Environmental Law Alliance Worldwide

TRANSBOUNDARY IMPACTS
ON CITIZENS OF THE DEMOCRATIC REPUBLIC OF CONGO
OF THE TILENGA AND KINGFISHER OIL PROJECTS IN UGANDA

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ABOUT THE AUTHOR

I possess a Ph.D. in Biochemistry from Johns Hopkins University (August 1990) and a J.D. from the University of Oregon Law School (May 1993), complementing my B.S. in Biochemistry from the University of Massachusetts, Amherst (May 1984). This academic background provides a strong scientific and legal foundation for my work on complex environmental issues, including those associated with the oil and gas industry. Since 1992, I have served at the Environmental Law Alliance Worldwide (ELAW), where I currently hold the position of Science Program Director. In this role, I direct the scientific program, providing comprehensive scientific research and analysis for public interest lawyers in 60 countries. A significant component of my work involves advising on the impacts of extractive industries on communities and the environment and coordinating expert witness testimony of scientists.

My expertise covers a full range of environmental issues such as industrial pollution, habitat restoration, public health, and impacts to indigenous communities, which are frequently central to oil & gas projects. My experience includes drafting judicial affidavits, expert reports, and witness statements for cases in various international courts that address fossil fuel-related environmental impacts. I have authored numerous selected reports involving the evaluation of Environmental Impact Assessments (EIAs) and Environmental and Social Impact Assessments (ESIAs) for a diverse range of oil & gas projects. I am a co-author of the guidebook *How to Evaluate Environmental Impact Assessments for Oil and Gas Projects* (2024), published by the Environmental Law Alliance Worldwide.

SUMMARY

Oil & gas projects in Uganda have the potential to cause environmental impacts to citizens and residents of the Democratic Republic of Congo in two consequential ways, described in further detail below: 1) Lake-wide eutrophication of Lake Albert; and 2) Disposal into Lake Albert of oil processing wastes.

LAKE-WIDE EUTROPHICATION OF LAKE ALBERT

Lake Albert, located on the border between Uganda and the Democratic Republic of the Congo, is the northernmost of the chain of African Great Lakes along the Albertine Rift. As for the lake's hydrology: the lake is fed primarily by the Victoria Nile (flowing northward from Lake Kyoga) and the Semliki River (draining Lake Edward). Lake Albert discharges northward via the Albert Nile, which becomes part of the White Nile system. The surface area of Lake Albert is about 5,300 km², with an average depth of approximately 25 meters and a maximum depth of about 58 meters. Water residence time in the lake is substantial, but relatively short compared to larger rift lakes, owing to stronger inflow and outflow.

As for the lake's biological features: The lake supports diverse fisheries, including commercially important species such as *Nile perch* (*Lates niloticus*), *Nile tilapia* (*Oreochromis niloticus*), and several endemic haplochromine cichlids. The lake is also important for migratory bird species and supports wetland habitats along its shores. Primary productivity in the lake is relatively high compared to deep stratified lakes, due to frequent mixing and nutrient replenishment from rivers.

The trophic state of a lake describes its level of biological productivity, usually determined by nutrient concentrations (especially phosphorus and nitrogen), algal biomass, and water clarity. Its significance is that it indicates the lake's ecological health: Oligotrophic lakes are nutrient-poor, clear, and support low algal growth; Mesotrophic lakes have moderate nutrients and productivity; Eutrophic lakes are nutrient-rich, with high algal growth and often poorer water quality.

As for Lake Albert's trophic state**:** Lake Albert presently lies near the boundary between mesotrophic and eutrophic conditions. Nutrient inputs from river inflows, especially the Semliki, and from shoreline human activity, are sufficient to sustain moderately high phytoplankton biomass, but the lake has not historically experienced severe algal blooms on the scale of heavily eutrophied systems. However, nutrient enrichment from increased agriculture, urban development, or **oil and gas–related activities** could push Lake Albert toward persistent eutrophic or hypereutrophic conditions, increasing risks of algal blooms, hypoxia, and fish kills, resulting from the reduction of oxygen in the water.

Algal blooms are known to occur in Lake Albert. Microcystins are toxic compounds produced by certain cyanobacteria during harmful algal blooms. In lakes and reservoirs, fish can accumulate microcystins in their liver, muscle, and other tissues after exposure through contaminated water or food. This creates a risk to human health if fish from bloom-affected waters are consumed, since microcystins are stable, can persist in tissue after cooking, and are linked to liver damage and other toxic effects. A study published by researchers with the Uganda National Bureau of Standards, Kyambogo University, the University of Natural Resources and Life Sciences Vienna (BOKU), Jaramogi Oginga Odinga University of Science and Technology, Gulu University, and Makerere University, found levels of microcystins up **to 300 times higher than safe levels** in Lates niloticus (Nile Perch) and Tilapia zilli (Redbelly Tilapia).[1]

There is a growing awareness among scientists that oil & gas development poses the risk of pushing Lake Albert into a eutrophic state. Earlier this year (2025), researchers from Kabale University, Makerere University, Kyambogo University and the National Fisheries Resources Research Institute published the following findings about the status and future of Lake Albert:

> "Lake Albert is one of the AGLs located in the East African Rift Valley. It is a transboundary lake shared by Uganda (54%) and DRC (46%) …
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> "The petroleum potential of Uganda was documented in 1925, and the first well was drilled in 1938 in the Albertine Graben, with the commercial viability of the oil and gas deposit declared in 2006. The oil and gas exploration in the Albertine Graben is an

[1] Omara, T., Nagawa, C. B., Kyarimpa, C., Böhmdorfer, S., Rosenau, T., Lugasi, S. O., ... & Ssebugere, P. (2023). Lacustrine cyanobacteria, algal blooms and cyanotoxins in East Africa: implications for human and ecological health protection. Phycology, 3(1), 147-167

anthropogenic activity of serious concern, with the potential to contaminate the entire lake ecosystem. …

"Microbial studies of Lake Albert are relatively scarce, with the most notable being the comparison of its aerobic anoxygenic phototrophs with those of lakes Victoria, Edward and Kivu and other lakes from Mongolia, Germany and Antarctica. Another relevant study is the characterization of the protistan composition of four East African lakes: Victoria, Albert, Edward and Kivu. Generally, there is very limited scientific information about Lake Albert. The impacts brought about by climatic disturbances on the microbiology of the lake can be examined by replicating the approaches discussed above for Lake Kyoga. Another innovative aspect of microbiological research is a focus on the impacts of oil production on microbial community dynamics, preferably on a long-term basis. More specifically, both lake sediment and water should be sampled to analyze sediment-associated dense non-aqueous-phase liquids and water-associated light non-aqueous-phase liquids together with miscible fractions, respectively. In both sample types, extended chemical analyses should be complemented with that of microbial ecology such that the presence of aromatic-degrading microbes is used as a proxy for oil hydrocarbon pollution of the lake, but will also suggest an ongoing in situ bioremediation. Lake morphometric aspects to consider for the study design are distance from bays to offshore sites, depth and seasonality.

"**Nutrient enrichment, especially at the south and north shores of the lake, likely transported by the inflow rivers, holds a high potential for eutrophication and other negative impacts. The flourishing economic activities in the Albertine region are likely to lead to rapid population growth, whose activities, e.g. deforestation, intensive land cultivation and livestock rearing, will aggravate the problem of eutrophication**. Thus, there is an urgent need for continuous monitoring of the lake, given the current climatic and anthropogenic pressures."[2]

Why Impacts Can be Lake-wide

Nutrient-driven eutrophication from development near Lake Albert will usually start as a local problem (within a few kilometres of the nutrient inputs — river mouths, bays, lagoons), but because Lake Albert is large and has a fairly long water residence time, sustained or large nutrient loads can propagate and produce lake-wide water-quality impacts over months to years. Below is a concise explanation and practical guidance about key concepts.

Local plumes of eutrophication form first. When nutrients enter a lake from a river, drainage channel, sewage outfall or diffuse runoff, they form a buoyant or neutrally buoyant plume that initially affects the nearshore area — bays, mouths, shallow lagoons and embayments — typically on the order of hundreds of meters to a few kilometres from the source, depending on

[2] Abiriga, D., Odong, R., Bakyayita, G. K., Semyalo, R., Okello, W., & Grossart, H. P. (2025). The microbiology of Uganda's large freshwater lakes experiencing anthropogenic and climatic perturbations: why it matters—a review. Proceedings B, 292(2048), 20243072. https://royalsocietypublishing.org/doi/pdf/10.1098/rspb.2024.3072. [Emphasis added].

local currents and wind. These nearshore zones are where phytoplankton and macrophytes most rapidly respond.

Lake hydrodynamics determine how fast and how far nutrients travel. Transport away from the source depends on wind forcing, density-driven flows, inflow/outflow currents (e.g., the Semliki and Nile connections), and internal circulation patterns. Lake Albert has appreciable inflow/outflow and wind-driven circulation, so nutrients and algal biomass can be advected away from the source and spread alongshore and across the basin under the right conditions.

Residence time determines nutrient persistence. Lake Albert is a large lake, with a volume of about 133 billion cubic meters (m^3) (equivalent to 52 million Olympic swimming pools!). Published water-balances for Lake Albert suggest annual throughflow on the order of only a few billion cubic meters per year.[3] A simple division gives a rough residence time on the order of more than a decade, which means nutrients introduced to the lake can persist in the system for years and accumulate if inputs are sustained. This long residence time greatly increases the chance that local enrichment in Lake Albert will become a basin-scale problem.[4]

Lake Albert's deep and stratified water layers (with respect to oxygen levels) can worsen the extent of eutrophication. In shallow, well-mixed areas, eutrophication appears rapidly as algal blooms and macrophyte growth; in deeper stratified areas, blooms may be seasonal but nutrient recycling from anoxic bottom waters can sustain or worsen eutrophication over time. Lake Victoria's experience shows that whole-lake eutrophication developed where watershed nutrient loading was large and sustained, which is a relevant precedent in the region for what might happen to Lake Albert.[5]

The bottom line is that **i**f nutrient inputs are small and short-lived, eutrophication in Lake Albert will probably remain localized to nearshore zones. If inputs are large or chronic, Lake Albert's size and long residence time mean the effects could accumulate and spread — possibly affecting much of the lake over months to years. It's not a question of either/or; the outcome depends on the load, location, and physics — so quantitative loading estimates and hydrodynamic/water-quality modelling are essential to know how far eutrophication would spread. This leads to the important question of the phosphorus budget for Lake Albert.

What is a Phosphorus Budget and What is the Best Estimate of the One for Lake Albert?

In Lake Albert and many other similar lakes, phosphorus is the key nutrient that determines the lake's trophic status. To maintain a lake in a mesotrophic status, phosphorus levels should not exceed 15–25 micrograms per liter (µg/L), with 20 µg/L often as a maximum conservative

[3] Lake Albert https://www.africangreatlakesinform.org/page/lake-albert

[4] Some sources estimate that the residence time of Lake Albert is more than 700 years. https://www.lakepedia.com/lake/albert.html

[5] Verschuren, D., Johnson, T. C., Kling, H. J., Edgington, D. N., Leavitt, P. R., Brown, E. T., ... & Hecky, R. E. (2002). History and timing of human impact on Lake Victoria, East Africa. Proceedings of the Royal Society of London. Series B: Biological Sciences, 269(1488), 289-294; Hecky, R. E., Mugidde, R., Ramlal, P. S., Talbot, M. R., & Kling, G. W. (2010). Multiple stressors cause rapid ecosystem change in Lake Victoria. Freshwater Biology, 55, 19-42.

estimate. A phosphorus budget for a lake is the total amount of external input of phosphorus that keeps long-term total phosphorus levels within mesotrophic limits, given the lake's depth and residence time. Considering that the trophic status of Lake Albert lies near the boundary between mesotrophic and eutrophic, what is the best estimate of the phosphorus budget required to maintain Lake Albert in a mesotrophic status? We can make a defensible best-estimate of the phosphorus budget of Lake Albert by using commonly used steady-state loading models[6] and published morphometry for Lake Albert. Below I show the method and the numbers.

We can start with the following features of Lake Albert

- Surface area ≈ **5,300 km^2**
- Mean depth ≈ **25 meters**
- Reported long-term inflow to the lake (Victoria–Kyoga contribution + local catchment) is ~**13.3 km^3/yr** (used below to calculate residence time).

From area and mean depth we get a lake volume ≈ $5.3\times10^9\ m^2 \times 25\ m$ = **$1.33\times10^{11}\ m^3$** (≈133 km^3). Using the inflow above gives a central estimate of hydraulic residence time τ ≈ volume / inflow ≈ **133 / 13.3 ≈ 10 years** (note published sources give somewhat different residence time estimates depending on which data set is used; I use 10 yr as a defensible central value).
We can use the commonly applied OECD/Vollenweider empirical relation in the form[7]:

$$L_c = P_c \times \left(\frac{z}{\tau} + 10\right)$$

Where

- Lc = **critical areal loading** (mg nutrient $m^{-2}\ yr^{-1}$),
- Pc = target in-lake concentration (in µg/L),
- z = mean depth (m),
- τ = residence time (yr).

Then, we use a **mesotrophic** total-phosphorus concentration of **20 µg/L** as the value for Pc.

[6] Vollenweider/OECD steady-state loading models use a simple mass-balance approach that relates a lake's mean depth, water residence time, and phosphorus retention to the long-term average in-lake total phosphorus concentration. By choosing a target TP level (e.g., for mesotrophy), the model calculates the maximum allowable annual phosphorus load—the "critical load"—that the lake can receive without exceeding that concentration.

[7] Jones, R. A., & Lee, G. F. (1988). Use of Vollenweider-OECD modeling to evaluate aquatic ecosystem functioning. In Functional Testing of Aquatic Biota for Estimating Hazards of Chemicals (pp. 17-27). ASTM International.

Calculations

Inputs: z = 25 m; τ = 10.0 yr; Pc(TP) = **20 µg/L**

1. Hydraulic term

$$z/\tau = 25/10 = 2.5 \Rightarrow (z/\tau + 10) = 12.5$$

2. Areal phosphorus loading

$$L_P = 20 \times 12.5 = \mathbf{250} \text{ mg P m}^{-2} \text{ yr}^{-1}$$

3. Total annual P load

$$250 \times 5.3 \times 10^9 = 1.325 \times 10^{12} \text{ mg/yr}$$
$$= 1.325 \times 10^6 \text{ kg/yr} = \mathbf{1,325\ tonnesP/yr}$$

Therefore, to keep Lake Albert comfortably mesotrophic **(**levels of total phosphorus below 20 µg/L) a rough external loading budget should not exceed **1325 tons of phosphorus per year**.

How Climate Change Might Impact the Phosphorus Budget of Lake Albert

Climate change could influence both the trophic status of Lake Albert and the amount of phosphorus it can assimilate without becoming eutrophic, through several linked physical, chemical, and biological pathways.

Climate change causes physical changes that affect phosphorus retention and recycling.

First, warmer surface waters in Lake Albert would lead to stronger and longer-lasting thermal stratification. In deeper parts of Lake Albert (~25 m mean depth), prolonged stratification can: 1) Reduce vertical mixing of oxygen to bottom waters; and 2) Increase hypolimnetic anoxia (oxygen depletion at depth). Anoxic bottom sediments release soluble reactive phosphorus (internal loading), which can significantly increase in-lake P concentrations even without higher external inputs. This makes the phosphorus budget "looser" — more of the phosphorus entering stays in circulation and is available for algae.

Second, if Lake Albert shifts from a reliably mixed monomictic pattern to more stable stratification, seasonal flushing of nutrients to the outflow may decrease. The critical loading threshold (e.g., the 1,325 t/year I estimated for mesotrophy) could drop, because less flushing means more retention of incoming phosphorus.

Climate change would cause hydrological changes affecting phosphorus loading and flushing:

First**,** stronger storms increase **soil erosion** in the catchment, especially from agriculture and deforested slopes, washing particulate-bound phosphorus into tributaries. Storm-driven pulses of runoff can exceed the capacity of wetlands or riverine filtering systems, delivering more bioavailable phosphorus.

Second, if annual inflow decreases due to altered rainfall patterns or upstream water withdrawals (e.g., irrigation), hydraulic residence time increases. Longer residence time equals more time for algae to use the same nutrient input, thus resulting in a lower allowable external phosphorus load to maintain a mesotrophic state.

Climate change would induce the following biological changes: Warmer water speeds algal growth and decomposition, which can shorten the time it takes for a given nutrient input to cause a bloom and increase oxygen demand in bottom waters, worsening anoxia and internal phosphorus releases. Climate change can also cause shifts in phytoplankton species**.** Cyanobacteria (blue-green algae) often thrive under warmer, more stable, nutrient-rich conditions. These can dominate even under phosphorus loads that previously supported more balanced mesotrophic communities.

The net effect on trophic status and phosphorus budget of climate change would be significant. Climate-driven changes (warmer water, stronger stratification, longer residence times) likely reduce the maximum annual phosphorus input the lake can absorb while staying mesotrophic. With increasing climate change, a budget of **1325 tons of phosphorus per year** to keep Lake Albert from transitioning to eutrophic conditions could drop by **10–30 %** or more, depending on climate change severity. With moderately severe climate change severity, we should assume that the phosphorus budget for Lake Albert is no more than **1200 tons of phosphorus per year, a 10% decrease.**

How Oil & Gas Projects in Uganda Could Exceed Lake Albert's Phosphorus Budget

Several kinds of human activities, including those associated with induced growth caused by extraction of oil from new nearby oil fields, might lead to the input of 1,200 tonnes of total phosphorus per year to Lake Albert. Specifically, there are several realistic pathways by which human activity — including induced growth from oil development — could supply that magnitude of input.

The analysis begins with an investigation into the population living around Lake Albert and how this population might grow. Data published in 2024 by the Uganda Bureau of Statistics shows that nearly 1.3 million persons live in six districts (Ntoroko, Kibaale, Hoima, Buliisa, Nwoya, and Nebbi) that border Lake Albert in Uganda.[8] Reliable population data for communities in the Democratic Republic of Congo are less available, but it is estimated that 900,000 persons live in Bunia, which is within the Lake Albert watershed, and makes a direct hydrological connection to Lake Albert via the Semliki River, which passes through Bunia on its way to Lake Albert. Taking into account other towns on the western shore of Lake Albert, including Kasenyi, Tchomia and Mahagi, a conservative estimate is that three million people presently live in the Lake Albert watershed. Stimulated by oil exploration activities, the population of Hoima grew

[8] Uganda Bureau of Statistics 2024: The National Population and Housing Census 2024 – Final Report - Volume 1 (Main), Kampala, Uganda, Available at: https://www.ubos.org/wp-content/uploads/2024/12/National-Population-and-Housing-Census-2024-Final-Report-Volume-1-Main.pdf

by 22% from 2014 to 2020.[9] It is reasonable to assume that unconstrained oil production around Lake Albert could similarly increase the population living in its watershed by 20%, equivalent to an influx of 600,000 persons.

We can now examine direct point sources and diffuse nonpoint sources, and then link them to oilfield-related population growth impacts.

Inputs of phosphorus from domestic and municipal wastewater: Sewage from population growth in towns along the shoreline (e.g., Butiaba, Pakwach, Tonya) and oil-development hubs (e.g., Buliisa, Hoima district) would generate wastewater with typical phosphorus concentrations of ~2–8 mg/L for untreated municipal effluent. The more people from oil-related migration and employment, the more sewage that is generated. On average, one additional person generates sewage containing approximately 600 grams of phosphorus per year. At this rate, the in-migration of 600,000 persons could cause **360 tons per year of external phosphorus** loads in untreated sewage discharges to Lake Albert or its tributaries.[10]

Input of phosphorus from agricultural runoff: The in-migration associated with oil & gas development would require an expansion of cropland to feed the growing population and workers. Fertilizer use in oil-company supply chains (maize, cassava, sugarcane) and local market farming would add to the external load of phosphorus to Lake Albert as rainfall and irrigation runoff washes applied phosphorus fertilizer and manure into rivers draining to Lake Albert. The loss of phosphorus from poorly managed fertilized cropland ranges from 0.5 to 2.0 kilograms of phosphorus per hectare per year. An expansion of cropland of 200,000 hectares required to feed an additional 600,000 persons who move into the Lake Albert water basin could add **up to 400 tons per year of external phosphorus** in runoff entering Lake Albert.[11]

Input of phosphorus from livestock waste: With more people come more cattle, goats, and pigs near the lake shore or streams. Phosphorus from livestock leaches out during rains or is directly deposited in streams that drain into the lake. Each cow produces approximately 10 kilograms of phosphorus per year in manure. Using typical milk consumption rates in East Africa of 60-110 liters per person per year, and a typical milk production rate of 2000 liters per milking cow, a total additional herd (adding 30–50% for dry cows, heifers, and replacements) of 36,000 cows can be expected to support an additional 600,000 persons who move into the Lake Albert water basin This would add **360 tons per year of external phosphorus** to Lake Albert from livestock waste.[12]

Input of phosphorus from urban stormwater runoff: The in-migration caused by new oil & gas development would bring new roads, housing estates, and paved areas that would be part of oil-related urbanization. Compared to soil, impervious surfaces accumulate dust, litter, soil particles, detergents; storms wash these to waterways. In general, the discharge of phosphorus in urban runoff can exceed 10 kilograms per hectare per year. Medium-density township

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[9] Busisa, E. S. (2023). Oil Discovery, Internal Migration and Autochthony. The Impact on Community Social and Cultural Life in Hoima City in Uganda's Albertine Graben.

[10] 0.6 kg per person per year x 0.001 tons per kg x 600,000 persons = 360 tons per year

[11] 200,000 hectares x 2.0 kg per hectare per year x 0.001 tons per kilogram = 400 tons per year

[12] 10 kg per cow per year x 36,000 cows x 0.001 tons per kilogram = 360 tons per year

development, the most likely kind of development for rapid oilfield growth, has a typical development footprint of 200 square meters per person. Therefore, medium-density township development for an additional 600,000 persons would have a development footprint of 12,000 hectares. Therefore, the clearing of land and construction of paved surfaces to house an additional 600,000 persons who move into the Lake Albert water basin could add another **120 tons per year of external phosphorus** in runoff entering Lake Albert.[13] Note: these figures do not include large industrial footprints (refineries, major processing facilities, large quarries), major new highways or airfields — which could add substantial additional cleared area.

If Lake Albert's sustainable phosphorus load is ~1,200 tons per year (under a moderate climate change scenario), this could be reached by a **mix** such as:

- ~360 t/year from untreated sewage (≈0.5 million people at 0.6 kg P/year lost to water);
- ~400 t/year from cropland runoff (~200,000 ha at 2 kg/ha/year);
- ~360 t/year from livestock manure runoff; and
- ~120 t/year from erosion and stormwater in expanding urban areas

This combination, although an estimate, is entirely plausible under rapid development without strict controls.

What Would be the Consequences if Lake Albert's Phosphorus Budget were Exceeded?

If Lake Albert's phosphorus budget is exceeded and eutrophication becomes persistent, the consequences for people living along the shore of the lake in Uganda and the Democratic Republic of Congo would be broad and severe: increased human illness risk (from toxic blooms and degraded drinking water), sharp declines in fisheries and household protein security, lost incomes and local economies, reduced water availability/quality for domestic and irrigation uses, damaged biodiversity, and heightened transboundary tensions and costs for remediation and management. Of course, the degradation in water quality would also affect the basic use of the lake by the population for bathing and laundry. Many effects begin locally (shoreline and bays) but can expand lake-wide over months to years if loads are sustained.

There would be direct human-health consequences if Lake Albert's phosphorus budget were exceeded. These consequences would include toxic algal blooms**:** Certain cyanobacteria and algae produce toxins (microcystins, anatoxins, cylindrospermopsin, etc.) that contaminate drinking water, fish and shellfish and can cause liver, gastrointestinal, neurological illness, and sometimes fatalities. Acute outbreaks (vomiting, liver damage) and chronic exposure risks (liver cancer risk, other long-term effects) are documented worldwide. Algal blooms degrade taste/odour and complicate water treatment; conventional community water systems and household treatment (boiling) often do not remove algal toxins, raising the risk to people relying on untreated lake water. These direct consequences would also include fish contamination & food poisoning**:** Toxins and hypoxic fish kills create direct risks from eating contaminated fish

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[13] 10 kg per hectare per year x 200 square meters per person x 0.0001 hectares per meter x 600,000 persons x 0.001 tons per kilogram = 120 tons per year

and indirect nutrition losses from reduced catches. Shellfish and small fish species may bioaccumulate toxins. The net effect on people would be increased acute illnesses, possible chronic health burdens, and higher health-care demand and costs — particularly where access to safe piped water and medical care is limited, which are widespread conditions in parts of the Lake Albert basin.

There would be indirect human consequences if Lake Albert's phosphorus budget were exceeded. These consequences would include impacts on food security and livelihoods resulting from the collapse or major declines of fisheries. Eutrophication produces low-oxygen "dead zones," fish kills and shifts in species composition (loss of valued species, proliferation of less-valuable species). Small-scale, artisanal fisheries that supply protein and income for thousands on the shore of the Democratic Republic of Congo are highly vulnerable. Studies from African Rift lakes (e.g., Lake Victoria) show strong negative socioeconomic impacts on fisher communities during bloom and invasive-plant events.[14] For many lakeside households fish are a primary source of animal protein and micronutrients. Reduced availability/increased prices raise malnutrition risk, especially for children and pregnant women These indirect consequences would include income loss and poverty escalation**.** Reduced fish catches results in lower household income, leading to less money for school, healthcare and basic needs. Fishing supply chains (boat builders, fish traders, market vendors) also suffer. Recovery can be slow, particularly if stocks collapse or markets reject fish due to toxin fears.[15]

The consequences of Lake Albert's phosphorus budget being exceeded include impacts on infrastructure and public services**.** Local authorities and utilities (and households) may need to invest in advanced treatment (activated carbon, membrane filtration, advanced oxidation) to remove toxins — which would be a significant cost burden for under-resourced provinces in the Democratic Republic of Congo. The consequences would include damage to tourism and transportation: Reduced recreational use, foul odours and unsightly scums lower tourism and dense mats or floating vegetation can impede navigation. The costs of responding to and cleaning up algal blooms would be high. Fisheries restocking (if attempted), bloom management (mechanical removal, algicide — which has its own risks), public health campaigns, and expanded monitoring all cost money and administrative capacity.

The consequences of Lake Albert's phosphorus budget being exceeded include impacts to socioeconomic and cultural impacts. The impacts of lake eutrophication fall disproportionately on vulnerable groups**:** Women, children and the poor typically bear the brunt — women collecting water, preparing food, and processing fish face greater exposure and reduced incomes, worsening gendered poverty. Fishing traditions, rituals and local food culture tied to particular species may be lost or weakened. Large, persistent shocks to livelihoods can prompt migration to towns, increased competition for jobs, and potentially conflict over dwindling resources.

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[14] Roegner, A. F., Corman, J. R., Sitoki, L. M., Kwena, Z. A., Ogari, Z., Miruka, J. B., ... & Miller, T. R. (2023). Impacts of algal blooms and microcystins in fish on small-scale fishers in Winam Gulf, Lake Victoria: implications for health and livelihood. *Ecology and society: a journal of integrative science for resilience and sustainability*, 28(1), 49.

[15] Obuya, J. A., Onyango, H. O., Olokotum, M., Zepernick, B., Natwora, K., Otieno, D., ... & Keyombe, J. L. (2024). Socioeconomic consequences of cyanobacterial harmful algal blooms in small-scale fishing communities of Winam Gulf, Lake Victoria. *Journal of Great Lakes Research*, *50*(5), 102236.

The consequences of Lake Albert's phosphorus budget being exceeded include long-term ecological impacts that would reinforce human impacts. Submerged aquatic vegetation, benthic communities and some fish species decline; invasive species (e.g., water hyacinth) may proliferate in nutrient-rich waters, further degrading habitat and blocking fishing and transport. These impacts could become persistent**:** Nutrients buried in sediments can be recycled and sustain blooms for years even if external loading is reduced — meaning recovery may be slow and expensive.

The consequences of Lake Albert's phosphorus budget being exceeded have implications for transboundary governance as well as political and security risks**.** Lake Albert is shared between Uganda and the DRC; upstream development in Uganda causing downstream harm can create diplomatic tensions, legal disputes and demands for compensation or remedial action. Cooperative management institutions may be weak or underfunded, making rapid resolution difficult. Shrinking fisheries and water access can catalyze local disputes between communities and across the border, especially where institutional conflict-resolution capacity is limited.

In summary, if phosphorus inputs from development push Lake Albert into a substantially worse trophic state, the most immediate consequences for DRC communities will be poorer and more dangerous drinking water, higher rates of illness, marked reductions in fish catches and household incomes, and resulting social and economic stress. These local impacts can cascade into lake-wide ecological change and long-term economic harm unless excessive external loads are prevented.

DISPOSAL INTO LAKE ALBERT OF OIL PROCESSING WASTES

The Central Processing Facility (CPF), which is part of the Kingfisher project and integral to all oil & gas activities in Uganda, is located on the Buhuka Flats along the south-eastern side of Lake Albert. The CPF is described in the Environmental and Social Impact Assessment (ESIA) for the CNOCC Uganda Ltd Kingfisher Oil Development, Uganda (September 2018).

The primary purpose and function of the CPF is to process and stabilize the raw well fluids collected from the production wells, preparing the crude oil for export and managing the associated water and gas. Key functions of the CPF include: Processing Well Fluids: The CPF receives well fluids (a mixture of crude oil, gas, and formation water) through buried flowlines from the four onshore well pads. The facility is designed for a throughput of 120,000 barrels of well fluid per day. Separation and Stabilization: The facility processes the fluids by separating and removing the produced water, sand, salts, and associated gas to produce crude oil that meets the export standard. This process involves initial separation (1st stage separator) followed by heating and further separation (2nd stage separator) to stabilize the crude. The crude is processed to meet specifications such as a basic sediment and water (BS&W) content of less than 0.5% and a salt content of 60mg/l. Water Management (Produced Water Treatment and Injection): The CPF incorporates water treatment facilities. Produced water separated from the crude is treated to meet injection water specifications. This treated produced water is then combined with make-up water abstracted from Lake Albert and is injected back into the oil reservoir via dedicated injection wells to maintain reservoir pressures and ensure environmentally responsible disposal.

Gas Processing and Utilization: The associated gas separated from the oil is utilized as fuel gas for power generation, the heating system, and other utilities within the facility. Construction of the CPF is now more than 90% complete.[16]

According to page 2-47 of the ESIA for the Kingfisher project, **the CPF will generate 200 metric tons per year of 'waste oil sludge'** derived from the produced water treatment system. This waste oil sludge contains high levels of hydrocarbons (primarily oil). These hydrocarbons originate from the crude oil phase that is separated from the well fluids in the CPF. Produced water removed from the well fluids contains hydrocarbons which must be cleaned before the water is injected back into the reservoir. The sludge represents the concentrated residue of this separation and cleaning process.

As for the disposal of this high volume hazardous waste, page 2-41 of the ESIA states: "Solids will be drummed and **removed by a third party contractor for disposal**." Page 2-42 of the ESIA states: "The effluent through the spiral sludge dehydrator will be pumped back into the inlet header of the skim tanks, while the dewatered sludge will be transferred to the waste disposal areas for **disposal by a third party waste contractor**." Page 2-46 of the ESIA states: "A Waste Storage Area (WSA) will be determined as the central collection area for all stored waste generated at the CPF and as the transit station for c**ollection by waste contractors for disposal.**"

However, a recent report by Climate Rights International documents reported instances of improper disposal into Lake Albert of oil field wastes by third-party waste contractors.[17] One might assume therefore that reliance on third-party waste contractors for the disposal of waste oil sludge from the CPF could result in the disposal of half of this waste (100 metric tons per year) into Lake Albert. Hydrocarbon-containing waste oil sludge is classified as a hazardous production waste. Disposal of this waste into Lake Albert would result in a major impact on the lake's highly sensitive aquatic environment. The contaminants of concern in this sludge include hydrocarbons, which are recognized as toxic to aquatic organisms. Crude oils are highly persistent, lasting over a year on water. The oil extracted at the Kingfisher and Tilenga projects possesses an extremely high wax content. If this crude-based sludge were released into Lake Albert, it would likely float, spreading slowly, breaking into patches, and pooling in layers that could be centimeters thick.

Some of the impacts from disposal of 100 metric tons per year of waste oil sludge into Lake Albert would likely be transboundary. Near-shore habitats are crucial for supporting the high biomass and strong multi-species fishery in Lake Albert. Lake-wide mixing and currents could carry oil slicks, dissolved hydrocarbons, and contaminated sediments across the international

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[16] Uganda Radio Network (4 September 2025) "Construction Works of Kingfisher Central Processing Facility (CPF) Hit 92 Percent." https://ugandaradionetwork.net/story/construction-works-of-kingfisher-central-processing-facility-cpf-hit-92-percent

[17] Climate Rights International (September 2024) "*They Don't Want People to Stay Here*" How CNOOC's Kingfisher Oil Project in Uganda Is Causing Human Rights, Environmental, and Climate Harms, available at: https://cri.org/reports/they-dont-want-people-to-stay-here/

boundary.[18] Near-shore releases in Uganda could, over time, disperse into Congolese waters. Fish are mobile: contaminated fish can migrate across borders or be caught in one country and sold in the other. Bioaccumulation of PAHs and metals in fish tissues would create cross-border food safety risks and potentially lead to fish-consumption advisories in both Uganda and the DRC. Benthic community damage and sediment contamination on one side of the lake can affect shared fish spawning grounds and migratory species important to both nations' fisheries. If fisheries decline or fish are considered unsafe, both Ugandan and Congolese communities dependent on Lake Albert for protein and livelihoods would be affected.

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[18] Currents in Lake Albert are almost entirely dependent on prevailing winds. As such, the lake has northward currents along the east, and southward return currents along the west, forming a counter-clockwise gyre under the prevailing southeasterly trade winds, with seasonal and local variations.

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