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WATER CHEMISTRY AND ITS RELATION WITH ALGAE OF RAWAL DAM, ISLAMABAD AND WAH GARDEN, DISTRICT ATTOCK

M. K. Leghari, M. Y. Leghari* and S. M. Leghari**

Pakistan Museum of Natural History, Islamabad,

Abstract

The study of water chemistry and algal flora of Rawal Dam and Wah Garden was carried out from 1st June 2000 to 31st May 2002. Physico-chemical analysis of water under taken at the same sampling point as for the collection of algae on the monthly basis. The parameters studied were temperature, pH, free carbondioxide, dissolved oxygen, ammonia nitrogen, humidity, total hardness and orthophosphate. The biological samples were found to contain 296 algal species belonging to 114 genera of 11 phyla. They included Phylum Cyanophyta (68 species & 21 genera, 22.97 %), Phylum Volvocophyta (107 species & 42 genera, 36.15 %), Phylum Chlorophyta (18 species & 13 genera, 6.08 %), Phylum Bacillariophyta (66 species & 19 genera, 22.29 %), Phylum Chrysophyta (3 species & 2 genera, 1.01 %) Phylum Xanthophyta (5 species & 5 genera, 1.7 %), Phylum Vaucheriophyta (1 species & 1 genus, 0.33 %), Phylum Euglenophyta (16 species & 4 genera, 5.4 %), Phylum Dinophyta (5 species & 2 genera, 1.7 %), Phylum Perphysidiophyta (1 species & 1 genus, 0.33 %), (Phylum Charophyta (2 species & 1 genus, 0.7 %), and Phylum Rhodophyta (4 species & 3 genera, 1.35 %). Water was found to be alkaline and rich in primary productivity. The abundance of algal species due to the ratio of D.O. remained high throughout the year.

Keyword: Water chemistry, Algal flora, Wah Garden, Rawal Dam, Pakistan.

Introduction

Water body displaying a large population of algae presents a major problem to the water purification department of many inland cities which depend upon surface supplies as their source of water. Such water when used in the purification process of public supplies has obnoxious taste and odour which can not be completely removed by known treatments. The heavy population of algae will also cause filter matting and clogging which is another problem of equal importance. Qualitative and quantitative determinations of algal flora are essential for determining the aquatic productivity. They are the chief source of food for aquatic animals including fishes. Algal flora is also good indicator of pollution (Patric, & Reimer 1966).

Some physico-chemical parameters of Rawal Lake were recorded from the viewpoint of fishes (Ahmed *et al.*, 1985), and in other parts of the country little work has been done. Limnological survey of Haleji Lake (Baqai *et al.*, 1974), seasonal distribution of phytoplankton in Kalri and Haleji Lakes (Nazneen, 1974; Nazneen & Bari, 1984), seasonal variation of phytoplankton of Bakar Lake (Leghari & Leghari 1999); limnological study of Tatta Pani and River Punch (Leghari *et al.*, 2000) and comparative ecological study of phytoplankton of Bakar and Phoosna lakes (Leghari & Leghari 2001). Therefore, it appeared beneficial to know a pre-requisite factor for algal growth and changes occurring in the water at Rawal Dam and Wah Garden.

* Department of Pharmacy, University of Sindh, Jamshoro

** Department Fresh Water Biology and Fisheries, University of Sindh, Jamshoro, 76080,Sindh

Materials and Methods

At Rawal Dam the collections were made from the lake and Korang nallah upto the bridge on the way to NARC at latitude 33°.42' north, longitude 73°.07' east at the altitude 1800m above sea level at a distance of about 10 km from Rawalpindi.

Wah Gardens are located at 12 km west of Taxila on G.T. Road and about 50 km away from Islamabad. They are located at an altitude of 727 meters from above sea level at latitude 33°.50' North and longitude 72°.47' East.

Algal species were collected monthly from June, 2000 to May, 2002 between 11 a.m. to 3 p.m with the help of phytoplankton net of 5-10 µm mesh. Filamentous algae were collected with the help of forceps, blue green algae with slide cover, diatoms with tooth brush and macro-algae were picked up with hands from the different zones at Nullah of Wah Garden and Rawal Dam.

Water samples were obtained using water sampler (Nansen bottle), the physico-chemical features were studied by using standard methods (APHA, 1985). Samples of algae were preserved in 4 % formalin solution (Mason, 1967). The species composition was determined by Utremohal method (Lund, 1958). The micro-algae (ultra nannoplankton) were not counted. Identification and counts of other algal species were done using inverted light microscope. The specimens were identified with the help of available literature (Tilden, 1910; Husted, 1930; Majeed, 1935; Smith, 1950; Desikachary, 1959; Prescott, 1962; Siddiqi & Faridi, 1964; Patrick & Reimer, 1966; Philpose, 1967; Tiffany & Britton, 1971; Vinyard, 1979; Akiyama & Yamagishi, 1981) and were systematically arranged according to the recent classification (Shameel, 2001).

The organisms of an aliquot portion of the collected samples were concentrated by filtering through fine sand in a Sedgwick-Rafter funnel. The sand and the final 10 ml of the sample were then collected in a small beaker which was swirled gently to dislodge adhering organisms. One ml of this concentrated sample was then poured into a Sedgwick-Rafter plankton counting chamber. It was allowed to stand for about 10 minutes before examination. This permits most of the organisms to settle to the floor of the chamber. The counting chamber was then placed on the mechanical stage of the microscope and examined by using a 20 objective and 10^x eyepiece. The eyepiece was fitted with a ruled ocular micrometer. The outer boundaries forming a square field which was divided into 100 smaller squares by the rulings. For a representative count of a sample all organisms in 10. The 10 fields selected for counting were evenly spaced along the linear axis of the counting chamber from one end to the other. Each organism or colony was counted as one unless it was filamentous or elongated, and then it was counted once for each of the small squares it spanned (Leghari *et al.*, 2003).

Results and Discussion

In this study a total number of 296 algal species belonging to 114 genera of 11 phyla were observed (Table 1). They included Phylum Cyanophyta (68 species and 21 genera, 22.97 %), Phylum Volvocophyta (107 species and 42 genera, 36.15 %), Phylum Chlorophyta (18 species and 13 genera, 6.08 %), Phylum Bacillariophyta (66 species and 19 genera, 22.29 %), Phylum Chrysophyta (3 species and 2 genera, 1.01 %), Phylum Xanthophyta (5 species

and 5 genera, 1.7 %), Phylum Vaucheriophyta (1 species and 1 genus, 0.33 %) Phylum Euglenophyta (16 species and 4 genera, 5.4 %), Phylum Porphysidiophyta (1 species and 1 genus, 0.33 %), Phylum Dinophyta (5 species and 2 genera, 1.7 %), Phylum Charophyta (2 species and 1 genus, 0.7 %), and thisarrangement is in accordance with the most recent classification (Shameel,2001). Phylum Rhodophyta (4 species and 3 genera, 1.35 %). The water samples were analyzed and 37 physico-chemical parameters were recorded.

The physical and chemical parameters oh Rawal Dam and Wah garden have been presented in Table 2, both these areas exhibited similar values High air temperature (12-44° & 13-38° C) appeared to change the climate, directly affecting surface water temperature (10-31° and 17-26°C). High temperature of water surface helps in dissolving the organic and inorganic matter and temperature often controls the horizontal distribution of many algae. The photosynthetic rate of phytoplankton has been found to enhance with increase of temperature. The pH (7.6-8.5 & 7.8-8.5) shows that the water is alkaline, pH increase is due to high concentration of dissolved organic and inorganic matter, temperature and algal species. The T.D.S. (200-300 ppm) showing the concentration of total dissolved solids of the water is quite productive for aquatic life. The T.S.S. (1-2.6 & 0.5-4 mg/l) shows the ratio of total suspended solids in water, high T.S.S. value indicates high concentration of non living particulates originate as catchment, derived silts, clay, mud, organic matter. This high value is due to rain and flood. The flood episodes are the major disturbance in water affecting composition and biomass of the planktonic algae. The high turbidity (1.2-4 & 0.8-1.5) shows that water is too turbid. High concentration of abiogenic turbidity, whether due to disturbance or not, water colum mixing as such or in combination with inorganic turbidity may cause concomitant changes in the light field over time. Consequently, vertical mixing and suspended solids significantly affect phytoplankton photosynthesis and productivity in aquatic environment.

Conductivity (11. 2 - 22.8 and 40–62 M ohmsx^{10}) of Rawal Dam and Wah Garden shows that the current ions are enough for productivity. Salinity (2-4 and 0.5-3 ppt) and orthophosphate (0.02-0.33 and 0.08-0.4ug/l) were low. The results show that low salinity, orthophosphate, low temperature provide chances for the presence of the species of the phylum Chrysophyta (Tables 3 and 4). High humidity (42-72 and 46-68 %) shows that fungi, bacteria, Cyanophytes, aerial algae could be present as humidity directly affects light and temperature. Light transparency was 1-4 feet, at one feet the water is too much turbid which affects the light limit as a result of algal/phytoplankton photosynthesis and therefore restricts biomass development. Dissolved oxygen (7.1-10.9 and 8.2-9.4 mg/l) was in sufficient quantity. Carbon dioxide (80-180 and 80-100 ppm) was also in sufficient quantity for the growth of phytoplankton/algal species, as CO_2 causes enhanced algal species. Blue green algae were found in colonies like *Nostoc, Anabaina, Oscillatoria, Phormidium* and green algae making mats like *Cladophora, Spirogyra, Chara* as well as layer of *Cosmarium*. High value of CO_2 shows availability of carbonaceous rocks. High nitrate (0.7-2.6 and 0.3-2.3 µg/L) in summer season increased chlorophyll-a distribution and alternate high value in cold/winter season low chlorophyll-a were observed, which means that both nitrate and temperature play significant role in chlorophyll distribution. Phosphate (0.02-0.9

and 0.1-0.9 µg/L) plays significant role to control the algal growth.

Total hardness (1200-1800 and 1200-1500 ppm) of Rawal Dam and Wah Garden indicates that sufficient quantity of blue green algae was available in these water. Increase in Calcium hardness (900-1400 and 900-1100 ppm) enhancedthe production of green algae. Increase in the concentration of magnesium hardness (300-400 ppm) resulted in the production of colonies of Cyanophyta. High wave (1-2 and 4-10 inch) was due to fast flow of water. Furthermore,the samples of both - Rawal Dam and Wah garden showed that the water was tasteless, odourless but sometimes gave a vegetation smell due to thick aquatic vegetation and reduced water level winter and in spring season.

The species of blue green algae were dominant in summer and in monsoon season, Those of green algae were dominant in winter season, Bacillariophyta was prevalent autumn and in spring season and Charophyta common throughout the year. The species of Euglenophyta were common in mid winter and beginning of spring and those of Rhodophyta toward the end of autumn untill the beginning of spring season. This phylum is represented by 5 species at a time in this locality, otherwise it is represented by one species in one locality and other species on the other site. Species of *Batrachospermum* were available here and even collected from Kuzakhella near Mangora. *Comsopogon,* is also represented here in the month of March 2002 in Katass mixed with the aquatic vegetation like *Potamogeton pectinalis, P. crispus, Hydrilla vallisnaria, Cyprus, Phragmites, Typha latifolia.* These results are in agreement with the previous observations (Leghari *et al.*, 2003)

Particular attention was given to any factor which seemed to deviate from normal immediately preceeding algal/plankton rise. In the examination and interpretation of these fluctuations the very important factor appeared to be the rainfall. This affects the physico-chemical values and the algal count by dilution, and may also affect plankton multiplication by substituting soft water for hard water, as is usually found in their natural environment. It was noted that when a large amount of rainfall occurred, the algal count made a sharp decline which was simply due to dilution. During the summer and fall when small amount of rainfall occurred, there was a marked increase in the algal count which was probably due to flushing of heavily populated algal pools in the stream and on the watershed.

Table 1: Algal species belonging to different taxonomic groups with their percentages

Phylum	Class	Order	Family	Genera	Species	Percentage
Cyanophyta	2	2	5	21	68	22.97
Volvocophyta	2	4	17	42	107	36.15
Chlorophyta	3	6	8	13	18	6.08
Bacillariophyta	1	2	9	19	66	22.29
Chrysophyta	1	1	2	2	3	1.01
Xanthophyta	1	1	2	5	5	1.7
Vaucheriophyta	1	1	1	1	1	0.33
Euglenophyta	1	1	1	4	16	5.4
Porphysidiophyta	1	1	1	1	1	0.33
Dinophyta	1	1	2	2	5	1.7
Charophyta	1	1	1	1	2	0.7
Rhodophyta	1	2	3	3	4	1.35
Total:	16	23	52	114	296	100

Table 2: Comparative physico-chemical properties of Rawal Dam, Islamabad and Wah Garden, District Attock

	Rawal Dam		Wah Garden	
	Range	Mean ± S.D.	Range	Mean±S.D.
1. Soil temperature (°C)	Max. 23.8-24.2 Min. 4.5-5.5	24 ± 0.2 5 ± 0.5	24-26 11-13	25 ± 1 12 ± 1
2. Air temperature (°C)	Max. 42-44 Min. 12-13	43 ± 1 12.5 ± 0.5	36-38 13-15	37 ± 1 14 ± 1
3. Water surface temperature (°C)	Max. 30.9-31.1 Min. 10.8-11.2	31 ± 0.1 11 ± 0.2	24-26 17-19	25 ± 1 18 ± 1
4. Water bottom temperature (°C)	Max. 29.8-30.2 Min. 10.9-11.1	30 ± 0.2 11 ± 0.1	24-26 17-19	25 ± 1 18 ± 1
5. pH	Max. 8.3-8.5 Min. 7.6-7.8	8.4 ± 0.1 7.7 ± 0.2	8.3-8.5 7.8-8	8.4 ± 0.1 7.9 ± 0.1
6. Turbidity in NTU range on 100	Max. 4-4 Min. 1.2-1.2	4 ± 0.0 1.2 ± 0.0	1.5-1.5 0.8-0.8	1.5 ± 0.0 0.8 ± 0.0
7. T.D.S (ppm)	Max. 300-300 Min. 200-200	300 ± 0.0 200 ± 0.0	300-300 200-200	300 ± 0.0 200 ± 0.0
8. T.S.S. (mg/l)	Max. 2.4-2.6 Min. 1-1	2.5 ± 0.1 1 ± 0.0	2-4 0.5-0.7	3 ± 1 0.6 ± 0.1
9. Conductivity (m.Ohms x^{10})	Max. 228-228 Min. 112-112	228 ± 0.0 112 ± 0.0	60-62 40-44	61 ± 1 42 ± 2
10. Salinity (ppt)	Max. 3.8-4 Min. 2-2	3.9 ± 0.1 2 ± 0.0	1-3 0.5-0.9	2 ± 1 0.7 ± 0.2
11. Humidity (%)	Max. 70-72 Min. 42-44	71 ± 1 43 ± 1	66-68 46-50	67 ± 1 48 ± 2
12. Light transparency by Secchi disc (feet)	Max. 4-4 Min. 1-1	4 ± 0.0 1 ± 0.0	3-5 1-1	4 ± 1 1 ± 0.0
13. Dissolved oxygen (mg/l)	Max. 10.8-11 Min. 7.1-7.3	10.9 ± 0.1 7.2 ± 0.1	9.2-9.4 8.2-8.4	9.3 ± 0.1 8.3 ± 0.1
14. Saturation (%)	Max. 85.8-87 Min. 56-58	86.25 ± 0.75 57 ± 1	71.5-74.5 65.3-67.5	73 ± 1.5 66.4 ± 1.1
15. CO_2 (ppm)	Max. 178-182 Min. 79-81	180 ± 0.1 80 ± 1.0	90-100 80-84	95 ± 5 82 ± 2
16. Ammonia nitrogen (NH_3 N_2 ppm)	Max. 0.04-0.04 Min. 0.02-0.02	0.04 ± 0.0 0.02 ± 0.0	0.04-0.06 0.01-0.03	0.05 ± 0.01 0.02 ± 0.01
17. Nitrate µg/l.	Max. 2.4-2.6 Min. 0.7-0.9	2.5 ± 0.1 0.8 ± 0.1	2.1-2.3 0.3-0.5	2.2 ± 0.1 0.4 ± 0.1
18. Density (30°C g/v)	Max.1.006-1.006 Min.1.005-1.005	1.006 ± 0.0 1.006 ± 0.0	1.005-1.009 1.004-1.006	1.007 ± 0.002 1.005 ± 0.001
19. Orthophosphate (µg/l)	Max. 0.33-0.33 Min. 0.02-0.02	0.33 ± 0.0 0.02 ± 0.0	0.2-0.4 0.08-0.1	0.3 ± 0.1 0.09 ± 0.01
20. Phosphate (µg/l)	Max. 0.9-0.9 Min. 0.02-0.02	0.9 ± 0.0 0.02 ± 0.0	0.7-0.9 0.1-0.3	0.8 ± 0.1 0.2 ± 0.1

21. Total hardness ($CaCO^3$ ppm)	Max.1800-1800 Min.1200-1200	1800 ± 0.0 1200 ± 0.0	1500-1500 1200-1200	1500 ± 0.0 1200 ± 0.0
22. Ca++ hardness (ppm)	Max.1400-1400 Min.900-900	1400 ± 0.0 900 ± 0.0	1100-1100 900-900	900 ± 0.0 1100 ± 0.0
23. Mg hardness (ppm)	Max. 400-400 Min. 300-300	400 ± 0.0 300 ± 0.0	400-400 300-300	400 ± 0.0 300 ± 0.0
24. $CaCl_2$ hardness (ppm)	Max.1554-1554 Min.999-999	1554 ± 0.0 999 ± 0.0	1221-1221 999-999	1221 ± 0.0 999 ± 0.0
25. Mg Cl_2 (ppm)	Max. 380-380 Min. 285-285	380 ± 0.0 285 ± 0.0	380-380 285-285	380 ± 0.0 285 ± 0.0
26. Grain per gallon (Gpg)	Max.104.4-104.4 Min.69.6-69.6	104.4 ± 0.0 69.6 ± 0.0	87-87 52.2-52.2	87 ± 0.0 52.2 ± 0.0
27. Refractiv index (30°C)	Max.1.33-1.33 Min.1.33-1.33	1.33 ± 0.0 1.33 ± 0.0	1.334-1.334 1.334-1.334	1.334 ± 0.0 1.334 ± 0.0
28. Wave (inch)	Max. 2-2 Min. 1-1	2 ± 0.0 1 ± 0.0	6-10 4-6	8 ± 2 5 ± 1
29. Taste	Tastless		Tastless	
30. Water colour	Gray and colourless		Grey and Green	
31. Odour	Odourless		Vegetation smell and Odourless	
32. Wind	Cold in winter & Dry hot in summer			
33. Day	Cloudy and Clear		Cloudy and Clear	
34. Weather	Fogy and Dry Clear		Fogy and Dry Clear	
35. Water	Shallow		Slow running water	
36. Soil	Muddy and Rocky		Muddy and Rocky	
37. Zone	Subtropical		Subtropical	

Max.= Maximum Min.= Minimum, S. D.= Standard deviation

Table 3: Qualitative and Quantitative Study of Algal Flora in Rawal Dam, Islamabad and Wah Garden, District Attock

	Range			Occurrence	
	Min:	Max:	Mean±S.D	Rawal Dam	Wah Garden
Kingdom: MONERA					
Phylum:- Cyanophyta					
Class:- Chroocophyceae					
Order:- Chroococcales					
Family:- Chroococcaceae					
1. *Aphanocapsa montana* Cramer	3	7	5±2	c	c
2. *A. virescens* (Hass.) Raben.	1	3	2±1	c	c
3. *Aphanothece castagnei* (Breb.) Raben.	8	12	10±2	a	c
4. *A. nidulans* Richter	6	10	8±2	r	c
5. *A. saxicola* Naegeli	2	4	3±1	r	r
6. *Chroococcus bituminosus* (Bory) Hansgirg	3	5	4±1	r	r
7. *C. cohaerens* (Breb. Naegeli	5	9	7±2	r	a
8. *C. endophyticus* Copeland	6	8	7±1	c	c
9. *C. giganteus* West & West	1	3	2±1	r	r
10. *C. lithophilus* Erceg.	1	1	1±00	vr	vr
11. *C. minutus* var. *thermalis* Copeland	1	3	2±1	vr	vr
12. *C. turicensis* (Naeg.) Hansgirg	2	2	2±00	vr	a
13. *C. turgidus* (Kuetz.) Naeg.	2	4	3±1	vc	vc
14. *C. turgidus* var. *tenax* Kirchin	1	1	1±00	r	a
15. *C. turgidus* var. *turgidus*	6	10	8±2	c	a
16. *Eucapsis minuta* Fritsch	2	2	2±00	vr	a
17. *Gloeocapsa ambigua* var. *violacea* Naeg.	1	1	1±00	vr	a
18. *G. compacta* Kuetz.	2	2	2±00	r	r
19. *G. gelatinosa* (Carm.) Kuetz.	1	3	2±1	vc	vc
20. *G. lithophila* (Ereeg.) Hollenb.	1	1	1±00	vr	vr
21. *G. nigrescens* Naeg.	1	1	1±00	vr	vr
22. *Gloeothece confluens* Naeg.	2	6	4±2	r	r
23. *Gomphosphaeria aponina* Kuetz.	6	10	8±2	vc	a
24. *G. aponina* var. *cordiformis* Elenk.	2	4	3±1	c	c
25. *G. aponina* var. *delicatula* Virieux	3	5	4±1	c	c
26. *G. lacustris* Chod.	5	7	6±1	c	c
27. *Merismopedia convoluta* Breb.	12	24	18±6	vc	vc
28. *M. glucum* (Ehr.) Naegeli	16	32	24±8	vc	vc
29. *Microcystis aeruginosa* Breb.	1	3	2±1	vc	vc
30. *M. flos-aquae* (Wittrock) Kirchner	1	1	1±0	vr	vc
31. *Pseudoholopedia convoluta* (Breb.)	12	16	14±2	c	c

a = absent, c = common, r = rare, vc = very common, vr = very rare

Elekin.					
32. *Synechococcus aquatilis* Sauv.	1	3	2±1	a	c
Class: Nostocophyceae					
Order:- Nostocales					
Family:- Oscillatoriaceae					
33. *Lyngbya bornettii* Zukal	2	2	2±00	vc	vc
34. *L. confervoides* Agardh	1	1	1±00	vc	vc
35. *L. martensiana* Meneghini	2	6	4±2	vc	vc
36. *Oscillatoria agardhii* Gomont	4	6	5±1	vc	vc
37. *O. agardhii* f. *aequicrassa* Elenk.	2	2	2±00	vr	a
38. *O. curv ceps* Agardh	6	10	8±2	a	vr
39. *O. formosa* Bory	2	6	4±2	vc	vc
40. *O. iwanoffiana* (Nyg.) Geitler	2	2	2±00	vc	vc
41. *O. limosa* Agardh	6	10	8±2	a	vr
42. *O. minnesotensis* Tilden	4	8	6±2	vr	vr
43. *O. musicola* Woronich.	2	6	4±2	vr	a
44. *O. princeps* Vaucher	1	3	2±1	a	vr
45. *O. proboscidea* Gom.	1	1	1±00	vr	vr
46. *O. tenuis* Agardh	2	2	2±00	vc	vc
47. *Phormidium faveolarum* (Mont.) Gom.	1	2	2±00	vc	vc
48. *P. orientale* West	1	1	1±00	vr	a
49. *P. subfuscum* (Ag.) Kuetz.	1	3	2±1	vr	vr
50. *P. tenue* (Menegh.) Gom.	3	5	4±1	vc	vc
51. *P. uncinatum* (Agardh) Goment	1	1	1±0	r	r
Family: Nostocaceae					
52. *Anabaina aequalis*	1	1	1±00	vr	a
53. . An*abaenopsis reciborskii* Wolos.	2	6	4±2	c	vc
54. *A. azollae* Born.	2	2	2±00	vr	a
55. *A. inaequalis* (Kuetz.) Born.	2	2	2±00	vc	vc
56. *A iyengar*tvar. *tenuis*	1	1	1±00	vr	a
57. *A. variabilis* Kuetz.	2	4	3±1	vc	vc
58. *Nostoc commune* Vaucher	18	22	20±1	vr	vr
59. *N. muscorum* Agardh.	8	12	10±2	vr	vr
60. *N. populorum* (Geit.) Hollenb.	2	2	2±00	vr	a
Family: Rivulariaceae					
61. *Calothrix centarenii* (Zanard.) Born.	2	2	2±00	vr	a
62. *C. stagnalis* Gomont	1	1	1±00	vr	a
63. *C. parietana* (Naeg.) Thuret	1	3	2±1	a	vr
64. *Rivularia atra* Roth	2	2	2±00	vr	a
65. *R. minutula* (Kuetz.) Born.	1	1	1±00	vr	a
66. *R. natans* (Hedw.) Welw.	2	2	2±00	r	r
Family: Scytonemataceae					
67. *Tolypothrix distorta* var. *penicillata*	4	6	5±1	vr	a
68. *Sacconema rupestre* Borzi	1	1	1±00	vr	a

Kingdom: PROTISTA					
Phylum: Volvocophyta					
Class: Volvocophyceae					
Order: Chlorococcales					
Family: Oocystaceae					
1. *Ankistrodesmus falcatus* (Corda) Ralfs	2	4	3±1	vr	a
2. *A. falcatus* var. *acicularis* (A. Br.) West	1	1	1±00	vr	a
3. *A. falcatus* var. *stipitatus* (Chod) Lemm.	1	1	1±00	r	r
4. *Chlorella ellipsoidea* Gerneck	8	10	9±1	c	c
5. *C. pyrenoidosa* Chick	4	6	5±1	vc	vc
6. *C. vulgaris* Beyerinck	5	7	6±1	vc	vc
7. *Closteriopsis longissima* var. *tropica* West & West.	1	1	1±00	vr	a
8. *Gloeotaenium loitelsbergerianum* Hansgirg	1	1	1±00	vr	a
9. *Kircheneriella lunaris* (Kirch.) Moebius	2	2	2±00	vc	vc
10. *K. subsolitoria* West	2	2	2±00	r	r
11. *Nephrocytium agardhianum* Naegeli	1	1	1±00	vr	vr
12. *Oocystis borgei* Snow	7	8	7.5±0.5	vc	vc
13. *O. crassa* Wittrock	3	3	3±00	vc	vc
14. *O. parva* West & West	3	3	3±00	vc	vc
15. *Quadrigula lacustris* (Chod.) Smith	1	1	1±00	vr	a
16. *Tetraedron asymmetricum* Prescott	4	6	5±1	a	vr
17. *Trochiscia hirta* West	3	4	3.5±0.5	vc	vc
Family: Chlorococcaceae					
18. *Chlorococcum humicola* (Naeg.) Rab.	8	12	10±2	vc	vc
Family: Radiococcaceae/Myurococcaceae					
19. *Coenochloris pyrenoidosa* Korschikoff	4	8	6±2	vr	a
Family: Dictyosphaeriaceae					
20. *Dictyosphaerium ehrenbergianum* Naegali	3	5	4±1	vc	vc
21. *D. pulchellum* Wood	2	4	3±1	r	r
22. *D. pulchellum* var. *ovatum*	1	1	1±00	vr	a
Family: Micractiniaceae					
23. *Golenkinia paucispina* West & West	1	1	1±00	vr	a
Family: Coelastraceae					
24. *Coelastrum cambricum* Archer	3	5	4±1	vr	a
25. *C. microporum* Naegeli	4	6	5±1	c	c
26. *C. scabrum* Reinsch	3	4	3.5±1.5	vr	a
27. *C. sphaericum* Naegeli	2	2	2±00	vr	vr
Family: Hydrodictyaceae					
28. *Hydrodictyon reticulatum* (L.) Lagerheim	1	1	1±00	vr	a
29. *Pediastrum boryanum* (Turp.) Men.	2	3	2.5±0.5	c	c

30. *P. duplex* var duplex Meyen	2	2	2±00	c	c
31. *P. duplex* var. *clathratum* (A. Braun) Lagerheim	1	1	1±00	vr	vr
32. *P. intergrum* Naegeli	2	2	2±00	vr	vr
33. *P. tetras* (Ehr.) Ralfs	4	6	5±01	c	c
Family: Scenedesmaceae					
34. *Crucigenia lauterbornii* Schmidle	1	1	1±00	vr	a
35. *C. tetrapedia* (Kirch.) West & West	5	7	6±1	vc	vc
36. *Scenedesmus abundans* (Kirch.) Chodat	2	2	2±00	vr	a
37. *S. acuminatus*	3	4	3.5±0.5	vr	a
38. *S. arcuatus* var	4	5	4±1	c	c
39. *S. arcuatus* var. platydisca Smith	1	1	1±00	vr	a
40. *S. aculeolatus* Lemm.	1	1	1±00	vr	a
41. *S. bijuga* (Turp.) Lager.	8	10	9±1	a	vr
42. *S. dimorphus* (Turp.) Kuetz.	1	1	1±00	vr	a
43. *S. acutiformis* Schroeder	1	1	1±00	vr	vr
44. *S. circumfusus* Hortobagyi	1	1	1±00	vr	a
45. *S. longus* Meyen	1	1	1±00	vr	a
46. *S. minutus* (Smith) Chodat	2	4	3±1	vr	a
47. *S. opliquus* (Turp.) Kuetz.	2	2	2±00	vr	a
48. *S. quadricauda* Breb.	3	5	4±1	c	c
49. *S. tibiscensis* Uherkovich	1	1	1±00	vr	vr
Order: Tetrasporales					
Family: Palmellaceae					
50. *Asterococcus limneticus* Smith	8	12	10±2	vc	a
51. *Palmella mucosa* Kuetz.	6	10	8±2	vc	vc
52. *Sphaerocystis schroeteri* Chodat	2	4	3±1	vr	a
Family: Cocomaxaceae					
53. *Elakatothrix gelatinosa* Wille	2	2	2±00	vr	a
54. *E. viridis* Kuetz.	8	10	9±1	a	vc
Family: Tetrasporaceae					
55. *Tetrospora lacustris* Lemm.	10	16	13±3	vc	vc
56. *T. lubrica* (Roth.) Agardh	8	10	10±2	vc	vc
Family: Chlorangiaceae					
57. *Chlorangium stentorinum* (Ehr.) Stein	1	1	1±00	vr	a
Order: Volvocales					
Family: Chlamydomonadaceae					
58. *Chlamydomonas pseudopertyi* Pascher	6	8	7±1	vc	vc
59. *Platymonas elliptica* Smith	2	4	3±1	r	a
60. *Sphaerellopsis fluviatile* (Stein) Pasch.	2	4	3±1	r	a
Family: Phacotaceae					
61. *Pteromonas angulosa* (Cart.) Lemm.	1	3	2±1	vr	a
Family: Volvocaceae					
62. *Gonium quadratum* Pringsheim	1	1	1±00	vr	vr

63. *Eudorina elegans* Ehr.	2	5	3.5±0.5	c	c
64. *Pandorina morum* Prins.	2	4	3±1	c	c
65. *Pleodorina illinoisensis* Kafoid.	2	6	4±2	c	c
Class: Desmidiophyceae					
Order: Desmidiales					
Family: Desmidiaceae/Closterieae					
66. *Closterium calosporium* var. *majus* West& West	1	1	1±00	vr	a
67. *Cl. Dianae* Ehr.	2	4	3±1	c	c
68. *Cl. Ehrenbergii* Menegh.	3	5	4±1	c	c
69. *Cl. Leibleinii* Kuetz.	1	3	2±1	vr	a
70. *Cl. Ralfsii*	4	6	5±1	vc	a
71. *Cl. Littorale* Gay	1	1	1±00	vr	a
72. *Cl. Moniliferum* (Bory) Ehr.	1	1	1±00	vr	vr
73. *Cl. P0usillum* var. *minus* Allorge	1	1	1±00	vr	vr
Subfamily: Cosmarieae					
74. *Cosmarium constrictun* Delponte	8	12	10±2	vc	vc
75. *C. baergesenii* Gronbl.	2	2	2±0	a	vr
76. *C. contractum* var. *ellipsoideum* West & West	4	6	5±1	vc	a
77. *C. circulare* Reinsch	3	5	4±1	vc	a
78. *C. dichondrum* var. *subhexagonum* West & West	1	3	2±1	r	a
79. *C. gibberulum* Latkem.	2	4	3±1	c	a
80. *C. innotum*	1	2	1.5±0.5	vr	a
81. *C. impressulum* var. *suborthogonum* (Racib.) West& West.	1	1	1±00	vr	a
82. *C. nitidulum* Denotaris	2	2	2±00	vr	a
83. *C. occidentale* (Turp.) Gerloff	2	4	3±1	r	a
84. *C. subtumidum* var. *rotundum* Hirano	1	2	1.5±0.5	vr	vr
85. *C. oreniferum*	2	2	2±00	r	a
86. *C. palustren*	2	4	3±00	r	a
87. *C. reniforme* var. *alaskanum* Croasdole	1	3	2±1	vr	a
88. *C. phaseolus* var. *phaseolus*	1	3	2±1	vr	a
89. *C. pseudoconnatum* f. *major* Wille	2	2	2±00	vr	a
90. *C. ralfsii* var. *spinigerum* Scott & Gron.	1	1	1±00	vr	a
91. *C. speciosum* L.	1	1	1±00	vr	a
92. *C. supergranatum* f. *minor*	2	2	2±00	vr	vr
93. *C. tetrachondrum* var. *perornatum* Skuja	1	1	1±00	vr	vr
94. *C. trachypleurum* var. *cornutum*	1	1	1±00	vr	a
95. *C. undulatum* Corda.	2	2	2±00	r	r
96. *C. punctulatum* Breb.	1	3	2±1	r	r
97. *Cosmocladium constrictum* Archer.	1	3	2±1	vr	a

98. *Dysphinctium retusum*	1	2	1.5±0.5	vr	a
99. *Euastrum pectinatum* Breb.	1	2	1.5±0.5	vr	a
100. *Penium simplex*	2	2	2±00	c	c
101. *Pleurotaenium ehrenbergii* var. *undulatum* Scha.	2	4	3±1	c	c
102. *Staurastrum dilatalum* Ehr.	2	2	2±00	vr	a
103. *S. hexacerum* (Ehr.) Wittr.	1	3	2±1	vr	a
104. *S. iotanum* Wolle	2	4	3±1	vr	a
105. *S. margaritaceum* (Ehr.) Menghini	1	1	1±00	vr	a
106. *S. punctulatum* Breb.	1	1	1±00	vr	a
Family: Gonatozygaceae					
107. *Gonatozygon kinahani* (Archer.) Hasting	2	6	4±2	c	a

Phylum: Bacillariophyta					
Class: Bacillariophyceae					
Order: Biddulphiales (Centric)					
Family: Coscinodiscaceae					
1. *Cyclotella antiqua* Smith	4	8	6±2	c	a
2. *C. glomerata* Hustedt	1	3	2±1	c	a
3. *C. planctonica* Hustedt	2	8	5±3	c	c
Order: Bacillariales (Pennate)					
Family: Achnanthaceae					
4. *Achnanthes inflata* Kuetz.	7	9	8±1	vc	vc
5. *A. lanceolata* (Breb.) Grun.	6	10	8±2	vc	a
6. *Cocconeis placentula* var. *lineata* (Ehr.) Cleve	1	3	2±1	vr	vr
7. *C. disculus* Schum.	3	5	4±1	c	a
8. *C. thumensis* Mayer	2	4	3±1	c	a
Family: Epithemiaceae					
9. *Epithemia argus* Kuetz.	2	4	3±1	c	c
10. *E. ocellata* (Ehr.) Kuetz.	1	1	1±00	vr	a
11. *E. zebra* (Ehr.) Kuetz.	2	2	2±00	vr	vr
12. *Denticula elegans* Kuetz.	1	3	2±1	vr	a
Family: Cymbellaceae					
13. *Amphora delicatissima* Krab.	4	8	6±2	vc	vc
14. *A. ovalis* Kuetz.	4	6	5±1	vc	vc
15. *A. ovalis* var. *gracilis* Meister	8	12	10±2	a	vc
16. *Cymbella brehmii* Hust.	6	8	7±1	vc	a
17. *C. laevis* Naegeli	2	4	3±1	vc	a
18. *C. leptoceros* (Ehr.) Grunow.	1	1	1±00	vr	vr
19. *C. tumida* (Breb.) van Heurck	2	4	3±1	r	r
20. *C. turgida* Gregory	1	1	1±00	vr	vr
21. *C. ventricosa* Kuetz.	2	2	2±00	vr	a

22. *Dedymosphena geminata*	2	2	2±00	vr	a
Family: Gomphonemaceae					
23. *Gomphonema abbreviatum* Agardh	6	8	7±1	vc	vc
24. *G. affine* var. *insigne*	4	6	5±1	vc	vc
25. *G. augur* Ehr.	1	3	2±1	vc	vc
26. *G. longiceps* f. *gracilis* Hust.	2	4	3±1	vc	a
27. *G. olivaceum* var. *calcarea* Cleve	6	10	8±2	vc	vc
28. *G. parvulum* var. *subelliptica* Cleve	1	1	1±00	r	a
29. *G. ventricosum* Gregory	1	3	2±1	r	a
30. *G. ghosea* Grun.	6	12	9±3	vc	vc
Family: Naviculaceae					
31. *Gyrosigma kuetzingii* (Grun.) Cleve	2	6	4±2	vr	vr
32. *G. scalproides* (Rabh.) Cl.	2	4	3±1	a	vr
33. *Navicula cryptocephala* var. intermedia Grun.	2	4	3±1	vr	a
34. *N. disjuncta* Hust.	3	4	3.5±0.5	c	a
35. *N. exilissima* Grun.	2	5	3.5±1.5	c	a
36. *N. fluens* Hust.	1	1	1±00	vr	a
37. *N. incerta* Grun.	1	3	2±1	vr	a
38. *N. longirostris* Hust.	2	2	2±00	c	a
39. *N. pupula* var. *mutata* (Krab.) Hust.	3	5	4±1	c	a
40. *N. radiosa* var. *tenella* Grun.	6	12	9±3	c	c
41. *N. salinarum* Grunow	4	6	5±1	c	a
42. *N. simlex* Krabke	2	2	2±00	c	a
43. *N. sohrensis* Krabke	1	1	1±00	vr	a
44. *Neidium dubium* (Ehr.) Pfitzer	1	1	1±0	a	vr
45. *Pinnularia gibba* (van Heurk) Boyer	6	8	7±1	vc	vc
46. *P. debesi* Schale	2	4	3±1	vc	vc
47. *Rhopaldia gibba* (Kuetz.) Mueller	6	8	7±1	vc	vc
Family: Fragilariaceae					
48. *Diatoma elongatum* (Lyn gb.) Ag.	6	8	7±1	a	vc
49. *D. heimale* (Roth) Heib.	4	6	5±1	vc	vc
50. *D. vulgare* Bory	8	12	10±2	a	vc
51. *Fragilaria capucina* Desmazieres	8	12	10±2	vc	a
52. *F. construens* (Ehr.) Grunow	6	8	7±1	vc	a
53. *F. virescens* Ralfs	2	6	4±2	vc	a
54. *Synedra accus* Kuetz.	2	8	5±3	vc	vc
55. *S. affinis* (Kuetz.) Pascher	6	8	7±1	vc	vc
56. *S. amphicephala* var. *austriaca*	2	4	3±1	r	a
57. *S. minuscula* Grun.	6	8	7±1	a	vc
58. *S. rumpens* var. *meneghiniana* Grun.	2	4	3±1	c	a
59. *S. ulna* (Nitzsch) Ehr.	12	16	14±2	vc	vc
60. *S. ulna* var. *aequalis* (Kuetz.) Hust.	6	12	9±3	vc	vc
61. *S. ulna* var. *oxyrhynchus*	5	10	7.5±2.5	vc	vc

62. *S. ulna* var. *danica* (Kuetz.) Grunow	2	4	3±1	vr	vr
Family: Nitzschiaceae					
63. *Nitzschia ignorata* Krabke	1	1	1±00	vr	vr
64. *N. filiformis* (Smith) Hust.	1	1	1±00	vr	vr
65. *N. vermicularis* Hantzsch	2	4	3±1	vr	a
Family: Surirelliaceae					
66. *Surirella elegans* Ehr.	1	1	1±00	vr	a
Phylum: Chrysophyta					
Class: Chrysophyceae					
Order: Ochromonadales					
Family: Chrysocapsaceae					
1. *Chrysocapsa planctonica* (West & West) Pascher	2	2	2±0	vr	a
Family: Dinobryaceae					
2. *Dinobryon divergens* Imhof	1	1	1±00	vr	a
3. *D. sociale* Her.	1	1	1±00	vr	vr
Phylum: Xanthophyta					
Class: Xanthophyceae					
Order: Mischococcales					
Family: Chlorobotrydaceae					
1. *Botryococcus brunii* Kuetz.	4	6	5±1	a	c
2. *Chlorellidiopsis separabilis* Pascher	2	2	2±00	vr	a
3. *Chlorobotrys regularis* (W. & W.) Bahlin	2	6	4±2	r	r
4. *Perone dimorpha* Pascher	1	1	1±00	vr	vr
Family: Pleurochloridaceae					
5. *Diachros simplex* Pascher	1	1	1±00	vr	a
Phylum: Euglenophyta					
Class: Euglenophyceae					
Order: Euglenales					
Family: Euglenaceae					
1. *Cyclidiopsis acus* Korschikoff	2	2	2±00	c	a
2. *Euglena cyclopicola* Geik.	1	1	1±00	vr	vr
3. *E. desus* Ehr.	1	1	1±00	vr	vr
4. *E. elongata* Schewiakoff	2	2	2±00	vr	vr
5. *E. intermedia* (Klebs.) Schmitz	2	2	2±00	vr	vr
6. *E. mutabilis* Schmitz	1	1	1±00	vr	vr
7. *E. proxima* Dangeard	1	1	1±00	vr	vr
8. *E. viridis* Kuetz.	2	2	2±00	vr	vr
9. *E. pascheri* Swirenko	2	2	2±00	vr	vr
10. *Phacus caudatus* (Hulb.)	2	2	2±00	vr	vr
11. *P. caudatus* var. *ovalis*	1	1	1±00	vr	vr
12. *P. curvicauda* Swirenko	2	2	2±00	vr	a
13. *P. orbicularis* Huebner	2	2	2±00	a	vr

14. *P. suecicus* Lemm.	1	1	1±00	vr	vr
15. *P. longicauda* (Ehr.) Diyardin	1	1	1±00	vr	a
16. *Trachelomonas volvocina* Ehr.	2	2	2±00	vr	vr
Phylum: Dinophyta					
Class: Dinophyceae					
Order: Peridiniales					
Family: Ceratiaceae					
1. *Ceratium hirundinella* (Muller) Duja.	1	1	1±00	vr	a
Family: Peridiniaceae					
2. *Peridinium cinctum* (Muell.) Ehr.	2	2	2±00	vr	a
3. *P. marchicum* Lemm.	1	1	1±00	vr	a
4. *P. bipes* Stein.	1	1	1±00	vr	a
5. *p. inconspicum* Lemm.	1	1	1±00	vr	a
Phylum: porphyriodiophyta class: porphysio-plyceae					
Kingdom: PROTOCTISTA					
Phylum: Chlorophyta					
Class: Siphonocladophyceae					
Order: Cladophorales					
Family: Cladophoraceae					
108. *Cladophora glomerata* (L.) Kuetz.	6	8	7±1	vc	vc
Order: Chaetophorales					
Family: Chaetophoraceae					
109. *Chaetophora elegans* (Roth) Agardh	6	10	8±2	c	a
Family: Coleochaetaceae					
110. *Coleochaete orbicularis* Pringsheim	1	1	1±00	vr	a
Order: Sphaeropleales					
Family: Sphaeropleaceae					
111. *Sphaeroplea annulina* (Roth) Agardh	2	2	2±00	vr	a
Class: Ulvophyceae					
Order: Ulotrichales					
Family: Ulotrichaceae					
112. *Koliella helvetica* (Kol.) Hindok	2	3	2.5±0.5	vr	vr
113. *Ulothrix aequalis* Kuetz.	4	6	5±1	vc	vc
114. *U. bacillaris* (Naeg.) Com.	2	4	3±1	c	a
115. *U. tenuissima* Kuetz.	1	1	1±00	vr	a
116. *U. zonata* (Web. & Mohr.) Kuetz.	2	2	2±00	vr	a
117. *Uronema confervicola* Lagerheim	2	4	3±1	vr	a
Family: Microsporaceae					
118. *Microspora tumidula* Hazen.	2	6	5±1	c	a
Class: Zygnemophyceae					
Order: Oedogoniales					
Family: Oedogoniaceae					

119. *Oedogonium olevaceum* Ehr.	4	6	5±1	vc	vc
120. *O. angustissimum* W.&W.	2	4	3±1	vc	vc
Order: Zygnematales					
Family: Zygnemataceae					
121. *Sirogonium sticticum* Kuetz.	1	3	2±1	vr	a
122. *S. aequinoctialis* West	1	3	2±1	c	c
123. Spirogyra crassa Kuetz.	2	4	3±1	c	c
124. *Mougeotia gracillima* (Hassal) Wittrock	1	3	2±1	c	a
125. *Zygnema sterile* Transeau	1	3	2±1	vr	a
Phylum. Porphysidio phyta Class porphysidiophceae **Order: Porphyridiales**					
Family: Cyanidiaceae					
1. *Cyanidium caldarium* (Tilden) Geitler	2	2	2±0	a	vr
Phylum: Charophyta					
Class: Charophyceae					
Order: Charales					
Family: Characeae					
1. *Chara fibrosa* Ag.	3	3	3±00	c	c
2. *Chara vulgare* L.	2	2	2±00	c	c
Phylum: Vaucheriophyta					
Class: Vaucheriophyceae					
Order: Vaucheriales					
Family: Vaucheriaceae					
1. Vaucheria sessilis	2	6	4±2	c	c
Phylum: Rhodophyta					
Class: Nemaliphyceae					
Order: Batrachospermales					
Family: Batrachospermaceae					
2. *Batrachospermum moniliforme* Roth	10	14	12±2	a	c
Family: Audouinellaceae					
3. *A udouinella chalybea* Bory	3	5	4±1	a	c
4. *A. hermanii* (Roth) Duby	4	6	5±1	a	c
Order: Compsopogonales					
Family: Compsopogonaceae					
4.Compsopogon coeruleus (Babis) Mont.	8	12	10±2	a	vc

Table 4: Occurrence of algal species

Occurrence	Rawal Dam		Wah Garden	
	Algal species	**Percentage**	**Algal species**	**Percentage**
Very rare (vr)	133	48.72	55	33.33
Rare (r)	27	9.89	14	8.48
Common (c)	50	18.32	36	21.82
Very common (vc)	63	23.07	60	36.37
Total:	273	100	165	100

Conclusion

1. Flow, turbidity, rain factors were affecting on the growth of the algae/plankton.

2. The species of green algae were dominant over other groups.

3. The algal peaks were fairly constant from year to year in their periodicity and were usually the major peaks of the season. The green algae reached their maxima during winter season.

4. The high algal/plankton peaks were accompanied by an increase in dissolved oxygen and pH.

5. The pH seemed to be governed by the amount of free carbon dioxide *i. e.* the greater the carbon dioxide content of water the lower the pH.

6. The nitrite and nitrate contents of water decreased with algal/plankton pulses represented by a mixed flora, thus indicating that these compounds were essential for multiplication of most algal organisms.

7. The heaviest algal/plankton population was always down streams from the point of sewage pollution and the location of the algae/plankton peak seemed to be governed by the rate of water flow.

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