沙漠研究 **24**-1, 105-108 (2014)
Journal of Arid Land Studies

－ DT11 Refereed Paper －

Water Quality in the Lake Issyk-Kul and the River Flowing into It

Yoshiko KAWABATA*[1)], Tomoko KURITA[1)], Masahiro NAGAI[2)], Vyacheslav APARIN[3)], Siaw ONWONA-AGYEMAN[1)], Masaaki YAMADA[1)], Yoshikazu FUJII[2)] and Yukio KATAYAMA[2)]

Abstract: Lake Issyk-kul is an inland and saline lake in the northern Tian Shan Mountains in eastern Kyrgyzstan. Vertical profile components in the lake water showed that major components and alkalinity were conservative type, concentrations of which were almost homogenized vertically, and nutrients were of the middle type between conservative and nutrient, concentrations of which were a little higher in deep water than in surface water. Concentrations of major components and alkalinity were compared to those in 1986. Both Na^+ and alkalinity increased by only 12 meq/L for two decades, but the others remained almost unchanged in concentration. Concentrations of nutrients in the rivers through lands were not related to the land-use types.

Key Words: CIS, Kyrgyz Republic, Lake Issyk-kul, Water quality

1. Introduction

Brackish Lake Issyk-kul is located in the northeastern part of the Kyrgyz Republic and is a high altitude lake in Central Asia (**Fig. 1**). With a maximum depth of 665m it is the world's fifth deepest lake (Lyons *et al*., 2000).

There are concerns that the water quality of Lake Issyk-kul, in whose catchment area agriculture, grazing and tourism have been developed since the Soviet era, is worsening. As the development of industries increases water withdrawal from the rivers discharge (flowing) into the lake year by year, there are fears that salinity of the lake water may be increasing. Development of agriculture and grazing are also likely to increase concentrations of nutrients in the lake water.

The lake is in a semiarid setting with precipitation highest in spring and summer whereas winters are relatively dry (Lyons *et al*., 2000). Open Lake water never freezes and the winter mixed layer temperatures are greater than 4°C (Romanovsky *et al*., 2002). The lake does not overturn fully during the summer season and the deep water is ventilated by local convection in addition to vertical turbulent mixing (Martin *et al*., 2002). Past climate changes have caused shifts in the lake's hydrological budget, which have led to lake level fluctuations with occasional basin closures (Rasmussen *et al*., 2000). Due to its basin closure during such a shift about 6900 yrs to 4900 yrs ago, the lake has evolved from a freshwater body to a saline one (Ricketts *et al*., 2001).

Kadyrov (1986) researched water quality in Lake Issyk-kul from 1958 to 1980. Savvaitova and Petr (1992) revealed that the major components of the Lake were $Na^+ + K^+ > Mg^{2+} > Ca^{2+}$, $Cl^- \geq SO_4^{2-} >> HCO_3^-$ and salinity was ~ 6 g / L. Lyon *et al*. (2000) reported that the ion major components of the Lake Issyk-kul were similar to the composition of the Caspian Sea and the Aral Sea in Central Asia. In this paper, we discuss the water quality of Lake Issyk-kul, in August 2007, and twenty seven rivers flowing into the lake in order to understand the present water quality of the lake and its catchment area and to compare to the previous years.

Fig. 1. Map showing the location of Lake Issyk-kul.

2. Materials and Methods

The sampling sites are shown in **Figure 2**. Water samples from Lake Issyk-kul were collected in August 2007, while samples from river water were collected in August 2006 and August 2007. The position of each sampling spot was determined by using an eTrex Legend portable Global Positioning System. Water temperature, pH, EC, DO and

* Corresponding Author: yoshikok@cc.tuat.ac.jp
2-24-16, Nakacho, Koganei, Tokyo, 184-8588, Japan
1) Tokyo University of Agriculture and Technology
2) University of Human Environments
3) State Committee of Geology and mineral resources of Uzbekistan

(Received, September 9th, 2013; Accepted, December 30th, 2013)

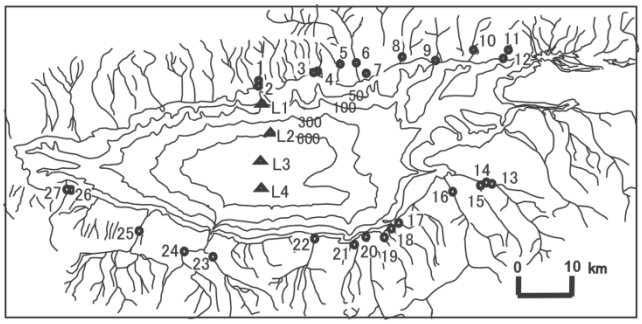

Fig. 2. Sampling Sites in Lake Issyk-kul, Kyrgyzstan.

Turbidity were all determined in the field.

Water samples were filtered through a 0.45 μm Membrane filter (DISMIC 25AS020AS, ADVANTEC Corporation) and collected in polypropylene bottles. Concentrations of major components (K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, Alkalinity) were determined using ion chromatographic analyzer. Concentrations of Na^+ were determined using an atomic absorption spectrophotometer. Alkalinity was calculated from concentrations of major components (Alkalinity = $Na^+ + K^+ + Mg^{2+} + Ca^{2+} - Cl^- - SO_4^{2-}$). Nutrient concentrations (PO_4-P, NO_3-N, NO_2-N, NH_4-N) were determined by an Auto-analyzer (Buran Luebee Corporation), while those of $Si(OH)_4$-Si were determined by a visible-ultraviolet spectrophotometer. Finally, accuracy and precision of the analytical methods were shown to be satisfactory with 2-5% error.

3. Results and Discussion

3.1. Water quality of Lake Issyk-kul

Horizontal distribution of Na^+, K^+, Mg^{2+}, Ca^{2+} concentrations are shown in **Figure 3** while Vertical distribution of concentrations of Na^+, K^+, Mg^{2+}, Ca^{2+} are shown in **Figure 4**. Horizontal distribution of concentrations of $Si(OH)_4$-Si, NO_3-N, PO_4-P can be seen in **Figure 5** while **Figure 6** shows the vertical distribution of $Si(OH)_4$-Si, NO_3-N, PO_4-P concentrations.

In summer 2007, cation concentrations of distribution in both the vertical and horizontal directions were substantially uniform. From these results, in the range of measuring depth, the lake was found to be stirred.

The same trend in the horizontal distribution of nutrients in the lake water was observed from the shore to the center of sampling site on the lake. With the vertical distribution, no changes in the concentrations of NO_2-N and NH_4-N were observed from the bottom of the lake to near surface. However, concentrations of PO_4-P, and NO_3-N had increased in the 20 - 40 m depth. This trend is considered to be the influence of biological activities.

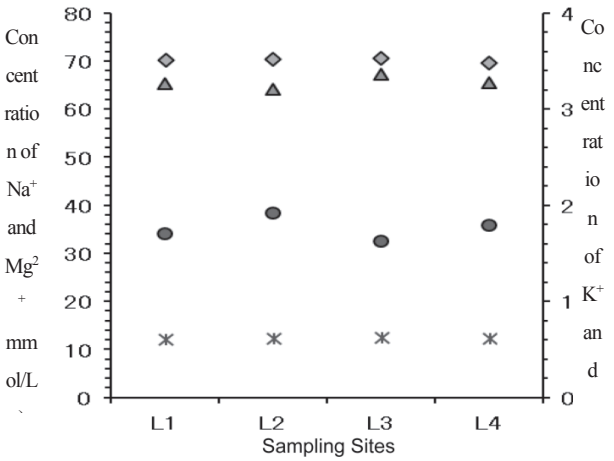

Fig. 3. Horizontal distribution of concentrations of Na^+, K^+, Mg^{2+}, Ca^{2+} in Lake Issyk-kul (◆: Na^+, ●: K^+, ×: Mg^{2+}, ▲: Ca^{2+}).

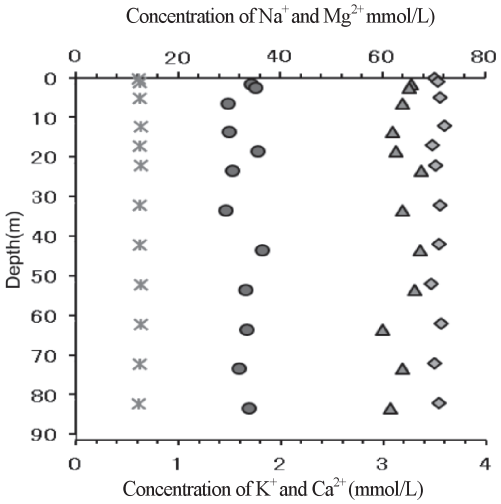

Fig. 4. Vertical Distribution of Concentrations of Na^+, K^+, Mg^{2+}, Ca^{2+} in Lake Issyk-kul (◆: Na^+, ●: K^+, ×: Mg^{2+}, ▲: Ca^{2+}).

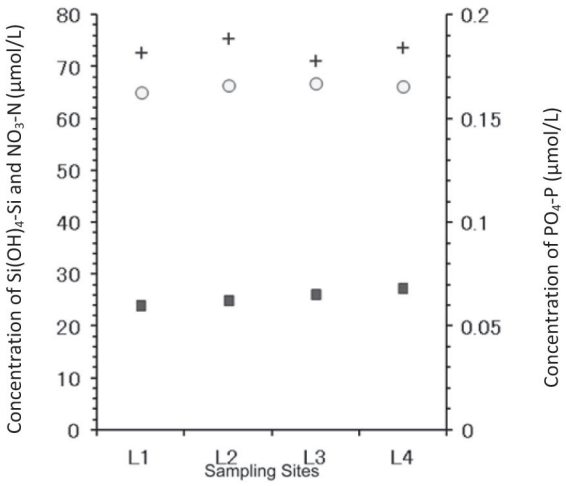

Fig. 5. Horizontal Distribution of Nutrient Concentrations in Lake Issyk-kul (●:$Si(OH)_4$-Si, +:NO_3-N, ■:PO_4-P).

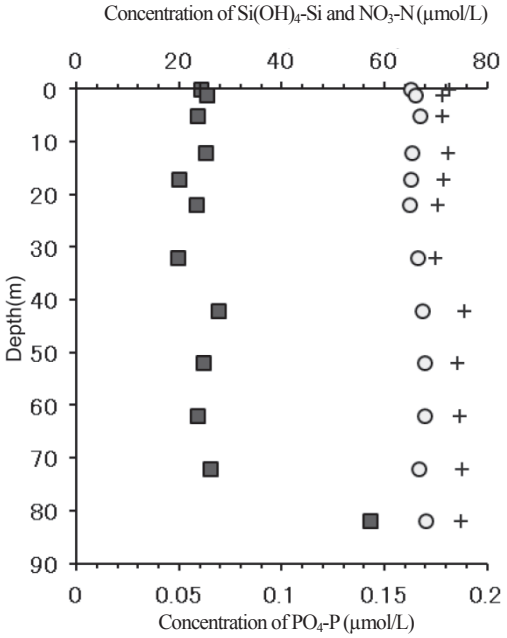

Fig. 6. Vertical Distribution of Nutrient Concentrations in Lake Issyk-kul (●:$Si(OH)_4$-Si, +:NO_3-N, ■:PO_4-P).

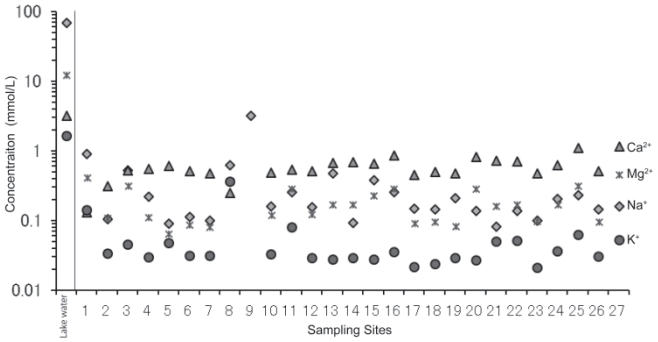

Fig. 7. Comparing the Cation Component of River Water (No.1-27) and Lake Waters.

3.2. Comparison of river water and lake

The results of comparing the major ion component of river and lake waters are shown in **Figure 7**. Major cation concentrations in the lake water were higher than the river water. Trends of major anion concentrations were similar to the cations. Compared with river water, Na+ concentration was 450 times, Mg^{2+} concentration was 150 times, K^+ concentration was 50 times, Ca^{2+} concentration was 10 times higher in the lake water. Trends of anion concentrations (Cl^-, SO_4^{2-}, alkalinity) were similar to the cation concentrations. In particular, Cl^- ions were 950-fold concentrated in the lake water.

The results obtained by comparing the nutrients component of river and lake waters are shown in **Figure 8**. There was no significant difference in concentration when the lake and river waters were compared. The concentration ratios of $Si(OH)_4$-Si, NH_4-N, NO_2-N were reduced in the lake compared to river water. However, there were observed

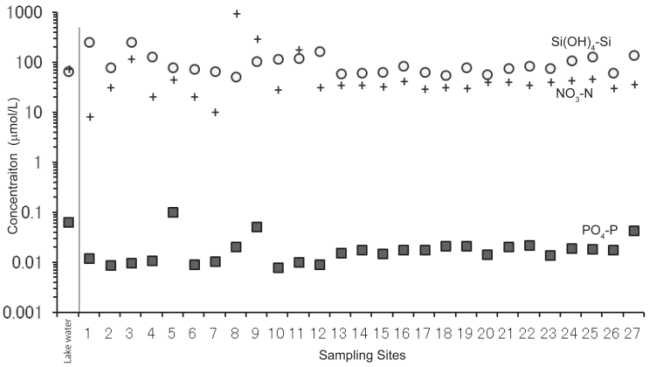

Fig. 8. Comparing the Nutrient Component of River Water (No.1-27) and Lake Waters.

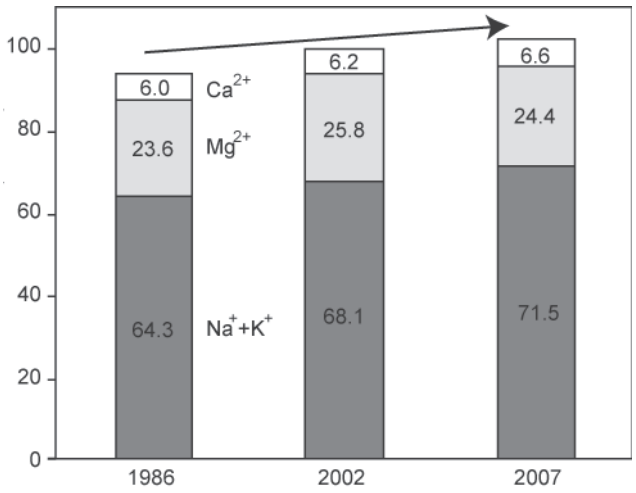

Fig. 9. Comparing the Cation Component with Our Results and Past Research.

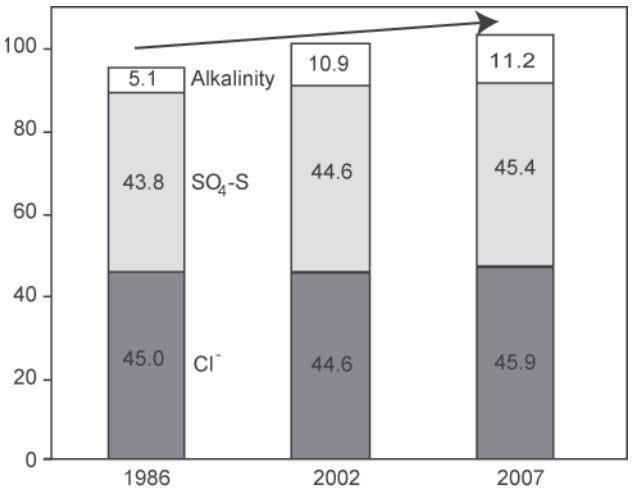

Fig. 10. Comparing the Anion Component with Our Results and Past Research.

increments in PO_4-P and NO_3-N.

3.3. Comparison with past data

A vast collection of data on major ions has been reported by Kadyrov (1986), and more recently by Vollmer *et al*. (2002)

as well as Karmanchuk (2002). Results of major ion concentrations obtained in our investigations compared reasonably well with those in these studies (**Figs. 9** and **10**).

Concentrations of cation components (K^+, Ma^{2+}, Ca^{2+}) and also those of anion components (Cl^-, SO_4^{2-}, alkalinity) are increasing every year. From these results, it is clear that the buildup of salt concentration is in progress in the Issyk-kul Lake. Due to the increasing alkalinity and Na^+, the composition of the main component has changed.

4. Conclusion

The horizontal distribution of PO_4-P, and NO_3-N in the Lake Issyk-kul increased in the 20 - 40 m depth. This trend is considered to be the influence of biological activities. The results indicate that major ion concentrations of the lake water were higher than river water and that there is an annual increase in the concentrations of major components. Due to the increasing alkalinity and Na^+, the composition of the main component has changed. However the others remained almost unchanged in terms of concentration. Concentrations of nutrient components in river waters were compared, but the reason why concentrations of only two components increased could not be ascertained.

Acknowledgments

This work was supported Grant-in-Aid for Science Research, by Ministry of Education, Culture, Sports, Science and Technology of Japan, 2004-2007 and 2008-2011 (Monbusho International Scientific Research Program, represented by KAWABATA Y.).

References

Karmanchuk A.S. (2002): Water chemistry and ecology of Lake Issyk-Kul. *In* Jean Klerkx, Beishen Imanackunov eds., *Lake of Issyk-Kul: Its Natural Environment: Proceedings of the NATO Advanced Research Workshop on the Issyk-Kul Lake: Evaluation of the Environmental State and its Remediation, NATO Science Series IV, Earth and Environmental Sciences 13*. Springer-Verlag.

Kaydyrov V. K. (1986): *Hydrochemistry of Lake Issyk-Kul and its Basin*. Ilim Publishing (in Russian).

Lyons W.B., Welch K.A., Bonozongo J.C., Ganham E.Y., Shabunin G., Gaudette H.E., Poreda R.J. (2001): A preliminary assessment of the geochemical dynamics of Issyk-Kul Lake, Kirghizstan. *Limnol. Oceanogr.*, **46**: 713-718.

Romanovsky V.V. (2002): Water level variations and water balance of Lake Issyk-Kul. *In* Jean Klerkx, Beishen Imanackunov eds., *Lake of Issyk-Kul: Its Natural Environment: Proceedings of the NATO Advanced Research Workshop on the Issyk-Kul Lake: Evaluation of the Environmental State and its Remediation, NATO Science Series IV, Earth and Environmental Sciences 13*. Springer-Verlag.

Savvaitova K., Petr T. (1992): Lake Issyk-Kul, Kirgizia. *Int. J. Salt Lake Res.*, **1**: 21-46.

Vollmer M.K., Weiss R.F., Falkner K.K., Qiu X., Ralph E.A., Romanovsky V.V. (2002): Physical and chemical properties of the waters of saline lakes and their importance for deep-water renewal: Lake Issyk-Kul, Kyrgyztan. *Geochim Cosmochim. Acta*, **66**(24): 4235-4246.