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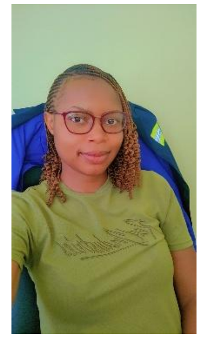


Biography

Chikomborero Mukuwe is an Environmental Graduate Scientist with the Zambezi River Authority, working on the Kariba Dam Rehabilitation Project (KDRP) that includes the Plunge Pool Rehabilitation and Spillway Rehabilitation (Phases 1 and 2). She supports key infrastructure activities integrating environmental management and safety practices. Her work involves implementing environmental safeguards, supporting the integration of safety and sustainability measures, and facilitating coordination across multidisciplinary teams to ensure compliance with international best practices. With hands-on experience in hydropower systems and ongoing NEBOSH Certification. Chikomborero is deeply committed to advancing regional and global sustainability. She is passionate about sustainable development and aims to drive climate and environmental solutions in Zimbabwe through the Water-Energy-Food-Ecosystems (WEFE) nexus- contributing meaningfully to Africa's sustainable development agenda and environmental resilience, particularly in Zimbabwe.

Title: Assessing the effect of seasonal variations on water quality in Zambezi River Basin. A case study of Lake Kariba in 2024.

ORAL PRESENTATION PREFERED

Theme 1: Sustainable Water Management on the WEFE Nexus

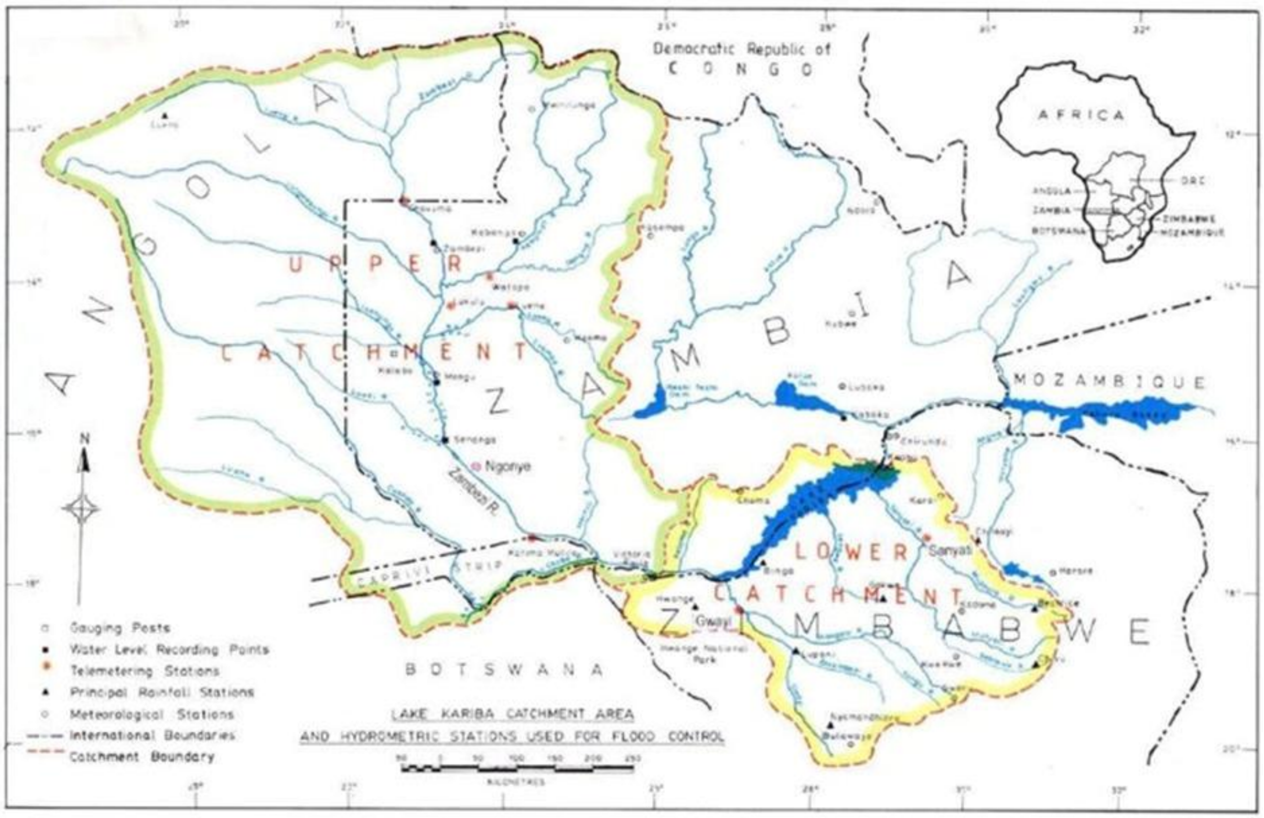
- Fits under Sub- Theme: **Water Quality Management**
- Focus on: **Assessing the effects of water quality nutrients in Lake Kariba Eastern Basin fostering Integrated Water Resources Management (IWRM).**

ABSTRACT

This study examines the impact of seasonal variations on water quality, along the Lake Kariba within the Zambezi River Basin, with a specific focus on the water resources and environmental management practices of the Zambezi River Authority (ZRA) in 2024. Seasonal changes in rainfall, temperature, and river discharge significantly influence key water quality parameters such as nutrient concentrations, sediment loads, dissolved oxygen, and biological activity. Using on-site field data, laboratory analysis/tests, and previous years data, the study assesses how wet season that is, (January to March) and dry seasons that is, (August-September) alter the chemical and physical composition along the Zambezi River System and its tributaries, particularly in areas influenced by dam operations. To evaluate the water pollution quality, the following 12 parameters were analyzed water temperature, pH, Electroconductivity (EC), Dissolved Oxygen (DO), Total Suspended Solids (TSS), Total Dissolved Solids, Total Chlorophyl and Secchi Depth, alkalinity, turbidity, Total Phosphorus (TP), and ammonia-nitrogen (NH_3 -N). Findings highlight critical periods of water quality deterioration, primarily during the onset of the rainy season when surface runoff intensifies pollutant loads. The study underscores the need for adaptive and seasonally informed water management strategies by the ZRA to maintain ecosystem health and ensure sustainable use of the basin's water resources. It is also made clear that the water exiting Lake Kariba is generally free of any significant pollution across all seasons.

INTRODUCTION

Water is recognized as a key driver for social and economic development in the Zambezi basin. The basin is riparian to eight southern African countries and the transboundary nature of the basin's water resources can be viewed as an agent of cooperation between the basin countries. The Zambezi is the fourth-longest river in Africa, and the largest flowing into the Indian Ocean. The area of its basin is 1,570,000 square kilometers. The 2,574 kilometers-long river has its source in Zambia and flows through Angola, along the border of Namibia, Botswana, Zambia, and Zimbabwe, to Mozambique, where it empties into the Indian Ocean (Zambezi River, 2008). recently, found suffering from an unknown and apparently fatal disease (Zambezi River pollution warning, 2007; Magadza, 2006). Pollution of surface and groundwater resources and the atmosphere have become major environmental problems for the Zambezi River Basin. The increase in pollution discharges is largely attributed to urbanization, increased industrial and agricultural activities, mining and soil erosion. The urban centers produce sewage effluent, industries emit greenhouse gases and other industrial wastes, and the agricultural sector uses fertilizers and other pesticides which all contribute to the pollution of the surface and groundwater resources. In the Zambezi River Basin, gold panning is prevalent resulting in soil erosion and water resources pollution. Mine wastes, if not disposed and managed properly, result in heavy metal water pollution (Tumbare, 2004). There is a specific legislative framework that governs the management of the Zambezi River, focusing on its use for economic, industrial, and social development, particularly in relation to water use for energy generation. This framework is established under an inter-state agreement between Zambia and Zimbabwe known as the **Zambezi River Authority Act, Chapter 467** (Nwasco, n.d.). A significant portion of the basin's water is utilized for **hydroelectric power (HEP)** generation, primarily sourced from the two largest artificial lakes—**Lake Kariba**, covering **5,250 km²** with a storage capacity of **156 km³**, and **Lake Cabora Bassa**, covering **2,739 km²** and holding **56 km³** of water (Mpande & Tawanda, 1998).



Sampling sites along the Zambezi River, Lake Kariba and its tributaries

Source: Map data ©2012 Google

Although pollution of water resources has not yet created regional conflicts, the likelihood of such conflict exists in the future. The issue, however, has the potential of becoming a regional problem, particularly regarding pollution from heavy metals, as evidenced by the existence of dichlorodiphenyltrichloroethane (DDT) and heavy metals in Lake Kariba. The riparian countries, therefore, need to cooperate in formulating and monitoring legislation to prevent such contamination. Furthermore, other authors suggest that legislation should include the establishment of limits on effluent as well as punitive measures for offenders. . The world over, four principal theories or doctrines have been maintained by riparian states regarding the rights on international waters. It is not very apparent as to which theory guides the management of the Zambezi River amongst the riparian countries. However, the theory of community of interests seems to be at play as evidenced by the recent reference to ‘shared water courses’ in the protocol on Shared Watercourse Systems. the upper part of the Zambezi River is thinly populated by pastoralist farmers and fishermen and that wildlife is sparse; it is remarkably free of pollution (Zambia National Tourist Board, n.d.). However, with the coming of new mines near the source of the river in Kabompo, there is a possibility of new sources of pollution. The pollution in the Kabompo River, which feeds into the Zambezi River, would affect hundreds of thousands of people further downstream. It is the purpose of this study to provide current information (in 2011) about the seasonal variations of the water quality along the Zambezi River. This study therefore is intended to analyse and disseminate hydrological and environmental data and environmental conditions of the Zambezi River, its tributaries and the Lake Kariba.

METHODOLOGY

Tools used include the following:

- The Houseboat (Mukunganyika)
- The speed boat
- The Sonde Multi-parameter data equipment
- Arch – GIS

Water quality data for Lake Kariba, the Zambezi River, and its tributaries were obtained from the Zambezi River Authority (ZRA) - Kariba Environmental Laboratory. Samples were collected monthly, quarterly and bi-annual during the environmental monitoring Programme, from January to September 2024, at over 50 locations: some of the key locations includes Victoria Falls, Kariba at Charara area, Lake Kariba at Andora Harbour, Lake Kariba Dam-Wall (Upstream and Downstream), Nyaozda, Gatche Gatche, Sanyati Mouth, Sanyati Mouth-Further, B51, Manchinchi Bay, Ulkrs, Crocodile Farm, Deka River, Kalomo River, and Gwayi River.

A variety of methods were employed to analyze different water quality parameters. Physical parameters - such as temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), total suspended solids (TSS), total dissolved substances (TDS), turbidity, total chlorophyll, and Secchi depth - were measured in situ using a multi-parameter Sonde.

Chemical parameters—including total nitrogen (TN), total phosphorus (TP), ammonia, nitrate, nitrite, total alkalinity, total chloride, and fecal coliforms—were analyzed in the ZRA Environmental Laboratory. The FIAlab system was used for the analysis of ammonia, nitrogen, nitrite, and total phosphate concentrations. Seasonal variation in water quality was assessed using a Fialyser, comparing data from two periods: the high-flow season (January to March) and the low-flow season (August to September).

Titration methods were applied to determine alkalinity (as $CaCO_3$) and chloride concentrations. Fecal coliforms were analyzed using bacteriological testing procedures in the laboratory.

In addition, GIS tools were used to map the spatial distribution of pollutants within Lake Kariba, enhancing the understanding of water quality trends and potential pollution hotspots across the sampling locations.

Total Nitrogen (TN) Analysis by Cadmium Reduction Method.

Reagent	Before Digestion	After Digestion
Digestion reagent/ Oxidizing Agent	-100 mL of de-ionized water. -16g $K_2S_2O_8$. -20 mL of 3N NaOH. **(16g $K_2S_2O_8$ was dissolved in the 100 mL of D.I Water, 20 mL of 3N NaOH was added and mixed thoroughly, and mixture was diluted to**	N/A

	250mls).	
Samples	-6 mL of sample -1.25 mL digestion reagent **(6 mL of sample and 1.25 mL were mixed using a vortex mixer).**	-50µL 3N NaOH was added to neutralize the digested samples. -The neutralized samples were then diluted to 20 mL with D.I Water. **(at this stage final dilution factor for samples=3.33).**
Calibration Standards	10ppm of the Nitrate- Nitrogen std stock solution was diluted according to the table below.	-Same amounts of the acid that was added before is the same amount of 3N NaOH that was added to neutralize the digested calibration standards.

NO_3 -N Standards Preparation

- 5mL of 100ppm Nitrate-Nitrogen standard stock solution was used.

3N NaOH Solution

- 30g NaOH was dissolved in 200mL DI water, cool to room temperature and was diluted to 250mL final volume with DI water.

Final Conc (ppm)	**10ppm STD (mL)**	**D.I Water (mL)**	**Digestion Reagent (mL)**	**Final Volume (mL)**
0.4	2	10	3.1	50
0.6	3	10	3.1	50
0.8	4	10	3.1	50
1	5	10	3.1	50

The five (4) TN standards were prepared according to the table above and they were digested for 45mins at 123°C using a block digester. After digestion process, they we all let to cool to room temperature. 3N NaOH was added to both samples and standards as indicated as indicated table above and they were ready for analysis. The samples and reagents were introduced to FIAlab using FIAsoft App. The Total Nitrogen test was then run using the same FIAlab steps / procedures.

Total Phosphorus (TP) Analysis by Ascorbic acid Method.

Reagent	Before Digestion	After Digestion
Blank/Carrier/Wash Water	-250 mL of de-ionized water was measured in the beaker. -20 mL of 11N H_2SO_4 was	-20 mL 11N NaOH was added to neutralize the digested blank/carrier/wash water added

	added to the DI water. -10g $K_2S_2O_8$ was weighed and dissolved in the D.I Water. It was then filled to the marked area of the volumetric flask.	before digestion and was diluted to 1L with DI water final volume.
Samples	-20 mL of sample was added. -0.5 mL of 11N H_2SO_4 was added to the sample. -0.20g $K_2S_2O_8$ (2 Scoops) were added and digested in an autoclave at 120^{O}C overnight.	-0.5 11N NaOH was added to neutralize the digested samples and was diluted to 20 mL final volume with D.I water.
Standards	1 mL of 1000ppm Phosphorus standard diluted with DI water as shown in the table below.	-0.5 11N NaOH was added to the standard and diluted to a final volume of 50 mL with D.I water.

<u>Reagents Preparation</u>

Total Phosphorus (TP) Standard Preparation: 10ppm (P)

- 1mL of 1000 ppm Phosphorus std diluted to 100mL with D.I. Water

11N NaOH Solution

- 44g NaOH was dissolved in 80mL DI water, cool to room temperature and dilute to 100mL with DI water.

11N H_2SO_4 Solution

- 300mL Conc H_2SO_4 was diluted to 1L D.I. Water

Final Conc (ppm)	**10ppm STD (mL)**	**11N H_2SO_4** mL **(mL)**	**D.I Water (mL)**	**Digestion Reagent (mL)**	**Final Volume (mL)**
0.4	2	0.5 mL	23	0.25g(2 Scoops)	50
0.6	3	0.5 mL	22	0.25g(2 Scoops)	50
0.8	4	0.5 mL	21	0.25g(2 Scoops)	50
1.0	5	0.5 mL	20	0.25g(2 Scoops)	50
1.2	6	0.5 mL	19	0.25g(2 Scoops)	50

The five (5) TP standards were prepared according to the table above and they were digested for more than two (2) hours in an autoclave. After digestion process, they were all let to cool to room temperature. 11N NaOH was added to both sample and standards according to the table above and they were ready for analysis. The samples and reagents were introduced to FIAlab using FIAsoft App. The Total Phosphorus test was run using the same FIAlab steps / procedures from.

Alkalinity Analysis

To begin, the blank sample was prepared and titrated first to determine the expected color change at the endpoint. This color change served as a reference for all subsequent titrations. Each water sample was then introduced into the titrator. The titration was monitored using the mixed indicator, which was added dropwise until a distinct color change was observed—signaling the endpoint. For this analysis, the color transition from blue to yellowish indicated the completion of the titration. After titrating each sample, the electrode was thoroughly rinsed with distilled water, dried, and reused for the next sample to avoid cross-contamination. The titration results for each sample, including the blank, were recorded on the alkalinity results sheet. The same procedure was used for the chloride analysis using different reagents.

Bacteriological Test for feacal coliforms using Colilert System

A bacteriological test was carried out to determine fecal coliforms using the IDEXX reagent solution in combination with Quanti-Trays. A 100 mL water sample was mixed thoroughly with the IDEXX reagent specific for fecal coliform detection. The prepared mixture was then poured into a Quanti-Tray, which was subsequently sealed using the Quanti-Tray Sealer Plus to ensure even distribution of the sample into individual wells and to prevent contamination. The sealed tray was incubated at 44.5°C for 24 hours. Following incubation, the wells were examined for color change or fluorescence, indicating the presence of fecal coliforms. The number of positive wells was recorded, and the results were interpreted using the IDEXX MPN table to estimate the Most Probable Number (MPN) of fecal coliforms per 100 mL of sample.

As part of the analysis, the results obtained from both the field and the environmental laboratory during the review period were assessed against the Authority's water quality guidelines to determine whether they exceeded or fell within the permissible threshold limits.

RESULTS AND OBSERVATIONS

JANUARY 2024

DATE	STATION ID	Temp oC	pH	EC mS/m	DO mg/l	TSS mg/l	TDS mg/l	T.Alkalinity mg/l as CaCO3	NO_2-N µg/l	NO_3-N µg/l	TN µg/l	NH_3-N µg/l	TP µg/l	Cl^- mg/l	Total Chloro µg/L	Secchi Disk (m)	FC MPN/ 100ml
17.01.24	Charara	29.44	7.30	10.30	5.18	7	65.80	43	5	40	314	54	34	<10	3.20	2.1	38
16.01.24	Andora	29.85	8.22	10.10	7.51	3	64.04	42	5	<3	278	54	68	<10	2.20	2.8	411
24.01.24	Manchinchi	29.97	8.20	10.20	8.01	<1	64.20	42	4	15	250	45	36	<10	1.90		96
16.01.24	Damwall Up	29.82	8.43	10.10	7.90	3	63.74	43	25	<3	237	58	37	<10	1.70	2.3	
24.01.24	Damwall Down	28.47	7.71	9.70	6.75	6.00	62.85	41	5	21	237	79	49	<10	2.59		117
16.01.24	B 51 0.5m	29.81	8.37	10.10	7.45	3	64.00	40	5	<3	1562	60	49	<10	2.33	2.4	<1
	B 51 10m	28.49	8.23	9.80	7.08	3	63.40	41	4	<3	355	55	52	<10			
	B 51 20m	26.02	6.95	9.10	1.41	4	61.65	40	4	85	265	36	175	<10			
	B 51 30m	24.97	6.95	9.00	1.28	1	63.14	***8**	6	66	91	53	50	<10			
	B 51 50m	24.96	7.07	9.10	1.87	4	62.90	40	3	171	406	75	75	<10			
16.01.24	Sanyati 0.5m	31.46	8.58	10.80	7.79	36	66.05	52	29	46	1610	40	65	<10	2.90	1.1	210
	Sanyati 10m	29.51	7.87	13.40	6.34	241	84.91	52	7	341	899	60	32	<10			
	Sanyati 20m	26.51	6.98	9.00	2.78	627	60.64	51	7	433	871	74	310	<10			
	Sanyati 30m	25.28	6.94	8.80	1.66	471	60.60	56	34	401	699	23	233	<10			
	Sanyati 50m	25.36	7.21	9.30	1.71	305	63.93	60	100	791	468	46	190	<10			
16.01.24	Sanyati further	28.88	7.84	14.20	7.26	652	91.20	89	10	396	975	24	122	<10	7.32	0.5	
17.01.24	Nyaodza	30.54	7.18	11.10	3.54	43	69.03	46	35	108	529	57	121	<10	3.30	0.9	86
17.01.24	Gatchegatche	29.98	7.35	10.80	5.15	9	67.74	47	7	30	601	146	120	<10	7.52	0.9	225
17.01.24	ULKRS	30.61	7.78	11.90	6.69	20	73.90	45	8	29	686	160	118	<10	9.83	1.2	>2419.6
17.01.24	Croc Farm	29.46	7.75	10.20	7.01	19	64.70	47	6	22	871	446	187	<10	3.90	1.6	>2419.6
24.01.24	Chirundu	30.70	7.81	12.00	6.97	42	74.44	47	5	135	405	59	125	<10	3.40		>2419.6
19.01.24	Vlcfalls	26.57	7.58	8.90	6.93	8	69.80	36	4	43	688	90	97	<10	3.85		
19.01.24	ZESA Pump	27.44	7.82	10.20	7.76	204	67.20	44	5	82	885	48	259	<10	5.33		
19.01.24	Deka	25.58	7.85	28.30	7.49	408	194.30	119	21	394	1469	73	762	17.4	7.85		
21.01.24	Zongwe	24.98	7.96	10.20	8.04	70	70.71	52	6	148	597	10	185	<10	5.90		
20.01.24	Kalomo	22.33	7.29	3.30	7.71	387	24.00	73	15	197	663	43	252	<10	8.00		
19.01.24	Gwayi	25.41	7.99	10.70	7.80	1915	74.00	86	11	237	2191	49	966	<10	10.30		
21.01.24	Sikalamba	25.31	8.16	38.00	7.81	130	262.00	98	21	482	1015	68	307	<10	4.79		

FEBRUARY 2024

DATE	STATION ID	Temp oC	pH	EC mS/m	DO mg/l	TSS mg/l	TDS mg/l	T.Alkalinity mg/l as CaCO3	NO_2-N µg/l	NO_3-N µg/l	TN µg/l	NH_3-N µg/l	TP µg/l	Cl^- mg/l	Total Chloro µg/L	Secchi Disk (m)	FC MPN/ 100ml
15.02.24	Charara	31.46	7.92	10.80	8.03	23	66.12	38	<3	56	445	<10	86	<10	7.92	1.2	4
15.02.24	Andora	30.54	8.20	11.20	7.69	6	70.00	34	3	41	406	<10	79	<10	11.10	2.5	3
22.02.24	Manchinchi	31.41	8.70	10.50	8.11	3	64.44	36	<3	<3	1545	<10	53	<10	1.90	2.3	1
22.02.24	Damwall Up	31.43	8.74	10.50	8.19	2	64.43	39	<3	<3	224	<10	84	<10	1.92	2.0	
27.02.24	Damwall Down	27.77	7.13	9.60	3.76	7	63.16	30	<3	80	186	<10	48	<10	1.24		1
22.02.24	B 51 0.5m	31.26	8.70	10.50	8.02	<1	64.46	34	3	22	1481	<10	70	<10			<1
	B 51 10m	29.74	8.61	10.00	7.87	3	63.40	41	3	<3	371	21	67	<10			
	B 51 20m	28.02	7.26	9.70	3.53	<1	63.23	36	3	67	415	<10	68	<10			
	B 51 30m	25.68	7.00	9.10	2.20	13	62.64	38	<3	4	2474	10	64	<10			
	B 51 50m	24.71	7.38	9.10	2.46	2	63.61	39	4	68	456	<10	71	<10			
16.02.24	Sanyati 0.5m	30.73	7.70	13.90	5.27	13	87.42	46	11	36	608	<10	78	<10	4.41	0.9	16
	Sanyati 10m	29.34	7.27	11.10	3.99	2	71.01	32	3	108	606	<10	91	<10			
	Sanyati 20m	27.22	7.00	10.20	2.57	83	67.54	32	8	235	782	23	90	<10			
	Sanyati 30m	26.61	7.04	9.90	2.86	145	66.71	37	3	179	677	<10	84	<10			
	Sanyati 50m	24.96	7.08	10.20	3.20	76	70.92	43	12	43	523	60	103	<10			
16.02.24	Sanyati further	30.74	7.72	18.90	5.45	51	117.20	66	24	95	1631	21	153	<10	10.27	0.5	
15.02.24	Nyaodza	31.58	7.50	11.20	6.75	12	68.70	42	19	12	656	<10	91	<10	4.20	1.8	5
15.02.24	Gatchegatche	32.94	9.07	12.00	11.63	22	71.54	46	3	34	1147	<10	128	<10	17.20	0.9	43
15.02.24	ULKRS	30.87	7.23	12.70	5.23	25	76.80	38	3	74	1089	84	141	<10	13.50	0.9	148
15.02.24	Croc Farm	30.13	7.24	10.50	5.13	11	66.31	37	7	530	569	146	111	<10	6.41	1.4	>2419.6
27.02.24	Chirundu	29.58	7.70	10.30	6.58	16	66.62	33	<3	22	324	<10	78	<10	1.95		14
29.02.24	Vlcfalls	28.13	7.68	8.80	7.05	7	57.61	32	<3	7	430	<10	476	<10	2.30		
29.02.24	ZESA Pump	29.06	8.14	9.20	8.05	10	58.70	32	4	9	347	<10	48	<10	2.73		
29.02.24	Deka	32.22	8.16	129.6	8.02	10	784.50	125	3	<3	426	<10	98	46.5	10.62		
21.02.24	Zongwe	31.87	7.39	21.70	5.89	38	135.50	69	<3	<3	432	17	100	<10	22.20		
	Kazungula					30		-	<3	<3	418	<10	57	<10			
	Chobe					8		30	<3	<3	246	22	64	<10			
	Mowano					9		34	9	<3	219	<10	53	<10			
	Kalomo	LITTLE or NO FLOW															
	Gwayi																
	Sikalamba																

MARCH 2024

DATE	STATION ID	Temp oC	pH	EC mS/m	DO mg/l	TSS mg/l	TDS mg/l	T.Alkalinity mg/l as CaCO3	NO_2-N µg/l	NO_3-N µg/l	TN µg/l	NH_3-N µg/l	TP µg/l	Cl^- mg/l	Total Chloro µg/L	Secchi Disk (m)	FC MPN/ 100ml
19.03.24	Charara	29.96	7.49	10.50	5.25	4.00	66.30	34	<3	<3	583	<10	39	<10	3.3	1.40	9
20.03.24	Andora	30.92	8.07	10.90	7.10	<0.1	67.70	17	<3	<3	436	24	79	<10	3.4	1.50	548
27.03.24	Manchinchi	29.97	8.01	10.60	7.13	2.00	66.72	33	<3	13	587	<10	55	<10	1.9		190
20.03.24	Damwall Up	30.25	8.18	10.50	7.23	<0.1	65.80	33	<3	<3	515	27	65	<10	1.5	2.50	
27.03.24	Damwall Down	28.97	7.86	10.30	6.83	8.00	66.00	33	5	128	245	<10	64	<10	3.0		72
20.03.24	B 51 0.5m	30.36	8.21	10.60	7.23	<0.1	66.03	33	<3	23	534	18	68	<10	1.1	2.60	<1
	B 51 10m	29.62	8.24	10.30	7.37	<0.1	65.60	35	<3	<3	492	<10	73	<10			
	B 51 20m	29.12	7.92	10.20	6.70	<0.1	65.60	32	<3	<3	533	<10	66	<10			
	B 51 30m	28.42	7.60	10.10	5.17	4.00	65.40	35	<3	<3	360	<10	157	<10			
	B 51 50m	26.99	7.29	9.80	3.35	4.00	65.65	33	<3	<3	889	18	53	<10			
20.03.24	Sanyati 0.5m	31.00	8.18	11.40	7.14	10.00	73.50	36	<3	<3	246	16	66	<10	2.0	1.80	<1
	Sanyati 10m	29.74	7.75	11.90	5.87	10.00	75.22	39	<3	4	577	12	67	<10			
	Sanyati 20m	29.41	7.63	11.60	5.67	10.00	73.50	37	<3	4	742	47	52	<10			
	Sanyati 30m	27.39	7.02	10.50	1.79	33.00	69.40	35	<3	14	294	80	61	<10			
	Sanyati 50m	26.07	6.99	11.10	1.76	37.00	75.30	39	<3	34	511	283	88	<10			
20.03.24	Sanyati further	30.38	7.55	16.10	4.86	23.00	100.44	51	<3	7	501	26	91	<10	7.7	0.60	
19.03.24	Nyaodza	30.52	8.03	11.10	7.48	10.00	68.90	37	<3	14	508	24	69	<10	8.3	1.30	17
19.03.24	Gatchegatche	31.40	8.31	11.80	8.48	18.00	72.54	40	<3	6	524	23	131	<10	15.1	1.10	47
19.03.24	ULKRS	30.38	7.74	13.30	6.29	18.00	70.40	35	<3	58	1210	49	115	<10	6.2	0.70	435
19.03.24	Croc Farm	30.26	7.46	11.10	5.41	9.00	69.30	34	<3	34	814	354	124	<10	6.5	1.20	>2419.6
14.03.24	Chirundu	30.23	7.70	10.60	6.50	16.00	66.60	34	<3	234	543	195	66	<10	1.6		980
11.03.24	Vic falls	29.26	7.80	9.00	7.01	7.00	57.30	27	4	438	474	458	75	<10	2.2		
11.03.24	ZESA Pump	29.97	8.14	9.20	8.13	9.00	57.85	29	<3	23	735	<10	59	<10	2.4		
11.03.24	Deka	32.90	8.10	146.40	7.65	13.00	876.90	115	<3	24	939	124	99	48.8	12.4		
13.03.24	Zongwe	32.20	8.46	24.40	8.50	9.00	147.84	89	<3	12	962	23	131	<10	6.2		

AUGUST 2024

DATE	STATION ID	Temp oC	pH	EC mS/m	DO mg/l	TSS mg/l	TDS mg/l	T.Alkalinity mg/l as CaCO3	NO_2-N µg/l	NO_3-N µg/l	TN µg/l	NH_3-N µg/l	TP µg/l	Cl^- mg/l	Total Chloro µg/L	Secchi Disk (m)	FC MPN/ 100ml
14.08.24	Charara	24.36	7.74	10.30	6.81	11	67.70	44	<3	10	397	32	65	1.80	5.47	1.60	2
14.08.24	Andora	24.86	8.48	10.30	8.07	7	67.13	44	<3	40	325	24	48	1.60	3.60	2.10	5
22.08.24	Manchinchi	27.84	8.78	10.70	8.41	1	66.22	40	<3	<3	548	25	42	1.30	2.30	1.90	5
22.08.24	Damwall Up	27.72	8.84	10.70	8.68	1	66.21	40	<3	3	297	25	64	1.00	2.52	2.20	
28.08.24	Damwall Down	27.99	8.65	10.80	7.71	2	66.43	42	27	187	261	34	47	1.10	3.70		<1
22.08.24	B 51 0.5m	26.96	8.85	10.90	8.87	2	65.71	42	<3	<3	339	32	35	1.20	2.50	1.90	<1
	B 51 10m	24.78	8.80	9.90	9.20	2	64.71	41	19	<3	283	21	27	1.00			
	B 51 20m	23.67	7.47	9.70	8.81	<1	64.50	40	<3	67	320	34	49	1.00			
	B 51 30m	23.74	7.48	9.70	5.89	<1	64.62	38	<3	60	380	28	57	0.80			
	B 51 50m	24.71	7.31	9.80	5.28	1	64.30	41	<3	76	407	38	72	0.90			
14.08.24	Sanyati 0.5m	25.26	7.83	10.30	7.01	3	66.60	41	<3	52	379	24	35	1.40	3.10	2.50	<1
	Sanyati 10m	24.21	7.74	10.00	6.70	3	60.15	41	<3	27	312	46	61	1.40			
	Sanyati 20m	23.80	7.50	10.00	5.83	2	69.20	45	<3	55	287	25	50	1.00			
	Sanyati 30m	23.57	7.26	10.10	3.21	3	67.18	45	6	79	321	27	38	0.90			
	Sanyati 50m	25.11	7.32	10.60	4.94	17	68.90	45	3	84	331	21	53	1.00			
14.08.24	Sanyati Further	24.85	7.46	11.00	4.60	7	72.00	50	<3	9	317	42	47	1.50	5.32	1.50	
14.08.24	Nyaodza	24.83	7.82	10.30	7.34	8	67.10	43	<3	29	338	19	57	1.10	5.14	1.40	1
14.08.24	Gatchegatche	24.86	7.41	11.50	5.72	8	74.70	48	<3	15	520	35	70	1.00	9.84	1.70	<1
14.08.24	ULKRS	24.41	8.15	10.80	7.36	21	70.85	48	<3	182	507	56	83	2.10	8.90	1.70	5
14.08.24	Croc Farm	24.55	8.18	10.10	7.48	9	66.40	46	<3	3	465	31	65	0.80	8.80	1.70	33
29.08.24	Chirundu	26.77	7.84	10.70	7.38	6	67.50	41	18	26	413	18	57	0.80	1.80		27
30.08.24	VIcfalls	27.34	7.97	12.60	7.47	4	78.30	50	3	28	289	39	55	2.30	2.52		
30.08.24	ZESA Pump	27.55	8.15	12.90	7.93	1	79.72	49	<3	52	177	39	36	2.00	2.90		
30.08.24	Deka	29.32	7.85	201.70	7.86	10	1211.9	106	10	100	433	32	60	50.60	5.82		
20.08.24	Zongwe/Kanzinze	26.20	7.72	32.40	6.76	19	205.80	84	<3	<3	513	47	92	0.20	9.60		

SEPTEMBER 2024

DATE	STATION ID	Temp oC	pH	EC mS/m	DO mg/l	TSS mg/l	TDS mg/l	T.Alkalinity mg/l as CaCO3	NO_2-N µg/l	NO_3-N µg/l	TN µg/l	NH_3-N µg/l	TP µg/l	Cl^- mg/l	Total Chloro µg/L	Secchi Disk (m)	FC MPN/ 100ml
14.09.24	Charara	24.36	7.74	10.30	6.81	11	67.70	44	<3	10	397	32	65	1.80	5.47	1.60	2
14.09.24	Andora	24.86	8.48	10.30	8.07	7	67.13	44	<3	40	325	24	48	1.60	3.60	2.10	5
22.09.24	Manchinchi	27.84	8.78	10.70	8.41	1	66.22	40	<3	<3	548	25	42	1.30	2.30	1.90	5
22.09.24	Damwall Up	27.72	8.84	10.70	8.68	1	66.21	40	<3	3	297	25	64	1.00	2.52	2.20	
28.09.24	Damwall Down	27.99	8.65	10.80	7.71	2	66.43	42	27	187	261	34	47	1.10	3.70		<1
22.09.24	B 51 0.5m	26.96	8.85	10.90	8.87	2	65.71	42	<3	<3	339	32	35	1.20	2.50	1.90	<1
	B 51 10m	24.78	8.80	9.90	9.20	2	64.71	41	19	<3	283	21	27	1.00			
	B 51 20m	23.67	7.47	9.70	8.81	<1	64.50	40	<3	67	320	34	49	1.00			
	B 51 30m	23.74	7.48	9.70	5.89	<1	64.62	38	<3	60	380	28	57	0.80			
	B 51 50m	24.71	7.31	9.80	5.28	1	64.30	41	<3	76	407	38	72	0.90			
14.09.24	Sanyati 0.5m	25.26	7.83	10.30	7.01	3	66.60	41	<3	52	379	24	35	1.40	3.10	2.50	<1
	Sanyati 10m	24.21	7.74	10.00	6.70	3	60.15	41	<3	27	312	46	61	1.40			
	Sanyati 20m	23.80	7.50	10.00	5.83	2	69.20	45	<3	55	287	25	50	1.00			
	Sanyati 30m	23.57	7.26	10.10	3.21	3	67.18	45	6	79	321	27	38	0.90			
	Sanyati 50m	25.11	7.32	10.60	4.94	17	68.90	45	3	84	331	21	53	1.00			
14.09.24	Sanyati Further	24.85	7.46	11.00	4.60	7	72.00	50	<3	9	317	42	47	1.50	5.32	1.50	
14.09.24	Nyaodza	24.83	7.82	10.30	7.34	8	67.10	43	<3	29	338	19	57	1.10	5.14	1.40	1
14.09.24	Gatchegatche	24.86	7.41	11.50	5.72	8	74.70	48	<3	15	520	35	70	1.00	9.84	1.70	<1
14.09.24	ULKRS	24.41	8.15	10.80	7.36	21	70.85	48	<3	182	507	56	83	2.10	8.90	1.70	5
14.09.24	Croc Farm	24.55	8.18	10.10	7.48	9	66.40	46	<3	3	465	31	65	0.80	8.80	1.70	33
29.09.24	Chirundu	26.77	7.84	10.70	7.38	6	67.50	41	18	26	413	18	57	0.80	1.80		27
30.09.24	VIcfalls	27.34	7.97	12.60	7.47	4	78.30	50	3	28	289	39	55	2.30	2.52		
30.09.24	ZESA Pump	27.55	8.15	12.90	7.93	1	79.72	49	<3	52	177	39	36	2.00	2.90		
30.09.24	Deka	29.32	7.85	201.70	7.86	10	1211.9	106	10	100	433	32	60	50.60	5.82		
20.09.24	Zongwe/Kanzinze	26.20	7.72	32.40	6.76	19	205.80	84	<3	<3	513	47	92	0.20	9.60		
	Kalomo	Little or no flow															
	Gwayi																
	Sikalamba																

OCTOBER 2024

DATE	STATION ID	Temp oC	pH	EC mS/m	DO mg/l	TSS mg/l	TDS mg/l	T.Alkalinity mg/l as CaCO3	NO_2-N µg/l	NO_3-N µg/l	TN µg/l	NH_3-N µg/l	TP µg/l	Cl^- mg/l	Total Chloro µg/L	Secchi Disk (m)	FC MPN/ 100ml
14.10.24	Charara	24.36	7.74	10.30	6.81	11	67.70	44	<3	10	397	32	65	1.80	5.47	1.60	2
14.10.24	Andora	24.86	8.48	10.30	8.07	7	67.13	44	<3	40	325	24	48	1.60	3.60	2.10	5
22.10.24	Manchinchi	27.84	8.78	10.70	8.41	1	66.22	40	<3	<3	548	25	42	1.30	2.30	1.90	5
22.10.24	Damwall Up	27.72	8.84	10.70	8.68	1	66.21	40	<3	3	297	25	64	1.00	2.52	2.20	
28.10.24	Damwall Down	27.99	8.65	10.80	7.71	2	66.43	42	27	187	261	34	47	1.10	3.70		<1
22.10.24	B 51 0.5m	26.96	8.85	10.90	8.87	2	65.71	42	<3	<3	339	32	35	1.20	2.50	1.90	<1
	B 51 50m	24.71	7.31	9.80	5.28	1	64.30	41	<3	76	407	38	72	0.90			
14.10.24	Sanyati 0.5m	25.26	7.83	10.30	7.01	3	66.60	41	<3	52	379	24	35	1.40	3.10	2.50	<1
	Sanyati 50m	25.11	7.32	10.60	4.94	17	68.90	45	3	84	331	21	53	1.00			
14.10.24	Sanyati Further	24.85	7.46	11.00	4.60	7	72.00	50	<3	9	317	42	47	1.50	5.32	1.50	
14.10.24	Nyaodza	24.83	7.82	10.30	7.34	8	67.10	43	<3	29	338	19	57	1.10	5.14	1.40	1
14.10.24	Gatchegatche	24.86	7.41	11.50	5.72	8	74.70	48	<3	15	520	35	70	1.00	9.84	1.70	<1
14.10.24	ULKRS	24.41	8.15	10.80	7.36	21	70.85	48	<3	182	507	56	83	2.10	8.90	1.70	5
14.10.24	Croc Farm	24.55	8.18	10.10	7.48	9	66.40	46	<3	3	465	31	65	0.80	8.80	1.70	33
29.010.24	Chirundu	26.77	7.84	10.70	7.38	6	67.50	41	18	26	413	18	57	0.80	1.80		27
30.10.24	VIcfalls	27.34	7.97	12.60	7.47	4	78.30	50	3	28	289	39	55	2.30	2.52		
30.10.24	ZESA Pump	27.55	8.15	12.90	7.93	1	79.72	49	<3	52	177	39	36	2.00	2.90		
30.10.24	Deka	29.32	7.85	201.70	7.86	10	1211.9	106	10	100	433	32	60	50.60	5.82		
20.10.24	Zongwe/Kanzinze	26.20	7.72	32.40	6.76	19	205.80	84	<3	<3	513	47	92	0.20	9.60		
	Kalomo	Little or no flow															
	Gwayi																
	Sikalamba																

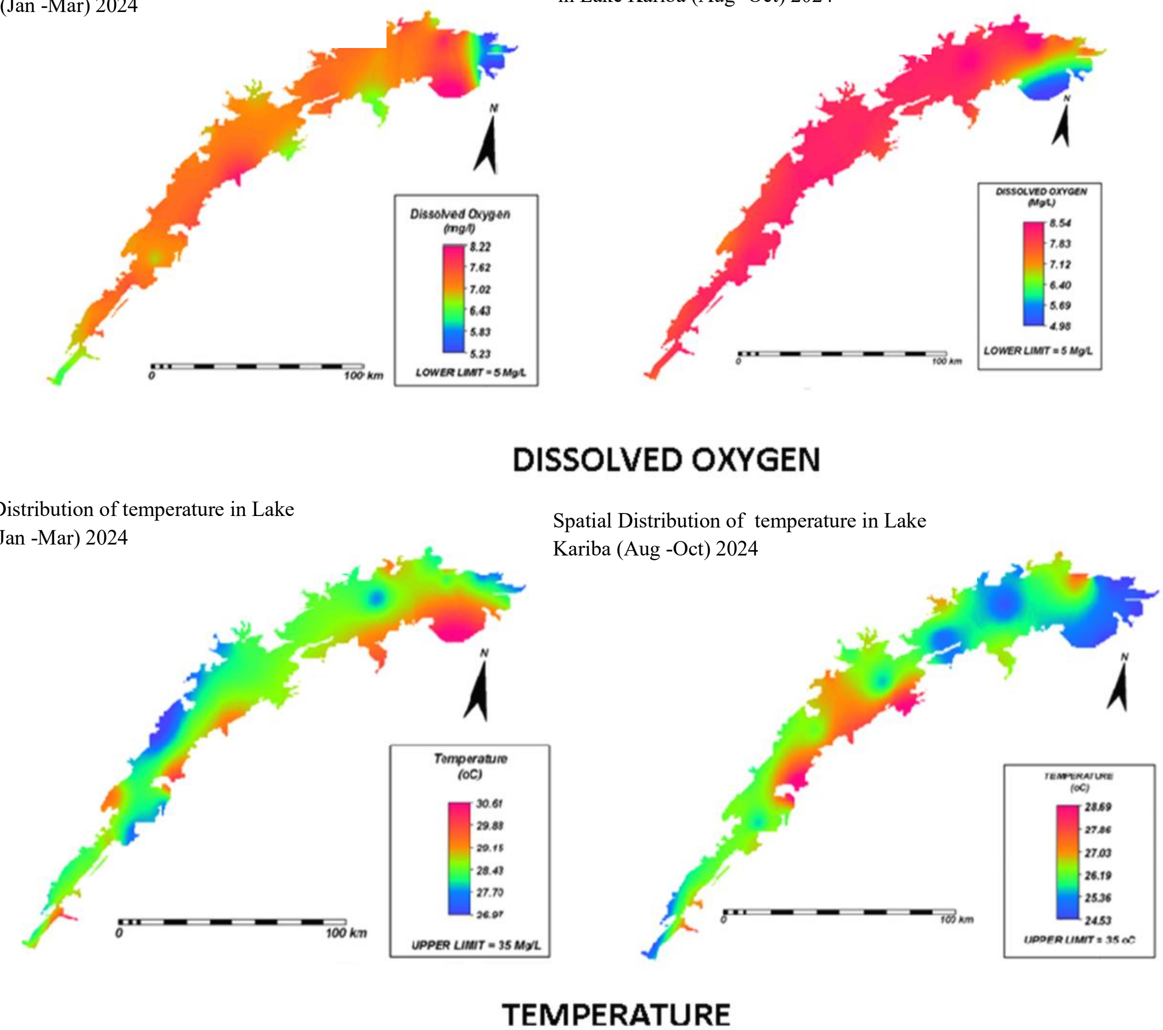
August- October results 2024

It was observed that pollution levels for certain water quality parameters peaked during the high-flow season (January to March 2024). In contrast, water quality significantly improved during the low-flow season (August to October), largely because some tributaries—identified as point sources of pollution—had ceased flowing.

The primary sources of pollution were found to be tributaries such as Deka, Gwayi, and Sanyati on the Zimbabwean side, and Kalomo and Kanzinze on the Zambian side. During the high-flow season, the Deka River exhibited elevated alkalinity levels. Meanwhile, the Gwayi and Sanyati Rivers showed high concentrations of Total Suspended Solids (TSS), Total Nitrogen (TN), and Dissolved Oxygen (DO), largely due to ongoing gold panning activities along these tributaries.

Among the parameters of concern, Total Suspended Solids, Total Nitrogen, Alkalinity, and Dissolved Oxygen were consistently highlighted as critical indicators of water quality deterioration in the basin.

KEY FINDINGS AND RESULTS

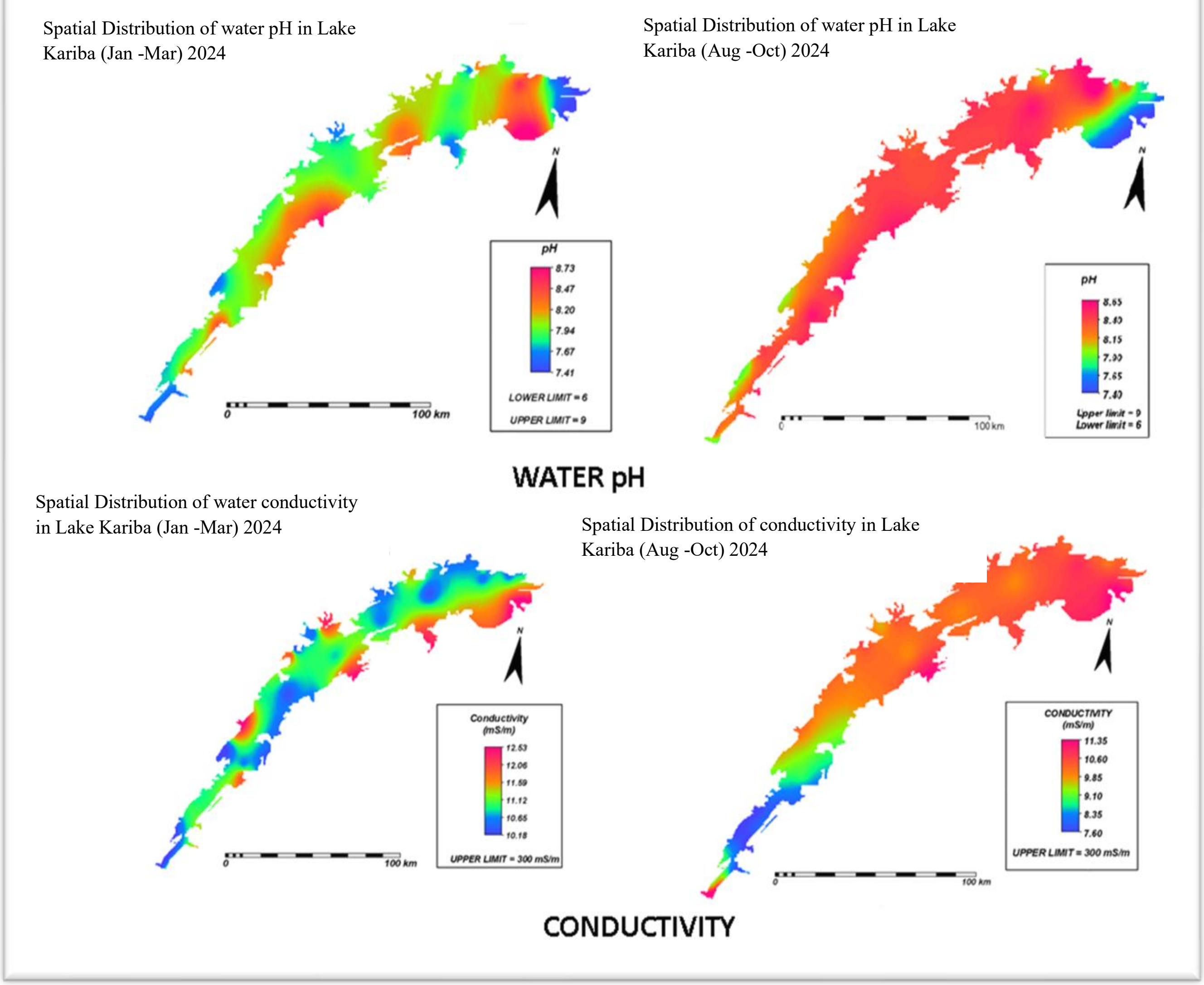


Spatial Distribution of Dissolve Oxygen in Lake Kariba (Jan -Mar) 2024

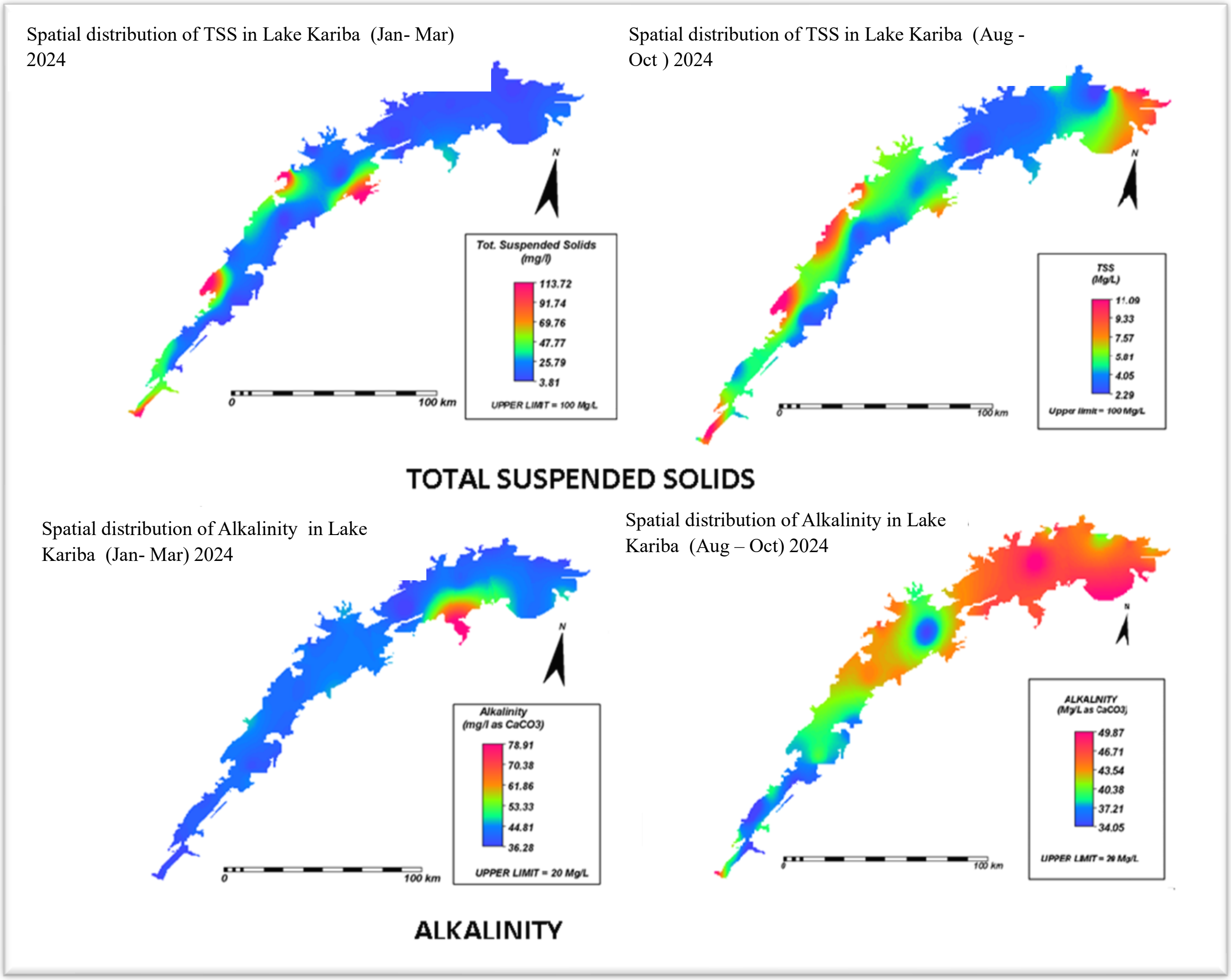
Spatial Distribution of Dissolve Oxygen in Lake Kariba (Aug -Oct) 2024

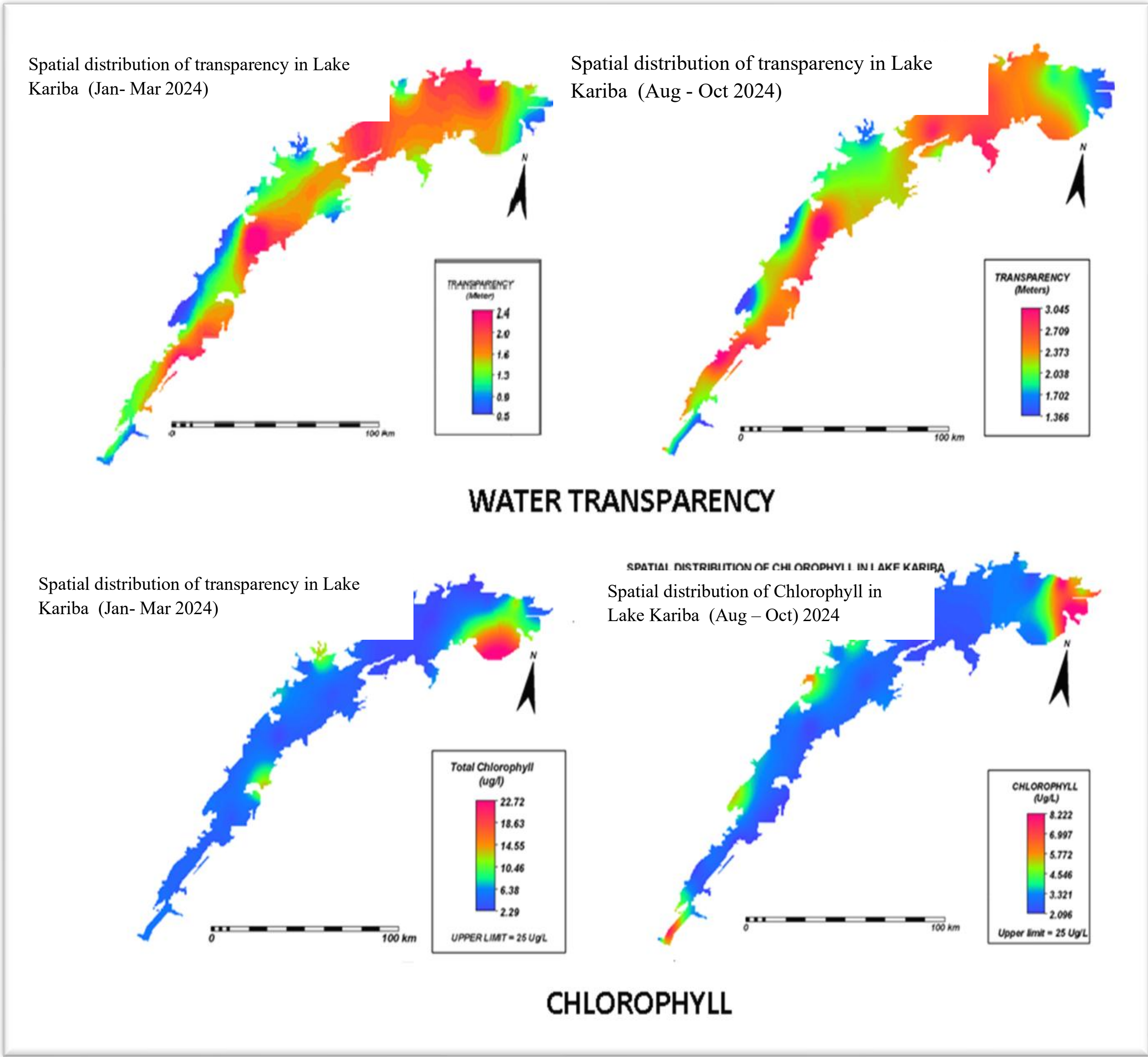
Spatial Distribution of temperature in Lake Kariba (Jan -Mar) 2024

Spatial Distribution of temperature in Lake Kariba (Aug -Oct) 2024



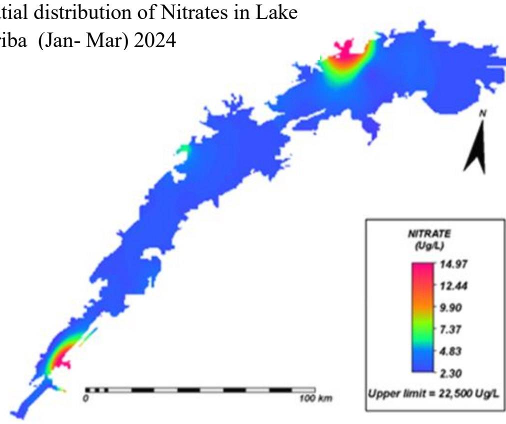
Spatial Distribution of water pH in Lake Kariba (Jan -Mar) 2024
N
pH
8.73
8.47
8.20
7.94
7.67
7.41
LOWER LIMIT = 6
UPPER LIMIT = 9
0
100 km
Spatial Distribution of water pH in Lake Kariba (Aug -Oct) 2024
N
pH
8.65
8.40
8.15
7.65
7.40
Upper limit = 9
Lower limit = 6
0
100 km
WATER pH
Spatial Distribution of water conductivity in Lake Kariba (Jan -Mar) 2024
N
Conductivity (mS/m)
12.53
12.06
11.59
11.12
10.65
10.18
UPPER LIMIT = 300 mS/m
0
100 km
Spatial Distribution of conductivity in Lake Kariba (Aug -Oct) 2024
N
CONDUCTIVITY (mS/m)
11.35
10.60
9.85
9.10
8.35
7.60
UPPER LIMIT = 300 mS/m
0
100 km
CONDUCTIVITY


Spatial distribution of TSS in Lake Kariba (Jan- Mar) 2024
Tot. Suspended Solids (mg/l)
113.72
91.74
69.76
47.77
25.79
3.81
UPPER LIMIT = 100 Mg/L
0
100 km
N
Spatial distribution of TSS in Lake Kariba (Aug - Oct) 2024
TSS (Mg/L)
11.09
9.33
7.57
5.81
4.05
2.29
Upper limit= 100 Mg/L
0
100 km
N
TOTAL SUSPENDED SOLIDS
Spatial distribution of Alkalinity in Lake Kariba (Jan- Mar) 2024
Alkalinity (mg/l as CaCO3)
78.91
70.38
61.86
53.33
44.81
36.28
UPPER LIMIT = 20 Mg/L
0
100 km
N
Spatial distribution of Alkalinity in Lake Kariba (Aug – Oct) 2024
ALKALNITY (Mg/L as CaCO3)
49.87
46.71
43.54
40.38
37.21
34.05
UPPER LIMIT = 20 Mg/L
0
100 km
N
ALKALINITY

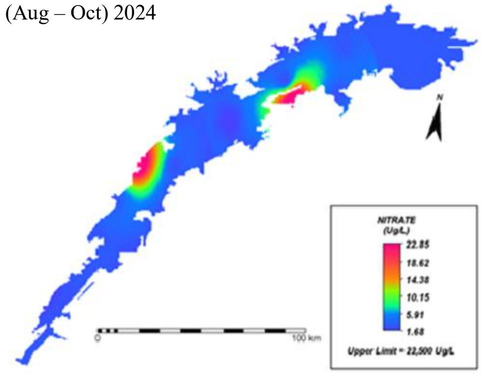


Spatial distribution of transparency in Lake Kariba (Jan- Mar 2024)
2.4
2.0
1.6
1.3
0.5
0
100 km
Spatial distribution of transparency in Lake Kariba (Aug - Oct 2024)
TRANSPARENCY (Meters)
3.045
2.709
2.373
2.038
1.702
1.366
0
100 km
WATER TRANSPARENCY
Spatial distribution of transparency in Lake Kariba (Jan- Mar 2024)
Total Chlorophyll (ug/l)
22.72
18.63
14.55
10.46
6.38
2.29
UPPER LIMIT = 25 Ug/L
0
100 km
SPATIAL DISTRIBUTION OF CHLOROPHYLL IN LAKE KARIBA
Spatial distribution of Chlorophyll in Lake Kariba (Aug – Oct) 2024
CHLOROPHYLL (Ug/L)
8.222
6.997
5.772
4.546
3.321
2.096
Upper limit = 25 Ug/L
0
100 km
CHLOROPHYLL

Spatial distribution of Nitrates in Lake Kariba (Jan- Mar) 2024

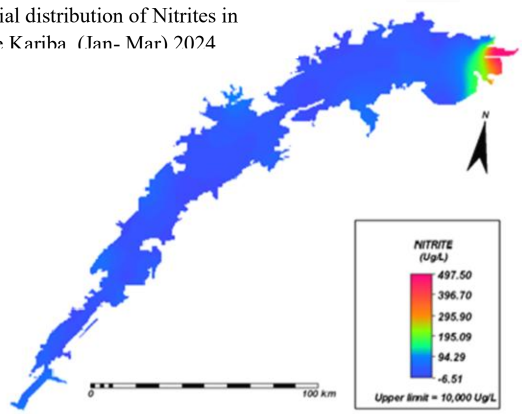


Spatial distribution of Nitrates in Lake Kariba (Aug – Oct) 2024

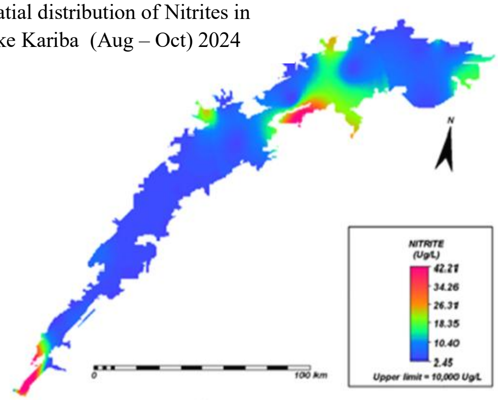


NITRATES

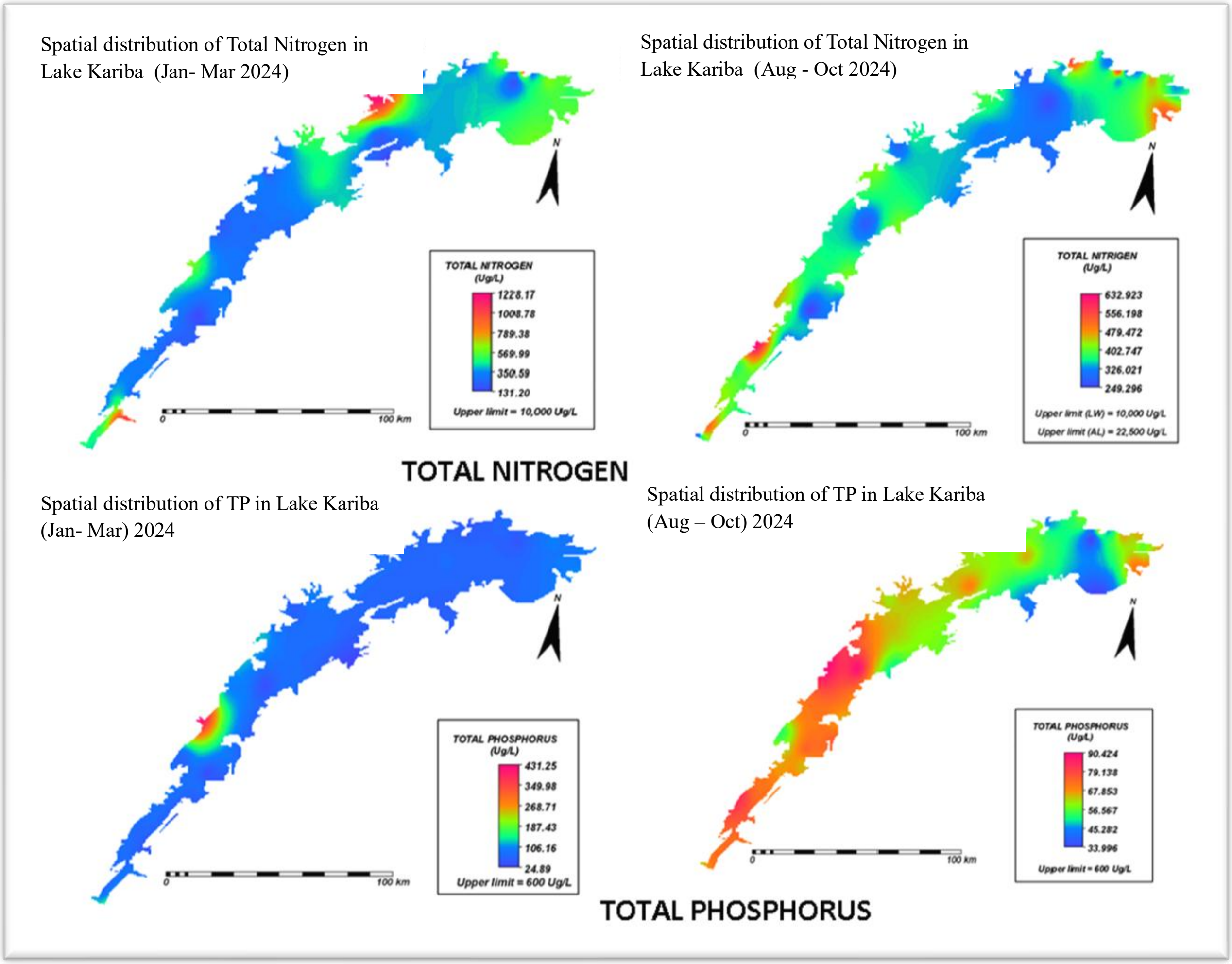
Spatial distribution of Nitrites in Lake Kariba (Jan- Mar) 2024

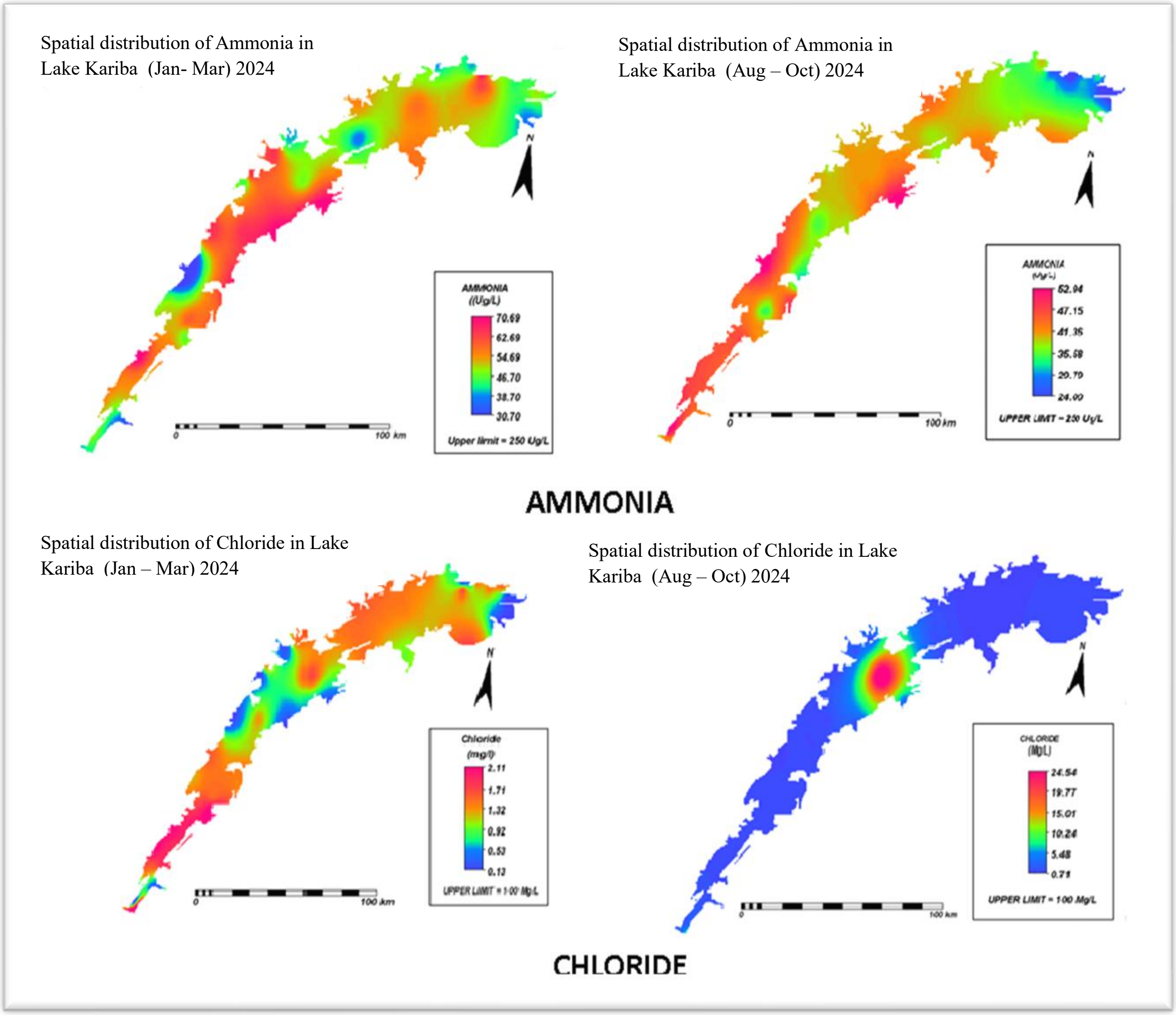


Spatial distribution of Nitrites in Lake Kariba (Aug – Oct) 2024



NITRITES


Spatial distribution of Total Nitrogen in Lake Kariba (Jan- Mar 2024)
TOTAL NITROGEN (Ug/L)
1228.17
1008.78
789.38
569.99
350.59
131.20
Upper limit = 10,000 Ug/L
0
100 km
N
Spatial distribution of Total Nitrogen in Lake Kariba (Aug - Oct 2024)
TOTAL NITRIGEN (Ug/L)
632.923
556.198
479.472
402.747
326.021
249.296
Upper limit (LW) = 10,000 Ug/L
Upper limit (AL) = 22,500 Ug/L
0
100 km
N
TOTAL NITROGEN
Spatial distribution of TP in Lake Kariba (Jan- Mar) 2024
TOTAL PHOSPHORUS (Ug/L)
431.25
349.98
268.71
187.43
106.16
24.89
Upper limit = 600 Ug/L
0
100 km
N
Spatial distribution of TP in Lake Kariba (Aug – Oct) 2024
TOTAL PHOSPHORUS (Ug/L)
90.424
79.138
67.853
56.567
45.282
33.996
Upper limit = 600 Ug/L
0
100 km
N
TOTAL PHOSPHORUS


Spatial distribution of Ammonia in Lake Kariba (Jan- Mar) 2024
AMMONIA
((Ug/L)
70.69
62.69
54.69
46.70
38.70
30.70
Upper limit = 250 Ug/L
0
100 km
N
Spatial distribution of Ammonia in Lake Kariba (Aug – Oct) 2024
AMMONIA
52.94
47.15
41.35
35.58
20.79
24.00
UPPER LIMIT = 250 Ug/L
0
100 km
N
AMMONIA
Spatial distribution of Chloride in Lake Kariba (Jan – Mar) 2024
Chloride
(mg/l)
2.11
1.71
1.32
0.92
0.53
0.13
UPPER LIMIT = 1·00 Mg/L
0
100 km
N
Spatial distribution of Chloride in Lake Kariba (Aug – Oct) 2024
CHLORIDE
(Mg/L)
24.54
19.77
15.01
10.24
5.48
0.71
UPPER LIMIT = 100 Mg/L
0
100 km
N
CHLORIDE

DISCUSSION

Seasonal Characteristics of Pollution

The data obtained using the FIAlab test, as presented in the figure, highlights seasonal trends in pollution levels. The results clearly indicate that October**,** which falls within the low flow season**,** is characterized by very safe water quality based on the ten parameters assessed in this study.

When comparing the 16 sampled locations, it was found that tributaries discharging into Lake Kariba and the Zambezi River contributed the most to water quality degradation. Field results from locations such as the Gwayi River**,** Kariba at Sanyati-Further**,** Kalomo River, and Deka River showed higher pollution levels, suggesting that these tributaries are key sources of contaminants.

The data further reveals that water quality deteriorates during the high **-** flow season (January to March), reaching its worst levels due to increased surface runoff that carries pollutants from inland areas, particularly from human settlements and agricultural lands. As the low **-** flow season progresses, water quality gradually improves, reaching optimal conditions in the low**-** flow season (August to October)**,** before declining again with the onset of the next rainy season. This cyclical pattern suggests that the start of the dry season in October marks a period of pollutant settling and reduced runoff, leading to cleaner water.

Bacteriological analysis further supports these findings. The method proved effective for rapidly detecting fecal contamination and identifying pollution sources, particularly in tributaries such as the Gwayi, Kalomo, and Deka Rivers. The presence of fecal coliforms showed clear seasonal variation, with higher Most Probable Number (MPN) values observed in February—during the peak of the rainy season. This spike is linked to increased surface runoff transporting contaminants into the lake.

In contrast, significantly lower MPN values were recorded in October, confirming improved water conditions during the dry season. This improvement is likely due to minimal runoff and greater dilution capacity from elevated water levels in Lake Kariba.

These results underscore the significant influence of seasonal hydrological dynamics on both chemical and microbial water quality. They highlight the importance of implementing targeted water safety and pollution control measures during the rainy season to protect public health and the integrity of aquatic ecosystems in the Lake Kariba and Zambezi River system.

CONCLUSION

The findings of this study reveal that the water quality deterioration along Lake Kariba, Zambezi River and its tributaries is particularly in a critical condition during the rainy reason. In February we had less pollution, and we had more water pollution in September and hence more care is particularly needed when using the water from the watershed during these seasons. Furthermore, using principal factor analysis, the ten parameters yielded four factors and the most predominant (as evidenced from factor loadings) factors controlling water quality along the watershed are: factor 1 dominated by turbidity, factor 2 dominated by TDS, factor 3 dominated by DO and factor 4 by temperature. These parameters were found to be very momentous, as reviewed by factor loadings, in explaining water quality across the seasons. By far the biggest problems (frequently exceeding their PVs) were caused by turbidity followed by alkalinity as CaCO3 , then TSS and to a less extent by total phosphorus. It is also important to note that the tributaries feeding Lake Kariba are the most polluted. Furthermore, the watershed waters (after traversing between Zambia and Zimbabwe) flows into the neighboring Mozambique and the results show that the water exiting Lake Kariba is generally free of any significant pollution, across all seasons, probably a consequence of the diluting effect of the vast water resources of the Lake. However, it is vitally important to alert the users of the water by the banks and further downstream of some of the hazards found in the water with changing seasons and especially during the late rainy season.

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