CHAPTER 6

Chemical Characteristics of the Main Valley Lakes.

6.1 PREVIOUS WORK

In 1936, Rawson collected surface water samples of Okanagan Lake for chemical analyses (Clemens *et al* 1939). Measurement of oxygen concentrations and pH in Okanagan, Kalamalka and Wood Lakes were taken in July and August 1935 as part of Rawson's survey. Coulthard and Stein (1968, 1969), Stein and Coulthard (1971) and Booth collected numerous samples for chemical analyses from all major lakes, including one of the first measurements of phosphorus concentrations. Clarke and Alcock (1968) measured nutrient input to some Okanagan Valley lakes to construct a preliminary nutrient budget based chiefly on sewage plant effluent.

6.2 RESULTS

6.2.1 Dissolved Oxygen

Hutchinson (1957) indicated probably more can be determined about the nature of a lake from a series of oxygen determinations than from any other kind of chemical data. These important data for spring, summer and fall are presented in Table 6.1. Epilimnetic oxygen concentrations remained near saturation levels in all lakes throughout the summer months. Dissolved oxygen in the hypolimnia of Osoyoos, Wood and Skaha Lakes was well below saturation for much of the summer. The hypolimnia of Kalamalka and Okanagan lakes remained well oxygenated.

Calculation of the rate of oxygen depletion of hypolimnetic water during the summer stratification provided an estimate of annual biological production. These data (Table 6.2) indicate Skaha Lake had the most rapid depletion rate, followed by Wood and Osoyoos Lakes. No attempt was made for computing areal depletion rates for Okanagan and Kalamalka Lakes since they are subject to limitations for such calculations imposed by Hutchinson (1957); i.e., maximum depths greater than 75 meters. Based on the trophic index of Dobson (1972) where mesotrophy equals 1.0, both Skaha and Wood Lakes are on the eutrophic side of the scale from a consideration of oxygen depletion rate. There has been little change in hypolimnetic dissolved oxygen concentration of Okanagan Lake since Rawson's measurements taken in 1935; however, Skaha Lake has exhibited an increase in it's hypolimnetic oxygen deficit over the past 25 years. Ferguson (1949) in July 1948, noted values of 10.35 mg/l or 85% saturation, while the current survey noted 8.55 mg/l or 70% saturation. The oxygen content of the hypolimnetic water of Wood Lake has not changed appreciably from the values noted by Rawson in 1936.

TABLE 6.1

CONCENTRATIONS OF DISSOLVED OXYGEN IN THE OKANAGAN MAIN VALLEY LAKES.

EXPRESSED IN PARTS PER MILLION

(PERCENT SATURATION IN BRACKETS)

LAKE	SPRING (April)		EARLY SUMMER (May-June)		LATE SUMMER (July-August)		FALL (October)	
	SURFACE	BOTTOM	EPILIMNION	HYPOLIMNION	EPILIMNION	HYPOLIMNION	EPILIMNION	HYPOLIMNION
OSOYOOS Station 1	12.4 (101)	12.4 (103)	9.8 (93)	9.4 (79)	8.0 (90)	5.5 (46)	10.1 (100)	3.3 (28)
North basin Station 3	9.7 (97)	9.4 (75)	9.7 (96)	9.3 (77)	8.5 (96)	5.9 (51)	9.8 (98)	10.1* (89)
Cent. basin	8.8 (73)	8.0 (66)	9.8 (96)	9.3 (88)	9.0 (105)	4.0 (40)	10.7 (106)	9.5 (97)
South basin	11.6 (99)	11.7 (99)	9.3 (96)	7.3 (67)	9.5 (105)	2.5 (27)	10.5 (107)	9.0 (90)
SKAHA	12.8 (103)	12.3** (97)	10.6 (104)	11.1 (92)	8.8 (106)	8.3 (70)	11.2 (105)	6.7 (56)
WOOD	11.4 (93)	11.4 (88)	11.4 (112)	7.5 (56)	9.8 (109)	2.2 (18)	9.8 L98)	0.8 (6)
KALAMALKA	12.0 (98)	12.0 (95)	10.3 (105)	11.6 (97)	8.8 (100)	11.3*** (89)	10.8 (106)	12.2 (97)
OKANAGAN South	14.8 (117)	14.8 (117)	11.3 (102)	12.4 (100)	9.6 (103)	10.8 (87)	10.7 (104)	11.5 (93)
North	13.0 (106)	12.6 (98)	10.8 (104)	11.6 (93)	9.6 (107)	10.7 (72)	10.4 (106)	10.9 (79)

*Mixing had occurred on Station 3 and overturn had occurred in Central and South basins.

**Data based on one station only.

***No data for July

TABLE 6.2

DAILY OXYGEN DEPLETION RATES, AREAL DEPLETION RATES AND TROPHIC INDICES FOR THE OKANAGAN MAIN VALLEY LAKES

LAKE	MAXIMUM DEPTH (m)	MEAN HYPOLIMNION THICKNESS (m)	NO. OF DAYS FROM SPRING OVERTURN	ORDINARY DEPLETION RATE (mg/l/day)	AREAL DEPLETION RATE ($mg/cm^2/day$)	TROPHIC INDEX MESOTROPHY = 1.0
WOOD	34	10.6	165	0.061	0.065	1.5
OSOYOOS	60	10.7	123	0.035	0.038	0.9
SKAHA	56	43.7	161	0.034	0.148	3.6
OKANAGAN	230	--	128	0.015	--	-
KALAMALKA	140	--	121	0.009	--	-

TABLE 6.3

AVERAGE CONCENTRATIONS OF NITROGEN. PHOSPHORUS AND CHLOROPYLL-*a* IN THE OKANAGAN MAIN VALLEY LAKES*

(EXPRESSED IN MICROGRAMS PER LITER)

LAKE	NITRATE NITROGEN [$NO_3(N)$]			TOTAL NITROGEN (TN)			PHOSPHATE PHOSPHORUS [$PO_4(P)$]			TOTAL PHOSPHORUS (TP)			CHLOROPHYLL-*a*[D]
	A	B	C	A	B	C	A	B	C	A	B	C	
OKANAGAN	126	20	20	232	189	120	12	2	--	29	31	30	5.0 (15.0)[E]
KALAMALKA	114	23	10	264	199	80	12	4	--	14	7	20	2.5
WOOD	102	26	40	427	539	200	125	83	--	213	293	150	50.0
SKAHA	327	10	40	323	208	180	32	15	--	97	64	70	31.0 (48.0)[F]
OSOYOOS	196	16	40	309	235	170	10	15	--	91	62	65	23.0

* Values of nitrogen and phosphorus at spring overturn, Chlorophyll-*a* mean summer value, 1971.

[A] B.C. Research Laboratory; spring overturn, 1970

[B] Water Quality Laboratory, Calgary; monitor program 1971, spring overturn

[C] Coulthard and Stein (1969-70); average values summer season, 1969

[D] Seasonal average Chlorophyll-*a* content in epilimnion, Williams (1972).

[E] Chlorophyll-*a* average concentration in Vernon-Armstrong Arms.

[F] Average for lake, including peak value of 214 micrograms per liter measured in October.

On the basis of oxygen data, the lakes of the main valley system can be ranked as follows:

1.	Skaha	Eutrophic
2.	Wood	Eutrophic
3.	Osoyoos	Mesotrophic
4.	Okanagan	Oligotrophic
5.	Kalamalka	Extremely Oligotrophic

6.2.2 Nutrients

The main valley lakes exhibited considerable seasonal and valley-wide variation in nutrient content. A representation of these data from a variety of sources are presented in Table 6.3. These data indicated general conditions. The data collected during the study is presented in Appendix C. These data were not presented in a concentrated form in the text since any condensation would result in losing some of the trends within lakes and/or time periods. The following discussions then refer to data in Appendix C.

(a) Wood Lake

Wood Lake had the highest observed concentrations of $NO_3(N)$ and $PO_4(P)$ of the five main valley lakes sampled during spring turnover - 20 ug/1 and 80 ug/1 respectively. Epilimnetic concentrations decreased throughout the summer, reaching the lower range of sensitivity of the analytical method used, by midsummer. The large $NO_3(N)$ and $PO_4(P)$ decrease with time, relates inversely to chlorophyll-a concentrations which increased from 9 to 100 ug/1 between April and June. Decrease in surface silica concentrations is likely linked to diatom periphyton dominance, *(Gonophonema ventricosums* and *Synedra sp.),* which accounted for 60 to 80% of the total numbers. (Chapter 7.3).

Depletion of epilimnetic nutrients was accompanied by increased $PO_4(P)$ and $NO_3(N)$ in the hypolimnion. PO_4 content of the sediments of Wood Lake was also comparatively high.

The depletion of $NO_3(N)$ in the hypolimnion toward the end of summer stratification was likely due to its reduction to NH_3 or N_2. The considerably lower concentrations of $NO_3(N)$ as compared to $PO_4(P)$ would indicate that $NO_3(N)$ is probably presently the limiting nutrient in phytoplankton growth in this lake.

(b) Skaha Lake

Mean concentrations of $NO_3(N)$ and $PO_4(P)$ at spring turnover were 10 ug/1 and 16 ug/1 respectively. Low epilimnetic $NO_3(N)$ concentrations throughout the summer tend to indicate this is the factor limiting phytoplankton production. The extremely high $PO_4(P)$ values in surface waters in June are attributed to surface runoff.

Horizontal PO_4(P) distribution showed a general north-to-south decrease in concentration throughout the sampling period, indicating that the main nutrient source was the Okanagan River. Station 1 on the east side of the lake (not directly influenced by the river plume - Section 5.2), showed the lowest phosphate concentration of the entire lake surface.

The rapid decrease of epilimnetic PO_4(P) from 51 to 0.005 ug/l between August and October correlates well with an increase in chlorophyll-*a* concentrations from 20 to 214 ug/l and a bloom of *anabaena flos-aquae*. The depletion of epilimnetic PO_4(P) and NO_3(N) also correlates with their increase in the hypolimnion during the August to October period.

(c) Osoyoos Lake

In the north basin, epilimnetic PO_4(P) levels were about 13 ug/1 from April to June, but had increased to 213 ug/1 by August. The general north-to-south decrease in concentration indicates the Okanagan River as the probable major source. The sharp decrease by October was probably due to an algal bloom, although no chlorophyll-*a.* data is available for October to corroborate this.

The central and southern basins developed only weak thermal stratification throughout the summer, thus nutrient concentrations were generally similar throughout the entire water column. These two basins showed similar nutrient concentrations and seasonal patterns to those of the north basin epilimnion, except that no peak PO_4(P) concentration was observed in the south basin in August.

The weak thermal stability observed has two important effects: First, the absence of a thermocline means that any organic matter produced on the surface falls freely to the bottom of the lake. Second, no thermocline means greater warming of the bottom waters, which results in an increased rate of oxidation of organic material.

(d) Okanagan and Kalamalka Lakes

The fact that the nutrient values over most of the lakes' surface were so low PO_4(P) values in the epilimnion and hypolimnion of both lakes falling below the detection level of the analytical method employed), attests to the Oligotrophic nature of both these bodies of water. Both lakes exhibited well defined orthograde oxygen curves with relatively poorer oxygen conditions being observed only in the Armstrong arm of Okanagan Lake. In Kalamalka, the analysis for chlorophyll-*a.* content showed a seasonal average of only 2.5 ug/l and only in the Armstrong and Vernon arms of Okanagan Lake did the values get above 15 ug/l with the main body of this lake averaging 5.0 ug/l

Both lakes exhibited peak concentrations of PO_4(P) in June with the 1m values in Kalamalka Lake averaging 90 ug/l and the 1m values in Okanagan Lake averaging

260 g/l in the north and 70 g/l in the south. It is interesting to note that during this period, the Vernon Arm of Okanagan Lake had a surface concentration of PO_4(P) of 10 ug/l (the lowest on the lake's surface). While there was a three-fold increase in surface chlorophyll-a from 6 to 18 ug/l, this alone could not account for such a low value. It is quite probable that the main portion of the nutrient input from Vernon Creek (which is noted as a major source of PO_4(P) input into the lake), was taken up by the aquatic macrophytic vegetation that showed a tremendous increase at this time. The high PO_4(P) concentrations off Lambly (Bear) Creek (690 ug/l) indicate this as a rich source of nutrient input into the lake during spring runoff. NO_3(N) concentrations in the epilimnia of both lakes decreased from a mean of 22 ug/l in the spring to below detection level. Concentrations in the hypolimnia increased to a mean value of 30 ug/l.

(e) Discussion

On the basis of nutrient availability, the lakes would have to be ranked in order of decreasing fertility:

1. Wood
2. Skaha
3. Osoyoos
4. Okanagan
5. Kalamalka.

The point of interest from the present study which should be emphasized, is that a11 the lakes (with the exception of Wood Lake) received "spike" inputs of PO_4(P) which have been attributed to runoff, at some time during the seasonal cycle. This puts increasing importance on the value of NO_3(N) or some other factor such as trace metals in having a limiting influence on algal growth. This (1971) was an atypical year for meteorological conditions, and time and amount of surface spring runoff, so that it might prove difficult to extrapolate the findings of the present study with any conclusiveness to those of previous or subsequent years.

6.2.3 Major Ions

The relative abundance of major ions is a reflection of natural aquatic chemical processes modified by regional geochemistry. The distribution within a given lake or among lakes is a result of biological activity, surface runoff, groundwater, precipitation and most importantly, the internal factor of sediment-water interaction.

Concentrations of major ions in the main valley lakes varied from lake to lake, but showed little seasonal variation (Table 6.4). An anion-cation balance sheet for all lakes appears in Table 6.4. The relative abundance of major ions within a particular lake was similar to the curve for the average of the world's freshwater, with HCO_3 >Ca >Na >Mg >SO_4 >F, on a molar basis.

When compared with other major lake districts, the concentration of major ions in the lakes of the Okanagan drainage basin are quite high, an order of magnitude higher than lakes on the Canadian Shield (Armstrong and Schindler, 1971), and higher than the world average for freshwater (Livingstone, 1963). These high concentrations are the result of an array of soluble geological materials in the watershed, including limestones, glacial drift, clay-silt terraces, and conglomerate rock or basaltic areas.

TABLE 6.4

AVERAGE SEASONAL CONCENTRATION AND LAKE AVERAGE OF MAJOR ANIONS/CATIONS IN OKANAGAN MAIN VALLEY LAKES

LAKE	NO.OF SAMPLES	ION							
		CATIONS				ANIONS			
		Ca	Mg	Na	K	HCO_3	SO_4	Cl	F
OSOYOOS									
April	17	37.3	9.2	10.3	2.3	149.0	32.1	1.5	0.21
June	22	32.2	7.5	9.1	2.3	132.7	26.5	1.8	0.19
August	20	33.4	8.7	10.3	2.3	132.2	27.3	1.5	0.20
October	17	33.7	9.3	10.0	2.3	138.5	28.3	1.5	0.23
Lake Average		34.2	8.7	9.9	2.3	138.1	28.5	1.6	0.21
SKAHA									
April	18	33.2	9.1	10.0	2.3	134.3	28.4	1.4	0.18
June	24	32.1	8.3	9.4	2.1	131.6	26.5	1.2	0.17
August	18	32.9	7.9	8.9	2.0	126.1	27.6	1.3	0.20
October	18	33.0	8.3	9.5	2.1	127.6	27.7	1.5	0.19
Lake Average		32.8	8.4	9.5	2.1	129.9	27.6	1.4	0.18
WOOD									
April	13	32.8	15.6	18.2	3.9	189.2	30.2	2.6	0.33
June	16	29.0	18.1	18.7	4.3	181.2	31.2	2.3	0.30
August	16	26.6	17.2	20.0	4.3	162.5	30.2	2.6	0.33
October	14	26.8	18.2	19.0	4.3	176.8	29.9	2.6	0.32
Lake Average		28.8	17.3	19.0	4.2	177.4	30.4	2.5	0.32
KALAMALKA									
April	11	37.6	17.9	15.6	4.5	179.9	56.0	1.4	0.29
June	12	38.1	17.3	15.9	4.7	180.25	55.7	1.1	0.27
August	12	39.0	16.5	16.1	4.6	174.7	55.3	1.3	0.33
October	11	36.9	16.9	15.8	4.6	174.5	55.6	1.3	0.31
Lake Average		37.9	17.1	15.9	4.6	177.3	55.7	1.3	0.30
OKANAGAN (North)									
April	20	32.5	8.7	9.1	2.1	133.2	27.1	1.0	0.17
June	20	32.8	8.3	9.1	2.1	132.3	27.1	1.1	0.17
August	20	33.7	7.9	9.2	2.2	131.7	26.2	1.1	0.16
October	19	32.8	8.4	9.2	2.2	131.6	27.5	1.1	0.17
OKANAGAN (Central)									
April	8	33.0	8.9	9.2	2.2	134.3	28.7	1.1	0.16
June	8	32.7	8.4	9.1	2.2	132.1	27.6	1.1	0.17
August	8	33.1	8.4	8.4	2.0	129.5	26.6	1.0	0.16
October	8	32.9	8.3	9.7	2.4	128.9	27.7	1.1	0.17
OKANAGAN (South)									
April	18	33.0	8.6	9.3	2.2	133.8	27.6	1.1	0.17
June	19	32.7	8.2	9.0	2.1	132.5	26.6	1.1	0.18
August	19	33.0	8.0	9.1	2.2	130.7	26.3	1.1	0.16
October	19	32.6	8.4	9.3	2.2	131.5	27.0	1.1	0.16
Lake Average		32.9	8.4	9.1	2.2	131.8	27.2	1.1	0.17