as products of bacteria action on dying *Aphanizomenon* and are believed to be the chief source of these compounds as they feast on the crashing bloom mats of *Aphanizomenon* in the fall. Later as the organic matter settles to the bottom further fermentation takes place. Acetone concentrations were always higher in the bottom interstitial mud water than in the lakes.

CONCLUSIONS

Because much of this work was exploratory and the work is continuing the following conclusions are largely tentative.

1. Six organic compounds were found to be present in Hyrum Reservoir: Methanol, ethanol, propanal, and acetone were found throughout the period of study, acetaldehyde and 2-propanol were only found in trace amounts on isolated occasions. Approximate maximum concentrations were: Methanol, 40 mg/l; ethanol, 20 mg/l; propanal, 1 mg/l; acetone, 35 mg/l; 2-propanol and acetaldehyde, trace.
2. The compounds were produced in the reservoir since they were not found to be present in the reservoir influent. *Chlamydomonas* may be a producer of at least three of the six compounds observed (ethanol, propanal, and acetone). Bacterial action is suggested as a possible source for the compounds; methanol, ethanol, and acetone.
3. The compounds observed may not affect the organisms studied at the levels found in the lake; however, subtle effects of stimulation and/or inhibition may be indicated.
4. The development of blooms or decreases in populations of specific organisms may be indicated by the presence of specific compounds (ethanol, methanol, acetone).
5. The results indicate that at high concentrations ($>$ 8,000 mg/l), the compounds were toxic to *Selenastrum capricornutum* being effective in decreasing order, ethanol, methanol, and acetone. Toxicity was apparently species specific.

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Appendix A

The Effects of Organic Compounds on Certain Life Forms

These tables are an expansion of the results found in the literature cited in Table 1 (natural occurring organics and their effects). Column one lists the compound studied. Column two lists the source of the compound (naming the algae or bacteria producing the compound), and the reference to the observance of the compound in nature; the group producing the compound studied (either algae or bacteria); and the reference citing the organism producing the compound studied. For example, the first compound actidone (also known as cycloheximide) is produced by a bacterium, *Streptomyces griseus;* references citing this production are 32.8 and 120. There is no citing of the natural observation of actidone listed.

Further laboratory conditions of the test are listed in columns four through nine, the organisms tested are listed in column three and the studies cited are listed in column ten.

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		MYXOPHYCEAE							
Actidone (cycloheximide)	Streptomyces griseus (--; Bacteria; 32.8, 120)	Anabaena cyclindrica	200	N	3 wk	culture solution (flask)	macro and/or microscopic comparison with control	25°C; --; 100-250 ft-c, continuous	128
"	"	" "	200	N	1, 2, 3 wk	agar slant	"	24°C; --; 200 ft-c, 12 hrs. daily	46
"	"	Aphanocapsa sp	200	N	3 wk	"	"	25°C; --; 100-250 ft-c, continuous	128
"	"	Coelosphaerium kuetzeingianum	200	N	"	culture solution (flask)	"	"	128
"	"	Cylindrospermum licheniforme B & F	2	P	3, 7 da	culture solution (25 ml Erlen-meyer flask)	"	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	" "	2	N	14, 21 da	"	"	"	81
"	"	Gloeothece rupestris	50	N	2 mo	agar slant	"	25°C; --; 200 ft-c, 12 hr daily	128
"	"	" "	100	P	"	"	"	"	128
"	"	" "	200	P	"	"	"	"	128
"	"	Gloeotrichia echinulata	200	N	3 wk	culture solution (flask)	"	"	128
"	"	Lyngbya sp	200	N	"	"	"	"	128
"	"	Microcystis aeruginosa	200	N	"	"	"	"	128
"	"	" "	2	N	3, 7, 14, 21 da	culture solution (25 ml Erlen-meyer flask)	"	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	Oscillatoria tennis	200	N	3 wk	culture solution (flask)	"	25°C; --; 100-250 ft-c, continuous	128
"	"	Phormidium lovedarum	200	N	"	"	"	"	128
"	"	" " sp	200	N	1, 2, 3 wk	" (150 x 16 mm test tube)	"	24°C; --; 200 ft-c, 12 hr daily	46

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		MYXOPHYCEAE (Continued)							
Actidone (cycloheximide)	Streptomyces griseus (--; Bacteria; 32.8, 120)	Tolypothrix tennis	200	N	3 wk	agar slant	macro and/or microscopic comparison with control	25°C; --; 100-250 ft-c, continuous	128
"	"	" " sp	200	N	"	culture solution (flask)	"	"	128
"	"	CHLOROPHYCEAE Ankistrodesmus plcatus	1	T	"	"	"	"	128
"	"	Chlamydomonas aglaeformis	2	P	"	culture solution (150 x 16 mm test tube)	"	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	50	T (algicidal)	"	"	" (subculture grown for one week)	"	46
"	"	" "	50	T	"	culture solution (flask)	"	25°C; --; 100-250 ft-c, continuous	128
"	"	Chlorella pyrenoidosa	20	T	"	"	"	"	128
"	"	" "	.25	T	15 min	culture solution	^{14}C-phenyl-alanine and ^{14}C-adenine uptake	25°C; --; darkness	72
"	"	" variegates B	2	T	3 da	culture solution (25 ml Erlen-meyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	" " "	2	P	7 da	"	"	"	81
"	"	" " "	2	N	14, 21 da	"	"	"	81
"	"	Chlorococcum minutum	50	T	3 wk	culture solution (flask)	"	25°C; --; 100-250 ft-c, continuous	128
"	"	Coccomyxa elongata	50	T	"	"	"	"	128
"	"	Haematococcus locustris	.001	N	16 da	"	"	" (500 cells/ml inoculated)	128

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE (Continued)							
Actidone (cycloheximide)	Streptomyces griseus (--; Bacteria; 32.8, 120)	Haematococcus locustris	.002	N	16 da	culture solution (flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (500 cell/ml inoculated)	81
"	"	" "	.004	340[a]	"	"	"	"	128
"	"	" "	.008	150[a]	"	"	"	"	128
"	"	" "	.016	6[a]	"	"	"	"	128
"	"	" "	.032	T	"	"	"	"	128
"	"	" "	.0625	T	"	"	"	"	128
"	"	" "	.25	T	"	"	"	"	128
"	"	" "	1.0	T	"	"	"	"	128
"	"	" "	.015	T	24 day	"	"	22°C; --; 140 ft-c, continuous (250,000 cell/ml inoculated)	128
"	"	" "	.0625	T (algistatic)	"	"	" (subculture grown for 6 wk)	"	128
"	"	" "	.25	"	"	"	macro and/or microscopic comparison with control	"	128
"	"	" "	.25	"	"	"	"	"	128
"	"	" "	1.0	"	"	"	"	"	128
"	"	" "	1.0	"	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	" (subculture grown for 1 wk)	24°C; --; 200 ft-c, 12 hr daily	46
"	"	Hormidium subtile	20	T	3 wk	culture solution (flask)	macro and/or microscopic comparison with control	25°C; --; 100-250 ft-c, continuous	128
"	"	Raphidonema longiseta	1	T	"	"	"	"	128
"	"	Scenedesmus obliquus	1	T	"	"	"	"	128

[a] cell factor increase

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE (Continued)							
Actidone (cycloheximide)	Streptomyces griseus (--; Bacteria; 32.8, 120)	Scenedesmus obliquus	2	T	3, 7, 14, 21 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	Stichococcous bacillaris	50	T	3 wk	culture solution (flask)	"	25°C; --; 100-250 ft-c, continuous	
		CHRYSOPHYCEAE							
"	"	Gomphonema parvulum	2	N	3 da	culture solution (25 ml Erlenmeyer flask)	"	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	" "	2	T	7, 14, 21 da	"	"	"	81
"	"	Navicula minima	20	T	3 wk	culture solution (flask)	"	25°C; --; 100-250 ft-c, continuous	128
"	"	" pelliculosa	2	P	1, 2 wk	agar slant	"	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	2	T	3 wk	"	"	"	46
"	"	" "	20	T	1, 2 wk	"	"	"	46
"	"	Nityschia palea (Ktz)	2	T	3, 7, 14, 21 da	culture solution (25 ml Erlenmeyer flask)	"	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated	81
"	"	Polydriella helvetica	20	P	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	"	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	200	T	1 wk	"	"	"	46
"	"	" "	50	T	2, 3 wk	"	"	"	46
"	"	Tribonema aequole	1	T	3 wk	culture solution (flask)	"	25°C; --; 100-250 ft-c, continuous	128

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		EUGLENOPHYCEAE							
Actidone (cycloheximide)	Streptomyces griseus --; Bacteria; 32.8, 120)	Euglena gracilis "Z"	1	P	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	"	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	100	T	1, 2, 3 wk	"	"	"	46
		MYXOPHYCEAE							
Aerosporin (polymyxin B sulphate)	Bacillus polymyxa (B. aerosporus) (--; Bacteria; 13, 102, 28.3)	Anabaena cylindrica	200	N	1, 2, 3 wk	agar slant (cyanophycean agar)	"	"	46
"	"	" variabilis	5	T	5 da	culture solution (inorganic, 500 ml Erlenmeyer flask)	light transmittance at 550 mμ with spectrophotometer	25°C; 7; 700-1000 ft-c, continuous	36
"	"	Cylindrospermun licheniforme B & F	2	P	3, 7 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	Microcystis aeruginosa	2	T	3, 7, 14, 21 da	"	"	"	81
"	"	Nostoc sp	10-20 units/ml	T (algicidal)	1 mo	"	"	22°C; 8.2; 140 ft-c, continuous	33
"	"	Phormidium sp	20-40 units/ml	"	"	"	"	"	33
"	"	" "	2	P	1 wk	culture solution (150 x 16 mm test tube)	"	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	20	T (algicidal)	1 mo	"	"	"	46

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays — Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Aerosporin (polymyxin B sulphate)	Bacillus polymyxa (B. aerosporus) (--; Bacteria; 13, 102, 28.3)	Chlomydomonas aglaeformis	1	P	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	50	T (algicidal)	"	"	"	"	46
"	"	Chlomydomonas sp	10-20 units/ml	"	1 mo	culture solution (24 ml Erlenmeyer flask)	"	22°C; 7.8; 140 ft-c, continuous	33
"	"	Chlorella pyrenoidosa	5	T	5 da	culture solution (400 ml Erlenmeyer flask)	optical density at 550 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	.5	P(30%)[b]	40 hr	culture solution (flask)	optical density at 610 mμ	25°C; 5.1; 700-1000 ft-c, continuous	106.5
"	"	" "	.5	N(0%)[b]	"	"	"	25°C; 6.0; 700, 1000 ft-c, continuous	106.5
"	"	" "	.5	N(0%)[b]	"	"	"	25°C; 7.4; 700-1000 ft-c, continuous	106.5
"	"	" "	5	T(100%)[b]	"	"	"	25°C; 5.1; 700-1000 ft-c, continuous	106.5
"	"	" "	5	T(100%)[b]	"	"	"	25°C; 6.0; 700-1000 ft-c, continuous	106.5
"	"	" "	5	P(93%)[b]	"	"	"	25°C; 7.4; 700-1000 ft-c, continuous	106.5

(%)[b] percent inhibition comparison with control

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE (Continued)							
Aerosporin (polymyxin B sulphate)	Bacillus polymyxa (B. aerosporus) (--; Bacteria; 13, 102, 28.3)	Chlorella variegata	2	T	3, 7, 14, 21 da	culture solution (25 ml Erlan-meyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	Chloroccum aplanasporum	300 units	T	0-3 wks	agar medium	examination of zone of inhibition (dish technique)	22°C; --; 250-300 ft-c, 12 hrs. daily	18
"	"	" diplobionticum	"	"	"		"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmoticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE (Continued)							
Aerosporin (polymyxin B sulphate)	Bacillus polymyxa (B. aerosporus) (--; Bacteria; 13, 102, 28.3)	Scenedesmus obliquus	2	T	3, 7, 14 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	"	2	N	21 da	"	"	"	81
"	"	"	40	T	5 da	culture solution (500 ml Erlenmeyer flask) (inorganic media)	% transmittance (spectrophotometer) 550 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	"	1000	P	5 da	culture solution (500 ml Erlenmeyer flask) (organic media)	"	"	36
"	"	SP	80 units/ml	N	1 mo	culture solution (25 ml Erlenmeyer flask	macro and/or microscopic comparison with control	22°C; 7.8; 140 ft-c, continuous	33
		CHRYSOPHYCEAE							
"	"	Gomphonema sp	5-10 units/ml	T	1 mo	"	"	22°C; 7.8; 140 ft-c, continuous	33
"	"	Gomphonema parvulum	2	T	3, 7, 14, 21 da	"	"	22°C; --; 140 ft-c, continuous; (125,000 ml inoculated)	81
"	"	Navicula pelliculosa	200	N	1, 2, 3 wk	agar medium	"	24°C; --; 200 ft-c, 12 hrs daily	46
"	"	Nitzschia palea	2	T	3, 7, 14, 21 da	culture solution (25 ml Erlenmeyer flask)	"	22°C; --; 140 ft-c, continuous; (125,000 ml inoculated)	81
"	"	Nitzschia sp	10-20 units/ml	T	1 mo	" "	"	22°C; 7.8; 140 ft-c, continuous	33
"	"	Polydriella helvetica	200	N	1, 2, 3wk	culture solution (150 x 16 mm test tube)	"	24°C; --; 200 ft-c, 12 hrs daily	46

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		EUGENOPHYCEAE (Continued)							
Aerosporin (polymyxin B sulphate)	Bacillus polymyxa (B. aerosporus) (--; Bacteria; 13, 102, 28.3)	Euglena gracilis "Z"	200	N	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hrs. daily	46
		BACTERIUM							
"	"	Archromobacter sp	1.25	T	2 da	culture solution (500 ml Erlen-meyer flask)	% transmittance (spectrophoto-meter) 615 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	5	T	3 da	"	"	"	36
"	"	Flavabacterium sp	5	T	3 da	"	"	"	36
"	"	Pseudomonas sp	5	T	3 da	"	"	"	36
		MYXOPHYCEAE							
Amphotericin	Streptomyces nodosus (--; Bacteria; 114.8)	Anabaena cylindrica	200	N	1, 2, 3 wk	agar medium	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hrs. daily	46
"	"	Phormidium sp	200	N	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	"	"	46
		CHLOROPHYCEAE							
"	"	Chlamydomonas agloeaformis	200	N	1, 2, 3 wk	"	"	"	46
"	"	Chlorococcum aplanosporum	100 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	100 meq	T	0-3 wk	"	"	"	18
"	"	" echinozygotum	100 meq	T	0-3 wk	"	"	"	18
"	"	" ellipsoideum	100 meq	N	0-3 wk	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE (Continued)							
Amphotericin	Streptomyces nodosus (--; Bacteria; 114.8)	Chlorococcum hypnosporum	100 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" intermedium	100 meq	T	0-3 wk	"	"	"	18
"	"	" macrostigmatism	100 meq	N	0-3 wk	"	"	"	18
"	"	" minutum	100 meq	P	0-3 wk	"	"	"	18
"	"	" multinucleatum	100 meq	N	0-3 wk	"	"	"	18
"	"	" oleofaciens	100 meq	N	0-3 wk	"	"	"	18
"	"	" perforatum	100 meq	T	0-3 wk	"	"	"	18
"	"	" pinguideum	100 meq	T	0-3 wk	"	"	"	18
"	"	" punctatum	100 meq	N	0-3 wk	"	"	"	18
"	"	" scabellum	100 meq	N	0-3 wk	"	"	"	18
"	"	" tetrasporum	100 meq	N	0-3 wk	"	"	"	18
"	"	" vacualatum	100 meq	N	0-3 wk	"	"	"	18
"	"	" wimmeri	100 meq	T	0-3 wk	"	"	"	18
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	2	P	1 wk	"	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	100	T (algicidal)	1 wk	"	"	"	46
"	"	" "	50	"	2, 3 wk	"	"	"	46
"	"	Polydriella hehetica	200	N	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	"	"	46

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		EUGLEMOPHYCEAE (Continued)							
Amphotericin	Streptomyces nodosus (--; Bacteria; 114.8)	Euglena gracilis sp	200	N	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hrs. daily	46
		MYXOPHYCEAE							
Anisomycin	Streptomyces griseolus " roseochromogenes (--; Bacteria; 114.8)	Anabaena cylindrica	200	N	1,2, wk	agar medium	"	"	46
"	"	Phormidium sp	200	N	1,2, 3 wk	culture solution (150 x 16 mm test tube)	"	"	46
		CHLOROPHYCEAE							
"	"	Chlamydomonas agloeoformis	20	P	1, 2 wk	"	"	"	46
"	"	" "	50	P	3 wk	"	"	"	46
"	"	" "	100	T (algicidal)	1, 2, 3 wk	"	"	"	46
"	"	Haematococcus lacustris	20	P	1,2 wk	agar medium	"	"	46
"	"	" "	100	T (algicidal)	1,2 wk	"	"	"	46
"	"	" "	50	"	3 wk	"	"	"	46
		CHRYSOPHYCEAE							
"	"	Navicula selliculosa	2	P	1 wk	"	"	"	46
"	"	" "	100	T (algicidal)	1 wk	"	"	"	46
"	"	" "	50	"	2, 3 wk	"	"	"	46
"	"	Polydriella helvetica	200	N	1,2, 3 wk	culture solution (150 x 16 mm test tube)	"	"	46

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		EUGLENOPHYCEAE	(Continued)						
Anisomycin	Streptomyces griseolus Streptomyces roseochromogenes (--; Bacteria; 114.8)	Euglena gracilis "Z"	200	N	1,2,3 wk	culture solution (140 x 16 mm test tube)	macro and or microscopic comparison with control	24°C; --; 200 ft-c, 12 hrs. daily	46
		MYXOPHYCEAE							
Aureomycin (chlortetracycline)	Streptomyce aureofaciens (--; Bacteria; 28.3)	Calothrix sp	2 µg	N	1 mo	culture solution (25 ml Erlen-meyer flask)	" (disk method zone of inhibition)	22°C; 8.2; 140 ft-c, continuous	33
"	"	" "	20 µg	N	1 mo	"	"	"	33
"	"	Microcystis sp	2 µg	T (18)	1 mo	"	"	"	33
"	"	" "	20 µg	T (13)	1 mo	"	"	"	33
"	"	Nostoc sp	2 µg	N	1 mo	"	"	"	33
"	"	" "	20 µg	N	1 mo	"	"	"	33
"	"	Phormidium sp	2 µg	N	1 mo	"	"	"	33
"	"	" "	20 µg	N	1 mo	"	"	"	33
"	"	Symploca sp	2 µg	T (15)[c]	1 mo	"	"	"	33
"	"	" "	20 µg	T (20)[c]	1 mo	"	"	"	33
		CHLOROPHYCEAE							
"	"	Ankistrodesmus sp	2 µg	N	1 mo	"	"	"	33
"	"	" "	20 µg	N	1 mo	"	"	"	33
"	"	Chlamydomonas sp	2 µg	N	1 mo	"	"	"	33
"	"	" "	20 µg	T (12)[c]	1 mo	"	"	"	33

( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Aureomycin (chlortetracycline)	Streptomyces aureofaciens (--; Bacteria; 28.3	Chlorococcum oplanosporum	30 units	N	0-3 wk	agar medium	zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	N	"	"	"	"	18
"	"	" echinozygotum	"	N	"	"	"	"	18
"	"	" ellipsoideum	"	N	"	"	"	"	18
"	"	" hypnosporum	"	N	"	"	"	"	18
"	"	" intermedium	"	T	"	"	"	"	18
"	"	" macrostigmaticum	"	N	"	"	"	"	18
"	"	" minutum	"	N	"	"	"	"	18
"	"	" multinucleatum	"	N	"	"	"	"	18
"	"	" oleofaciens	"	N	"	"	"	"	18
"	"	" perforatum	"	N	"	"	"	"	18
"	"	" pinguideum	"	N	"	"	"	"	18
"	"	" punctatum	"	N	"	"	"	"	18
"	"	" scabellum	"	N	"	"	"	"	18
"	"	" tetrasporum	"	T	"	"	"	"	18
"	"	" vacuolatum	"	N	"	"	"	"	18
"	"	" wimmeri	"	N	"	"	"	"	18
"	"	Oocystis sp	2 µg	N	1 mo	culture solution (25 ml Erlenmeyer flask)	examination of zone of inhibition (disk method)	22°C; --; 7.8; 140 ft-c, continuous	33
"	"	" "	20 µg	N	1 mo	"	"	"	33

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound					Conditions Temp.; pH; Light	
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured		
		MYXOPHYCEAE: (Continued)							
Bacitracin	Bacillus subtilis (--; Bacteria; 39.5)	Anabaena cylindrica	2	P	1, 2 wk	agar medium	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	1	P	3 wk	"	" "	"	46
"	"	" "	20	T (algicidal)	1, 2 wk	"	" "	"	46
"	"	" "	2	"	3 wk	"	" "	"	46
"	"	" variabilis	10	P	5 da	culture solution (400 ml Erlen-meyer flask)	% transmittance (spectophoto-meter 550 mμ)	25°C; 7; 700-1000 ft-c, continuous	36
"	"	Calothrix sp	2 units	N	1 mo	agar medium	macro and/or microscopic comparison with control (zoned inhibition disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	" "	20 units	T(30)[c]	1 mo	"	" "	"	33
"	"	Microcystis sp	2 units	T(25)[c]	1 mo	"	" "	"	33
"	"	" "	20 units	T(50)[c]	1 mo	"	" "	"	33
"	"	Nostoc sp	2 units	T(14)[c]	1 mo	"	" "	"	33
"	"	" "	20 units	T(46)[c]	1 mo	"	" "	"	33
"	"	Phormidium sp	2	T (algicidal)	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	" " (subcultures grown 1 wk)	24°C: --; 200 ft -c, 12 hrs. daily	46
"	"	" "	2 units	N	1 mo	agar medium	macro and/or microscopic comparison with control (zone of inhibition disk technique)	22°C; 8.2; 140 ft-c, continuous	33

T( )[c] zone in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		MYXOPHYCEAE: (Continued)							
Bacitracin	Bacillus subtilis (--; Bacteria; 39.5)	Phormidium sp	20 units	T(20)[c]	1 mo	agar medium	macro and/or microscopic comparison with control (zone of inhibition disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	Symploca sp	2 units	T(15)[c]	1 mo	"	"	"	33
"	"	" "	20 units	T(26)[c]	1 mo	"	"	"	33
		CHLOROPHYCEAE							
"	"	Ankistrodesmus sp	2	T(11)[c]	1 mo	"	"	"	33
"	"	" "	20	T(9)[c]	1 mo	"	"	"	33
"	"	Chlamydomonas agloeoformis	200	N	1,2,3 wk	culture solution (150 x 16 mm test tube)	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hrs. daily	46
"	"	" " sp	2	N	1,2,3 wk	culture solution (25 ml Erlen-meyer flask)	macro and/or microscopic comparison with control (zone of inhibition disk technique)	22°C; 7.8: 140 ft-c, continuous	33
"	"	" " "	20	N	1,2,3 wk	"	"	"	33
"	"	Chlorella pyrenoidosa	1000	N	5 da	culture solution (500 ml flask) (inorganic media)	% transmittance (spectrophoto-) meter 550 mμ)	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	1000	P	5 da	culture solution (500 ml Erlen-meyer flask) (organic media)	"	"	36
"	"	" "	500	P(11%)[b]	40 hr	culture solution (flask)	optical density (at 610 mμ)	25°C; 5.1; ---;	106.5
"	"	" "	500	N(0%)[b]	40 hr	"	"	25°C; 7.4: --;	106.5

(%)[b] percent inhibition comparison with control T( )[c] zone in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE (Continued)							
Bacitracin	Bacillus subtilis (--; Bacteria; 39.5)	Chlorella pyrenoidosa	1000	P(53%)[b]	40 hr	culture solution (flask)	optical density at 610 mμ)	25°C; 5.1: --·	106 5
"	"	" "	1000	N(0%)[b]	40 hr	"	"	25°C; 7.4; --;	106.5
"	"	" "	5000	T(100%)[b]	40 hr	"	"	25°C; 5.1; --;	106.5
"	"	" "	5000	P(19%)[b]	40 hr	"	"	25°C; 7.4; --;	106.5
"	"	Chlorococcum aplanosporum	10 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --· 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	10 meq	N	0-3 wk	"	"	"	18
"	"	" echimozygotum	10 meq	N	0-3 wk	"	"	"	18
"	"	" ellipsoideum	10 meq	N	0-3 wk	"	"	"	18
"	"	" hypnosporum	10 meq	N	0-3 wk	"	"	"	18
"	"	" intermedium	10 meq	N	0-3 wk	"	"	"	18
"	"	" macrostigmaticum	10 meq	N	0-3 wk	"	"	"	18
"	"	" minutum	10 meq	N	0-3 wk	"	"	"	18
"	"	" multinucleatum	10 meq	N	0-3 wk	"	"	"	18
"	"	" oleofaciens	10 meq	N	0-3 wk	"	"	"	18
"	"	" perforatum	10 meq	N	0-3 wk	"	"	"	18
"	"	" pinguideum	10 meq	N	0-3 wk	"	"	"	18
"	"	" punctatum	10 meq	N	0-3 wk	"	"	"	18
"	"	" scabellum	10 meq	N	0-3 wk	"	"	"	18
"	"	" tetrasporum	10 meq	N	0-3 wk	"	"	"	18

[b] ( ) % inhibition compared with control

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays — Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE (Continued)							
Bacitracin	Bacillus subtilis (--; Bacteria; 39.5)	Chlorococcum vacuolatum	10 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" wimmeri	10 meq	N	0-3 wk	"	"	"	18
"	"	Haematococcum locustris	200	N	1, 2, 3 wk	"	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	Scenedesmus obliquus	1000	N	5 da	culture solution (500 ml Erlenmeyer flask)	"	25°C; 7; 700-1000 ft-c, continuous	36
"	"	Oocystis	2 units	N	1 mo	agar medium	examination of zone of inhibition	22° C; 7.8; 140 ft-c, continuous	33
"	"	" "	20 units	N	1 mo	"	"	"	33
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	50	P	1 wk	"	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	
"	"	" "	100	T (algicidal)	1 wk.	"	"	"	46
"	"	" "	50	"	1 wk.	"	"	"	46
"	"	Polydriella helvetica	200	N	1, 2,3 wk.	culture solution (150 x 16 mm test tube)	"	"	46
		EUGLENOPHYCEAE							
"	"	Euglena gracilis "Z"	200	N	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	"	"	46
"	"	BACTERIUM Archromobacter sp 1	1000	P	2 da.	culture solution (500 ml Erlenmeyer flask)	% transmittance (spectrophotometer 615 mμ)	25°C; 7; 700-1000 ft-c, continuous	36

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		BACTERIUM							
Bacitracin	Bacillus subtilis (--; Bacteria 39.5)	Archromobacter sp2	1000	N	3 da	culture solution (500 ml Erlen-meyer flask)	% transmittance (spectrophoto-meter 615 mμ)	25°C; 7; 700-1000 ft-c, continuous	36
"	"	Flavabacterium sp	.01	P	5 da	"	"	"	36
"	"	" "	1	T	5 da	"	"	"	36
"	"	Pseudomonas sp	1000	N	3 da	"	"	"	36
		CHLOROPHYCEAE							
Carbomycin (Magnamycin)	Streptomyces holstedii " hygroscopi " albireticuli (--; Bacteria; 39.5)	Chlorella pyrenoidosa	100	T	40 hr	culture solution (flask)	optical density (at 610 mμ)	25°C; 7.4; --;	106.5
"	"	" "	100	P(98%)[b]	40 hr	"	"	25°C; 6.0; --;	106.5
"	"	" "	100	P(92%)[b]	40 hr	"	"	25°C; 5.1; --;	106.5
"	"	Chlorococcum aplanosporum	15 meq	N	0-3 wk	agar medium	examination of zone of inhibit-ion (disk tech-nique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18

(%)[b] % inhibition compared to control

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE: (Continued)							
Carbomycin (magnamycin)	Streptomyces holstedii " hygroscopi " albireticuli (--; Bacteria; 39.5)	Chlorococcum pinguideum	15 meq	T(?)[d] P	0-3 wk	agar medium	examination of zone of inhibition (disk technique	22°C; --;250-300 ft-c, 12 hrs. daily	18
"	"	" punctatum	"	T(?)[d] N	"	"	"	"	18
"	"	" scabellum	"	T(?)[d] P	"	"	"	"	18
"	"	" tetrasporum	"	T(?)[d] N	"	"	"	"	18
"	"	" vacuolatum	"	N	"	"	"	"	18
"	"	" wimmeri	"	T	"	"	"	"	18
		MYXOPHYCEAE							
Chloramphenieol (Chloromycetin)	Streptomyces venezuelae (--; Bacteria; 28.3)	Anabeana variabilis	1	P	5 da	culture solution (500 ml Erlenmeyer flask)	% transmittance (spectrophotometer 550 mμ)	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	10	T	5 da	"	"	" "	36
"	"	Calothrix sp	2 μg	N	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	" "	20 μg	N	"	"	"	"	33
"	"	Microcystis sp	2 μg	T(20)[c]	"	"	"	"	33
"	"	Microcystis sp	20 μg	T(14)[c]	"	"	"	"	33
"	"	Nostoc sp	2 μg	N	"	"	"	"	33
"	"	" "	20 μg	N	"	"	"	"	33
"	"	Phormidium sp	2 μg	N	"	"	"	"	33
"	"	" "	20 μg	N	"	"	"	"	33
"	"	Symploca sp	2 μg	T(11)[c]	"	"	"	"	33
"	"	" "	20 μg	T(5)[c]	"	"	"	"	33

( )[c] zone in millimeters (?)[d] both results reported

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE (Continued)							
Chloramphenical (Chloromycetin)	Streptomyces venezuelae (--; Bacteria; 28.3)	Ankistrodesmus sp	20 µg	N	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	Chlamydomonas sp	20 µg	N	"	"	"	"	33
"	"	Chlorella pyenoidosa	100	P	5 da	culture solution (organic medium) (500 ml Erlenmeyer flask)	% transmittance (spectrophotometer 550 mµ)	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	1000	T	"	" "	"	"	36
"	"	" "	100	T	"	culture solution (inorganic medium) (500 ml Erlenmeyer flask)	"	"	36
"	"	Chlorococcum aplanosporum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE (Continued)							
Chloramphenical (Chloromycetin)	Streptomyces venezuelae (--; Bacteria; 28.3)	Chlorococcum perforatum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18
"	"	Scenedesmus obliquus	10	P	5 da	culture solution (500 ml Erlen-meyer flask)	% transmittance (spectrophoto-meter 550 mμ)	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	100	T	"	"	"	"	36
"	"	Oocystis sp	20 μg	N	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 7.8; 140 ft-c, continuous	33
		BACTERIUM Archromobacter sp 1	10	T	2 da	culture solution (500 ml Erlen-meyer flask)	% transmittance (spectrophoto-meter 550 mμ)	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" sp 2	100	T	3 da	"	"	"	36
"	"	Flavabacterium sp	1	P	5 da	"	"	"	36
"	"	" "	10	T	"	"	"	"	36
"	"	Pseudomonas sp	1000	T	3 da	"	"	"	36

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE (Continued)							
Colistin Sulfate (polymyxin E)	Bacillus polymya " colistinus (--; Bacteria; 39.5)	Chlorococcum aplanosporum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE (Continued)							
Cycloserine (chelation with some metals, reg. 39.5, also unstable in acid solution)	Streptomyces lavendulae " orchidaceus " garyphalus " roseochromogenus (--; Bacteria; 39.5)	Chlorococcum aplanosporum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE (Continued)							
Demethylchlortetracycline (DMTC)	Streptomyces aureofaciens (--; Bacteria; 39, 6)	Chlorococcum aplanosporum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hrs. daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	T	"	"	"	"	18
"	"	" vacuolatum	"	N	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE (Continued)							
Dihydrostreptomycin	Streptomyces humidus (--; Bacteria; 39.6)	Chlorococcum aplanosporum	10 meq	T	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hrs. daily	18
"	"	" diplobionticum	"	T(?)[d]N	"	"	"	"	18
"	"	" echinozygotum	"	T(?)[d]N	"	"	"	"	18
"	"	" ellipsoideum	"	T(?)[d]N	"	"	"	"	18
"	"	" hypnosporum	"	T(?)[d]P	"	"	"	"	18
"	"	" intermedium	"	T	"	"	"	"	18
"	"	" macrostigmaticum	"	T(?)[d]N	"	"	"	"	18
"	"	" minutum	"	T(?)[d]N	"	"	"	"	18
"	"	" multinucleatum	"	T	"	"	"	"	18
"	"	" oleofaciens	"	P(?)[d]T	"	"	"	"	18
"	"	" perforatum	"	T(?)[d]N	"	"	"	"	18
"	"	" pinguideum	"	T	"	"	"	"	18
"	"	" punctatum	"	T	"	"	"	"	18
"	"	" scabellum	"	T(?)[d]N	"	"	"	"	18
"	"	" tetrasporum	"	T	"	"	"	"	18
"	"	" vacuolatum	"	T(?)[d]N	"	"	"	"	18
"	"	" wimmeri	"	T(?)[d]N	"	"	"	"	18
Erythromycin	Streptomyces erythreus (--; Bacteria; 28.3 39.5)	Chlorella pyrenoidosa	36	N(0%)[b]	40 hrs.	culture solution (flask)	optical density (610 mμ)	25°C; 5.1; --	106.5
"	"	" "	36	N(0%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	36	P(2%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	145	P(15%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	145	P(37%)[b]	"	"	"	25°C; 7.4; --	106.5

(%)[b] percent inhibition comparison with control (?)[d] both results reported

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE (Continued)							
Erythromycin	Streptomyces erythreus (--; Bacteria; 28.3, 39.5)	Chlorella pyrenoidosa	725	P(63%)[b]	40 hrs.	culture solution (flask)	optical density (610 mμ)	25°C; 5.1; --	106.5
"	"	" "	725	P(78%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	725	P(87%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	Chlorococcum aplanosporum	15 meq	T(?)[d]N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; 250-300 ft-c; 12 hr daily	18
"	"	" diplobionticum	"	T(?)[d]N	"	"	"	"	18
"	"	" echinozygotum	"	T(?)[d]N	"	"	"	"	18
"	"	" ellipsoideum	"	T(?)[d]N	"	"	"	"	18
"	"	" hypnosporum	"	T(?)[d]P	"	"	"	"	18
"	"	" intermedium	"	T	"	"	"	"	18
"	"	" macrostigmaticum	"	T(?)[d]N	"	"	"	"	18
"	"	" minutum	"	T(?)[d]N	"	"	"	"	18
"	"	" multinucleatum	"	T	"	"	"	"	18
"	"	" oleofaciens	"	P(?)[d]T	"	"	"	"	18
"	"	" perforatum	"	T(?)[d]N	"	"	"	"	18
"	"	" pinguideum	"	T	"	"	"	"	18
"	"	" punctatum	"	T	"	"	"	"	18
"	"	" scabellum	"	T(?)[d]N	"	"	"	"	18
"	"	" tetrasporum	"	T	"	"	"	"	18
"	"	" vacuolatum	"	T(?)[d]N	"	"	"	"	18
"	"	" wimmeri	"	T(?)[d]N	"	"	"	"	18

(%)[b] % inhibition, comparison with control (?)[d] both results reported

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		MYXOPHCEAE							
Gliotoxin	Trichoderma viride (--; Bacteria; 39.6)	Nostoc sp	125-250	T	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 7.8; 140 ft-c, continuous	33
"	"	Phormidium sp	8-16	T	"	"	"	"	33
		CHLOROPHYCEAE:							
"	"	Chlamydomonas sp	31-62	T	"	"	"	"	33
"	"	Chlorella pyrenoidosa	2	P(93%)[b]	40 hr	culture solution (flask)	optical density (610 mμ)	25°C; 5.1; --	106.5
"	"	" "	2	P(92%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	2	P(95%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	2	P(75%)[e]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	2	P(82%)[e]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	2	P(57%)[e]	"	"	"	25°C; 7.4; --	106.5
"	"	Scenedesmus sp	125-250	T	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 7.8; 140 ft-c, continuous	33
		CHRYSOPHYCEAE							
"	"	Gomphonema sp	0 - 8	T	"	"	"	"	33
"	"	Nitzschia sp	0 - 8	T	"	"	"	"	33
		MYXOPHCEAE							
Gramicidin S	Bacillus brevis (--; Bacteria; 11.22, 39.5)	Anabaena variabilis	100	P	5 da	culture solution (25 ml Erlenmeyer flask)	"	25°C; 7; 700-1000 ft-c, continuous	36
"	"	"	1000	T	"	"	"	"	36
		CHLOROPHYCEAE							
"	"	Chlorella pyrenoidosa	100	P	"	"	"	"	36
"	"	" "	1000	P	"	(organic media) "	"	"	36
"	"	" "	1000	N	"	culture solution (25 ml Erlenmeyer flask) (inorganic media)	"	"	36

[b] (%) inhibition, comparison with control

[e] (%) aerated 24 hrs before experiment

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Gramicidin S	Bacillus brevis (--; Bacteria; 11.22, 39.5)	Scenedesmus obliquus	1000	N	5 da	culture solution (25 ml Erlenmeyer flask)	examination of zone of inhibition (disk technique)	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	"	N	"	"	"	"	36
		BACTERIUM							
"	"	Archromobacter sp 1	"	N	2 da	"	"	"	36
"	"	" sp 2	100	N	3 da	"	"	"	36
"	"	Flavabacterium sp	100	P	5 da	"	"	"	36
"	"	" "	1000	T	5 da	"	"	"	36
"	"	Pseudomonas sp	1000	N	3 da	"	"	"	36
		CHLOROPHYCEAE							
Kanamycin	Streptomyces kanamycetius (--; Bacteria; 114.8)	Chlorococcum aplanosporum	30 meq	T	0-3 wk	agar medium	"	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	T	"	"	"	"	18
"	"	" echinozygotum	"	N	"	"	"	"	18
"	"	" ellipsoideum	"	N	"	"	"	"	18
"	"	" hypnosporum	"	T	"	"	"	"	18
"	"	" intermedium	"	T	"	"	"	"	18
"	"	" macrostigmaticum	"	T	"	"	"	"	18
"	"	" minutum	"	T	"	"	"	"	18
"	"	" multinucleatum	"	T	"	"	"	"	18
"	"	" oleofaciens	"	T	"	"	"	"	18
"	"	" perforatum	"	T	"	"	"	"	18
"	"	" pinguideum	"	T	"	"	"	"	18
"	"	" punctatum	"	T	"	"	"	"	18
"	"	" scabellum	"	T	"	"	"	"	18
"	"	" tetrasporum	"	T	"	"	"	"	18
"	"	" vacuolatum	"	T	"	"	"	"	18
"	"	" w immeri	"	T	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		MYXOPHYCEAE							
Neomycin	Streptomyces fradiae (--; Bacteria; 28.3)	Nostos sp	0 - 4	T	5 da	culture solution (25 ml Erlenmeyer flask)	examination of zone of inhibition (disk technique)	22°C; 8.2, 140 ft-c, continuous	33
"	"	Phormidium sp	"	T	"	"	"	"	33
		CHLOROPHYCEAE							
"	"	Chlamydomonas	"	T	"	"	"	"	33
		Chlorococcum aplanoporum	30 meq	T	0-3 wk	agar medium	"	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	T	"	"	"	"	18
"	"	" echinozygotum	"	T	"	"	"	"	18
"	"	" ellipsoideum	"	N	"	"	"	"	18
"	"	" hypnosporum	"	N	"	"	"	"	18
"	"	" intermedium	"	T	"	"	"	"	18
"	"	" macrostigmaticum	"	T	"	"	"	"	18
"	"	" minutum	"	N	"	"	"	"	18
"	"	" multinucleatum	"	T	"	"	"	"	18
"	"	" oleofaciens	"	N	"	"	"	"	18
"	"	" perforatum	"	T	"	"	"	"	18
"	"	" pinguideum	"	N	"	"	"	"	18
"	"	" punctatum	"	N	"	"	"	"	18
"	"	" scabellum	"	N	"	"	"	"	18
"	"	" tetrasporum	"	P	"	"	"	"	18
"	"	" vacuolatum	"	T	"	"	"	"	18
"	"	" wimmeri	"	P	"	"	"	"	18
"	"	" scenedesmus sp	16-32 units	T	1 mo	culture solution (25 ml Erlenmeyer flask)	examination of zone of inhibition	22°C; 8.2; 140 ft-c, continuous	33
		CHRYSOPHYCEAE							
"	"	Gomphonema sp	0-4 units	T	"	"	"	"	33
"	"	Nitzschia sp	"	T	"	"	"	"	33

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE							
Neothiolutin	(--; --; --)	Chlorella pyrenoidosa	2.5	P(21%)[b]	40 hr	culture solution (flask)	optical density at 610 mμ	25°C; 5.1; --	106.5
"	"	" "	"	P(48%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	T(100%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	5	P(37%)[b]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	"	P(75%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	T(100%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	10	T(100%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	T(100%)[b]	"	"	"	25°C; 7.4; --	106.5
Netrospsin	Streptomyces ambofaciens " chromogenus " netropsis " reticuli (--; Bacteria; 114.8)	" "	5	P(67%)[b]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	"	P(71%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	P(70%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	10	T(100%)[b]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	"	T(100%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	T(100%)[b]	"	"	"	25°C; 7.4; --	106.5
Novobiocin (streptonivicin, cathomycin, albamycin, cardelmycin)	Streptomyces niveus (--; Bacteria; 39.6)	Chlorococcum aplanosporum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18

[b] (%) inhibition, comparison with control

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Novobiocin (streptonivicin, cathomycin, albamycin, cardelmycin)	Streptomyces niveus (--; Bacteria; 39.6)	Chlorococcum perforatum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" pinguideum	"	N	"	"	"	"	18
"	"	" punctatum	"	N	"	"	"	"	18
"	"	" scabellum	"	N	"	"	"	"	18
"	"	" tetrasporum	"	N	"	"	"	"	18
"	"	" vacuolatum	"	T	"	"	"	"	18
"	"	" w immeri	"	N	"	"	"	"	18
		MYXOPHYCEAE							
Nystatin (Mycostatin)	Streptomyces noursei (--; Bacteria; 39.6)	Anabaena cylindrica	200	N	1, 2, 3 wk	"	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	Fremyella diplosiphon	200	N	"	"	"	"	46
"	"	Nostoc sp	200	N	"	"	"	"	46
"	"	Phormidium sp	50	P	1 wk	"	"	"	46
"	"	" "	100	P	2, 3 wk	"	"	"	46
"	"	" "	200	T(algicidal)	1, 2, 3 wk	culture solution (50 ml Erlenmeyer flask)	"	"	46
"	"	Plectonema boryanum	1	"	5 da	culture solution (150 x 16 mm test tube)	optical density (Klett colorimeter at 540 mu)	23°C; --; 500 ft-c, continuous	58.8
		CHLOROPHYCEAE							
"	"	Ankistrodesmus falcotus	2	P	1, 2, 3 wk	agar medium	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	20	T(Algicidal)	"	"	"	"	46
"	"	Chlamydomonas agloeoformis	20	"	"	culture solution (50 ml Erlenmeyer flask)	"	"	46

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Nystatin (Mycostatin)	Streptomyces noursei (--; Bacteria; 39.6)	Chlamdomonas reinhardti	1	T(algicidal)	3 da	culture solution (50 ml Erlenmeyer flask)	optical density (Klett colorimeter at 540 mμ)	23°C; 6.8; 500 ft-c, continuous	58.8
"	"	" "	4	"	"	nutrient broth	"	"	58.8
"	"	Chlorella vulgaris	3	"	"	culture solution (50 ml Erlenmeyer flask)	"	"	58.8
"	"	" "	3	"	"	nutrient broth	"	"	58.8
"	"	" pyrenoidosa	50	P	1 wk	culture solution (150 x 16 mm test tube)	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	48
"	"	" "	100	T	"	"	"	"	48
"	"	" "	50	T	2, 3 wk	"	"	"	48
Nystatin	"	Chlorococcum aplanosporum	100 units	N	0-3 wk	agar medium	examination of zone of inhibition	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	T	"	"	"	"	18
"	"	" echinozygotum	"	T	"	"	"	"	18
"	"	" ellipsoideum	"	N	"	"	"	"	18
"	"	" hypnosporum	"	N	"	"	"	"	18
"	"	" intermedium	"	N	"	"	"	"	18
"	"	" macrostigmaticum	"	N	"	"	"	"	18
"	"	" minutum	"	P	"	"	"	"	18
"	"	" "	1	P	1 wk	"	Macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	2	T(algicidal)	1, 2, 3, wk	"	"	"	46
"	"	" multinucleatum	100 units	N	0-3 wk	"	examination of zone of inhibition	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" oleofaciens	"	N	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Nystatin	Streptomyces noursei (--; Bacteria; 39. 6)	Chlorococcum perforatum	100 units	T	0-3 wk	agar medium	examination of zone of inhibition	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" pinguideum	"	N	"	"	"	"	18
"	"	" punctatum	"	N	"	"	"	"	18
"	"	" scabellum	"	N	"	"	"	"	18
"	"	" tetrasporum	"	N	"	"	"	"	18
"	"	" vaculatum	"	N	"	"	"	"	18
"	"	" wimmeri	"	N	"	"	"	"	18
"	"	Goccomyxa elongata	200	N	1, 2, 3 wk	culture solution (150 x 16 mm test tube)	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	Haematococcum lacustris	50	P	1 wk	agar medium	"	"	46
"	"	" "	100	P	2, 3 wk	"	"	"	46
"	"	" "	200	T(algicidal)	1, 2, 3, wk	"	"	"	46
"	"	Hormidium sp	1	"	"	"	"	"	46
"	"	Scenedesmus obliquus	200	N	"	culture solution (150 x 16 mm test tube)	"	"	46
"	"	" "	1	T(algicidal)	3 da	culture solution (50 ml Erlenmeyer flask)	optical density (at 540 mμ)	23°C; --; 500 ft-c, continuous	58. 8
"	"	Stichococcum bacillaris	100	P	1 wk	culture solution (150 x 16 mm test tube)	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	200	T (algicidal)	1 wk	"	"	"	46
"	"	" "	100		2, 3 wk	"	"	"	46
"	"	Prototheca zopfi	1	"	3 da	culture solution (50 ml Erlenmeyer flaks)	optical density (at 540 mμ)	23°C; --; 500 ft-c, continuous	58. 8

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays — Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Nystatin	Streptomyces noursei (--; Bacteria; 39.6)	Navicula pelluclosa	1	T(algicidal)	1, 2, 3 wk	agar medium	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	60	"	3 da	culture solution (50 ml Erlenmeyer flask)	optical density (at 540 mμ)	23°C; --; 500 ft-c, continuous	58.8
"	"	Ochromonas malhamensis	1	"	"	"	"	"	58.8
"	"	Polydriella helvetica	50	P	1, 2 wk	culture solution (150 x 16 mm test tube)	macro and/or microscopic comparison with control	24°C; --; 200 ft-c, 12 hr daily	46
"	"	" "	100	P	3 wk	"	"	"	46
"	"	" "	200	T(algicidal)	1, 2, 3 wk	"	"	"	46
		EUGLENOPHYCEAE							
"	"	Euglena gracilia "z"	50	P	1 wk	"	"	"	46
"	"	" "	100	T(algicidal)	"	"	"	"	46
"	"	" "	50	"	2, 3 wk	"	"	"	46
"	"	" " No. 752	30	"	3 da	culture solution (50 ml Erlenmeyer flask)	optical density at 540 mμ	23°C; --; 500 ft-c, continuous	58.8
"	"	" " "	10	"	"	nutrient broth (50 ml Erlenmeyer flask)	"	"	58.8
"	"	" " No. 753	30	"	"	culture solution 50 ml Erlenmeyer flask)	"	"	58.8
"	"	" " "	5	"	"	"	"	"	58.8

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Oleandomycin	Streptomyces antibioticus (--; Bacteria; 39.5)	Chlorococcum aplanosporum	15 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18
Paromomycin	Streptomyces rimosus forma paromomycinus (--; Bacteria; 114.8)	" aplanosporum	30 meq	T	"	"	"	"	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	N	"	"	"	"	18
"	"	" multinucleatum	"	T	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Paromomycin	Streptomyces rimosus " " forma paromomycinus (--; Bacteria; 114.8)	Chlorococcum pinguideum	30 meq	T	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18
		MYXOPHYCEAE							
Penicillin G	Penicillium chrysogenum (--; Bacteria; 28.3)	Anabaena variabilis	.1	"	5 da	culture solution (500 ml Erlen-meyer flask)	% transmittance (spectrophoto-meter) 550 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	Calothrix sp	10 unit	N(0)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	cylindiospermun licheniforme	2	P	3, 7 da	culture solution (25 ml Erlen-meyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	" "	2	N	14, 21 da	"	"	"	81
"	"	Microcystis aeruginosa	2	T	3, 7, 14, 21 da	"	"	"	81
"	"	" " sp	1 unit	N(0)[c]	5 da	agar medium	examination of zone of inhibition (disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	" " "	10 unit	T(65)[c]	"	"	"	"	33
"	"	Nostoc sp	1 unit	T(12)[c]	"	"	"	"	33
"	"	" "	10 unit	T(18)[c]	"	"	"	"	33
"	"	Phormidium sp	10 unit	N(0)[c]	"	"	"	"	33
"	"	Symploca sp	1 unit	T(14)[c]	"	"	"	"	33
"	"	" "	10 unit	"	"	"	"	"	33

( )[c] zone of dilution in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Penicillin G	Penicillium chrysogenum (--; Bacteria; 28.3)	Ankistrodesmus sp	1 unit	N(0)[c]	5 da	agar medium	examination of zone of inhibition (disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	" "	10 unit	T(4)[c]	"	"	"	"	33
"	"	Chlamdomonas sp	10 unit	N(0)[c]	"	"	"	"	33
"	"	Chlorella pyrenoidosa	1000 unit	P	"	culture solution (500 ml Erlen-meyer flask) (organic media)	% transmittance (spectrophoto-meter) 550 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	1000 unit	N	"	culture solution (500 ml Erlen-meyer flask) inorganic media	"	"	36
"	"	" variegata	2	N	3, 7, 14, 21 da	culture solution (25 ml Erlen-meyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cell/ml inoculated)	81
"	"	Chlorococcum aplanosporum	10 units	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18

( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays — Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Penicillin G	Penicillium chrysogenum (--; Bacteria; 28.3)	Chlorococcum vacuolatum	10 units	N	0 - 3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" wimmeri	"	"	"	"	"	"	18
"	"	Scenedesmus obliquus	1000	"	5 da	culture solution (500 ml Erlenmeyer flask)	% transmittance (spectophotometer) 550 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	Oocystis sp	10 units	N(0)	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 7.8; 140 ft-c, continuous	33
		CHRYSOPHYCEAE							
"	"	Gomphonema parvulum	2	N	3, 7, 14, 21 da	culture solution (25 ml Erlenmeyer flask)	macro and /or microscopic comparison with control	27°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated)	81
"	"	Nitzschia palea	2	"	"	"	"	"	81
		BACTERIUM							
"	"	Archromobacter sp 1	100	P	2 da	culture solution (500 ml Erlenmeyer flask)	% transmittance (spectophotometer) 615 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" " "	1000	T	"	"	"	"	36
"	"	" " sp 2	1000	N	3 da	"	"	"	36
"	"	Flavabacterium sp	.1	P	5 da	"	"	"	36
"	"	" "	1	"	"	"	"	"	36
"	"	" "	10	T	"	"	"	"	36
"	"	Pseudomonas sp	1000	N	3 da	"	"	"	36
		CHLOROPHYCEAE							
Pleocidin	Streptomyces sp resembling Streptomyces lavendulae (--; Bacteria; 114.8)	Chlorella pyrenoidosa	1	P(75%)[b]	40 hr	culture solution	optical density (610 mμ)	25°C; 5.1; --	106.5
"	"	" "	1	P(75%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	1	P(30%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	5	T(100%)[b]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	5	T(100%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	5	T(100%)[b]	"	"	"	25°C; 7.4; --	106.5

( )[b] percent inhibition comparison with control ( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Puromycin (stylomycin achromycin)	Streptomyces alboniger (--; Bacteria; 114.8)	Chlorella pyrenoidosa	10^{-4} M	S(-27%)[b]	40 hrs	culture solution (flask)	optical density (610 mμ)	25°C; 5.1; --	106.5
"	"	" "	"	S(-9%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	S(-21%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	10^{-3} M	S(-5%)[b]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	"	P(30%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	P(30%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	10^{-2} M	T(100%)[b]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	"	T(100%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	T(100%)[b]	"	"	"	25°C; 6.0; --	106.5
Rimocidin sulfate	(--; --; --)	" "	100	P(11%)[b]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	"	P(13%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	P(31%)[b]	"	"	"	25°C; 7.4; --	106.5
Ristocetin	Nocardia lurida (--; Bacteria; 39.5)	Chlorococcum aplanosporum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --: 250-300 ft-c, 12 hrs daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18

( )[b] percent inhibition comparison with control

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE							
Ristocetin	Nocardia lurida (--; Bacteria; 39.5)	Chlorococcum vacuolatum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" wimmeri	"	"	"	"	"	"	18
Spiramycin (rovamycin, sequamycin, selectomycin provomycin)	Streptomyces ambofaciens (--; Bacteria; 39.5)	" aplanosporum	"	"	"	"	"	"	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	P	"	"	"	"	18
"	"	" vacuolatum	"	N	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18
		MYXOPHYCEAE							
Streptomycin	Streptomyces griseus (--; Bacteria; 28.3)	Anabaena variabilis	.1	T	5 da	culture solution	% transmittance (spectophotometer) 615 mμ	25° C; 7; 700-1000 ft-c, continuous	36
"	"	Calothrix sp	10 μg	T(58)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 7.2; 140 ft-c, continuous	33
"	"	" "	100 μg	T(72)[c]	"	"	"	"	33

( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		MYXOPHYCEAE							
Streptomycin	Streptomyces girseus (--; Bacteria; 28.3)	Cylindrospermum licheniforme B & F	2	T	3, 7, 14, 21 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated)	81
"	"	Microcystis aeruginosa	2	T	"	"	"	"	81
"	"	" sp	10 µg	T(40)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 7.2; 140 ft-c, continuous	33
"	"	" "	100 µg	T(75)[c]	"	"	"	"	33
"	"	Nostoc sp	10 µg	T(50)[c]	"	"	"	"	33
"	"	" "	100 µg	T(70)[c]	"	"	"	"	33
"	"	" "	2	T(algicidal)	"	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	"	33
"	"	Phormidium sp	10 µg	T(14)[c]	"	agar medium	examination of zone of inhibition (disk technique)	"	33
"	"	" "	100 µg	T(56)[c]	"	"	"	"	33
"	"	" "	2	T (algicidal)	"	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	"	33
"	"	Scenedesmus obliquus	2	P	3, 7 da	"	"	"	81
"	"	" "	2	T	14, 21 da	"	"	"	81
"	"	Symploca sp	10 µg	T(28)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	" "	100 µg	T(80)[c]	"	"	"	"	33

( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Streptomycin	Streptomyces griseus (--; Bacteria; 28.3)	Ankistrodesmus sp	10 μg	T(19)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 7.8; 140 ft-c, continuous	33
"	"	" "	100 μg	T(58)[c]	"	"	"	"	33
"	"	Chlamydomonas sp	10 μg	T(10)[c]	"	"	"	"	33
"	"	" "	100 μg	T(30)[c]	"	"	"	"	33
"	"	" "	18	T(algicidal)	"	"	macro and/or microscopic comparison with control	"	33
"	"	Chlorella pyrenoidosa	1	P	5 da	culture solution (500 ml Erlenmeyer flask) inorganic media	%transmittance (spectophotometer) 550 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	10	T	"	"	"	"	36
"	"	" "	100	T	"	culture solution (500 ml Erlenmeyer flask); (organic media)	"	"	36
"	"	" variegata B	2	N	3, 7, 14, 21 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated)	81
"	"	Scenedesmus obliquus	.1	P	5 da	culture solution (500 ml Erlenmeyer flask) inorganic media	% transmittance (spectophotometer) 550 mμ	25°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	1	T	"	"	"	"	36
"	"	" "	100	P	"	culture solution 500 ml Erlenmeyer flask) (organic media)	"	"	36
"	"	" "	1000	T	"	"	"	"	36
"	"	" "	2	P	3, 7 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated)	81

( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Streptomycin	Streptomyces griseus (--; Bacteria; 28.3)	Scenedesmus obliquus	2	T	14, 21 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated)	81
"	"	" sp	36	T	1 mo	"			33
"	"	Oocystis sp	10 µg	T(12)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22° C; 7.8; 140 ft-c, continuous	33
"	"	" "	100 µg	T(28)[c]	"	"	"	"	33
		CHRYSOPHYCEAE							
" "	"	Gomphonema sp	9	T(algicidal)	"	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	"	33
"	"	" parvulum	2	N	3, 7, 14, 21 da	culture solution (500 ml Erlenmeyer flask)	"	25°C; 7; 700-1000 ft-c, continuous	36
"	"	Nitzschia sp	4	T(algicidal)	1 mo	culture solution (25 ml Erlenmeyer flask)	"	22°C; 7.8; 140 ft-c, continuous	33
"	"	" palea	2	N	3 da	culture solution (25 ml Erlenmeyer flask)	"	22°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated	81
"	"	" "	2	T	7, 14, 21 da	"	"	"	81
		BACTERIUM							
"	"	Archromobacter	100	P	3 da	culture solution (500 ml Erlenmeyer flask)	"	"	36
"	"	" sp 1	1000	T	"	"	"	"	36
"	"	" sp 2	1000	P	2 da	"	"	"	36
"	"	Flavabacterium sp	10	P	5 da	"	"	"	36
"	"	" "	100	T	"	"	"	"	36
"	"	Pseudomonas sp	1000	T	3 da	"	"	"	36

( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		MYXOPHYCEAE							
Terramycin (oxytetracycline) Note: Terramycin loses it's activity (strength) after 1 day in alkaline medium (ref. 33)	Streptomyces rimosus (--; Bacteria; 28.3)	Anabaena variabilis	1	P	5 da	culture solution (500 ml Erlenmeyer flask)	% transmittance (spectophotometer) 550 mμ	22°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	10	T	"	"	"	"	36
"	"	Calothrix sp	10 μg	N(0)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 7.2; 140 ft-c, continuous	33
"	"	" "	100 μg	N(0)[c]	"	"	"	"	33
"	"	Cylindrospermun licheneforme B & F	2	P	3, 7 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated)	81
"	"	" "	2	N	14, 21 da	"	"	"	81
"	"	Microcystis aragenosa	2	T	3, 7, 14, 21	"	"	"	81
"	"	" sp	10 μg	T(19)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 140 ft-c, continuous	33
"	"	" "	100 μg	T(33)[c]	"	"	"	"	33
"	"	Nostoc sp	10 μg	T(10)[c]	"	"	"	"	33
"	"	" "	100 μg	T(15)[c]	"	"	"	"	33
"	"	Phormidium sp	10 μg	N(0)[c]	"	"	"	"	33
"	"	" "	100 μg	N(0)[c]	"	"	"	"	33
"	"	Symploca sp	10 μg	T(20)[c]	"	"	"	"	33
"	"	" "	100 μg	T(20)[c]	"	"	"	"	33
		CHLOROPHYCEAE							
"	"	Ankistrodesmus sp	10 μg	N(0)[c]	"	"	"	"	33
"	"	" "	100 μg	N(0)[c]	"	"	"	"	33
"	"	Chlamydomonas sp	10 μg	N(0)[c]	"	"	"	"	33
"	"	" "	100 μg	T(11)[c]	"	"	"	"	33

( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Terramycin	Streptomyces rimosus (--; Bacteria; 28.3)	Chlorella pyrenoidosa	100	P	5 da	culture solution (500 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	1000	T	"	"	"	"	36
"	"	" "	1	S	40 hr	culture solution (flask)	optical density (610 mμ)	25°C; 5.1, 3.0, 7.4; --	106.5
"	"	" "	10	S	"	"	"	25°C; 5.1, 6.0, 7.4; --	106.5
"	"	Chlorococcum aplanosporum	30 meq	T(?)[d]N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" dilplobionticum	"	T(?)[d] N	"	"	"	"	18
"	"	" echinozygatum	"	T(?)[d] N	"	"	"	"	18
"	"	" ellipsoideum	"	N	"	"	"	"	18
"	"	" hypnosporum	"	N	"	"	"	"	18
"	"	" intermedium	"	T(?)[d] P	"	"	"	"	18
"	"	" macrostigmaticum	"	N	"	"	"	"	18
"	"	" minutum	"	P	"	"	"	"	18
"	"	" multinucleatum	"	N	"	"	"	"	18
"	"	" oleofaciens	"	N	"	"	"	"	18
"	"	" perforatum	"	N	"	"	"	"	18
"	"	" pinguideum	"	N	"	"	"	"	18
"	"	" punctatum	"	N	"	"	"	"	18
"	"	" scabellum	"	N	"	"	"	"	18
"	"	" tetrasporum	"	T	"	"	"	"	18
"	"	" vacuolatum	"	N	"	"	"	"	18
"	"	" wimmeri	"	N	"	"	"	"	18
"	"	Scenedesmus obliquus	2	N	3, 7, 14, 21 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated)	81
"	"	" "	100	P	5 da	culture solution (500 ml Erlenmeyer flask) (organic)	% transmittance (spectophotometer) 550 mμ	22°C; 7; 700-1000 ft-c, continuous	36

(?)[d] both results reported

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Terramycin	Streptomyces rimosus (--; Bacteria; 28.3)	Scenedesmus obliquus	1000	P	5 da	culture solution (500 ml Erlenmeyer flask) (organic)	% transmittance (spectophotometer) 550 mμ	22°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	"	T	"	culture solution (500 ml Erlenmeyer flask) (inorganic)	"	"	36
"	"	Oocystis sp	10 μg	(N(0)[c]	1 mo	agar medium	examination of zone of inhibition (disk technique)	22°C; 8.2; 140 ft-c, continuous	33
"	"	" "	100 μg	T(12)[c]	"	"	"	"	33
		CHRYSOPHYCEAE							
"	"	Gomphonema parvulum	2	N	3, 7, 14, 21 da	culture solution (25 ml Erlenmeyer flask)	macro and/or microscopic comparison with control	22°C; --; 140 ft-c, continuous (125,000 cells/ml inoculated)	81
"	"	Nitzschia palea	2	T	3 da	"	"	"	81
"	"	" "	2	P	7 da	"	"	"	81
"	"	" "	2	N	14, 21 da	"	"	"	81
		BACTERIUM							
"	"	Archromobacter sp 1	10	P	2 da	culture solution (500 ml Erlenmeyer flask)	% transmittance (spectophotometer) 550 mμ	22°C; 7; 700-1000 ft-c, continuous	36
"	"	" " "	100	T	"	"	"	"	36
"	"	" sp 2	10	P	3 da	"	"	"	36
"	"	" " "	100	T	"	"	"	"	36
"	"	Flavabacterium sp	10	P	5 da	"	"	"	36
"	"	" "	100	T	"	"	"	"	36
"	"	Pseudomonas sp	10	P	3 da	"	"	"	36
"	"	" "	100	T	"	"	"	"	36
Tetracycline	Streptomyces viridifaciens	Chlorella pyrenoidosa	100	P	5 da	"	"	"	36
"	"	" "	1000	T	"	"	"	"	36

( )[c] zone of inhibition in millimeters

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Tetracycline (achromycin)	Streptomyces viridifaciens	Chlorococcum aplanosporum	30 meq	T(?)[d] P	1 mo	agar medium	examination at zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	P	"	"	"	"	18
"	"	" echinozygotum	"	P	"	"	"	"	18
"	"	" ellipsoideum	"	N	"	"	"	"	18
"	"	" hypnosporum	"	N	"	"	"	"	18
"	"	" intermedium	"	T(?)[d] P	"	"	"	"	18
"	"	" macrostigmaticum	"	N	"	"	"	"	18
"	"	" minutum	"	P	"	"	"	"	18
"	"	" multinucleatum	"	N	"	"	"	"	18
"	"	" oleofaciens	"	P	"	"	"	"	18
"	"	" perforatum	"	N	"	"	"	"	18
"	"	" pinguideum	"	N	"	"	"	"	18
"	"	" punctatum	"	N	"	"	"	"	18
"	"	" scabellum	"	N	"	"	"	"	18
"	"	" tetrasporum	"	T	"	"	"	"	18
"	"	" vacuolatum	"	N	"	"	"	"	18
"	"	" wimmeri	"	N	"	"	"	"	18
"	"	Scenedesmus obliquus	100	P	5 da	culture solution (500 ml Erlenmeyer flask)	% transmittance (spectophotometer)	22°C; 7; 700-1000 ft-c, continuous	36
"	"	" "	1000	T	"	"	"	"	36
		BACTERIUM							
"	"	Archromobacter sp 1	100	T	3 da	"	"	"	36
"	"	" sp 2	10	T	2 da	"	"	"	36
"	"	Flavabacterium sp	10	T	5 da	"	"	"	36
"	"	Pseudomonas sp	100	T	3 da	"	"	"	36

(?)[d] both results reported

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays — Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
(Thiolutin triburon)	Streptomyces albus " celluloflavus " sp (--; Bacteria; 114.8)	Chlorococcum aplanosporum	1 mg	T	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18
"	"	Chlorella pyrenoidosa	2	P(82%)[b]	40 hr	culture solution (flask)	optical density (610 mμ)	25°C; 5.1; --	106.5
"	"	" "	"	P(77%)[b]	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	P(95%)[b]	"	"	"	25°C; 7.4; --	106.5
"	"	" "	5	T(100%)[b]	"	"	"	25°C; 5.1; --	106.5
"	"	" "	"	"	"	"	"	25°C; 6.0; --	106.5
"	"	" "	"	"	"	"	"	25°C; 7.4; --	106.5

( )[b] percent inhibition comparison with control

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE							
Vancomycin (vancosin)	Streptomyces orientalis (--; Bacteria; 39.5)	Chlorococcum aplanosporum	30 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"	"	"	"	"	"	18
"	"	" intermedium	"	"	"	"	"	"	18
"	"	" macrostigmaticum	"	"	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18
"	"	" punctatum	"	"	"	"	"	"	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18
Viomycin (viocin)	Streptomyces floridae (--; Bacteria; 39.5)	Chlorococcum aplanosporum	10 meq	"	"	"	"	"	18
"	"	" diplobionticum	"	"	"	"	"	"	18
"	"	" echinozygotum	"	"	"	"	"	"	18
"	"	" ellipsoideum	"	"	"	"	"	"	18
"	"	" hypnosporum	"		"	"	"	"	18
"	"	" intermedium	"	T	"	"	"	"	18
"	"	" macrostigmaticum	"	N	"	"	"	"	18
"	"	" minutum	"	"	"	"	"	"	18
"	"	" multinucleatum	"	"	"	"	"	"	18
"	"	" oleofaciens	"	"	"	"	"	"	18
"	"	" perforatum	"	"	"	"	"	"	18
"	"	" pinguideum	"	"	"	"	"	"	18

Class of Compound: ANTIBIOTICS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound						Ref.
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE							
Viomycin (viocin)	Streptomyces floridae (--; Bacteria; 39.5)	Chlorococcum punctatum	10 meq	N	0-3 wk	agar medium	examination of zone of inhibition (disk technique)	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" scabellum	"	"	"	"	"	"	18
"	"	" tetrasporum	"	"	"	"	"	"	18
"	"	" vacuolatum	"	"	"	"	"	"	18
"	"	" wimmeri	"	"	"	"	"	"	18

Class of Compound: CARBOHYDRATES

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays: Microorganism	Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Glucose	Chlamydomonas sp Chlorella miniota " vulgaris Scenedesmus obliquus (12, 17, 66, 110, 112, 122, 125, 124; Algae; 70.3[e])	Chlorella vulgaris	10,000	S	15 days	liquid cultures (25 ml Erlenmeyer flask)	cell count and material balance (Van Slyke macrometric)	30°C; --; 200 ft-c,	75
Fructose	(110, 112, 122; --;)	" "	"	"	"	"	cell count (hemocytometer)	"	75
Golactose	Chlamydomonas angulosa " chlamydogama " debaryana " sp (14, 66, 71, 110, 122; Algae; 70.3[e])	" "		"	"	"	"	"	75
Methyl - - D-glucoside	(--; ---; ---;)	" "	"	"	"	"	"	"	75
Cellobiose	(--; ---; ---;)	" "	"	"	"	"	"	"	75
Lactose	(110; ---; ---;)	" "	"	"	"	"	"	"	75
Aesculin	(---; ---; ---)	" "	5,000	"	"	"	"	"	75
Xylulose	(---; ---; ---)	Chlorococcum echinozygotum	.15	P	2 da	liquid cultures	colorimetric (535 mμ) & direct cell counting (Petroff-Hansen)	20°C; --; 800 ft-c, 12 hr daily	126
Arabinose	Chlorella miniata (110; Algae; 70.3[e])	Chlorococcum aplanosporum	5,000	S	2 wk	culture solution	macroscopic comparison with control	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" diplobionticum	5,000	P	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" echinozygotum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" ellipsoideum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" hypnosporum	5,000	P	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18

[e] free sugar formed by the induced hydrolysis of excreted polysaccharide

Class of Compound: CARBOHYDRATES

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays						Ref.
			Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE							
Arabinose	Chlorella miniata (110; Algae; 70.3[e])	Chlorococcum intermedium	5,000	P	2 wk	culture solution	macroscopic comparison with control	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" macrostigmaticum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" minutum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" multinucleatum	5,000	P	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" oleofaciens	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" perforatum	5,000	T	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" pinguideum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" punctatum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" scabellum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" tetrasporum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" vacuolatum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" wimmeri	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18

[e] free sugar formed by the induced hydrolysis of excreted polysaccharide

Class of Compound: CARBOHYDRATES

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Ribose	Chlamydomonas Debaryana (110; Algae; 70.3[e])	Chlorococcum aplanosporum	7,500	S	2 wk	culture solution	macroscopic comparison with control	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" diplobionticum	"	P	"	"	"	"	18
"	"	" echinozygotum	"	S	"	"	"	"	18
"	"	" ellipsoideum	"	P	"	"	"	"	18
"	"	" hypnosporum	"	S	"	"	"	"	18
"	"	" intermedium	"	P	"	"	"	"	18
"	"	" macrostigmaticum	"	P	"	"	"	"	18
"	"	" minutum	"	S	"	"	"	"	18
"	"	" multinucleatum	"	T	"	"	"	"	18
"	"	" oleofaciens	"	S	"	"	"	"	18
"	"	" perforatum	"	P	"	"	"	"	18
"	"	" pinguideum	"	P	"	"	"	"	18
"	"	" punctatum	"	S	"	"	"	"	18
"	"	" scabellum	"	P	"	"	"	"	18
"	"	" tetrasporum	"	P	"	"	"	"	18
"	"	" vacuolatum	"	S	"	"	"	"	18
"	"	" wimmeri	"	T	"	"	"	"	18
Xylose	Scenedesmus obliquus (110; Algae; 70.3[e])	" aplanosporum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" diplobionticum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" echinozygotum	5,000	P	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" ellipsoideum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" hypnosporum	5,000	S	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18

[e] free sugar formed by the induced hydrolysis of excreted polysaccharide

Class of Compound: CARBOHYDRATES

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays — Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Xylose	Scenedesmus obliquus (110; Algae; 70.3[e])	Chlorococcum intermedium	7,500	P	2 wk	culture solution	macroscopic comparison with control	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" macrostigmaticum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" minutum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" multinucleatum	5,000	T	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" oleofaciens	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" perforatum	5,000	T	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" pinguideum	5,000	T	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" punctatum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" scabellum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" tetrasporum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" vacuolatum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" wimmeri	5,000	P	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18
Fructose	(110; ---; ---)	" aplanosporum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" diplobionticum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" echinozygotum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18

[e] free sugar formed by the induced hydrolysis of excreted polysaccharide

Class of Compound: CARBOHYDRATES

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Fructose	(110; ---; ---)	Chlorococcum ellipsoideum	5,000	S	2 wk	culture solution	macroscopic comparison with control	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" hypnosporum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" intermedium	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" macrostigmaticum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" minutum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" multinucleatum	5,000	P	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" oleofaciens	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" perforatum	5,000	T	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" pinguideum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" punctatum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" scabellum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" tetrasporum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" vacuolatum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" wimmeri	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18

Class of Compound: FATTY ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect % control	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Sodium Formate (utilized 93)	Chlorella pyrenoidosa " vulgaris (73.8, 110; Algae; 65)	Chlamydomonas reinhardi	0.5	P(98)[f]	4 da	culture solution (125 ml Erlenmeyer flask)	cell count, growth rate	18°C; 7.25; 250-300 ft-c, continuous	104
"	"	" "	1.0	P(95)[f]	"	"	"	"	104
"	"	" "	2.0	P(92)[f]	"	"	"	"	104
"	"	" "	4.0	P(88)[f]	"	"	"	"	104
"	"	" "	10.0	P(72)[f]	"	"	"	"	104
Sodium acetate (utilized 87, 96, 93)	" (104, 110; Algae; 65)	" "	0.5	S(109)[f]	"	"	"	"	104
"	"	" "	1.0	S(111)[f]	"	"	"	"	104
"	"	" "	2.0	S(111)[f]	"	"	"	"	104
"	"	" "	4.0	S(112)[f]	"	"	"	"	104
"	"	" "	10.0	S(114)[f]	"	"	"	"	104
"	"	Chlorococcum aplanosporum	5,000	P	2 wk	"	macroscopic comparison with control	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" diplobiontic um	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" echinozygotum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" ellipsoideum	5,000	S	"	"	"	"	18
"	"	" "	7,500	S	"	"	"	"	18
"	"	" hypnosporum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" intermedium	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" macrostigmaticum	5,000	P	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18

( )[f] percent growth comparison with control

Class of Compound: FATTY ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Sodium acetate (utilized 93, 87, 96)	Chlorella pyrenoidosa " vulgaris (104, 110; Algae; 65)	Chlorococcum minutum	5,000	P	2 wk	culture solution	macroscopic comparison with control	22°C; --; 250-300 ft-c, 12 hr daily	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" multinucleatum	5,000	T	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" oleofaciens	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" perforatum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" pinguideum	5,000	P	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" punctatum	5,000	S	"	"	"	"	18
"	"	" "	7,500	T	"	"	"	"	18
"	"	" scabellum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" tetrasporum	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" vacuolatum	5,000	S	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
"	"	" wimmeri	5,000	P	"	"	"	"	18
"	"	" "	7,500	P	"	"	"	"	18
Acetic acid (utilized 93, 87, 96)	Chlorella pyrenoidosa " vulgaris (73.8, 104, 110; Algae; 65)	Haematococcus pluvialis	0.5	P(98)[f]	8 da	liquid cultures (125 ml Erlenmeyer flask)	turbidity (250 mμ)	21°C; 5; 3000 lux continuous	69
"	"	" "	1.0	T	"	"	"	"	69
"	"	" "	3.0	T	"	"	"	"	69
"	"	" "	5.0	P(75)[f]	4 da	"	"	21°C; 7.5; 3000 lux continuous	69
"	"	" "	5.0	T	"	"	"	21°C; 5.0; 3000 lux continuous	69

( )[f] percent growth comparison with control

Class of Compound: FATTY ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Acetic acid (utilized 93, 87, 96)	Chlorella pyrenoidosa	Haematococcus pluvialis	5.0	T	8 da	liquid cultures (125 ml Erlenmeyer flask)	turbidity (250 mμ)	21°C; 5.0; 3000 lux continuous	69
"	" vulgaris (73.8, 104, 110; Algae; 65)	" "	5.0	N	"	"	"	21°C; 7.5; 3000 lux continuous	69
Sodium propionate (utilized 96)	(73.8, 104, 110; --; --)	Chlamydomanas reinhardi	0.5	P(96)[f]	4 da	culture solution (125 ml Erlenmeyer flask)	cell count, growth rate	18°C; 7.25; 250-300 ft-c, continuous	104
"	"	" "	1.0	P(88)[f]	"	"	"	"	104
"	"	" "	2.0	P(81)[f]	"	"	"	"	104
"	"	" "	4.0	P(67)[f]	"	"	"	"	104
"	"	" "	10.0	P(35)[f]	"	"	"	"	104
Propionic acid (utilized 96)	(73.8, 104, 110; --; --)	Haematococcus pluvialis	0.05	N	"	"	"	18°C; 6.7; 250-300 ft-c, continuous	104
"	"	" "	0.05	N	"	"	"	18°C; 7.0; 250-300 ft-c, continuous	104
"	"	" "	0.05	N	"	"	"	18°C; 7.3; 250-300 ft-c, continuous	104
"	"	" "	0.1	P(90)[f]	"	"	"	18°C; 6.7; 250-300 ft-c, continuous	104
"	"	" "	0.1	P(90)[f]	"	"	"	18°C; 7.0; 250-300 ft-c, continuous	104
"	"	" "	0.1	P(90)[f]	"	"	"	18°C; 7.3; 250-300 ft-c, continuous	104
"	"	" "	0.2	P(10)[f]	"	"	"	18°C; 6.6; 250-300 ft-c, continuous	104
"	"	" "	0.2	P(68)[f]	"	"	"	18°C; 6.8; 250-300 ft-c, continuous	104
"	"	" "	0.2	P(95)[f]	"	"	"	18°C; 7.0; 250-300 ft-c, continuous	104
"	"	" "	0.3	P(10)[f]	"	"	"	18°C; 6.8; 250-300 ft-c, continuous	104
"	"	" "	0.3	P(30)[f]	"	"	"	18°C; 7.0; 250-300 ft-c, continuous	104
"	"	" "	0.3	P(88)[f]	"	"	"	18°C; 7.1, 250-300 ft-c, continuous	104
"	"	" "	0.3	N	"	"	"	18°C; 7.3; 250-300 ft-c, continuous	104

( )[f] percent growth comparison with control

Class of Compound: FATTY ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays: Microorganism	Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Propionic acid (utilized 96)	(73.8, 104, 110; --; --)	Haematococcus pluvialis	5.0	T	4 da	liquid cultures (125 ml Erlenmeyer flask)	turbidity (250 mμ)	21°C; 5.0; 3000 lux continuous	69
"	"	" "	5.0	T	"	"	"	21°C; 7.5; 3000 lux continuous	69
"	"	" "	5.0	T	8 da	"	"	21°C; 5.0; 3000 lux continuous	69
"	"	" "	5.0	T	"	"	"	21°C; 7.5; 3000 lux continuous	69
Sodium butyrate (utilized 96)	(73.8, 110; --; --)	Chlamydomonas reinhardi	0.5	N(100)[f]	4 da	culture solution (125 ml Erlenmeyer flask)	cell count	18°C; 7.25; 250-300 ft-c continuous	104
"	"	" "	1.0	S(101)[f]	"	"	"	"	104
"	"	" "	2.0	N	"	"	"	"	104
"	"	" "	4.0	N	"	"	"	"	104
"	"	" "	10.0	P(97)[f]	"	"	"	"	104
Butyric acid (utilized 96)	(73.8, 110; --; --)	Haematococcus pluvialis	5.0	T	"	"	turbidity (750 mμ)	21°C; 5.0; 3000 lux continuous	69
"	"	" "	5.0	P(90)[f]	"	"	"	21°C; 7.5; 3000 lux continuous	69
"	"	" "	5.0	T	8 da	"	"	21°C; 5.0; 3000 lux continuous	69
"	"	" "	5.0	N	"	"	"	21°C; 7.5; 3000 lux continuous	69
Sodium valerate (utilized 96)	(110; --; --)	Chlamydomonas reinhardi	0.5	S(102)[f]	4 da	"	cell count	18°C; 7.25; 250-300 ft-c, continuous	104
"	"	" "	1.0	N	"	"	"	"	104
"	"	" "	2.0	P(99)[f]	"	"	"	"	104
"	"	" "	4.0	P(98)[f]	"	"	"	"	104
"	"	" "	10.0	P(97)[f]	"	"	"	"	104
Valeric acid (utilized 96)	(110; --; --)	Haematococcus pluvialis	5.0	T	"	"	turbidity (750 mμ)	21°C; 5.0; 3000 lux continuous	69
"	"	" "	5.0	T	8 da	"	"	"	69
"	"	" "	5.0	P(91)[f]	"	"	"	21°C; 7.5; 3000 lux continuous	69

( )[f] percent growth comparison with control

Class of Compound: FATTY ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays — Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Caproic acid (utilized 96)	(110; --; --)	Haematococcus pluvialis	5.0	T	8 da	culture solution (125 ml Erlenmeyer flask)	turbidity (750 mμ)	21°C; 5.0; 3000 lux continuous	69
"	"	" "	5.0	P(91)[f]	"	"	"	21°C; 7.5; 3000 lux continuous	69
Nonandic acid	"	Anacystics nidulans	100	T	2-3 da	liquid cutures (125 ml Erlenmeyer flask)	cell count	23°C; 8.2; 200 ft-c, constant	87.5
"	"	Chlamydomonas reinhardi	100	N(?)[d]P	"	"	"	"	87.5
"	"	Chlorella vulgaris	100	N(?)[d]P	"	"	"	"	87.5
"	"	Haematococcus pluvialis	5	T	6-8 da	"	"	"	87.5
"	"	Scenedesmus quadricauda	100	T	"	"	"	"	87.5
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	50	T	"	"	"	"	87.5
Decanoic acid	"	Anacystics nidulans	100	N(?)[d]P	2-3 da	"	"	"	87.5
"	"	Chlamydomonas reinhardi	100	N(?)[d]P	"	"	"	"	87.5
"	"	Chlorella vulgaris	100	N(?)[d]P	"	"	"	"	87.5
"	"	Haematococcus pluvialis	5	T	6-8 da	"	"	"	87.5
"	"	Scenedesmus quadricauda	100	N(?)[d]P	"	"	"	"	87.5
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	50	T	"	"	"	"	87.5
		CHLOROPHYCEAE							
Lauric acid (utilized 96)	"	Anacystics nidulans	10	T	2-3 da	"	"	"	87.5
"	"	Chlamydomonas reinhardi	25	T	"	"	"	"	87.5
"	"	Chlorella vulgaris	100	N(?)[d]P	"	"	"	"	87.5
"	"	Haematococcus pluvialis	5	T	6-8 da	"	"	"	87.5

(?)[d] both results reported ( )[f] percent growth comparison with control

Class of Compound: FATTY ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Lauric acid (utilized, 96)	(110; --; --)	Scenedesmus quadricauda	100	N(?)[d]P	6-8 da	liquid cultures (125 ml Erlenmeyer flask)	cell count	23°C; 8.2; 200 ft-c, continuous	87.5
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	5	T	"	"	"	"	87.5
		CHLOROPHYCEAE							
Myristic (utilized 96)	"	Anacystics nidulans	4	T	2-3 da	"	"	"	87.5
"	"	Chlamydomonas reinhardi	4	T	"	"	"	"	87.5
"	"	Chlorella vulgaris	100	N(?)[d]P	"	"	"	"	87.5
"	"	Haematococcus pluvialis	5	T	6-8 da	"	"	"	87.5
"	"	Scenedesmus quadricauda	100	N(?)[d]P	"	"	"	"	87.5
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	5	T	"	"	"	"	87.5
		CHLOROPHYCEAE							
Palmitic (utilized 96)	(110; --; --)	Anacystics nidulans	5	T	2-3 da	"	"	"	87.5
"	"	Chlamydomonas reinhardi	3	T	"	"	"	"	87.5
"	"	Chlorella vulgaris	25	T	"	"	"	"	87.5
"	"	Haematococcus pluvialis	3	T	6-8 da	"	"	"	87.5
"	"	Scenedesmus quadricauda	100	N(?)[d]P	"	"	"	"	87.5
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	3	T	"	"	"	"	87.5

(?)[d] both results reported

Class of Compound: FATTY ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Stearic acid (utilized, 96)	(110; --; --)	Anacystics nidulans	--		2-3 da	liquid cultures (125 ml Erlenmeyer flask)	cell count	23°C; 8.2; 200 ft-c, continuous	87.5
"	"	Chlamydomonas reinhardi	5	T	"	"	"	"	87.5
"	"	Chlorella vulgaris	50	T	"	"	"	"	87.5
"	"	Haematococcus pluvialis	5	T	6-8 da	"	"	"	87.5
"	"	Scenedesmus quadricauda	100	N(?)[d]P	"	"	"	"	87.5
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	5	T	"	"	"	"	87.5
		CHLOROPHYCEAE							
Oleic acid	(110; --; --)	Anacystics nidulans	4	T	2-3 da	"	"	"	87.5
"	"	Chlamydomonas reinhardi	5	T	"	"	"	"	87.5
"	"	Chlorella vulgaris	100	T	"	"	"	"	87.5
"	"	Haematococcus pluvialis	3	T	6-8 da	"	"	"	87.5
"	"	Scenedesmus quadricauda	100	N(?)[d]P	"	"	"	"	87.5
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	4	T	"	"	"	"	87.5

(?)[d] both results reported

Class of Compound: FATTY ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Linoleic acid	(110; --; --)	Anacystics nidulans	3	T	2-3 da	liquid cultures (125 ml Erlenmeyer flask)	cell count	23°C; 8.2; 200 ft-c, continuous	87.5
"	"	Chlamydomonas reinhardi	5	T	"	"	"	"	87.5
"	"	Chlorella vulgaris	50	T	"	"	"	"	87.5
"	"	Haematococcus pluvialis	2	T	6-8 da	"	"	"	87.5
"	"	Scenedesmus quadricauda	100	N(?)[d]P	"	"	"	"	87.5
		CHRYSOPHYCEAE							
"	"	Navicula pelliculosa	3	T	"	"	"	"	87.5

(?)[d] both results reported

Class of Compound: ORGANIC ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Benzoic acid	(110; --; --)	Haematococcus pluvialis	5.0	T (0)[f]	8 da	liquid cultures (125 ml Erlenmeyer flask)	turbidity (750 mμ)	21°C; 5.0; 3,000 lux, continuous	69
Malonic acid	(--; --; --)	" "	5.0	P(78)[f]	"	"	"	21°C; 7.5; 3,000 lux, continuous	69
"	"	" "	5.0	P(76)[f]	4 da	"	"	21°C; 5.0; 3,000 lux, continuous	69
"	"	" "	5.0	N	"	"	"	21°C; 7.5; 3,000 lux, continuous	69
"	"	" "	5.0	P(96)[f]	8 da	"	"	21°C; 5.0; 3,000 lux, continuous	69
"	"	" "	5.0	P(98)[f]	"	"	"	21°C; 7.5; 3,000 lux, continuous	69
Succinic acid	"	" "	1.0	P(78)[f]	4 da	"	"	21°C; 5.0; 3,000 lux, continuous	69
"	"	" "	1.0	P(90)[f]	"	"	"	21°C; 7.5; 3,000 lux, continuous	69
"	"	" "	1.0	P(96)[f]	8 da	"	"	21°C; 5.0; 3,000 lux, continuous	69
"	"	" "	1.0	P(97)[f]	"	"	"	21°C; 5.0; 3,000 lux, continuous	69
"	"	" "	2.0	P(78)[f]	4 da	"	"	"	69
"	"	" "	2.0	P(98)[f]	8 da	"	"	"	69
"	"	" "	3.0	P(81)[f]	4 da	"	"	"	69
"	"	" "	3.0	P(98)[f]	8 da	"	"	"	69
"	"	" "	5.0	P(78)[f]	4 da	"	"	"	69
"	"	" "	5.0	P(99)[f]	8 da	"	"	"	69
" (utilized, 96)	"	" "	10.0	P(72)[f]	4 da	"	"	"	69
"	"	" "	10.0	P(82)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	10.0	P(91)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	10.0	N	"	"	"	21°C; 7.5; 3,000 lux continuous	69

( )[f] percent growth comparison with control

Class of Compound: ORGANIC ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		CHLOROPHYCEAE							
Glutaric acid	(110; --; --)	Haematococcas pluvialis	0.5	N	8 da	liquid cultures (125 ml Erlenmeyer flask)	turbidity (750 mμ)	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	1.0	P(43)[f]	"	"	"	"	69
"	"	" "	3.0	T(0)	"	"	"	"	69
"	"	" "	5.0	T(0)	"	"	"	"	69
"	"	" "	5.0	25	"	"	"	"	69
Adipic acid	"	" "	0.5	N	"	"	"	"	69
"	"	" "	1.0	51	"	"	"	"	69
"	"	" "	3.0	T(0)	"	"	"	"	69
"	"	" "	5.0	T(0)	"	"	"	"	69
"	"	" "	5.0	P(36)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Pimelic acid	"	" "	5.0	T(0)	"	"	cell count	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(38)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(67)[f]	4 da	"	"	21°C; 5.0; 3,000 lux continuous	69
Fumaric acid (utilized 96)	"	" "	5.0	P(98)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(95)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(99)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Maleic acid	"	" "	5.0	P(79)[f]	4 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	S(101)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(96)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	S(102)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69

( )[f] percent growth comparison with control

Class of Compound: ORGANIC ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays — Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Citric acid (utilized, 96)	(110, 73.8; --; --)	Haematococcus pluvialis	5.0	P(59)[f]	4 da	liquid cultures (125 ml Erlenmeyer flask)	cell count	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(74)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(91)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(91)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Aconitic acid (utilized, 96)	(110; --; --)	" "	5.0	P(79)[f]	4 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(96)[f]	8 da	"	"	"	69
Tartaric acid	"	" "	5.0	P(67)[f]	4 da	"	turbidity (750 mμ)	"	69
"	"	" "	5.0	P(97)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(90)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(96)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Malic acid (utilized 96)	Chlamydomonas debaryana " sp Chlorella ellipsidea " miniata Scenedesmus bijugatus " obliquus (73.8, 110; Algae; 70.3)	" "	5.0	P(76)[f]	4 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(97)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(90)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(96)	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Lactic acid (utilized, 96)	Chlamydomonas defaryana Chlorella pyrenoidose " vulgaris (73.8, 110, Algae; 70.3 6.5)	" "	5.0	P(79)	4 da	"	"	21°C; 5.0; 3,000 lux continuous	69

( )[f] percent growth comparison with control

Class of Compound: ORGANIC ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
Lactic acid (utilized, 96)	Chlamydomonas debaryana Chlorella pyrenoidosa " vulgaris (73.8, 110; Algae; 70.3, 6.5)	Haematococcus pluvailis	5.0	P(96)[f]	4 da	liquid cultures (125 ml Erlenmeyer flask)	turbidity (750 mμ)	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(95)[f]	8 da	"	"	21°C; 5.0; 3000 lux continuous	69
"	"	" "	5.0	P(95)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Pyruvic acid (utilized, 96)	Chlorella sp (73.8, 110; Algae; 65)	" "	5.0	P(16)[f]	4 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(75)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(19)	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(93)	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Glycolic acid	Chlamydomonas debaryana " sp Chlorella pyrenoidosa " vulgaris Euglena gracilis "Z" (32, Algae; 70.3, 106, 65, 63)	" "	5.0	P(81)[f]	4 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	S(117)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	S(117)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	S(124)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Glyoxylic acid	Chlorella vulgaris (--; Algae; 65)	" "	5.0	P(79)[f]	4 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(107)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(82)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	S(119)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69

( )[f] percent growth comparison with control

Class of Compound: ORGANIC ACIDS

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHLOROPHYCEAE							
α- Ketoglutaric (utilized, 96)	Chlorella pyrenoidosa " bulgoris (--; Algae; 65)	Haematococcus pluvailis	5.0	P(79)[f]	4 da	liquid cultures (125 ml Erlenmeyer flask)	turbidity (750 mμ)	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	N	"	"	"	21°C; 7.5; 3,000 lux continuous	69
"	"	" "	5.0	P(95)[f]	8 da	"	"	21°C; 5.0; 3,000 lux continuous	69
"	"	" "	5.0	P(95)[f]	"	"	"	21°C; 7.5; 3,000 lux continuous	69
Sodium pyruvate	(73.8; --; --)	Chlorococcum aplanosporum	7,500	T	2 wk	culture solution	macroscopic comparison with control	22°C; --; 250-300 ft-c 12 hr daily	18
"	"	" diplobionticum	"	P	"	"	"	"	18
"	"	" echinozygotum	"	P	"	"	"	"	18
"	"	" ellipsoideum	"	P	"	"	"	"	18
"	"	" hypnosporum	"	T	"	"	"	"	18
"	"	" intermedium	"	P	"	"	"	"	18
"	"	" macrostigmaticum	"	T	"	"	"	"	18
"	"	" minutum	"	P	"	"	"	"	18
"	"	" multinucleatum	"	T	"	"	"	"	18
"	"	" oleofaciens	"	P	"	"	"	"	18
"	"	" perforatum	"	P	"	"	"	"	18
"	"	" pinguideum	"	P	"	"	"	"	18
"	"	" punctatum	"	S	"	"	"	"	18
"	"	" scabellum	"	P	"	"	"	"	18
"	"	" tetrasporum	"	P	"	"	"	"	18
"	"	" vaculoatum	"	S	"	"	"	"	18
"	"	" wimmeri	"	P	"	"	"	"	18

( )[f] percent growth comparison with control

Class of Compound: PHENOL-LIKE

Compound	Source of Compound (Observance in natural system; group; reference)	Laboratory Bioassays							Ref.
		Microorganism	Response to Compound						
			Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	
		MYXOPHYCEAE							
Catechol	(22; --; --)	Microcystis aeruginosa	5.0	T	24 hr	liquid culture (125 ml Erlenmeyer flask)	macro and/or microscopic examination	22°C; --; --	30
Vanillin	(22, 110; --; --)	Cylindrospermun licheniforme, B & F	2	N	3 da	liquid culture (25 ml Erlenmeyer flask)	macro-microscopic comparison of control	22°C; --; 140 ft-c, continuous	81
"	"	" "	2	N	7 da	"	"	"	81
"	"	" "	2	N	14 da	"	"	"	81
"	"	" "	2	N	21 da	"	"	"	81
"	"	Microcystis aeruginosa (KTZ)	2	N	3 da	"	"	"	81
"	"	" "	2	N	7 da	"	"	"	81
"	"	" "	2	N	14 da	"	"	"	81
"	"	" "	2	N	21 da	"	"	"	81
		CHLOROPHYCEAE							
"	"	Scenedesmus obliquus (KTZ)	2	P	3 da	"	"	"	81
"	"	" "	2	N	7 da	"	"	"	81
"	"	" "	2	N	14 da	"	"	"	81
"	"	" "	2	N	21 da	"	"	"	81
"	"	Chlorella varcegata B	2	P	3 da	"	"	"	81
"	"	" "	2	N	7 da	"	"	"	81
"	"	" "	2	N	14 da	"	"	"	81
"	"	" "	2	N	21 da	"	"	"	81
		CHRYSOPHYCEAE							
"	"	Gomphonema parvulum (KTZ)	2	T	3 da	"	"	"	81
"	"	" "	2	P	7 da	"	"	"	81
"	"	" "	2	P	14 da	"	"	"	81
"	"	" "	2	P	21 da	"	"	"	81

Class of Compound: PHENOL-LIKE

Compound	Source of Compound (Observance in natural system; group; reference)	Microorganism	Laboratory Bioassays: Response to Compound: Concentration (mg/l)	Effect	Time of Observation	Study Method	Parameter Measured	Conditions Temp.; pH; Light	Ref.
		CHRYSOPHYCEAE							
Vanillin	(22, 110; --; --)	Nitzschia palea (KTZ)	2	N	3 da	liquid culture (25 ml Erlenmeyer flask)	macro-microscopic comparison of control	22°C; --; 140 ft-c, continuous	81
"	"	" "	2	P	7 da	"	"	"	81
"	"	" "	2	N	14 da	"	"	"	81
"	"	" "	2	N	21 da	"	"	"	81

Appendix B

Gas Chromatograph/Mass Spectral Analysis, Finnigan Corporation, Sunnyvale, California

The analysis was done on a Finnigan 3300 GC/MS with a 6100 Data System under the following conditions:

Gas Chromatography

Column Packing:	Porapak P, 80/100 mesh
Column Type:	Glass U-tube, 1/8" i.d. x 5'
Column Temperature:	Programmed from 80°C to 180°C at 10°/min.
Injector Temperature:	200°C

GC/MS Interface

Glass Jet Separator:	230°C
Glass-lined Transfer Line:	210°C

Electron Impact Mass Spectrometry

Analyzer Temperature:	60°C
Analyzer Pressure Reading:	5×10^{-5} torr
Electron Energy:	70 eV
Ion Energy:	Programmed
Filament Current:	1 ma.
Electron Multiplier Voltage:	2.3 kV
Preamplifier Setting:	10^{-8} amps/volts

Data System

Calibration of Mass Set:	FC-43 (perfluorotributylamine)
Mass Range Scanned:	10 - 500
Integration Time:	8 msec/amu
Scans/second:	1
Threshold:	1

Three microliters of sample were used for analysis. In the interpretation of the data extensive use of limited mass searches were made to locate and identify the various compounds. Such plots are with the corresponding mass spectra so that it may be seen how the technique is used.

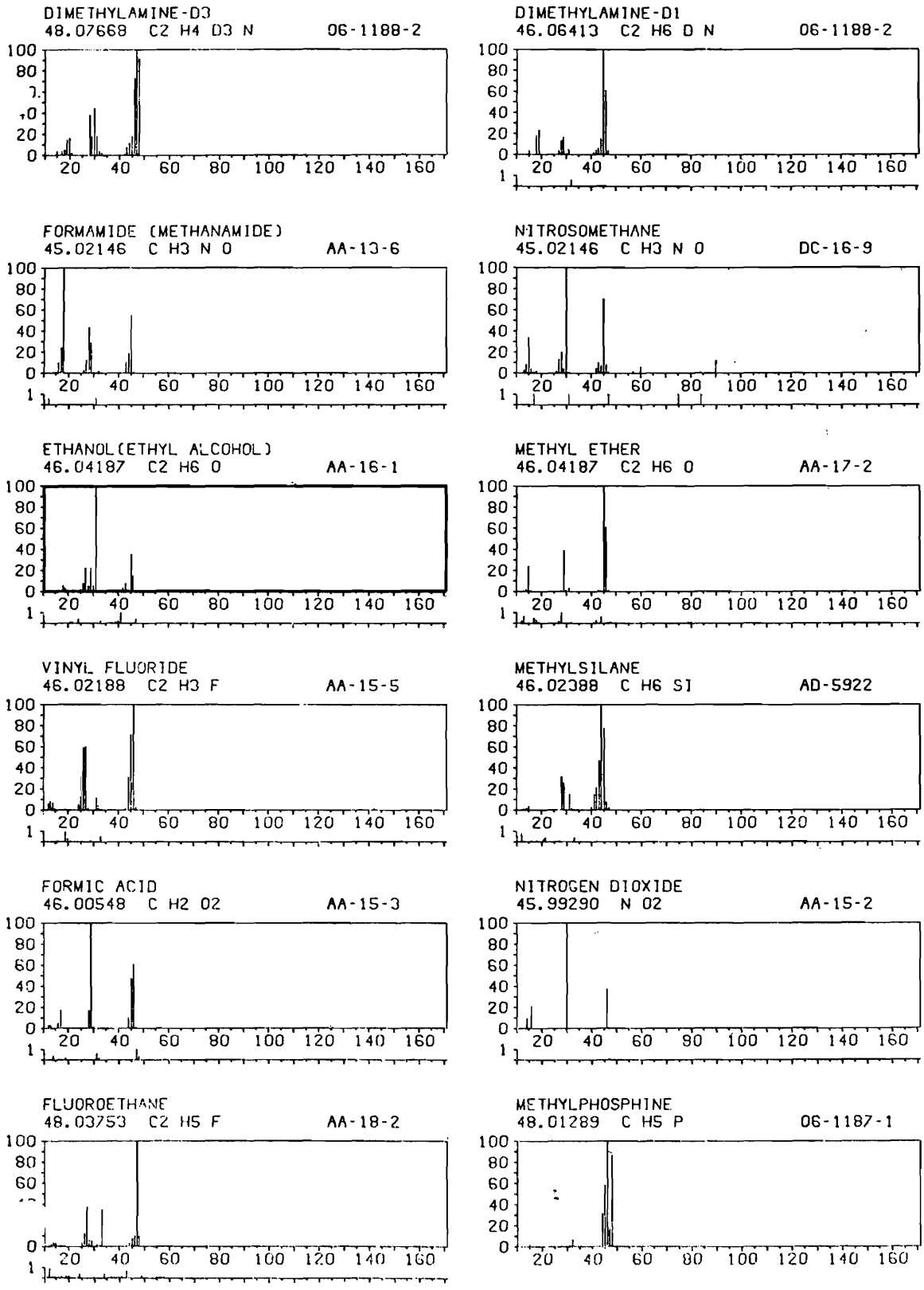

Figure 14. Compounds having mass spectral characteristics similar to the unknown (relative retention of 34 mm, Figure 7) compound in Figure 15.

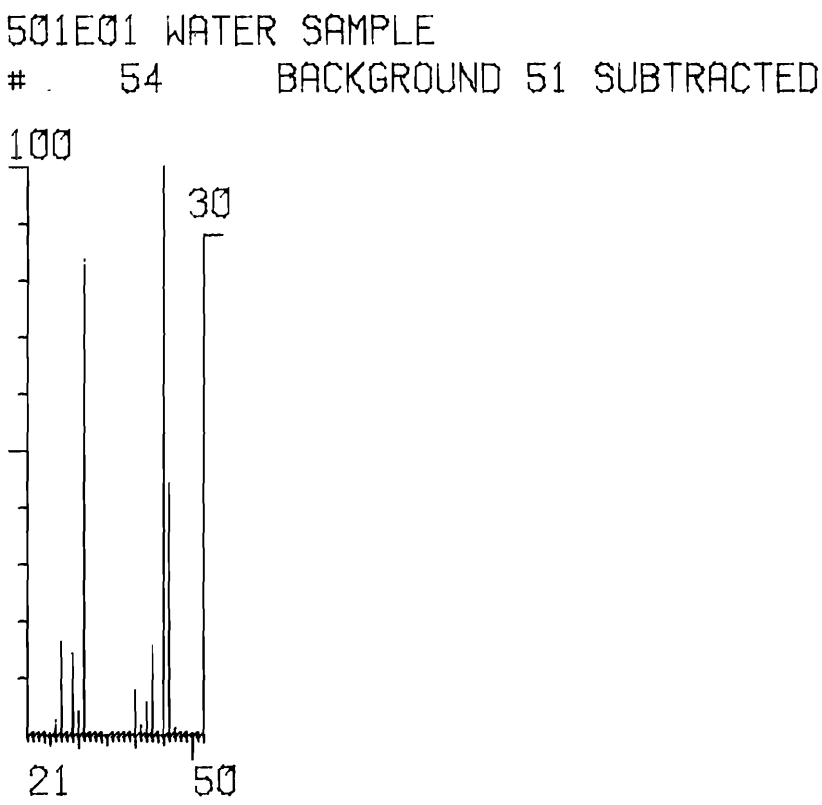

Figure 15. Mass spectrograph of an unknown (relative retention of 34 mm, Figure 7) with a mass of 46 amu which from Figure 14 was identified as ethanol.

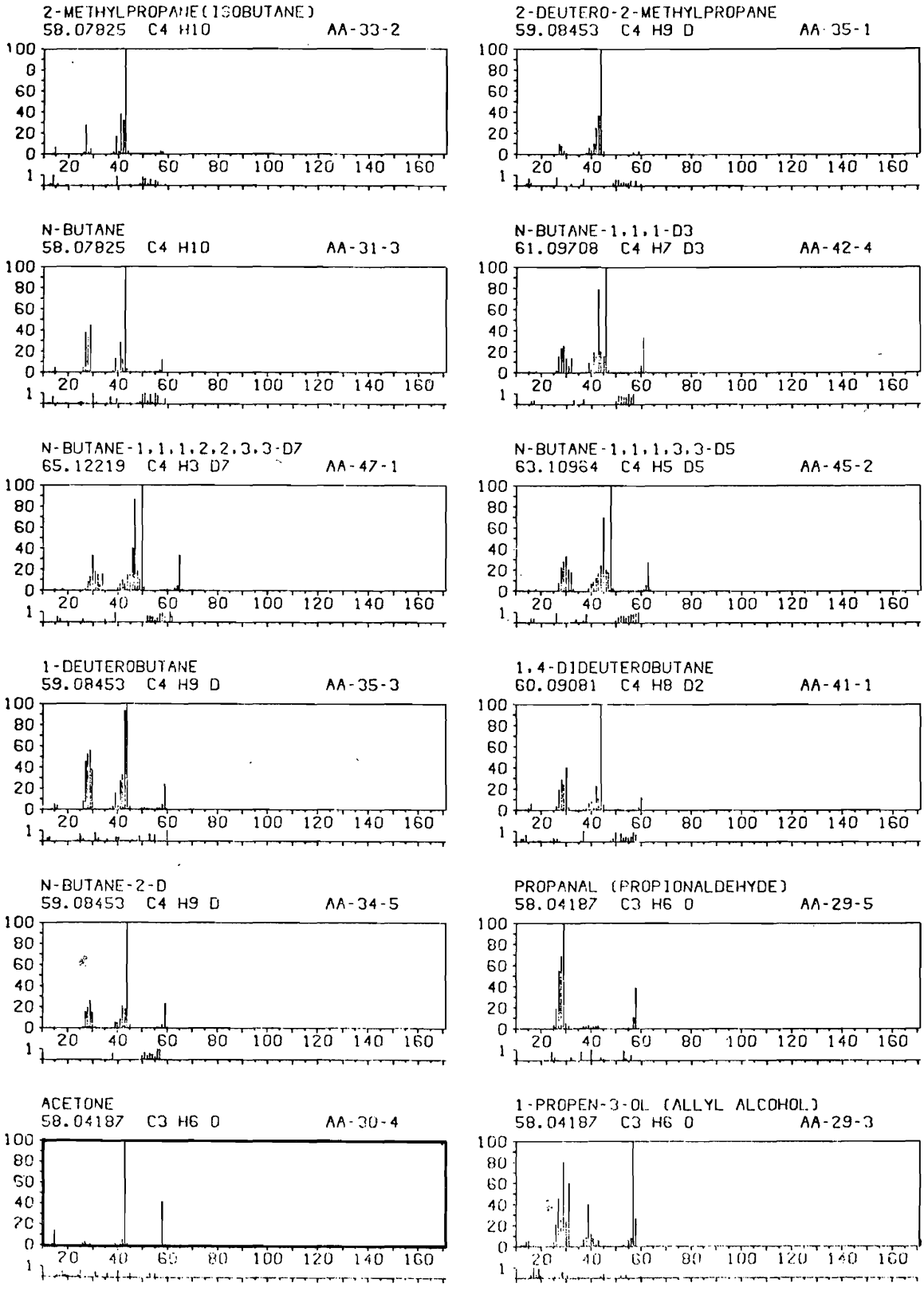

Figure 16. Compounds having mass spectral characteristics similar to the unknown (relative retention of 45 mm, Figure 7) compound in Figure 17.

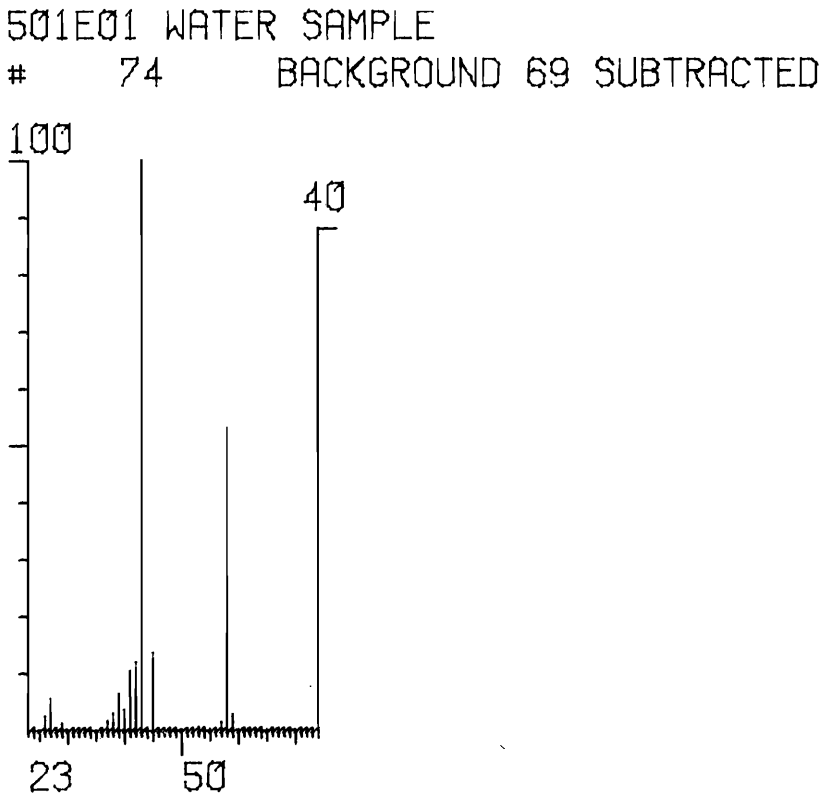

Figure 17. Mass spectrograph of an unknown (relative retention of 45 mm, Figure 7) with a mass of 58 amu which from Figure 16 was identified as acetone.

Appendix C

Gas Chromatograph/Mass Spectral Analysis, Material Science Department, University of Utah, Salt Lake City, Utah

The analysis was done on a Hewlett Packard 7620 GC/5930AMS with a 5933A data system under the following conditions:

Gas Chromatography

Column Packing:	Porapak S, 100/120 mesh
Column Type:	1/8" x 5' stainless steel
Column Temperature:	Programmed from 70°C to 190°C at 10°C/min
Injector Temperature:	200°C

GC/MS Interface

Dimethyl silicone membrane:	170°C

Electron Impact Mass Spectrometry

Source Temperature:	200°C
Mass Filter Temperature:	170°C
Inlet Lines:	180°C
Pressure Reading:	3×10^{-5} to RR
Electron Energy:	70 eV

Data System

Mass Range Scanned:	23-200

A five microliter aqueous sample was injected using a Hamilton syringe.

Table 16. List of compounds having mass spectral characteristics similar to the unknown (relative retention of 45 mm, Figure 7) compound in Figure 18.

SAMPLE 13007		SPECTRUM 28 RET 1 9 HITS 83
12	9	AZOMETHANE 58
12	8	VINYL METHYL ETHER 58
8	5	ACETIC ANHYDRIDE 102
8	5	HYDRAZOIC ACID (AZOIMIDE) 43
8	5	ACETIC ANHYDRICE 102
8	5	5-METHOXYCARBONYL-5-METHYLISOXAZOLIDINE 145
12	6	2-PROPANONE (ACETONE) 58
12	6	1,2-EPOXYPROPANE (PROPYLENE OXIDE) 58
12	6	TRIMETHYLENE OXIDE 58
12	6	OXETAN 58
16	7	N-METHYLACETAMIDE 73

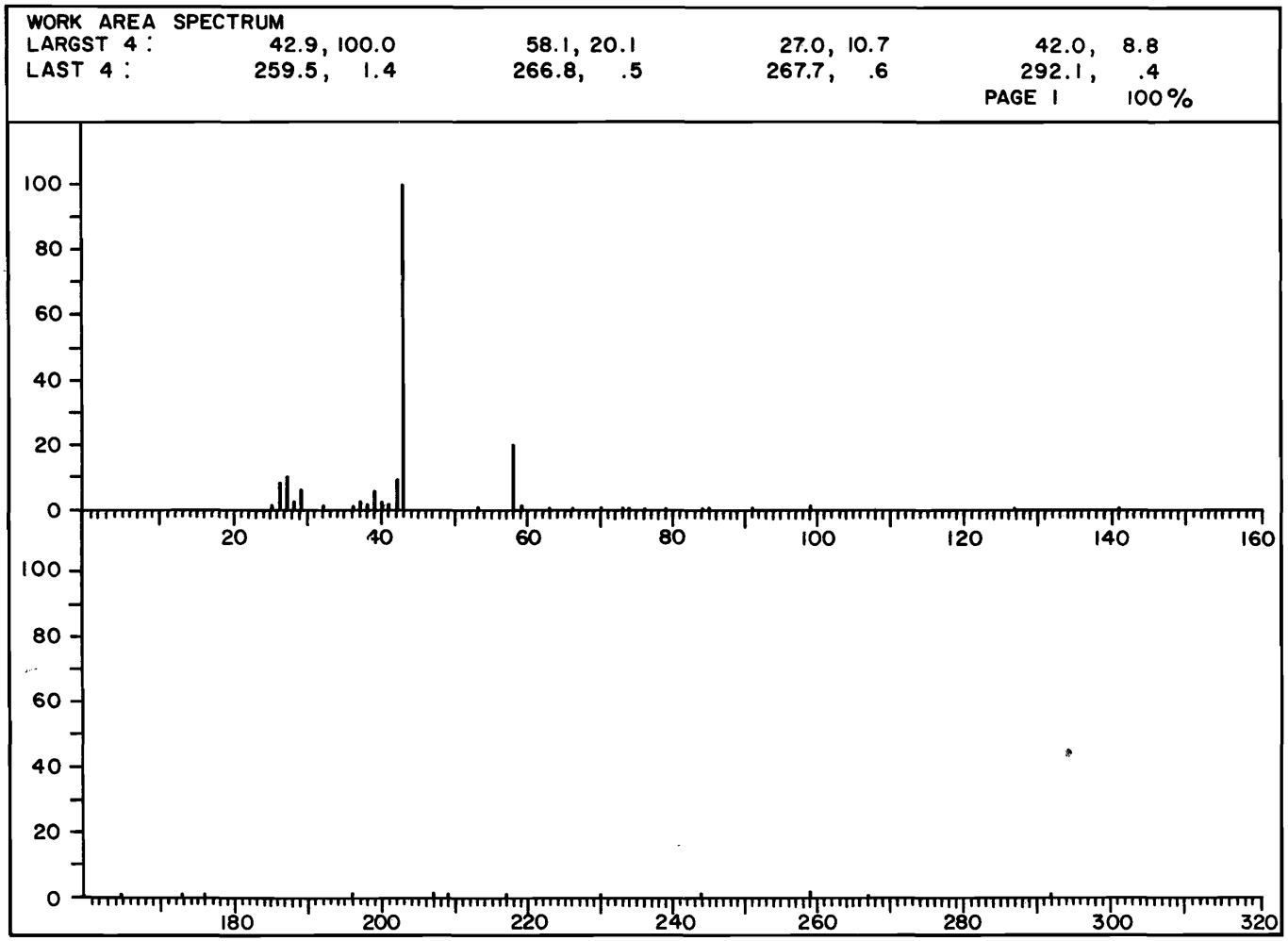

Figure 18. Mass spectrograph of an unknown (relative retention of 45 mm, Figure 7) with a mass of 58 amu which from Table 16 was identified as acetone.