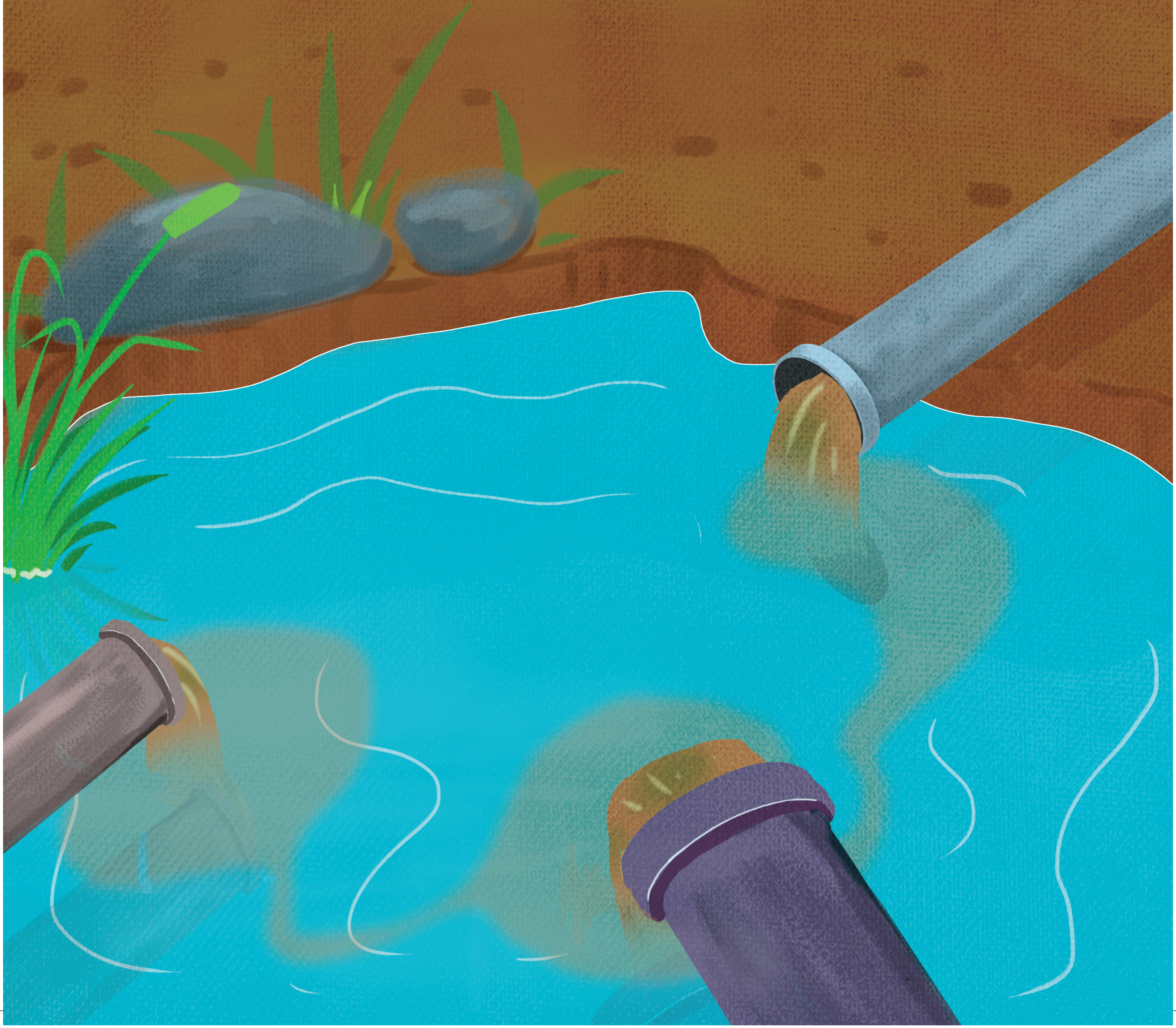
LAKE VICTORIA

TOOLKIT FOR POLLUTION LOAD ASSESSMENT



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1. Background

Lake Victoria, one of the world's largest freshwater lakes with a surface area of 68,800 km^2 and a volume of 2,424 km^3, spans across three countries in Africa. This ecologically unique water body is shared by Tanzania (51 per cent), Uganda (44 per cent) and Kenya (5 per cent), with the countries using its resources for fisheries, fresh water and transportation. Apart from the three host countries, its catchment area extends to Rwanda and Burundi, covering a total area of 1,69,858 km^2 (*see Table 1: Morphometric data for Lake Victoria*).

The lake supports the most productive freshwater fishery in the world, worth USD $600 million annually. The basin of Lake Victoria also supports extensive agriculture with over 70 per cent of the population in the catchment area dependent on farming. The natural ecosystem of the lake and its flora and fauna are the basis for an expanding population and burgeoning economic activity in the region.

Despite being the source of livelihood for 45 million people, Lake Victoria has suffered immensely from a variety of unsustainable human activities over the last five decades. Activities including deforestation, poor waste management, destructive fishing practices, introduction of invasive fish species, wetland encroachment, unsustainable farming practices, and uncontrolled mining have rendered the lake into a sink for excessive nutrients and untreated effluent. This has led to fish die-offs, algal blooms and the spread of a destructive waterweed—the water hyacinth.

Considering the dire need for a roadmap for Lake Victoria's restoration, Centre for Science and Environment (CSE), India, and National Environment Management Council (NEMC), Tanzania, collaborated and developed a strategy to improve the water quality of the lake. The joint collaboration released a report titled, *Roadmap for Management of Water Quality in Mwanza City-Tanzania* in 2023. The report is the final outcome of the discussion paper titled, *Development of Environmental Management Strategy for Lake Victoria* that was released in 2022 by both the institutions wherein Mwanza city was identified as a hotspot for pollution load.

The 2023 report highlighted that only three per cent of households are connected to sewer lines managed by Mwanza Urban Water Supply and Sanitation Authority (MWAUWASA) while 93 per cent are dependent on onsite sanitation (pit latrine and septic tanks), especially those living on the hills. MWAUWASA has started the process of linking these households to the main sewer system via a simplified sewer network, although the area's topography presents some challenges. The improved systems will address the current practices of emptying the septic tanks through vacuum tankers or direct discharge into the streams/drains by the owners during rains which ultimately reaches the lake. CSE analysis shows that 29 per cent of sewage (faecal sludge and waste water) is safely managed and the rest might be making its way into water bodies in some way.

The report also highlighted that although the city has a waste collection efficiency of 70–80 per cent, the lack of waste segregation practices—aside from glass and plastic—means that all other waste is dumped at sites without secure liners. As a result, leachate from the waste is discharged into the rivers. The proposed approach to improve the lake's water quality, in addition to treating pollution sources, included aspects such as management of the existing wetlands, developing waste management practices and pollution control systems along with continuous monitoring of water bodies entering the Lake.

Table 1: Morphometric data for Lake Victoria

Item Surface	Total	Kenya	Tanzania	Uganda	Rwanda	Burundi
Surface area (sq km)	68,800	4,128 (6%)	35,088 (51%)	29,584 (43%)	-	-
Catchment area (sq km)	1,94,200	42,724 (22%)	85,448 (44%)	31,072 (16%)	21,362 (11%)	13,594 (7%)

Source: Lake Victoria Basin Commission

The report was prepared for Mwanza City of Tanzania as a pilot study. However, one needs to acknowledge that since the lake is shared by three countries, there are various other such cities in all three countries where drains/streams/rivers directly discharge the pollutants into the lake. Therefore, identifying and mapping these drains, streams, and rivers is essential for understanding the distribution of discharge points, which is key to categorizing areas that require prioritized interventions.

The 2023 report emphasized the lack of available information, including data on the quantity and quality of wastewater discharged into the lake, both in the public domain and with regulatory bodies. The report thus insisted on developing a database for the three countries sharing the lake in order to put check and balances on the polluting sources discharging in the lake. Effort is required from all three countries in developing and sharing such information on a regular basis to undertake required measures. The role of Lake Victoria Basin Commission

(LVBC), an umbrella authority monitoring the basin, becomes crucial in this regard. The commission should develop an online portal that allows the countries to share the necessary data, making it accessible to all three countries. This will enable the development of a comprehensive management plan for the entire lake basin, rather than relying on country-specific measures.

Through this report, CSE has made an effort to create a toolkit for collecting and generating a comprehensive set of baseline data needed to assess the overall water quality of Lake Victoria. This includes the types of data needed, the methodology for collecting the required data, and how the generated information can be used to analyze the water quality of the lake. The toolkit also includes monitoring protocol for the rivers/streams/drains entering into the lake, and the lake itself. This monitoring protocol plays a vital role in determining the effectiveness of the measures taken.

2. Methodology for data collection

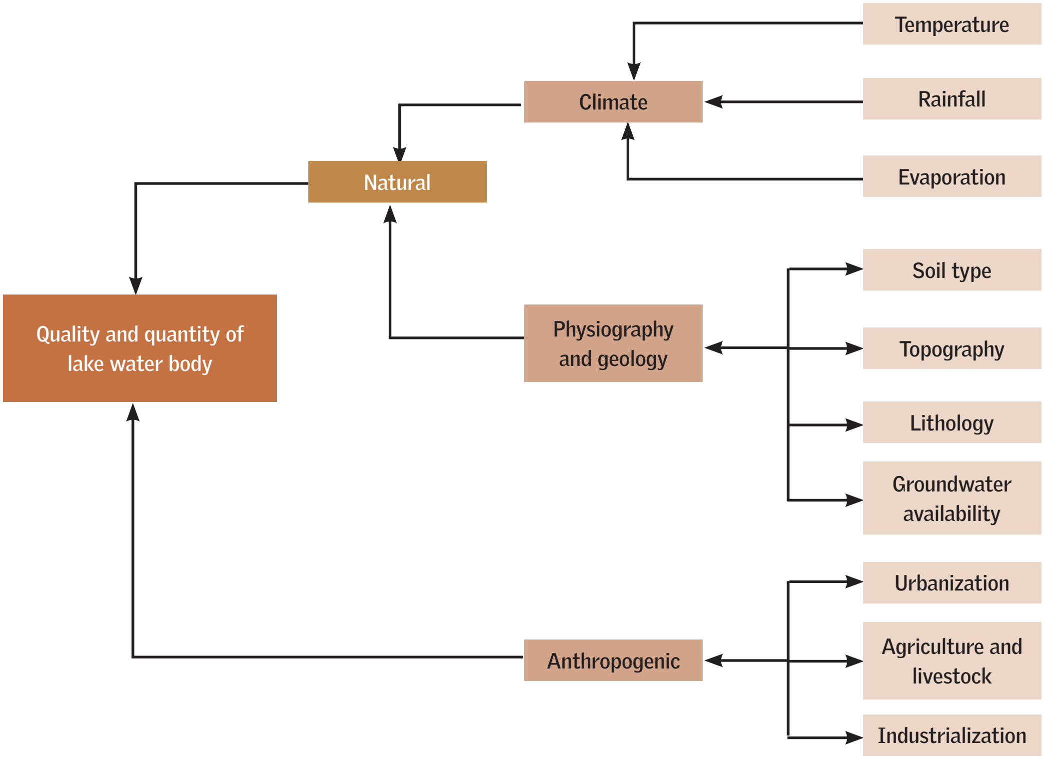
Lake Victoria's water primarily comes from two main sources: rainfall and rivers discharges. Seventeen rivers flow into the lake from three countries—seven from Tanzania, seven from Kenya, and three from Uganda. The Nile River is the single outlet from the lake, exiting the lake near Jinja, Uganda.

A holistic study on the lake requires information on both its input water and the output water sources. The input water comprises rainfall and discharges from various sources whereas the output relates to the use pattern of the lake i.e. purposes for which lake water is used. This includes use in drinking, irrigation, power generation, industrialization, fish farming, transportation, recreation etc. These two sources, which include both natural and anthropogenic factors, determine the quality and quantity of water in the lake (*see Figure 1: Factors affecting water quality of Lake Victoria*). Thus, it is imperative to have data on these factors for developing a strategy roadmap. The data collection can be done in two steps which are as follows

- **Baseline data:** This step, also termed as dry inventory, is conducted to collect and establish the baseline conditions of the lake. The information under this step is usually available with other government departments/research institutes etc. This data allows for the establishment of the lake's water budget with minimal impact from human activities.

- **Pollution load data**: The wet inventory or pollution load assessment includes collection of data on discharges from municipal, industrial, mining etc. In case of Lake Victoria, since this data is limited in all three countries, it needs to be collected and collated. Different factors are involved under these two steps and the type of data required to be collected is discussed in further sections.

Figure 1: Factors affecting water quality of Lake Victoria



Step 1: Baseline data

The baseline includes collection of data on rainfall, evaporation, river discharges, land use pattern, aquifer types, soil characteristics etc. The details on each parameter is discussed under:

Climate

The climate feature comprises temperature, rainfall and evaporation, where rainfall is an input source and evaporation are counted as output source from the lake. The input in the lake depends on the rainfall-runoff relationship as it leads to discharge of water through organized drainage systems such as rivers, streams and unorganized systems in form of surface runoffs. The data on rainfall (see Table 2: Rainfall data) assists in identifying the months with maximum rainfall and thus potential discharges with higher pollution load. This information will be helpful while deciding the frequency of sampling in monitoring network during different seasons. It will also aid in estimating capacity of sewage treatment plant (STP) in various towns located in the basin. Similarly, data on river discharges (see Table 3: Discharge from rivers/*drains (point sources)* will indicate input from various rivers/drains in the lake and thus the probable carriers of pollution load thereof. The discharge data of rivers will also be required to decide the number of sampling locations in rivers/streams while developing monitoring network.

Table 2: Rainfall data

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max												
Min												
Average												

Table 3: Discharge from rivers/drains (point sources)

Name of River/ drain	Type (Perennial/ seasonal)	Discharge (m3 / sec)			
		Annual	Pre-rainy	Rainy	Post-rainy

The data on evaporation which indicates loss (output) from the lake (*see Table 4: Evaporation data for the lake*) will identify the months with the highest evaporation since those months have the possibility of increased salinity and nutrient load in the lake. This information will be helpful in the selection of parameters while developing a water monitoring network.

Table 4: Evaporation data for the lake

Rate of evaporation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum												
Minimum												
Average												

For surface runoff data, information related to the type of land use in the lake basin is important (*see Table 5: Land use pattern*). The amount of surface runoff and pollution load is influenced by the land use pattern. A larger forested area typically results in regulated runoff and a lower pollution load, while a higher proportion of mining areas leads to increased pollution load due to runoff from overburden. In the absence of first-hand information on the quantity of surface runoff in the lake, this information can be used to estimate the quantity. It will also aid in the selection of parameters during monitoring protocol. The runoff is also dependent on the physiology and geology of the area, thus the information on these parameters also needs to be obtained.

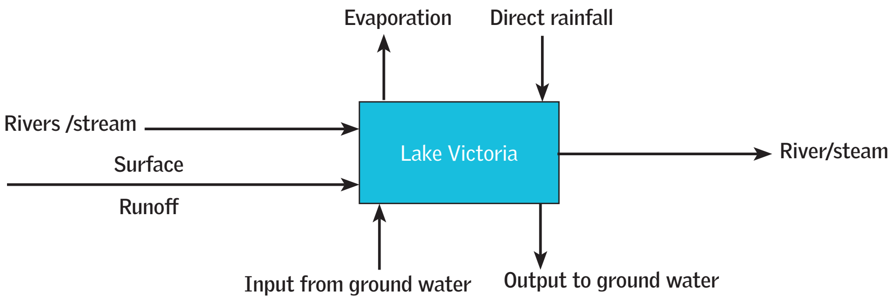
Table 5: Land use pattern

Land use pattern	District	Percentage
Forest		
Agriculture		
Water bodies		
Habitation		
Industries and mining		
Other		

Physiography and geology

The information on physiography and geology, involving soil type, topography and lithology, is required to obtain data on groundwater availability. Soil type and lithology governs the availability of groundwater which acts as both an input and output source to lake water. While soil characteristics determine the infiltration rate of surface runoff to ground, lithology decides the type of aquifers and their exchange water rate with lake water in different seasons. The type of soil also highlights on possible agricultural activity in the area and thus pollution load potential from the activity. The details of soil type and aquifers can be obtained in format as provided at Annexure 1. The quantum of groundwater acting as input and output is obtained by the difference in the depth of water table from an average depth measured monthly. If the depth of the groundwater table is less than the average, the water from the lake enters the groundwater and vice-versa in case the depth of water table is more than the average depth. With the availability of all the above data, a water budget for Lake Victoria can be established as follows:

Water budget = Input – output
= (Direct rainfall + water discharge + Input from Groundwater) – (Evaporation Loss + output to Groundwater)



As mentioned earlier, the exercise on baseline data collection involves information extraction from various government agencies/departments and research institutes as tabulated in Table 6. The water budget provides the baseline scenario for the lake in a relatively undisturbed condition. The next step involves estimation of pollution load to assess its impact on the water quality.

Table 6: Sources for dry inventory

S. No	Parameter	Source
1	Rainfall	Meteorology Department
2	Evaporation	Meteorology Department
3	Temperature	Meteorology Department
4	Soil type	Agriculture Department
5	Topography	National Survey Organisation
6	Lithology	Geological Survey Department
7	Ground water availability	Hydrogeology Department, Irrigation Department
8	Water supply and source	Public Health Department, Municipality (Water Supply and Sanitation Department)
9	Agricultural fertilizer use	Agriculture Department

Step 2: Pollution load assessment

The major contributors of pollution load in the water bodies are mostly anthropogenic activities that include urbanization, industrialization, mining and agriculture. While these activities discharge their wastewater into the water bodies, they also withdraw fresh water from the lake. Thus, pollution load assessment includes details on water withdrawal for these purposes and waste water discharged; quantity-wise and quality-wise. These details facilitate the identification of point-source polluters and their treatment thereof.

Urbanization

Urbanization consumes significant amount of water and generates wastewater in the form of sewage. Besides this, the urban runoff also contributes by carrying pollutants and disposing them into water bodies. Thus, obtaining town-wise information on the quantum of withdrawal, wastewater generated, availability of collection and treatment facilities and disposal mechanism is crucial (*see Table 7: Details of wastewater from urban areas*). These details pertain to the organized sewage collection system; however, there are many drains that discharge untreated sewage directly into water bodies, and these drains must also be accounted for.

Another set of details required includes characteristics of sewage before and after treatment for each town (*see Table 8: Sewage characterization*). This will provide an insight on the towns generating maximum wastewater, and those with no collection and treatment facilities. These towns need to be prioritized while deciding sampling location for monitoring network.

Table 7: Details of wastewater from urban areas

S. No.	Name of town/ district	Total water withdrawal from lake (KL/day)	Total wastewater generated (KL/day)	Total wastewater collected by sewer/tanker (KL/day)	Total wastewater treated (Kl/ day)	Disposal into river/lake/ land

Table 8: Sewage characterization

Name of town			
Wastewater generation (Kl/day)			
Characteristics of untreated sewage	pH		
	BOD		
	COD		
	TDS		
	Total nitrogen		
	Total phosphorus		
Characteristics of treated sewage	pH		
	BOD		
	COD		
	TDS		
	Total nitrogen		
	Total phosphorus		
Characteristics of sewage not collected and disposed directly	pH		
	BOD		
	COD		
	TDS		
	Total nitrogen		
	Total phosphorus		

*Except pH all values are in mg/l

Industrialization

Industries involve large variation with respect to scale of operation, type of product, water consumption and effluent generation. The water consumption and effluent quantity highly depends on the production capacity of the industry. Moreover, different types of industries generate different qualities of effluent, ranging from highly organic to toxic depending on the type of product being manufactured. Thus, assessing impact of industrial effluent on water quality requires an understanding of the type of industry, its production capacity and water requirements and effluent generation (*see Table 9: Industrial effluent load assessment*). This information is mostly available in the permit/license issued by the regulatory body to the industries.

In case of non-availability, inventorization needs to be done to collect data on the type of industries and their production capacities. This will be followed by a reconnaissance study where a handful of industries of various types (food processing, tannery, textiles etc) will be selected to measure the quantity of effluent generated, along with its characteristics. Once this industry-specific data is available, similar data can be extrapolated for other industries from the same sector based on their production capacities. Following this, the industry-wise pollution load for various parameters needs to be identified (*see Table 10: Industry-specific pollutant load*). This exercise will generate valuable statistics regarding the industries that contributes maximum pollution load and thus needs regulatory action.

Table 9: Industrial effluent load assessment

S. no	Name of the industry	Location of industry	Type of industry with respect to product (sector)	Production capacity	Water consumption Kl/day	Wastewater generation Kl/day

Table 10: Industry-specific pollutant load

S no	Name of industry	Type of industry	Pollution load before treatment (tonne/unit of product)				Pollution load after treatment (tonne/unit of product)				Concentration at final discharge (mg/l)			
			BOD	COD	TDS	Any specific	BOD	COD	TDS	Any specific	PH	BOD	COD	TDS

Mining

Besides urbanization and industry, mining is another important activity generating effluent. Although the volume of discharge is smaller compared to industrial waste and sewage, the effluent released is highly toxic, often containing heavy metals, and is frequently discharged untreated. Thus, similar to the industries, an inventory of the type and scale of operations must first be compiled (*see Table 11: Mining scenario in Lake Victoria basin*), followed by an assessment of the water requirements and effluent generation from these mines (*see Table 12: Water details for mining*). During the rainy season, runoff from overburdened areas and ground drains must also be considered as components of the wastewater generation.

Table 11: Mining scenario in Lake Victoria basin

Sl. No	Name of the mine	Location of mine	Mining ore	Mining type (open cast/ underground)	Scale of operation (large/ medium/ small)	Total mining area including township, if any

Table 12: Water details for mining

Sl. no	Name of mine	Mining ore	Water consumption (kl/ day)		Effluent generation (Kl/day)		
			Mining activity	Township (if applicable)	Ground water breaching	Mining activity	From township

The next step involves monitoring the characteristics of effluent generated from mines in terms of pH, TDS and concerned heavy metals. For domestic sewage, parameters to be monitored will be same as stated under urbanization.

Agriculture

The Lake Victoria basin supports extensive agriculture, with over 70 per cent of the population’s livelihood in the catchment area depending on agriculture. The extensive agricultural activity necessitates multiple cropping, which is supported by irrigation. One of the problems with irrigation is the use of fertilizers as well as deposition of salt due to evaporation of excess water. With the onset of rain, surface runoff carries away the accumulated salt and fertilizer residues into the lake. This results in eutrophication which is one of the major issues with Lake Victoria.

Thus, the data on cropping, sown area (net and gross), and fertilizer consumption is crucial (*see Table 13: Agricultural status*). The ratio of gross sown area and net sown area more than one implies multiple cropping and hence more use of fertilizer. This information helps identify districts that use higher amounts of fertilizers, allowing for targeted monitoring of their contribution to nutrient load in water bodies.

Table 13: Agricultural status

Name of the district	Net sown area (acre/hectare)	Gross sown area (acre/ hectare)	Ratio of gross sown area to net sown area	Water consumption for irrigation (kl/acre)	Fertilizer consumption (tonne/year)

The above discussed parameters, including dry and wet inventory, need to be collected individually by the three Victoria Lake-sharing countries. Once country-level data is available, an overall picture of the Lake basin for the three countries will be available in terms of:

- Total withdrawal of water from Lake Victoria
- Total source-specific wastewater generation
- Total pollutant load discharge

The Lake Victoria Basin Commission (LVBC), the governing body of the Lake Basin, with its established online system, should collect country-specific data on the three parameters mentioned above (*see Tables 14, 15, and 16*).This data will be an excellent basis of providing a clear understanding on the pollution sources from different countries, enabling the development of targeted strategies for pollution management at the country level.

Table 14: Country-wise water withdrawal pattern from Victoria Lake basin

Name of the country	Total water requirement (Kl/day)					Quantity of withdrawal (kl/day)			
	Urban	Industry	Mining	Agriculture (irrigation)	Other	Lake Victoria	River (provide name)	Ground water	Other
Tanzania									
Kenya									
Uganda									

Table 15: Country-wise wastewater generation

Name of the country	Quantity of waste water generated (kl/day)					Quantity of wastewater disposed (kl/ day)			
	Urban	Industry	Mining	Agriculture (irrigation)	Other	Lake Victoria	River (provide name)	Land	Other
Tanzania									
Kenya									
Uganda									

Table 16: Country specific pollutant load discharge to Lake Victoria

Name of the country	Pollutant load from sewage (tonne/day)	Pollutant load from to industry (tonne/day)	Pollutant load from mining (tonne/day)	Pollutant load from agriculture (tonne/day)
	BOD COD TDS TKN TP	BOD COD TDS	TDS Heavy metal	TN TP
Tanzania				
Kenya				
Uganda				

3. Water-quality monitoring network

Once the dry inventory has been established and an estimate of pollution load has been identified, the next step involves laying down a monitoring programme for all major rivers/drains discharging directly into the lake. This monitoring will become the basis of prioritization of rivers with respect to potential load. The prioritized rivers can further be considered for a pollution control programme.

A water quality monitoring network is the backbone of any water quality monitoring programme. Designing this network requires information on three essential components, namely sampling location, parameters to be monitored, and frequency of monitoring. The three components are discussed below.

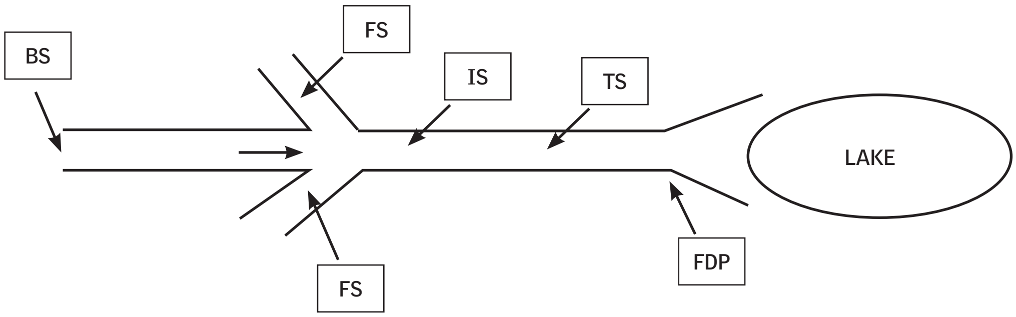
Sampling location

Identifying the location of sampling points in the Victoria Lake basin is a bit complex and thus, require sincere effort. The lake basin comprises riverine systems along with its tributaries and drainage channels, the transition zone (where the river merges with the lake), and the lake itself. To cover this complex basin system, different types of monitoring stations need to be considered where each station plays a vital role and is essential in assessing the degree of pollution. The relevance of each station is tabulated in Table 17 and their locations is depicted in Figure 2.

Table 17: Type of monitoring stations

Type of station	Location	Relevance
Base station (BS)	Head water of lake	To estimate natural condition of water quality with no or minimum human activities
Flux station (FS)	Where tributary and the irrigation drain discharges into the main water stream	To identify drains/tributary carrying pollution load in terms of organics, nutrients, pathogens.
Impact station (IS)	Where pollutants mix with the main stream	To assess impact of flux on to mainstream river
Trend station (TS)	After impact station to show how water quality parameters vary over time with the influence of human activity. This station is applicable only for large rivers	To assess long-term water quality
Final discharge point (FDP)	Where a river empties into a lake or the ocean	Assess pollution load of mainstream river in the lake

Figure 2: Location of sampling stations



The number of sampling points on a river is generally decided on the basis of water discharged by the rivers/drains as suggested by UNEP/WHO (*see Table 18: Guidelines on number of sampling points at each station*).

Table 18: Guidelines on number of sampling points at each station

Sr. No	Name of water body	Average discharge m3/sec	Type of steams or river	Number of sampling points
1		<5	Small stream	2
2		5 to <100	Stream	4
3		100<500	River	6
4		>800	Large River	6-8

Source: Water quality monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programme, UNEP/WHO

Monitoring parameters

The selection of monitoring parameters for different sampling points varies depending upon the activities such as agriculture, urbanization, industrialization, surface runoff in that area, etc. Different parameters that need to be monitored have been classified in Table 19.

Table 19: Classification of parameters

A) Physical parameters – pH, temperature, conductivity, colour, odour
B) Organic compounds– BOD, COD, DO
C) Nutrients – Total nitrogen, total phosphate
D) Ions – Calcium, Magnesium, Sodium, Bicarbonate, Carbonate, Sulfate, Chloride
E) Bacteriological –Total coliform, faecal coliform
F) Heavy metals – To be decided based on the inventory
G) Pesticides – To be decided based on the inventory

Monitoring frequency

The frequency of sampling is determined to account for seasonal variations in pollution load. The frequency is governed by the level of variations in the quality of water. If large variations occur in a short duration of time, sampling needs to be done frequently. However, in case of random variations, e.g., variations due to sudden rainfall in the catchment or unscheduled release of water from a dam, variations are not predictable and thus, increasing the frequency would not help much. Whereas, for water bodies that have frequent cyclic variations, sampling on a periodic basis is justified. The frequency also varies based on the type of monitoring station as listed in Table 20.

Table 20: Monitoring frequency for various stations

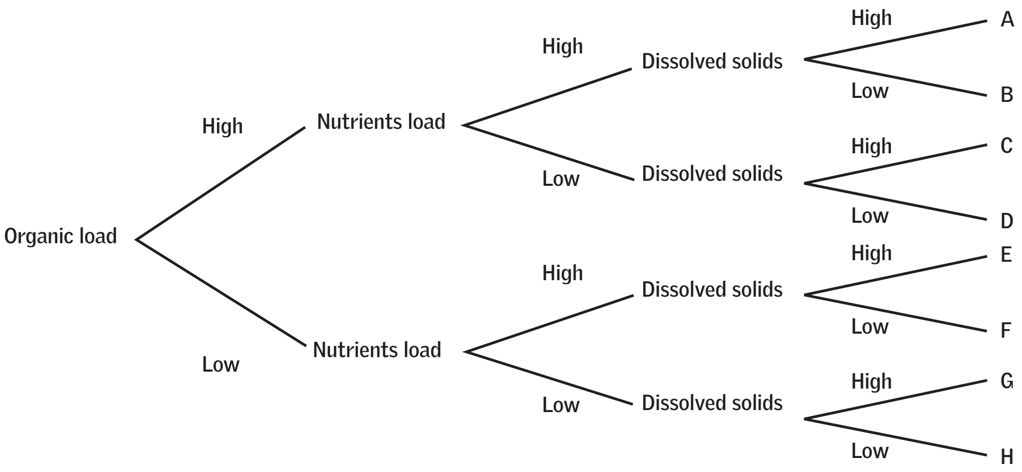
S. No.	Type of station	Parameters (as per table)	Frequency
1	Baseline station	All parameters except "f and g"	Twice a year (once pre-rainy and again post-rainy season)
2	Flux station	All parameters and flow	Six times a year, including rainy season. For pesticides, once a year
3	Impact station	All parameters	Five times a year, including rainy seasons Twice a year for heavy metals and pesticide (pre-rainy and post-rainy season)
4	Trend station	All parameters	Once a year during fair weather
5	Final discharge	A, B, C, D, E and flow	Every month
		Heavy metal, pesticide	Twice a year

Once monitoring is underway based on the above protocol, a comprehensive database will be created to assess the health of various water bodies (rivers and drains).The riverine monitoring system will provide the data on the total load of organic matter, nutrients, and dissolved solids being discharged into Lake Victoria from various rivers/drains (*see Table 21: Discharge of potential loads*). Based on this data, prioritization of rivers can be done depending on the load levels of these three parameters (*see Figure 3: River prioritization based on pollution load*).

Table 21: Discharge of pollution load

Name of the river	Discharge load to river		
	Organic load (BOD) (tonnes/year)	Nutrient load (Total N + Total P load) (tonnes/year)	Dissolved solid load (Total TDS load) (tonnes/year)

Figure 3: River prioritization based on pollution load



(i) Rivers/streams/drains falling under category A are to be given highest priority for pollution control across all three parameters (see Figure 3)
(ii) Rivers/streams/drains falling under category B, C, E are at second priority requiring pollution control for two high parameters.
(iii) Rivers/streams/drains falling under category D, F, G are at third priority with only one parameter with higher load.
(iv) Rivers/streams/drains falling under category H need not to be considered for prioritization.

In order to develop a pollution control programme for prioritized rivers, the source of pollution needs to be tracked. An initial indication of the pollution source can be identified as outlined below; however, it must be confirmed through a reconnaissance survey.

- In case of high nutrient load, agriculture runoff is expected to be a dominating factor;
- In case where organic load is high, sewage and industrial effluent is expected to be dominating factor; and
- In case of high TDS, mining and industrial effluent may be a dominating factor.

Water quality monitoring programme at Lake Victoria

The approach for lake monitoring is different from river/stream/drain monitoring. Lake monitoring is generally two-dimensional and, in a few cases, it is three-dimensional. A suggested method for lake monitoring is through designing a grid system. This involves dividing the lake area into square grids of particular sq kms.

Lake Victoria's surface area is estimated to be 68,000 sq km, thus even considering a grid of 10 sq km each, a total of 6,800 grids will be required for monitoring which is highly cost-prohibitive and logistically difficult. Increasing the grid size to 50 sq km reduces the total number of grids to 132; however, this raises concerns about representative sampling. Therefore, an off-grid system approach could be applied for Lake Victoria.

This approach also requires dividing the lake area into several grids, however, sampling is done only from the representative grids while other grids are discounted. The representative grids are selected for three zones of the lake, namely impact zone, trend zone and central zone, as described below and depicted in Figure 4 (*see Figure 4: Off-grid approach for lake monitoring*). Since a lake is a recipient body, there will be no flux station within it.

No sampling zone: The coastal zone of around **one kilometer** is considered a zero-sampling zone since the water quality in this zone is actually similar to the water quality of the river or drain that is discharging into the lake.

Impact zone: This is the mixing zone, where the water quality of the discharging rivers effectively blends with the lake water. This zone is expected to be eutrophic. Sampling can be done on grids located in this zone considering the dispersibility. The grids located next to the impact zone can be skipped from sampling i.e. off-grid.

Trend zone: Similar to riverine monitoring, trend zone is not as impacted by the discharge from water bodies but long-term pollution trends in the lake can be captured from this zone.

Central zone: Zoning, as described above, will be done from each side of the lake and some grids will fall in the central part of the lake. This zone needs to be monitored with specific intervals (*see Figure 4: Off-grid approach for lake monitoring*).

The average depth of Lake Victoria is 40m and maximum depth is 80m. Thus, sampling needs to be conducted at different depths of the lake. The frequency and parameters at different depths varies for all three zones. A suggestive protocol is tabulated in Table 22.

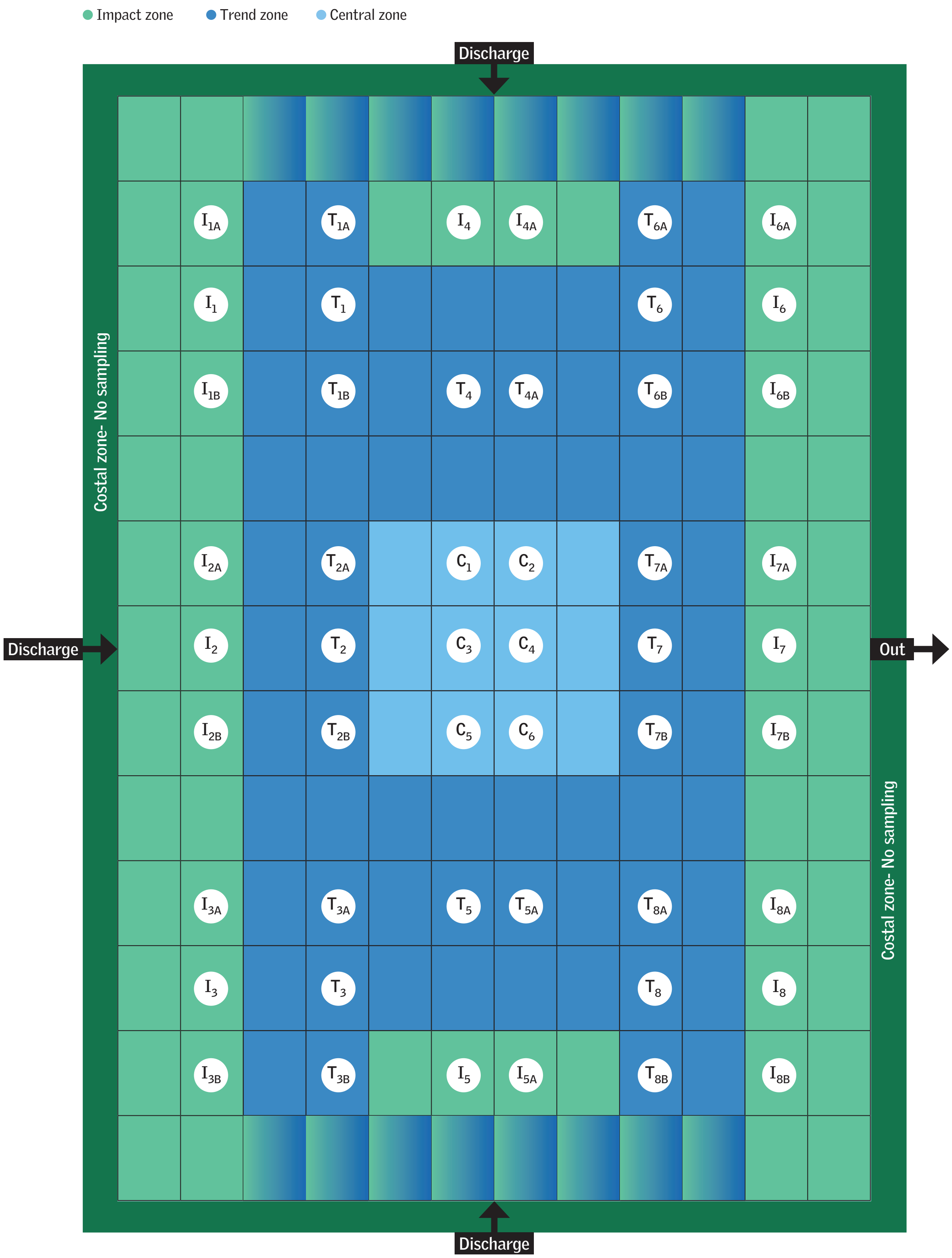
Table 22: Protocol for vertical sampling at Lake Victoria

Type of zone	Depth (m)	Parameters	Frequency
Impact zone	0–5	pH, temperature conductivity, DO, BOD Total N, Total P, Faecal and total coliform, diversity index, common ions	Four times a year
	5–15	-do-	Twice a year
	15–30	-do-	Twice a year
Trend zone	0–5	pH, temperature conductivity, DO,BOD Total N, Total P, Faecal and total coliform, diversity index, common ions	Twice a year (pre and post rainy)
	5–15	-do-	Once a year
	15–30	-do-	Once a year
	30–40	-do-	Once a year
Central zone	0–5	pH, temperature conductivity, DO, BOD, Total N, Total P, faecal and total coliform, diversity index, common ions	Twice a year
	5–15	-do-	Twice a year
	15–30	-do-	Once a year
	30–40	-do-	Once a year
	>40	-do-	Once a year

The collection of data from rivers and lake through periodic monitoring will not serve the purpose until the data is stored, validated, interpreted, and communicated. Moreover, since Lake Victoria is shared by three countries, numerous stakeholders are involved in different areas of the lake. However, their efforts are mutually exclusive, with no integration or coordination between them.

In order to have a holistic understanding of the health of the lake, and to take required policy decisions, it is essential to integrate and share the data generated by every stakeholder on a common platform. This integrated data management will aid in keeping track of fluctuations in lake water quality at different locations and developing a comprehensive management strategy. Lake Victoria Basin Commission (LVBC) should take the lead to develop an on-line portal to upload the data from different countries. This portal should also have monitoring data from different locations as per the monitoring programme and the real-time data from the facilities near the shore.

Figure 4: Off-grid approach for lake monitoring



ANNEXURE

Annexure 1: Details required on type of soil and aquifers

Table: Soil characteristics

Type of soil*	District	% of total basin area covered	Infiltration rate	Agriculture activity
Red sandy			Highest	Low
Red and yellow			High	Low
Deep black			Low	Moderate (fit for only cotton)
Medium black			Low	Moderate (fit for only cotton)
Mixed red black			Moderate	Low
Alluvial			Moderate	High

* soil type may vary with respect to Lake Victoria basin; may be updated with the help of Department of Geology, Soil and Agriculture.

Table: Type of aquifers

Classification of aquifer	% of Total Basin Area covered
Thick aquifer	
Aquifer with limited extent	
Aquifer with restricted extent and low yield potential	
Restricted aquifers with saline brackish water	

Lake Victoria, sharing its resources between Tanzania, Uganda and Kenya, is the most productive freshwater lake. However, the lake has suffered immensely from a variety of unsustainable human activities over the last five decades. Several studies have been conducted on the lake, however, the information on the pollution load from various sources has been missing.

Since the lake is shared by three countries, a database on pollution sources and load by the sharing countries is the need of the hour to develop a management plan for the entire lake basin, rather than relying on country-specific measures.

This toolkit provides the methodology for generating a comprehensive set of baseline data needed to assess the overall water quality of Lake Victoria. Once the data is collected, the toolkit has also discussed monitoring protocol for the rivers/streams/drains entering into the lake, and the lake itself to determine the effectiveness of the actions taken.

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