Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.18, 2014

Determination of Major Ion Concentration and Ionic Strength of Saline Water: A Case Study of Lakes; Nakuru, Bogoria-Kenya and Nata Saltpan Sanctuary –Botswana

Samuel Omboga[1], Barnabas K. Kurgat[2], Emily C. Cheshari[3], Moses K. Rotich[3]*, Ward J. Mavura[4]

[1]Department of Chemistry, Njoro Campus, Egerton University; P.O Box, 536, Egerton, Kenya

[2]Institute of Arid Lands Management, Laikipia University; P.O Box, 1100, 20300, Nyahururu, Kenya

[3]School of Science and Applied Technology, Laikipia University; P.O Box, 1100, 20300, Nyahururu, Kenya

[4]Department of Chemistry, Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000-00200, Nairobi, Kenya

*Email of corresponding author:rotichmoses@ymail.com

Abstract

Lakes Nakuru, Bogoria and Nata salt pan are of great ecological and economic importance. They are home to one of the world's renowned bird sanctuaries with over 400 bird species, lesser flamingoes and breeding ground for a host of water birds including pelicans and flamingoes. These aquatic ecosystems are however; threatened by environmental pollution mainly due to anthropogenic activities in the catchment basins. The current study therefore, sought to determine the concentration of individual ions of saline waters and ionic strength in Lake Nakuru, Lake Bogoria (Kenya) and Nata Saltpan Sanctuary (Botswana) so as to form the baseline information for periodic monitoring and remediation of such aquatic saline systems amid the environmental pollution. Identification of individual dissolved ions can also be used as an indicator of the source of pollution. Samples were collected during the dry season by stratified sampling technique using Van Dorn Sampler. Water temperatures were generally high and consistent with the ambient air temperatures and pH values were 10.55±0.09, 10.15±0.18 and 9.97±0.33 for Nakuru, Bogoria and Nata saltpan respectively. Mean conductivity of values of 47.77±0.78, 62.50±0.37 and 12.79±0.33 were recorded for Lakes Nakuru, Bogoria and Nata saltpans respectively. Cation concentration were dominated by Na^+ followed by K^+, Ca^{2+} and Mg^{2+} and significant amount of trace anions in Lake Nakuru, Bogoria and Nata saltpan. Ionic strength for lakes Nakuru, Bogoria and Nata saltpan waters was 0.166, 0.195 and 0.059 M respectively. The findings of the study showed high level of ions in lakes Nakuru and Bogoria compared to Nata Saltpan. This was attributed to high agricultural and industrial activities in the catchment area.

Key Words: Salinity**,** Conductivity, Ionic strength, Pollution, Water

1. Introduction

Lake Nakuru is one of the world's renowned bird sanctuaries with over 400 bird species (Curry Lindahl, 1971). Similarly, Lake Bogoria and Nata saltpan are also a home to the largest populations of lesser flamingoes and breeding ground for a host of water birds including pelicans and flamingoes. However, these great economic and ecological values from theses ecosystems are threatened by environmental pollution mainly due to anthropogenic activities in the catchment basins (Yasindi, 1995). Dissolved constituents of water bodies are often determined as a major component of limnological studies (Gebre et.al, 2002). Large quantities of dissolved compounds render fresh water unsuitable for domestic or industrial use. Total dissolved solids (TDS) refer to total concentration of inorganic solids, usually measured in mg/l. It is the presence of major ions commonly quantified in water to comprise TDS which gives water the ability to conduct electricity and essentially constitute the total ionic salinity of waters (Wetzel, 1983). In natural waters, these ions are present in balanced proportions that are determined by equilibrium between the solution and the geological formation as reported by Anderson (1999).

Electrical Conductivity determination has been used to estimate dissolved ionic matter in water. Electrical conductivity (EC) is expressed in terms of the specific electrical conductivity, which is defined as the reciprocal of electrical resistance in Ohms (Ω), in relation to water cube of edge length 1cm at 25 ℃ (Williams, 1966). The specific EC units is given in Siemens per centimeter (Scm^{-1}), where $S= \Omega^{-1}$ and is depended upon the concentration, mobility, oxidation state of dissolved ions and temperature of the water (AWRI, 2005). Low values of specific conductance are characteristics of high quality, oligotrophic (low nutrients) lake waters. High values are observed in eutrophic lakes where pollutants such as fertilizers are in greater abundance (AWRI, 2005). Therefore, sudden change in conductivity can indicate a direct discharge or other source of pollutants into water (Fang et al., 2005). Conductivity readings, however, do not provide information about specific ionic composition/strength and specific ions contribution to conductivity. Therefore, the objective of the study was to determine the concentration of individual dissolved ions of saline waters and ionic strength in Lake Nakuru, Lake Bogoria (Kenya) and Nata Saltpan Sanctuary in (Botswana) so as to form the baseline information for future monitoring of ecosystem health of such aquatic saline systems amid the environmental pollution resulting mainly from anthropogenic activities.

2. Research Materials and methods

2.1 Study areas

Lake Nakuru is a shallow alkaline-saline lake located in Eastern arm of the Rift valley (0° 22'S, 36° 05'E). The lake has an area of 36-49 km^2 and a catchment basin of 1800 km^2 and is fed by three major rivers, namely; Njoro, Makalia and Nderit. Similarly, Lake Bogoria is also a saline with a shallow depth of about 10 m, 34 km long and 3.5 km wide with drainage basin of 700 km^2. The lake is fed with water from Sandai and Emos rivers and, discharge from hot springs at onshore sites. Additionally, Nata saltpan is located in an endorheic basin, 170 km Northwest of Francis town on the eastern tip of Makagadikgadi pans. It is shallow with frequent seasonal drought and high degree of unpredictability. The sanctuary covers approximately 230 km^2 of which 55% is land surface and 45% is pan surface.

2.2. Instrumentation and Reagents

Field measurement of pH was done using OAKLON pH meter (OAKLON instrument; Singapore) and HANNA digital pH meter in the Laboratory. Conductivity and temperature were measured using HI 933300 portable microprocessor printing and logging multi-range model (HANNA Instrument inc; Portugal) both in the field and laboratory analysis. Measurement of pH in the field was done by dipping the calibrated probes into the water and allowing the meter reading to stabilize before the reading was taken. All values were corrected to 25 ℃ using temperature coefficient of 2.3% per ℃. A Varian Spectr *AA* 220 FS atomic spectrometer was used to determine calcium and magnesium. Sodium and potassium were measured by use of Sherwood Flame Photometer, model 410 while major dissolved anions in water except CO_3^{2-} and HCO_3^- were determined using Ion Chromatography System. Additionally, a micro pipette – BOECO was used for preparations of samples and standards. Reagents used included; distilled water, redistilled nitric acid, potassium chloride, sodium carbonate, sodium chloride, sodium fluoride, potassium hydrogen phosphate, sodium nitrate, sodium sulphate, hydrochloric acid, nitric acid, sulphuric acid, ascorbic acid , antimony potassium tartrate, barium chloride, ammonium molybdate, magnesium chloride and sodium acetate.

2.3. Analytical Procedures

Workings standard solutions for each metal were prepared by appropriate dilution of respective 1000-mg/l stocks solution. A high purity of $CsCl^-$ was added to all samples and standards in order to buffer the ionization potential (Mendham, et al. 1989). In the case of calcium, a high purity $LaCl_3$ solution was added to the standards and samples to improve sensitivity in the presence of oxide forming elements such as P and Al (ALHA, 1998).

2.4. Sampling and Sample Preservation

Representative sampling site of water in lakes Nakuru, Bogoria and Nata Salt Pan were established by selecting randomly sampling points of 10, 5 and 17 respectively. Surface water samples were collected from identified points during dry season in triplicate using Van Dorn Sampler and transferred to acid-washed polythene bottles. Samples for cation analysis were preserved by adding acid immediately after collection to a pH of about 2 using concentrated nitric acid (Analar) as documented by Mackereth (1978). The samples collected were placed in icebox container before being transported to laboratory for analysis. Ionic Strength was determined using semi empirical procedure as follows;

Ionic Strength (IS) = $1/2000\sum Z_{i2}$ (mM_i)

where: Z_i is the absolute value of the charge of the i^{-th} ion, mM_i is millimolar concentration of the i^{-th} ion.

3. Results and discussion

Table 1 below presents the results of mean values of physico-chemical parameters measured (temperature, pH, conductivity and salinity –TDS). Water temperatures were generally high and consistent with the ambient air temperatures. This was attributed to sampling which was done during severe drought season when the regions experienced the highest temperatures. In addition, the waters were shallow with slow movement and in some cases stagnant hence tend to heat up fast. The shallowest points in the saltpan and the lake where highest temperatures were recorded exhibited the greatest conductivity and salinity. The mean pH readings were

10.55±0.09, 10.15±0.18 and 9.97±0.33 for Nakuru, Bogoria and Nata saltpan respectively. The high pH values in the Rift Valley lakes can be explained fundamentally by the natural process of weathering in the study area (Yuretich, 1982). These values were outside the range of drinking water as observed by Hutton, et al., 1976 and typical of polluted water. High values of pH was thought to be due to high concentration of Na^+, CO_3^{2-}, HCO_3^-;Cl^-, SO_4^{2-} and PO_4^{3-}.

Table 1. Mean values of physico-chemical parameters measured

Study sites	Temperature (℃)	pH	Conductivity $mScm^{-1}$	Salinity (TDS) g/l
Lake Nakuru	26.64±0.32	10.55±0.09	47.77±0.78	31.25±2.18
Lake Bogoria	26.25±0.86	10.15±0.18	62.5±0.37	43.23±0.27
Nata Saltpan	27.01±0.73	9.97±0.23	12.79±0.33	8.18±0.18

The presence of high concentration of carbonates and bicarbonates may be attributed to minimal changes observed in pH levels. The steady state of pH while water level was receding could be linked to the CO_2 being always in equilibrium with dissolved CO_2 in the surface water, together with equilibria for dissolved ions as also reported by Omondi (2000). Mean conductivity of values of 47.77±0.78, 62.50±0.37 and 12.79±0.33 were recorded for Lakes Nakuru, Bogoria and Nata saltpans respectively. There was no significant spatial variation in conductivity recorded between sampling sites. However, a trend of increase was observed in different saltpans. Salinity (due to TDS) means values of 31.25±2.18, 43.23±0.27 and 8.18±0.18 were also recorded. The salinity means values of Lakes Nakuru were comparable to those of Shivoga, 1998 (48.00 $mScm^{-1}$), but lower than Bogoria's 72.00 $mScm^{-1}$ (Melack, 1981).

3.1 Chemical composition of Lakes Nakuru, Bogoria and Nata Saltpans Water Bodies

3.1.1. Major base cation composition

Table 2 below indicates the major base cation composition of Lakes Nakuru and Bogoria; values A, B and C are in mg/l, meq^{1-} and percentage equivalent of either cations or anions respectively in this paper unless otherwise stated. Similarly, table 3 indicates chemical composition of major base cations in Nata saltpan sanctuaries. Despite the wide fluctuations in the absolute concentration of major cations, expression of their concentration according to their percentage of equivalent sum of cations showed that cations proportion remained remarkably constant.

Table 2. Major base cation composition of Lakes Nakuru and Bogoria

Values	Mg^{2+}		Ca^{2+}		K^+ (g/l)		Na^+ (g/l)	
	Lake Nakuru	Lake Bogoria	Lake Nakuru	Lake Bogoria	Lake Nakuru	Lake Bogoria	Lake Nakuru	Lake Bogoria
A	0.2±0.01	0.83±0.10	0.21±0.04	3.63±0.71	1.38±0.23	0.03±0.01	2.37±0.05	3.68±0.01
B	0.01	0.07	0.01	0.18	34.86	8.10	103.8	160.00
C	0.01	0.04	0.01	0.11	25.27	4.81	74.72	95.04

Na^+ was the dominant cation in lakes Nakuru and Bogoria but K^+ was dominant in Nata salt pan sanctuary as shown in Table 2 and Table 3 above. The relatively high concentration of Na^+ and K^+ indicate weathering and/or contribution of alkaline saline soil are the important sources of ions in these waters. The low concentration of calcium and magnesium can be attributed to precipitation as the pH is very high especially in lakes Nakuru and Bogoria. Njenga (2004) reported that calcium and magnesium are removed from solution through precipitation at pH values above 9.

3.1.2. Major anions composition

Table 4 shows the major anions composition of lakes Nakuru and Bogoria while table 5 presents the major anions composition of Nata saltpan.

Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.18, 2014

Table 3. Major base cation composition in Nata saltpan

Sanctuary	Value	K^+	Na^+ (g/l)	Ca^{2+}	Mg^{2+}
1st	A	86.3±4.50	0.18±0.13	1.51±0.18	1.14±0.24
	B	2.21	7.78	0.08	0.09
	C	21.72	76.61	0.79	0.88
2nd	A	273.8±6.17	0.63±0.12	0.28±0.02	0.63±0.03
	B	7.00	27.25	0.01	0.05
	C	20.40	79.42	0.03	0.15
3rd	A	110.61±9.84	0.22±0.02	0.98±0.34	0.80±0.20
	B	2.77	9.61	0.05	0.07
	C	22.16	76.88	0.40	0.56
***Ref SLRS-3**		0.67±0.01	2.09±0.32	5.35±0.35	1.55±0.20
***Cert. values**		0.70±0.10	2.30±0.20	6.00±0.40	1.60±0.20

* Standard reference and certified values for systematic adjustments (National Research Council, Canada)

Table 4 major anion composition of lakes Nakuru and Bogoria

Anions		**Study areas**	
		Lake Nakuru	**Lake Bogoria**
Cl^-(g/l)	A	0.67±0.05	0.12±0.01
	B	18.76	3.49
	C	19.45	2.94
CO_3^{2-}(g/l)	A	2.60±0.15	3.25±0.28
	B	86.77	108.17
	C	76.00	90.25
HCO^{3-} (g/l)	A	0.15±0.03	0.47±0.19
	B	2.51	7.62
	C	4.47	6.36
SO_4^{2-}	A	0.07±0.04	15.52±0.86
	B	0.01	0.32
	C	0.01	0.20
PO_4^{3-}	A	2.19±0.26	7.79±0.54
	B	0.07	0.24
	C	0.06	0.20
NO_3^-	A	0.53±0.10	0.21±0.02
	B	0.01	0.01
	C	0.02	0.01

Table 5. major anion compositions of Nata saltpan sanctuaries

Sanctuary	Value	Cl^-(g/l)	CO_3^{2-}	HCO^{3-}	SO_4^{2-}	PO_4^{3-}	NO_3^-	F^-
1st	A	2.09±0.13	5.66±0.64	0.35±0.04	137.01±8.29	5.14±2.14	0.03±0.09	2.64±0.53
	B	58.87	0.19	0.01	2.85	0.16	0.05	0.14
	C	94.54	0.31	0.01	4.58	0.26	0.08	0.22
2nd	A	4.59±0.19	14.41±0.99	0.88±0.06	469.20±7.90	2.0±0.41	0.04±0.65	5.65±0.17
	B	129.55	0.48	0.01	9.76	0.07	0.05	0.30
	C	92.39	0.34	0.01	6.96	0.05	0.04	0.21
3rd	A	2.62±0.06	6.15±1.08	0.38±0.07	171.87±3.35	6.5±0.08	0.05±0.08	3.70±0.66
	B	73.80	0.21	0.01	3.58	0.02	0.01	0.19
	C	94.85	0.27	0.01	4.60	0.03	0.01	0.24

Sulphate ion was the dominant anion in lake Bogoria and Nata salt pan but carbonate ion was dominant in lake Nakuru. The saltpan was characterized as low in nutrient content but high in chloride and sulfates whereas both lake waters had significant amount of trace anions. Nitrate content was particularly low in the entire saltpan. This can be explained by the absence of agricultural or any industrial activities around the sanctuaries. The concentrations of other anions were generally high in the 2nd and 3rd saltpans. This may be ascribed to evaporation loading leading to increased concentration of dissolved solutes. The mean nitrate concentration for lakes Nakuru and Bogoria were 0.53±0.10 and 0.21±0.2 mg/l respectively as shown in table 5 above. These values were high as expected of hypereutrophic lakes (Wetzel, 1983), mean values of phosphates were 2.19±0.26 and 7.79±0.54 for lakes Nakuru and Bogoria respectively. This was attributed to the following; geology of the drainage basin through which the rivers supplying it passes, direct sediment resupply particularly in shallow waters and runoff and, river inflows. Lack of variations in the spatial distribution of anions in both saltpan and the lakes suggest high solubility of this analytes with good daily mixing of the waters. The ionic strengths for lakes Nakuru, Bogoria and Nata saltpan waters were 0.166, 0.195 and 0.059 M respectively.

4. Conclusion and recommendation

Sodium ion was the dominant cation in Lake Nakuru and Bogoria but in Nata salt pan potassium ion was the dominant cation. Lake Bogoria had the highest Ionic strength (0.195M) while Nata saltpan waters had the lowest (0.059 M). Sulphate ion was the dominant anion in lakes Bogoria and Nata saltpan waters and Carbonate ion was the dominant anion in Lake Nakuru. Comparatively, the Nitrate ion concentration was low in Nata salt pan waters, this can be attributed to absence of agricultural and industrial activities within the catchment basin as opposed to around the two lakes. From the findings of this study, it is recommended that similar studies should be carried out during the rainy season to compare the results. In addition, research is needed to determine the rate of salinisation for these saline water bodies.

Reference

American Public Health Association [APHA], (1989), "Standard Methods for the Examination of Water and Wastewater", 17th & 20th Eds., *American Public Health Association*, Washington DC, USA.

Anderson, H. & David, C. (1999), "Measuring the Salinity of Water. Melbourne", Available on .htt:/www.dpi.vic.gov ad/dpi/nrening/childdocs (29th August, 2014)

Annis Water Resource Institute [AWRI], (2005), "Information Services Center Ecological Research Education and Outreach Home Programs Vessels Manual", Water Data Events.

Curry-Lindahl, K. (1971), "A Short-term Ecological Survey of Lake Nakuru and Surrounding Area", *Mimeographel Report*, Baharini Wildlife Sanctuary. Nakuru, Kenya, pp. 29.

Fang, L. & Vipulanandan, C. (2005), "Conductivity of Water-in-oil Micro-emulsion Systems", Center for Innovative Grouting Material and Technology (CIGMAT).

Gebre, M., Z., Lauren, J.,C. & Colin, A.,C. (2002), "Conductivity as a Predictor to Total Cations and Salinity in Ethiopian Lakes and Rivers, Revisiting Earlier Models", *Limologica*, 32, 21-26.

Hutton, L., G. & Dincer, T. (1976), "An Investigation of the Okavango Delta as Primary Water Resource for Bostwana", *Technical note*, 23/UNDP:FAO,AG:DP/BOT/71/506.

Mackereth, F., J., Heron, J. & Talling J., F. (1998), "Water Analysis", *Fresh Water Biological Association*.

Mendham, J., Jeffery, G.,H., Basselt, J. & Denney, R.,C. (1989), "Vogels Quantitavie Chemical Analysis", 5th Eds., pp. 519-529.

Melack, J., M. (1981), "Photosynthetic Activity of Photoplankton in Tropical African Soda Lakes", *Hydrologia*, 81: 71-85.

Njenga, J.W. (2004), "Comparative studies of water Chemistry of four tropical lakes in Kenya and India", *Asian Journal of water environment and pollution*, 1 (2), 87-97.

Omondi, S.,O. (2000), "Diel Physico-chemical Dynamics, Primary Production and Algae of Lake Baringo-Kenya", *M.Sc. Thesis*, University of Vienna, Austria.

Shivoga, W.A. (1999), "Spatio-temporal Variations in Physico-chemical Factors and Stream Fauna Abundance and Composition in the Ozones of Transition between Baharini Springbrook, Njoro River and Lake Nakuru-Kenya", *A PhD Thesis*, University of Vienna, Austria.

Wetzel, R.G. (1983), "Limnology", 2nd Eds., Philadelphia, USA.

Williams, W., D. (1966), "Conductivity and concentration of total dissolved solids in Australian Lakes", Aust. J. Mar., Freshwater, Res. (17), 169-176.

Yasindi, A.W. (1995), "The Ecology of Ciliated Protozoa in an Alkaline Saline Lake Nakuru-Kenya", *M.Sc. Thesis*, Njoro, Egerton University, Kenya.

Yuretich, R.F. (1982), "Possible influences upon Lake Development in the East African Rift Valleys", *Journal of. Geology*, 90: 329-337.