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Study of Physico-Chemical Parameters of an Artificial Lake of Sindh

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To determine the cause of elimination of aquatic macrophytes, in a man made lake located in a big Safari Park of Karachi is situated at 24°-50'N latitude and 66°-55'E longitude, sixteen physico-chemical parameters of water were analyzed throughout the water column upto a period of one year from June, 1994 to July, 1995. Analysis of the data shows that most of the chemical constituents were present in high ranges, indicating pollution. The lake is in poor ecological condition as its basin is full of debris which may influence the growth of plants. Special measures to clean the basin will naturally be helpful in making it more picturesque as well as for the exploitation of fish and water fowl hunting.

Key words: Physico-chemical parameters, Artificial lake.

Introduction

Only 3% of the total water present on the earth is fresh water while 97% water is saline, occurring in oceans (Meybeck and Helmer 1996). It is, therefore, important to study freshwater resources in Pakistan for their better management and utilization. Lakes are important resources of freshwater and are used for multiple purposes as drinking water, irrigation, industrial power generation, commercial and recreational fisheries, boating and other aesthetic recreational uses (Khan 1990; Thomas *et al* 1996).

In addition to natural lakes, Pakistan has also a large number of man made polymictic shallow lakes (Nazneen 1995)but most of them are in poor ecological condition. Only a very little knowledge is available on the physico-chemical characteristic of these water bodies (Jawed *et al* 1993; Nazneen and Begum 1993). In the province of Sindh, such data is available only on Kinjhar, Haleji and Aziz Bhatti lakes as reported (Baqai *et al* 1974 a & b; Nazneen 1974; Baig and Khan 1976; Nazneen 1980; Nazneen and Jamal 1987).

Small lakes are considered very important from the recreational point of view because of their the clear water and rich aquatic vegetation (Scheffer 1998). Safari lake is a small man made recreational lake, located in Karachi, the most populated and industrialized city in Pakistan. This study was undertaken to know the reasons for the lack of aquatic vegetation in it.

Morphological features of lake. This lake is basically an ornamental lake and situated in a big Safari Park located in Karachi at the University Road near University of Karachi. Its basin is of destructive type some what circular in shape which was formed as the result of excavation. It covers an area of 2½ acres (Fig 1a & 1b), its bottom is made up of clay and its rim is stony. The lake is devoid of larger aquatic plants as it was earlier used for boating purposes and the plants were used to be eradicated manually. Due to the continuous silting and pollution the basin is filled with debris.

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Materials and Methods

Monthly collections of water samples both from surface and depth (3 meters) were made from July, 1994 to July, 1995 from three spots in the lake by Ruttner water sampler. Physical features were noted at the sampling spots the chemical parameters were measured immediately in the laboratory. The colour, light penetration level, euphotic limits and vertical attenuation coefficient were determined by the procedures given by (Chhatwal *et al* 1989). All samples were filtered before chemical analysis. The pH was recorded by the Merck pH paper while the dissolved oxygen and free carbon dioxide were measured by the Winkler procedure (Welch 1948 and Ellis *et al* 1948). The total alkalinity, total hardness, total iron, ammonia, nitrite, nitrate and dissolved phosphate were determined by the colorimetric methods of Orbeco Analyst System, using test kits (respectively 957-33, 76, 06, 43, 24, 26 and 10). Salinity was analysed by Mohr's method (Mackereth 1963).

Coefficient of correlation between various factors was determined by SPSS/PC+ Advanced Statistics V2-0 System (1988) for the IBM PC/XT/AT and PS/2 (Produced by Marija J, Nouris/ SPSS Inc.).

Results and Discussion

Distribution of sixteen physico-chemical features were studied round the year, throughout the water column of Safari Park lake (Table 2). Seasonal impact was felt prominent on the water temperature as the maximum ranges of water temperature were recorded in the late spring and summer months while the minimum ranges of water temperature were measured in December and January. The surface water temperature was recorded 1-3 Celsius warmer than the depth water except at spot 1 during the month of August, September and December when it was almost the same at both levels of depth (Table 1-2). It may be either due to the time of sampling (between 11 a.m. to 12 noon) or due to the presence of big trees in the surrounding. The water of small surrounded bodies usually remains calm (Welch 1952) on account of slow wind action resulting in the slow mixing of water at various depths.

The colour of water generally appeared blackish green or grayish by the naked eye. However, Florel-Ule colour scale units (90-100) showed intermittently green and bluish green colours.

Table 1

Monthly variations in the physical parameters of spots I, II and III

Obs. No.	Physical parameters	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
(1) Water temperature (°C)													
St. I	S	28.0	31.3	29.0	25.3	22.0	20.3	20.6	28.0	29.3	27.0	31.3	30.0
	D	27.0	31.0	29.0	23.0	21.0	20.0	21.0	26.0	31.0	26.0	30.5	29.5
St. II	S	26.0	31.0	29.0	25.0	22.0	20.0	21.0	28.0	29.0	27.0	31.0	30.0
	D	25.0	30.0	28.0	22.0	20.0	19.0	19.0	25.0	30.0	25.0	30.5	29.5
St. III	S	30.0	31.0	28.0	25.0	21.0	20.0	19.0	27.0	29.0	26.0	32.0	30.0
	D	29.0	30.0	26.0	22.0	19.0	18.0	16.0	24.0	30.0	24.0	31.0	29.0
(2) Light penetration level (transparency) (cm)													
St. I	S	40.0	32.5	38.0	38.5	40.0	28.75	42.0	38.0	24.75	36.0	19.0	23.0
St. II	S	39.0	39.5	41.25	37.6	42.0	33.0	30.5	31.0	29.5	36.5	35.3	30.05
St. III	S	35.5	37.5	30.0	33.5	48.0	42.5	27.0	36.5	43.5	39.5	33.8	27.0
(3) Euphotic limit (cm)													
St. I	S	100.00	81.25	95.00	96.25	100.00	71.87	105.00	95.00	61.87	90.00	47.50	57.50
St. II	S	97.50	98.70	103.12	94.00	105.00	82.50	77.50	73.75	77.50	73.75	91.25	88.25
St. III	S	88.70	93.75	75.00	83.75	120.00	106.25	67.50	91.25	73.75	91.25	88.25	75.12
(4) Vertical attenuation coefficient (cm)													
St. I	S	0.04	0.05	0.05	0.04	0.01	0.02	0.04	0.05	0.07	0.05	0.01	0.08
St. II	S	0.04	0.04	0.04	0.05	0.04	0.05	0.06	0.06	0.06	0.05	0.05	0.06
St. III	S	0.05	0.05	0.06	0.05	0.03	0.04	0.07	0.05	0.04	0.04	0.05	0.07
(5) Colour of water													
St. I	S	100 Blue Green	90 Green	90 Green	100 Blue Green	90 Green	100 Blue Green	100 Blue Green	100 Green	100 Blue Green	100 Green	100 Green	100 Green
St. II	S	90 Green	100 Green	100 Blue Green	90 Green	90 Green	100 Blue Green	100 Blue Green	100 Green	90 Green	100 Blue Green	90 Green	100 Blue Green
St. III	S	100 Blue Green	100 Blue Green	90 Green	100 Green	100 Blue Green	90 Green	100 Green	100 Blue Green	100 Green	90 Green	100 Blue Green	100 Green

S, Surface; D, Depth; Already given at the end of table.

100 refers to bluish green colour, 90 to green colour. However, the water mostly appeared dirty to the naked eye.

Table 2

Monthly variations in the chemical parameters of spot I, II and III (in surface and depth water samples).

Obs. Parameters No.	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
(1) Dissolved oxygen (mgl^{-1})												
St. I S	2.26	6.80	6.51	5.66	7.08	3.08	1.70	2.26	1.41	3.40	2.25	4.51
D	3.40	7.93	7.65	6.80	7.93	4.81	2.83	4.25	3.40	5.10	3.95	6.20
St. II S	1.98	6.51	5.59	5.38	6.80	3.68	1.41	1.98	1.70	2.83	2.54	4.23
D	3.68	7.36	7.36	6.51	7.65	4.53	2.55	3.96	3.68	4.53	3.66	6.20
St. III S	2.55	6.80	6.23	5.38	6.80	3.40	1.41	1.13	1.41	2.26	2.25	4.23
D	3.68	7.65	7.36	6.51	7.65	4.53	2.55	3.11	3.68	4.25	3.95	6.20
(2) Free carbon dioxide (mgl^{-1})												
St. I S	4	3	4	3	4	3	4	4	4	3	2	2
D	2	2	2	2	2	2	2	2	2	2	1	1
St. II S	4	2	4	3	3	4	3	4	4	3	2	3
D	2	2	3	2	2	2	2	3	2	2	1	2
St. III S	4	2	4	3	3	4	3	4	4	3	2	2
D	2	2	3	2	2	2	2	3	2	2	1	1
(3) Total alkalinity (mgl^{-1})												
St. I S	500	325	360	500	270	250	360	270	325	360	250	325
D	435	360	300	360	300	500	435	325	435	300	270	360
St. II S	435	300	325	435	250	235	270	250	300	325	235	300
D	395	325	300	500	270	435	360	300	360	270	250	500
St. III S	395	270	300	395	250	235	250	235	270	300	223	270
D	495	360	435	360	270	300	435	325	360	270	300	500
(4) Total hardness (mgl^{-1})												
St. I S	0.1	0.4	0.6	0.1	0.6	0.8	0.4	0.1	0.6	0.2	0.1	0.4
D	0.2	0.6	0.1	0.4	0.6	0.2	0.4	0.2	0.8	0.2	0.6	0.4
St. II S	0.2	0.1	0.6	0.1	0.4	0.6	0.2	0.1	0.4	0.1	0.1	0.2
D	0.1	0.4	0.1	0.6	0.6	0.2	0.4	0.2	0.6	0.1	0.4	0.4
St. III S	0.1	0.4	0.4	0.2	0.6	0.6	0.4	0.2	0.6	0.1	0.2	0.4
D	0.2	0.6	0.2	0.4	0.4	0.1	0.2	0.1	0.6	0.1	0.6	0.4
(5) Total iron (mgl^{-1})												
St. I S	5.11	4.00	4.90	4.60	3.25	3.45	3.55	3.90	2.95	5.30	3.80	4.40
D	6.00	5.60	4.30	3.35	3.35	4.10	3.05	3.45	2.59	5.11	3.35	3.80
St. II S	5.10	4.40	4.90	4.30	2.82	3.25	3.45	3.80	2.90	5.10	3.55	4.10
D	5.70	5.30	4.10	3.35	3.45	4.00	2.82	3.55	2.52	4.75	3.35	3.35
St. III S	4.90	4.40	4.75	4.00	3.25	3.35	3.25	3.55	2.82	5.30	3.45	4.00
D	5.60	5.10	4.00	3.55	3.35	3.90	2.73	3.45	2.45	4.60	3.25	3.80
(6) Ammonia nitrogen (mgl^{-1})												
St. I S	0.91	0.65	0.86	0.67	0.93	0.86	0.81	0.65	0.83	0.81	0.67	0.65
D	0.60	0.52	0.67	0.83	0.52	0.81	0.62	0.50	0.63	0.45	0.55	0.52
St. II S	0.86	0.63	0.83	0.65	0.91	0.83	0.83	0.63	0.81	0.83	0.65	0.63
D	0.58	0.45	0.65	0.81	0.50	0.83	0.60	0.58	0.65	0.44	0.54	0.45
St. III S	0.91	0.65	0.81	0.63	0.93	0.86	0.83	0.65	0.83	0.83	0.63	0.65
D	0.58	0.52	0.65	0.81	0.52	0.83	0.60	0.50	0.63	0.44	0.55	0.52

(Continue...)

Table 2 (contd.)

Obs. No.	Parameters	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
(7) Nitrite (mgl^{-1})													
St. I	S	0.145	0.120	0.165	0.190	0.150	0.220	0.180	0.170	0.150	0.160	0.180	0.280
	D	0.125	0.180	0.205	0.210	0.220	0.200	0.145	0.180	0.130	0.165	0.220	0.260
St. II	S	0.140	0.150	0.145	0.170	0.145	0.220	0.150	0.170	0.140	0.150	0.180	0.180
	D	0.170	0.180	0.200	0.220	0.240	0.190	0.145	0.220	0.150	0.165	0.190	0.150
St. III	S	0.120	0.180	0.170	0.190	0.165	0.260	0.165	0.180	0.160	0.190	0.140	0.150
	D	0.140	0.190	0.160	0.190	0.290	0.205	0.190	0.205	0.260	0.160	0.240	0.220
(8) Nitrate (mgl^{-1})													
St. I	S	0.47	0.52	0.55	0.27	0.41	0.53	0.29	0.40	0.47	0.64	0.53	0.29
	D	0.41	0.64	0.37	0.47	0.53	0.40	0.35	0.64	0.72	0.40	0.64	0.40
St. II	S	0.35	0.68	0.90	1.18	0.37	0.43	0.31	0.47	0.29	0.19	0.35	0.22
	D	0.22	1.67	1.02	1.40	0.29	0.27	0.37	0.25	0.18	0.05	0.20	0.07
St. III	S	0.10	1.18	1.07	0.98	0.41	0.35	0.27	0.20	0.25	0.22	0.39	0.29
	D	0.07	1.40	1.42	1.12	0.40	0.27	0.25	0.05	0.25	0.29	0.07	0.18
(9) Total phosphate (mgl^{-1})													
St. I	S	2.87	2.63	2.17	2.48	2.35	3.15	3.59	3.36	2.63	3.80	2.48	2.87
	D	4.30	3.36	3.70	2.48	2.63	3.80	3.26	2.75	3.70	4.05	2.70	3.80
St. II	S	2.78	2.56	2.11	2.41	2.28	3.07	3.47	3.26	2.56	3.70	2.41	2.78
	D	4.20	3.26	3.59	2.56	2.70	3.70	3.15	3.07	3.80	4.20	2.78	3.70
St. III	S	2.87	2.48	2.06	2.48	2.35	2.97	3.36	3.15	2.48	3.59	2.35	2.87
	D	4.05	3.15	3.70	2.48	2.76	3.59	3.26	3.15	3.98	4.30	2.70	3.80
(10) Hydrogen ion concentration (pH)													
St. I	S	7	7	7	7	7	7	7	7	7	7	7	7
	D	7	7	7	7	7	7	7	7	7	7	7	7
St. II	S	7	7	7	7	7	7	7	7	7	7	7	7
	D	7	7	7	7	7	7	7	7	7	7	7	7
St. III	S	7	7	7	7	7	7	7	7	7	7	7	7
	D	7	7	7	7	7	7	7	7	7	7	7	7
(11) Salinity (ppt)													
St. I	S	0.2	0.4	0.8	0.1	0.4	0.2	0.8	0.4	0.6	0.4	0.8	0.6
	D	0.6	0.8	1.0	0.6	0.8	0.4	1.0	0.8	1.0	0.8	1.0	0.8
St. II	S	0.1	0.6	0.5	0.2	0.3	0.1	0.6	0.3	0.5	0.4	0.7	0.5
	D	0.5	0.7	0.7	0.7	0.9	0.3	0.9	0.7	0.8	0.6	1.0	0.7
St. III	S	0.2	0.6	0.7	0.1	0.3	0.1	0.6	0.4	0.5	0.3	0.8	0.5
	D	0.6	0.7	0.8	0.7	0.9	0.4	0.9	0.7	1.0	0.7	0.9	0.7

St, Spots I to III; S, Surface; D, Depth; ppt, Parts per thousand.

In a water body, the colours not only reflect the growth of producer organisms but also show the impact of humic acid, fulvic acids, metallic ions and suspended matters (Chhatwal *et al* 1989).

The pattern of light penetration levels or transparency, euphotic limits and vertical attenuation coefficients appeared almost similar throughout the year at all the spots. Minimum levels of transparency and euphotic limits occurred in June at

Table 3

The values of correlation matrix between various physico-chemical parameters of Safari Park Lake

Name of parameters	1	2	3	4	5	6	7	8	9	10	11	12
Total alkalinity (surface sample)												
Total alkalinity (depth sample)	0.462											
Total phosphate (surface sample)	-0.084	0.776										
Total phosphate (depth sample)	0.197	0.339	0.429									
Nitrogen ammonia (surface sample)	0.076	0.018	0.040	0.406								
Nitrogen ammonia (depth sample)	0.258	0.456	-0.242	-0.172	0.125							
Nitrite ammonia (surface sample)	-0.329	0.229	0.210	-0.079	-0.155	0.590						
Nitrite ammonia (depth sample)	-0.490	0.378	-0.445	-0.679	-0.212	-0.041	0.242					
Nitrate ammonia (surface sample)	0.296	-0.096	-0.565	-0.334	-0.259	0.367	0.053	0.055				
Nitrate ammonia (depth sample)	0.284	-0.029	-0.528	-0.357	-0.328	0.236	-0.076	0.034	0.940			
Total iron (surface sample)	0.633	0.035	0.176	0.428	-0.046	-0.201	-0.250	-0.517	0.303	0.199		
Total iron (depth sample)	0.661	0.152	0.035	0.248	-0.042	0.014	-0.134	-0.393	0.427	0.410	-0.794	
Total hardness (surface sample)	-0.411	0.134	-0.341	0.123	0.493	0.329	0.334	0.258	0.093	0.078	-0.509	-0.386
Total hardness (depth sample)	-0.182	-0.028	-0.491	-0.432	-0.315	-0.161	-0.216	0.499	0.007	0.198	-0.533	-0.365
Salinity (surface sample)	-0.460	-0.270	-0.264	-0.112	-0.260	-0.418	-0.294	0.083	0.016	0.065	-0.199	-0.522
Salinity (depth sample)	-0.263	0.422	-0.252	-0.281	-0.122	-0.477	-0.568	0.179	-0.071	0.014	-0.262	-0.591
Water temperature (surface sample)	-0.043	-0.149	-0.286	0.148	-0.555	-0.453	-0.439	-0.086	0.195	0.233	0.342	0.199
Water temperature (depth sample)	0.058	-0.072	-0.317	0.246	-0.441	-0.418	-0.439	-0.121	0.110	0.161	0.240	0.124
Transparancy	0.246	-0.336	-0.097	-0.102	0.570	0.026	-0.275	0.042	0.271	0.262	0.162	0.379
Euphotic limit	0.230	-0.218	-0.211	-0.255	0.436	0.037	-0.186	0.196	0.318	0.297	0.193	0.444
Vertical attenuation coefficient	0.043	-0.020	-0.439	0.053	-0.333	-0.111	-0.185	-0.158	0.701	0.712	0.351	0.241
Dissolved oxygen (surface sample)	0.090	-0.142	-0.590	-0.321	-0.032	0.048	0.033	0.468	0.705	0.696	0.175	0.375
Dissolved oxygen (depth sample)	0.085	-0.162	-0.581	-0.274	-0.104	-0.037	0.017	0.498	0.682	0.672	0.197	0.343
Free carbon dioxide (surface sample)	0.195	0.178	0.080	0.340	0.594	0.334	-0.060	-0.316	-0.090	-0.162	-0.042	-0.101
Free carbon dioxide (depth sample)	0.057	-0.151	0.098	0.009	0.260	0.089	-0.057	-0.071	0.231	0.209	0.057	0.033

Name of Parameters	13	14	15	16	17	18	19	20	21	22	23	24
Total hardness (depth sample)	0.143											
Salinity (surface sample)	0.017	0.427										
Salinity (depth sample)	-0.050	0.522	0.820									
Water temperature (surface sample)	-0.369	0.273	0.429	0.312								
Water temperature (depth sample)	-0.230	0.344	0.465	0.319	0.975							
Transparancy	0.119	-0.289	-0.511	-0.202	-0.393	-0.439						
Euphotic limit	0.091	-0.266	-0.484	-0.284	-0.409	-0.482	0.909					
Vertical attenuation coefficient	0.130	0.038	0.520	0.223	0.559	0.523	-0.128	-0.053				
Dissolved oxygen (surface sample)	0.327	0.205	-0.059	-0.106	0.018	-0.037	0.434	0.599	0.474			
Dissolved oxygen (depth sample)	0.303	0.238	-0.023	-0.059	0.134	0.073	0.265	0.508	0.500	0.983		
Free carbon dioxide (surface sample)	0.299	-0.542	-0.377	-0.191	-0.319	-0.286	0.423	0.245	-0.162	-0.253	-0.259	
Free carbon dioxide (depth sample)	0.165	-0.520	-3.120	-0.110	-0.253	-0.336	0.615	0.502	0.106	0.125	0.128	0.755

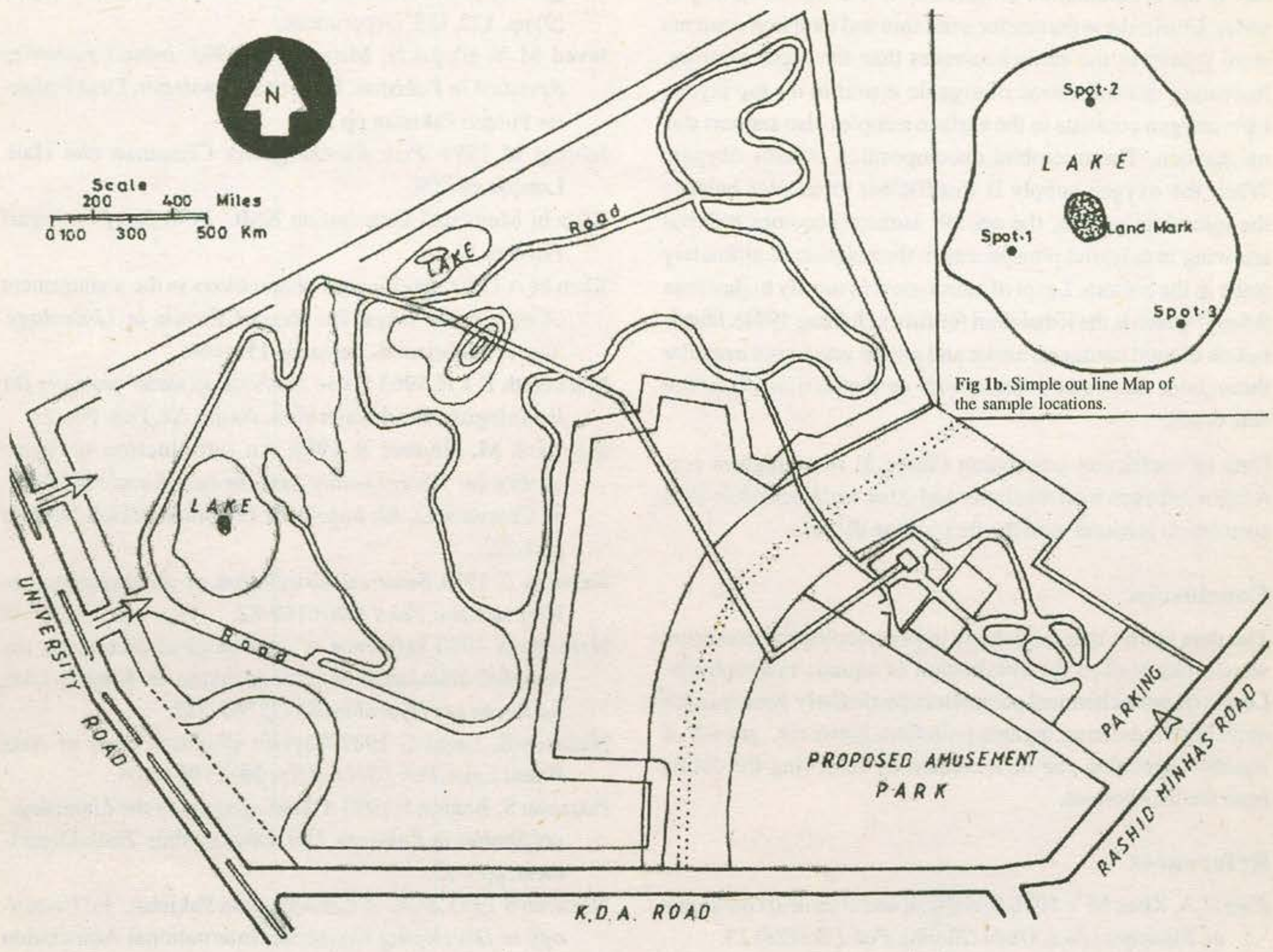

Fig 1b. Simple out line Map of the sample locations.

Fig 1a. Map of Safari Park, showing the location of lake (Reproduced from K.M.C Brief on Safari Park).

all the spots perhaps due to the cloudy weather while the maximum values of these variables were measured in November. Values of vertical attenuation coefficient showed a reverse pattern. Data of statistical analysis (Table 3) also support these observations. The light attenuation of radiation depends on the absorption coefficient but also increases with the product of scattering. Its values therefore, vary with the colours of the beam of light (Scheffer 1998). According to Chhatwal *et al* (1989), high values of vertical attenuation coefficient indicate higher rate of respiration compared to the rate of photosynthesis.

Freshwater bodies usually contain neutral pH (Chhatwal *et al* 1989), pH of the lane water remained neutral throughout this study.

Distribution of dissolved oxygen showed two tendencies, its concentrations were comparatively higher in the summer (except July) and autumn seasons throughout the water column perhaps due to the growth of microscopic algae during this period. It may also happen due to the interaction of light and temperature on the producer organisms especially phytoplankton. Many scientsits have involved the interaction of these factors on the abundance of phytoplankton as discussed by Nazneen (1980). The growth of these organisms naturally increases the level of oxygen in the water. Secondly, low values of oxygen and high concentration of free carbon dioxide were measured in the surface samples as compared to the depth samples. It reflects the impact of respiration as animals mostly move towards the surface during day time and inhale oxygen and exhale carbon dioxide at the surface. The rate of photosynthesis appears overall lower than the rate of respiration in this lake.

Total alkalinity values were highest at all the spots throughout this study. Total alkalinity, total phosphate and salinity contents were also higher in the depth samples than the surface. All these chemical parameters indicate high concentrations of total dissolved solids particularly at the bottom due to the accumulation of debris and to the poor mixing of water. Unlike these parameter ammonia and total iron contents were greater in the surface samples than the depth samples, indicating mineralization of organic matter in the top layers. Low oxygen contents in the surface samples also support this mechanism. The microbial decomposition utilizes oxygen. When the oxygen supply is insufficient to counter balance the microbial uptake, the aerobic surface becomes reduced allowing iron bound phosphorus in the solution to ultimately settle in the bottom. Level of ammonia was mostly higher than 0.5 mg^{-1} which is the lethal limit for fishes (Jobling 1994). Distribution of total hardness, nitrite and nitrate was found irregular throughout the water column with no distinction of surface and depth.

Data of coefficient correlation (Table 3) show highest correlation between total alkalinity and other variables while least correlation is found with the free carbon dioxide.

Conclusion

The data shows that the lake is in poor ecological condition which may lead to the elimination of aquatic macrophytes. Levels of most chemical parameters particularly ammonia are quite high indicating organic pollution. However, growth of aquatic vegetation can be increased by removing the debris from the lake bottom.

References

Baig N A, Khan M Y 1976 Biological and chemical conditions of Manchar Lake, Dadu (Sindh). *Pak J Sci* (28) 23.

Baqai I U, Zuberi V A, Iqbal M 1974a. Limnological studies of Kalri Lake. *Agric Pak* **25** (2) 119-135.

Baqai I U, Zuberi V A, Iqbal M 1974b Limnological studies of Haleji Lake. *Agric Pak* **25** (4) 321-344.

Chhatwal G R, Mehra M C, Satake M, Katyal T, Katyal M, Nagahiro T 1989. Encyclopedia of Environmental Pollution and its Control. Anmol Publications, 4878/4B, Gali Murari Lal, Asari Road, New Delhi-110002, Vol. VI, pp 1-204.

Ellis M M, Westfall A, Ellis M D 1948 *Determination of Water Quality - Fish and Wildlife Service.* Interior, Res., Report (9) pp. 122. U S Department.

Javed M Y, Bhatti N, Mirza M R 1993 *Inland Fisheries Research in Pakistan.* Fisheries Newsletter, Dept Fisheries Punjab Pakistan pp 51.

Jobling M 1994 *Fish Bioenergetics* Chapman and Hall, London pp 309.

Karachi Municipal Corporation KMC 1998 *Brief on Safari Park* pp 12.

Khan M A 1990 Significance of limnology in the management of man made lakes. In: *Recent Trends in Limnology.* Soc. of Biosciences. India pp 151-164.

Mackereth F J H 1963 *Some methods of water analysis for limnologists.* Freshwater Biol. Assoc. Sc. Pub. No. 21.

Meybeck M, Helmer R 1996 An introduction to water quality. In: *Water Quality Assessments. E and FN SPON.* ed Chapman D, An Imprint of Chapman & Hall London pp 1-22.

Nazneen S 1974 Seasonal distribution of phytoplankton in Kinjhar Lake. *Pak J Bot* (6) 69-82.

Nazneen S 1980 Influence of hydrological factors on the seasonal abundance of phytoplankton in Kinjhar lake. *Int Revue ges Hydrobiol* **65** (2) 269-282.

Nazneen S, Jamal G 1987 Physico-chemical study of Aziz Bhatti Lake. *Pak J Sci Ind Res* **30** (2) 901-904.

Nazneen S, Begum F 1993 *A Bibliography of the Limnological Studies in Pakistan.* Uni. Day Sp. Pub. Zool. Department, pp 1-27.

Nazneen S 1995 State of Limnology in Pakistan. In: *Limnology in Developing Countries.* International Association for Limnology pp 191-230.

Scheffer M 1998 *Ecology of Shallow Lakes.* Chapman & Hall, London pp 357.

Thomas R, Meybeck M, Beim A 1996 Lakes. In: *Water Quality Assessments. E & FN SPON.* (ed Chapman) An Imprint of Chapman & Hall. London pp 319-368.

Welch P S 1948 Limnological Method. McGraw Hill Book Co., XI, New York, pp 381.

Welch P S 1952 *Limnology.* 2nd ed. McGraw Hill Book Co., XI, New York, pp 538.