Chemical and Granulometric Analysis of Solid Matters in Suspension of Rivers Pouring in Lake Tanganyika: Burundi.

[1]Juvenal Mutima*, [1]Jian Wei Li, [2]Pascal Nkurunziza, [3]Gabriel Habiyaremye

1. Faculty of Earth Resources, China University of Geosciences, Hongshan District, 388 Lumo Road, Hubei, Wuhan, 430074, China

2. Faculty of Sciences, Department of Earth Sciences, University of Burundi, P.O.Box 2700, Bujumbura-Burundi
3. Institute of Ecology and Environmental Science, China University of Geosciences, Hongshan District, 388 Lumo Road, Hubei Wuhan, 430074, P.R. China
mutima_juve@yahoo.fr, habygaby@gmail.com

Abstract: Lake Tanganyika, the largest East African rift valley system holding about 1/6 of the world's liquid freshwater, faces a number of threats including excess sedimentation, pollution and habitat destruction. The impact of its inflows like Rusizi River, Ntahangwa River, Muha River and Kanyosha River has been evaluated. Water samples were taken at different distances from the shore and at different depths. Chemical analyses were carried out at four week intervals during nearly a year and were focused on nitrites, nitrates, ammoniacal nitrogen, phosphates, chlorides, carbonates-bicarbonates and sulfates.The samples analyzed in REGIDESO water laboratory with photospectrometer revealed that the concentration of these elements goes increasing from upstream to downstream .A granulometric analysis by sifting then by sedimentometry with aerometer contributed to determine the size of fine particles in suspension of those rivers. Certain physical parameters as pH, electrical conductivity, particulate matters in association with greater sediments and nutriments detected especially in Ntahangwa and Muha rivers worried us about potential pollution of Lake Tanganyika. It has been concluded that those inflows contribute to lake pollution and recommended that in order to maintain sustainability of the lake; both regional and global joint efforts are required for management of catchment and pollution control.
[Academia Arena, 2010;2(1):91-97]. (ISSN 1553-992X).

Keys words*:* Lake Tanganyika, pollution, sediments, particulate matters, eutrophication.

1. Introduction.

Lake Tanganyika is an African great lake. It is divided between four countries: Burundi, Democratic Republic of the Congo (DRC), Tanzania and Zambia. It is estimated to be the second largest freshwater lake in the world by volume, and the second deepest, after Lake Baikal in Siberia. It extends for 673 km in a general north-south direction and averages 50 km in width. The catchment area of the lake covers 231,000 km^2 with two main rivers flowing into the lake, numerous smaller rivers and streams (due to the steep mountains that keep drainage areas small)like Ntahangwa river, Muha, river. The major inflow beginning 10.6 ka is the Rusizi river, entering the north of the lake from Lake Kivu. The Malagarasi river, which is Tanzania's second largest river, entering in the east side of Lake Tanganyika. There is one major outflow, the Lukuga River, which empties into the Congo River drainage, on the way towards the Atlantic Ocean.The Lake Tanganyika is one of the most exceptional biotic resources on the world. A large number of species of animals and fauna of the lake are not found anywhere else in the world (Roest, 1991). Lake Tanganyika supports one of the most species-rich lacustrine biotas on the planet, with over 1500 species of organisms, at least 600 of which are endemic to the lake (Cohen, 2005). It houses an extraordinarily rich and complex ecosystem, which may be under threats from a variety of human activities, particularly those related to rapid deforestation in the lake's surrounding catchment (Coulter, 1991)and (Cohen, 1995). In the preliminary studies on physical pollution, the analysis of the Landsat images revealed that 40 to 60% of wood and forests recovering the center of the catchment area of the lake were cleared by passive and uncontrolled fires for agricultural ends (Cohen, 1991).

The fast erosion which rises from this deforestation generates a massive increase in the solid matters as well as rates of sedimentation raised in the neighborhoods in the lake (Patterson and Makin, 1998). The rates of erosion of the ground in the basin of the Ntahangwa river which has steep slopes and is cultivated intensively, rose between 20 and 100 tons/ha /an. Almost all these sediments return in the lake Tanganyika (Bizimana and

Duchaufour, 1991). It is also important to recognize that human impacts have been an important factor shaping the landscape of the northern Lake Tanganyika catchment for at least the last few millennia (Schoembrun, 1998).

The stratigraphy of Lake Tanganyika basin can be understood in the context of the stratigraphy of Burundi in general. However, Bedrock within the lake's catchment includes early-middle Proterozoic metasediments and metavolcanic rocks, upper Proterozoic and Karoo (upper Paleozoic-lower Mesozoic) nonmarine sedimentary rocks, and, at the north end of the basin, upper Tertiary volcanic rocks in the Ruzizi River valley (Cohen, 2005).

Rocks belonging to the mesoproterozoic Kibaran belt are widespread in Burundi and are locally termed as Burundian Supergroup. The Burundian rocks consists of quartzitic sequence, schists, graphitic schists who interbedded with Quartzitic rocks and poorly sorted sediments containing often arenites within them occur numerous lenticular congromeratic bands. The rocks of Burundian are intruded by synorogenic granites. (During the Kibaran orogen (1300Ma), sediments were intruded by G1 and G2 granites with foliated biotites. Postorogenic rifting in the eastern part of the belt (central and eastern Burundi and westernmost Tanzania) produced small layered mafic and ultramafic intrusions with Ni, Co,Cu, Pt, Cr,V, and Ti mineralizations, as well as alkaline and calcalkaline granites intrusions:G3 types(1250-1210Ma) (Brinckmann et al, 1994).

As tectonic features**,** the upper Burundian fold belts are narrow and deep structures separated by large outcrops of basement. These fold belts are stacked with an eastward vergence (towards the Tanzania craton) to the east and with a westward vergence (towards the Congo craton) to the West (Villeneuve and Chorowicz, 2004). In central of Burundi, a fault system crosscuts the kibaran belt and gives rise to an N-S trending corridor, which is known as the N-S accident. It has been assumed that the N-S accident is either representing a late kibaran suture, or a late kibaran lateral strike slip deformation, which culminated in a major shear zone (Thomas et al, 2008). There are two types of fractures: The fracture oriented NS-SSW in which Lake Tanganyika is located and another one oriented NW-SE [1] and the lake occupies a series of interconnected half-graben basins, the oldest of which are probably between 9 and 12 Ma (Cohen et al, 1993).

Many research works have been conducted on the Lake Tanganyika in keeping with its pollution and its threats. However, the problem of the pollution of the Lake Tanganyika is not exhausted thoroughly until now; reason for which other researches are continuing to be done for preventing the Lake Tanganyika from pollution. Thus our paper is a kind of contribution within this framework in proving the danger of possible pollution of Lake Tanganyika and how to prevent this pollution as well as many chemical elements such as nitrates, nitrites, ammonia, phosphates and chlorides are known as pollutants. In high concentration, NO_3**-** stimulate the watery flora in presence of other elements and increase the primary productivity. If those nitrates are in high concentration, they will involve an excess of this flora, leading to eutrophication. NO_2**-** are intermediate products of nitrification. They are unstable and toxic for the watery organisms especially fish. The toxicity of $NH_4^+$is directly related to its ionization and pH. The Ratio NH3/ NH_4^+ is defined by the value of pH. The presence of NH_4^+ in water with a high pH will be toxic. High concentration of PO_4^{3-} can cause an exaggerated growth of algae. These last form in thick carpet at water surface and while breaking up can be the cause of pollution, sometimes toxic for fish.

This paper is focused on chemical analysis of water containing particulate matters in suspension of Rusizi, Ntahangwa, Muha and Kanyosha Rivers pouring in Lake Tanganyika at its North-East side in Bujumbura city, capital of Burundi. The following elements will be analyzed: Nitrates, Nitrites, Ammoniacal nitrogen, orthophosphates and chlorides, carbonates and sulfates. Some Physical parameters controlling the concentration of the above elements and their toxicity will be measured: Temperature, pH, particulate matters (PM), and electric conductivity. A granulometric analysis is also made in order to determine the dimensions of the solid matters.

2. Sampling and Analytical Procedures

The samples have been taken in Rusizi River, Kanyosha River, Ntahangwa and Muha Rivers. The choise of sampling stations was guided by the state of vulnerability of the zone, thus some samples were taken upstream of rivers where slop and water speed are still high, others in overpopulated zones, in factories areas and finally at the mouths of all of these rivers. The catch of water samples in rivers and lake were carried out in polyethylene bottles, sterilized beforehand by irradiation in order to avoid further contamination. Samples have been analyzed in REGIDESO Laboratory on spectrometer with the wavelength fixed according to the nature of elements to analyze. Temperature, pH and electric conductivity were measured in situ with respectively thermometer, pHmeter and conductimeter.

Nitrites NO_2^- have been dosed by Zambelli reagent, after stabilization of water samples at 4℃. In this method, the sulphanilic acid ($C_6H_7NO_3S$) in hydrochloric environment and in presence of ammonium ions with phenol forms with NO_2^- a yellow colored complex whose intensity is proportional to the nitrites concentration. The dosage of Nitrates calls upon relatively complex methods with a great probability of presence of interfering components, so the determination of Nitrates is delicate. The spectrophotometric method suggested requires a limpid sample: The sample has been filtered on membrane 0.45 micrometer after having checked that it does not contain nitrates.

Nitrates NO_3^- have been dosed by sodium salicylate method. In presence of sodium salicylate ($C_7H_5NaO_3$), the nitrates give sodium paranitrosalicylate in yellow colored susceptible to a spectrophotometric dosage. The operator model consists on to introduce 10ml of water into a capsule of 60ml, alkalize slightly with the solution of Sodium Hydroxide. Add 1ml sodium salicylate solution. To add 2ml of sulphuric acid concentrated by having care to moisten completely. To wait 10 minutes, and then add 15ml.of distilled water then 15 ml of the solution of hydroxide of double potassium and sodium and sodium tartrate which develops the yellow color. To carry out the readings with the spectrometer with the wavelength of 415nm and to take account of the value read for the witness.

Ammoniacal nitrogen NH_4^+ has been dosed by Nessler method in which Nessler Reagent (K_2HgI_4) reacts with the ammonia present in the sample (under strongly alkaline conditions) to produce a yellow-colored species. The intensity of the color is in direct proportion to the ammonia concentration.

$2K_2HgI_4 + NH_3 + 3KOH \rightarrow Hg_2OINH_2 + 7KI + 2H_2O$.

Orthophosphates PO_4^{3-}, in acid environment and in the presence of ammonium molybdate, give a phosphomolybdic complex which, reduced by the ascorbic acid ($C_6H_8O_6$), develops a suitable blue coloring for a colorimetric dosage.

The granulometric analysis was carried out at the laboratory of Civil-Engineering of the Faculty of applied Sciences (F.S.A) at the University of Burundi. We initially made an analysis by sifting then by sedimentometry. While sifting, the sample is placed in the higher sieve of a set of 11 sieves placed one after one according to decreasing dimensions of their meshes. Sifting is carried out by washing with the fountain on the sample. As soon as water becomes limpid in the sieve, we successively removed the sieves until the last one of 0,125mm as mesh. The refusals were dried with the drying oven during 24 hours and were weighed.

The goal of the granulometric analysis by sedimentometry is to determine the grain-size distribution of the fraction of aggregates and movable grounds whose diameter is lower than 0,1mm. The grain-size distribution is determined by the method of the hydrometer using sedimentation of materials in suspension.

The readings in determined moments on the stem of the aerometer give the unit weight of the suspension. By application of STOKES' law, we determined the maximum diameters of the grains. In deed. The separation of the particles by sedimentation is based on the variation of the drop times according to their dimensions. When the spherical particles of ray R fall under the effect of their weight in the liquid of viscosity η , they are subjected to a frictional force also called drag force F given by the formula:

$$F = 6 \pi \eta R V$$

Where: F is the frictional force (in **N**),

η is the fluid's dynamic viscosity (in Pa)

R is the radius of the spherical object (in m), and

V is the particle's velocity (in m/s).

The force of gravity which involves the particles of ray R and density ρ in a liquid of density ρ_0 is :

$$F' = \frac{4}{3} \pi R^3 (\rho - \rho_0) g$$

The two forces acting in opposite direction, the sphere reaches a falling speed limits **V** when the two forces balance (F = F').

$$\text{Thus: } 6\pi \eta R V = \frac{4}{3} \pi R^3 (\rho - \rho_0) g$$

After simplification and by replacing the ray **R** by diameter **D**, we finally have:

$$V = \frac{D^2 (\rho - \rho_0) g}{18\eta}$$

Where:

D is the diameter of particles (in m)

g is the gravitational acceleration (m/s^2)

ρ is the mass density of the particles (kg/m^3), and

ρ_0 is the mass density of the fluid (kg/m^3).

This is Stokes' formula, from which we can calculate the diameter **of** small particles.

3. Results and Discussions

For certain parameters measured like temperature, pH, and electric conductivity, the results are in normal rates. The studies made in Rusizi and Kanyosha rivers show us a definitely basic pH (around 9), a high electric conductivity (between 620 and 650µS/cm) and dissolved oxygen of 10 with 12.2°). In Ntahangwa and Muha rivers, there is contrast on pH values. The Ntahangwa River has water whose pH is slightly acid whereas the Muha River has water whose pH is slightly basic. These differences would be due to the nature of the grounds crossed by these rivers, but also by certain discharges of various industries and households. A pronounced salinity as indicated by a high electric conductivity, is conferred for a great part by the high percentages of cations especially of Mg^{2+}, Na^{+}, K^{+}) and Ca^{2+}; balanced primarily by bicarbonates - carbonates ($MgCO_3$,$CaCO_3$,, Na_2CO_3) , sulfates (Na_2SO_4, K_2SO_4) and chlorides (KCl, NaCl) (Ntakimazi, 1995). The only difficulty appears at GATUMBA where conductivity was of 744µS/cm and the hardness of 12.7°. It is obviously the influence of Rusizi, the most important affluent of the lake, whose water coming from the Lake Kivu which has a conductivity of more than 840µS/cm. However, water of the lake has a very low content of Ca2+ and is still impoverished by it because the deposits on rock banks are mainly made up of CaCO3. The mollusk shells are almost exclusively also made up of CaCO3 and thus contribute to increase the imbalance which we already find in water of the lake between Ca^{2+} and Mg^{2+}.

The water of Rusizi and Kanyosha rivers show a very low contents in nitrates, ammonia and phosphates; contents of suspended matter rather weak when one moves away from broad (5 with 22mg/l), characteristic of a quite clear water. In Ntahangwa and Muha rivers, we notice a great concentration in particulate matters on the level of the mouths. That would be explained by the fact that upstream, the slopes being still strong; the rate of flow of water of these rivers is still high, not supporting the sedimentation of the fine particles. Thus, in fact the large particles heavy, difficult to put moving settle upstream; finest remainder in suspension to settle downstream. We also notice the great concentrations in PM in the Ntahangwa river compared to the Muha river. These differences would be due to the nature of the crossed rocks and their degree of alteration; quantity of precipitations; index of slope and erodibility of the crossed grounds; work of civil engineering (hardcore, sand extraction in the sharp bed of these rivers).

Studies made on water of Rusizi and Kanyosha (upstream and on lake), show the physicochemical characteristics as illustrated in Table 1:

Table 1: ***Results of physico-chemical analysis of water samples in Rusizi and Kanyosha rivers***

Analyzed Elements	Rusizi lake	Kanyosha river	Kanyosha lake
pH	9.01	7.77	8.76
Conductivity (µS /cm)	744	58	578
Dissolved Oxygen	12.78	0.98	10.13
Ca^{2+} (mg/l)	9	1.8	8.6
Mg^{2+} (mg/l)	49.2	3.1	38.1
NO_3-N (mg/l)	0.11	0.71	0.12
NO_2-N (mg/l)	0.005	0	0.92
NH_4^+-N (mg/l)	0.29	0	0.92
SiO_2 (mg/l)	5.89	17.28	3.6
Alkalinity (mg/l)	8.24	0.54	6
HCO_3^- (mg/l)	412	33	305
CO_3^{2-} (mg/l)	22	0	15
PO_4^{3-} (mg/l)	0.007	0.007	0.002
SO_4^{2-} (mg/l)	2	0	1
Cl^- (mg/l)	28	4.4	27.3
Particulate matter	262	215	5
Chlorophyll-a	5.8	7.3	2.6

Except pH, studies made on water of Ntahangwa river and Muha river show that temperature, conductivity, particulate matter increase from upstream to downstream, and are higher in the contact zone with the lake (mouth). This is the same for nitrates, nitrites, ammoniacal nitrogen, phosphates and chlorides.

The results of nitrites analysis for both Ntahangwa and Muha rivers are as shown in the Table 2 and Figure 1:

Table 2: ***Results of physico-chemical analysis in Ntahangwa and Muha mouths***

PARAMETERS/ELEMENTS	NTAHANGWA lake	MUHA lake
Temperature	23.5	23.5
Conductivity	300	280
Particulate matter (PM)	1250	1320
NO_2^- (mg/l)	0.1	0.081
NO_3^- (mg/l)	1.601	1.2
NH_4^+ (mg/l)	0.93	0.21
PO_4^{3-} (mg/l)	0.144	0.07
Cl^- (mg/l)	7.8	7.5

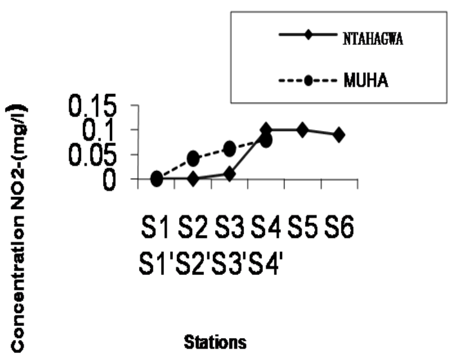


Figure 1: ***Upstream to downstream variation of NO2⁻ in Ntahangwa River and Muha River. S1-S6 and S'1-S'4 are the sampling stations respectively for Ntahangwa river and Muha river, upstream to downstream***

We notice a high concentration in nitrites, nitrates, ammonia and phosphates in water of Ntahangwa river and Muha river comparatively to Rusizi and Kanyosha ones. Indeed, the nitrites and nitrates found in water of Ntahangwa and Muha could come from the deterioration of the eruptive rocks, of the boggy grounds, in the schistous rocks; …. They can also come from the agricultural land using the chemical fertilizers, the atmosphere and the effluents of sewers. All water of the stormy rains contains minor amounts of nitrates and nitrites, formed graces to the electric shocks in the atmosphere. The nitrogen which, by mineralization, will form ammoniacal salts would have come from the putrefaction of the albuminoidal matters, of the products of fossilization of the plants.

The Figure 2 shows the evolution of nitrates upstream to mouth.

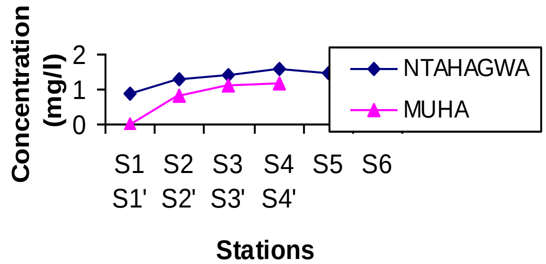


Figure 2: ***Upstream to downstream variation of NO3⁻ in Ntahangwa river and Muha river***.

The presence of ammonium in water of these rivers would be explained by recent feces pollution, if not it oxidizes quickly out of unstable nitrites and finally out of stable nitrates. The great concentrations appear after high populated zones (BUYENZI and BWIZA.). Ammonia is a product of the microbiological decay of animal and plant protein. It can be directly reused by plants to produce protein. Ammonia and ammonia compounds are applied directly as fertilizers. The presence of ammonia nitrogen in surface water usually indicates domestic pollution. Ammonia in ground water is normal and is due to microbiological processes.

Orthophosphates are present in the sediments. They are necessary for the life of the plants and of the aquatic animals because they are used for the development of the algae and the phytoplankton whose the zooplankton and various invertebrates nourish themselves; they are also consumed by fish. However, the great concentrations observed with the mouths worries us about a possible exaggerated growth of the algae. These last forming a thick carpet at water surface and, while breaking up can be the cause of pollution for fish.

The chlorides met in great quantity with the mouths of Ntahangwa and Muha Rivers are subject of several sources: Major the part comes primarily from rainwater, of the urines as well as excrements of animals. The remainder comes from various chlorinated organic compounds (the D.D.T, Lindane) and from the detergents. Most between them are not biodegradable. The pollutants are then all the more dangerous as they are not biodegradable or which can be recycled chemically. They can then remain accumulated a very long time.

As result of granulometric analysis, based on the triangle of classification of soils for granulometric analysis, we notice that the sediments on the mouths level of the Ntahangwa and Muha rivers are all sandy loam. That is explained by the fact why these rivers cross the formations of Cenozoic age represented mainly by the deposits filling the tectonic ditch in which Lake Tanganyika is located. The sand prevalence would be also explained by the fact these rivers take source in the buttresses bordering the town of Bujumbura; in the formations of Burundian consisted on pelitic and quartzitic metasediments. These sandy sediments are dangerous for the life of the aquatic animals because they block their habitats, increase the turbidity of water block the penetration of the light, etc. Certain chemical pollutants such heavy metals and the phosphates are fixed on the particles of the sediments, in the mud. They can remain stored or given in circulation there if oxygen is lacking in the medium.

4. Conclusion and Recommendations

The results of the analysis made on water and the sediments of rivers flowing in Lake Tanganyika prove to us an excessive entry of the sediments in the Lake Tanganyika through them. The quantity of the fine particles entering the lake becomes increasingly important during the rainy seasons.

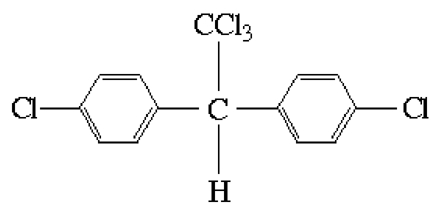
Considering the exceptional value of the Lake Tanganyika for the good being of the bordering populations and humanity as a whole and its vulnerability under the effect of the changes brought by the human activities, at the same time in the lake and its catchment area; considering the threats of pollution of the Lake Tanganyika via physical and chemical inputs of agriculture which appear dangerous already on the natural resources of the lake; This study recommends that an environmental evaluation of the "state of the lake" is carried out for the Lake Tanganyika. This would comprise the collection, the interpretation of information and the identification of the gaps of our knowledge as guides for future researches and future actions; that the lake should be protected from the potential damage of the chemical inputs of agriculture. This should comprise the establishment of an effective system of control in order to identify which products should be authorized for each particular use. Moreover, the quantity of fertilizers brought to a culture must correspond to the total needs for the plants and their capacity for absorption, although the calculation exact of the quantity to be used is not easy; that the State of Burundi and neighboring countries sharing the Lake Tanganyika should take conservation measures of the lake compatible with its long-term exploitation and that they bring their assistance to the research tasks for this purpose..

Appendix

List of abbreviations

REGIDESO: (Régie de distribution d'eau) is a company for distribution of drinking water in Burundi and Democratic Republic of Congo (DRC).

D.D.T: dichloro- diphenyl trichloroethane: It is a synthetic pesticide with chemical formula: $C_{14}H_9C_{15}$



PM: Particulate Matters

Acknowledgment

We are grateful for the assistance either in material and laboratory access offered by the staffs of REGIDESO and Soils mechanic Laboratory at Faculty of applied Sciences at University of Burundi. The authors are also thankful to the financial assistance from CSC and further guidance from China university of Geosciences/Wuhan.

Correspondence to:

Juvenal Mutima
China University of Geosciences Wuhan
Faculty of Earth Resources
Wuhan, Hubei, 430074
China People Republic of
Telephone: +862767885996
Cell phone: +8613026130944
Email: **mutima_juve@yahoo.fr**

Gabriel Habiyaremye
China University of Geosciences
Institute of Ecology and Environmental Science
388 Lumo Road
Hubei Wuhan
430074, P.R. China
Telephone: +862767885913
Email: **habygaby@gmail.com**

Jian Wei Li
China University of Geosciences Wuhan
Faculty of Earth Resources

Wuhan, Hubei, 430074

China People Republic of
Telephone: +862767883061
Email: **jwli@cug.edu.cn**

Pascal Nkurunziza
University of Burundi
Faculty of Earth Sciences
2700, Bujumbura
Burundi.
Telephone: +257 22 245336
Email: nkurupas2003@yahoo.fr

References

1. Bizimana., M. and Duchaufour, H.: A grainage basin management study. The case of Ntahangwa River basin. In: Cohen A.S. (ed.), Report of the First International Conference on Conservation and Biodiversity of Lake Tanganyika. Biodiversity Support Program, Washington, D.C, 1991, PP.43-45.

2. Brinckmann, J., Lehman, B. & Timm, F.: Proterozoic gold mineralization in NW- Burundi: Ore geology reviews, 1994, V.1, p 1-9.

3. Cohen A.S.: The impact of Sediments pollution on Biodiversity in Lake Tanganyika; 1991, p 667-677

4. Cohen A.S., Soreghan, M.J.and Scholz, C.A: Estimating the age of formation of lakes: An example from Lake Tanganyika, East African rift system, Geology, 1993, 21:511-514.

5. Cohen A.S., Kaufman L. and Ogutu Ohwayo R.: Anthropogenic threats, impacts and C conservation strategies in the African Great Lakes-A review, In: Johnson T.C. and Odada E.O. (eds),; The Limnology, Climatology and Paleoclimatology of the East African Lakes. Gordon and Breach. Publishers, Amsterdam, 1995, p 575- 624.

6. Cohen A.S.,: Paleolimnological investigations of Anthropogenic environmental change in Lake Tanganyika: An introduction to the project. Journal of Paleolimnology, 2005, 34: 1–18.

7. Coulter G.W.: Lake Tanganyika and its life: natural history Museum Publication, Oxford University Press, 1991, p 354.

8. Ntakimazi Gaspard, 1995 : Le rôle des Ecotones Terre/Eau dans la diversité et les ressources du lac Tanganyika: Projet renforcement des Capacité pour la mise en oeuvre de la SNPA- DB., 1995.

9. Patterson G. and Makin J. : L'état de la Biodiversité du Lac Tanganyika- un examen de la littérature. 1998, p 98.

10. Roest : Conservation et Biodiversité du lac Tanganyika. Bulletin, Centre technique de cooperation agricole et rurale, 1991, p. 112

11. Schoenbrun D.L..: A Green Place, A Good Place Agrarian Change, Gender and Social Identity in the Great LakesRegion to the 15th Century. Heinemann Publishers, Portsmouth. N.H, 1998, pp. 302

12. Thomas, S. & Martin, and H.Trauth: Geological Atlas of Africa.: ., 2008, pp.307

13. Villeneuve E, M. & Chorowicz, J**. :** Les sillons plissés du Burundien Supérieur dans la chaîne Kibarienne d'Afrique Centrale.C.R. Géosciences, 2004, 336, 807-814.

2009-10-26