A project funded by the United Nations Development Programme/Global Environment Facility (UNDP/GEF) and executed by the United Nations Office for Project Services (UNOPS)

# Pollution Special Study (PSS)

## ***Pesticide and heavy metals in fish and molluscs of Lake Tanganyika***

by
C. Foxall, F.Chale, A. Bailey-Watts
G. Patterson & K.West
2000

**Pollution Control and Other Measures to Protect Biodiversity in Lake Tanganyika (RAF/92/G32)**
**Lutte contre la pollution et autres mesures visant à protéger la biodiversité du Lac Tanganyika (RAF/92/G32)**

| | |
|---|---|
| Le Projet sur la diversité biologique du lac Tanganyika a été formulé pour aider les quatre Etats riverains (Burundi, Congo, Tanzanie et Zambie) à élaborer un système efficace et durable pour gérer et conserver la diversité biologique du lac Tanganyika dans un avenir prévisible. Il est financé par le GEF (Fonds pour l'environnement mondial) par le biais du Programme des Nations Unies pour le développement . | The Lake Tanganyika Biodiversity Project has been formulated to help the four riparian states (Burundi, Congo, Tanzania and Zambia) produce an effective and sustainable system for managing and conserving the biodiversity of Lake Tanganyika into the foreseeable future. It is funded by the Global Environmental Facility through the United Nations Development Programme. |

**Burundi: Institut National pour Environnement et Conservation de la Nature**
**D R Congo: Ministrie Environnement et Conservation de la Nature**
**Tanzania: Vice President's Office, Division of Environment**
**Zambia: Environmental Council of Zambia**

Enquiries about this publication, or requests for copies should be addressed to:

Project Field Co-ordinator
Lake Tanganyika Biodiversity Project
PO Box 5956
Dar es Salaam, Tanzania

UK Co-ordinator,
Lake Tanganyika Biodiversity Project
Natural Resources Institute
Central Avenue, Chatham, Kent, ME4 4TB, UK

# ***Pesticide and heavy metals in fish and molluscs of Lake Tanganyika***

## TABLE OF CONTENTS

# 1. GENERAL INTRODUCTION

In contrast to 30 years ago when Thorslund (1971) concluded that water pollution in African countries was not a serious problem - the situation has somewhat changed. The term 'somewhat' is used, as there is still dispute over whether Lake Tanganyika is polluted or even whether there are any real threats of pollution.

This reports considers the distribution of two key groups of pollutants, pesticides (Section 2) and heavy metals (Section 3). The report concentrates on the measurement of pollutants in the tissue of fish and molluscs for a number of reasons - particularly as tissue levels are likely to be elevated and therefore makes analysis both easier and somewhat more reliable (since the pollutant has by definition been mobilised into the biosphere). In addition the organisms analysed are also an important human food source and therefore the presence of pollutants in these organisms and therefore their consumption could form a threat to human health

Deelstra (1977a) considered that the pesticide residue levels that he measured in fish some 25 years ago, were well below the limits set in most African countries at that time. Indeed, he felt that those data would provide a useful benchmark with which future information could be compared and trends thus established. However, he (Deelstra, 1977b) suggests that the organochlorine levels in the fish tissues were higher in Lake Tanganyika than in other African waters. A new census of pesticide purchase and usage could give some indication of the trends, since Deelstra (1977a & 1997b) provides data for the period 1969-1972.

Levels of heavy metals measured in two species of fish *(Lates stappersi* and *Stolothrissa tanganyikae)* collected from the Burundi waters of the lake have been reported (Sindayigaya *et al.*, 1994) to be low and were considered by the authors to reflect natural background levels rather than pollution. Such concentrations may, however, not be representative of the levels in samples from other areas of the lake, or in other fish species.

The likely sources and fate of these two pollutants in Lake Tanganyika are:

- **pesticides** including chloro-hydrocarbons stemming from agricultural land including coffee and cotton-growing areas: residues of many of these compounds also accumulate progressively more acutely in sediments, in sediment-dwelling biota (especially molluscs) and the organisms including fish and birds at the top of the food chains (Mattheissen, 1977; Deelstra, Power and Kenner, 1976);

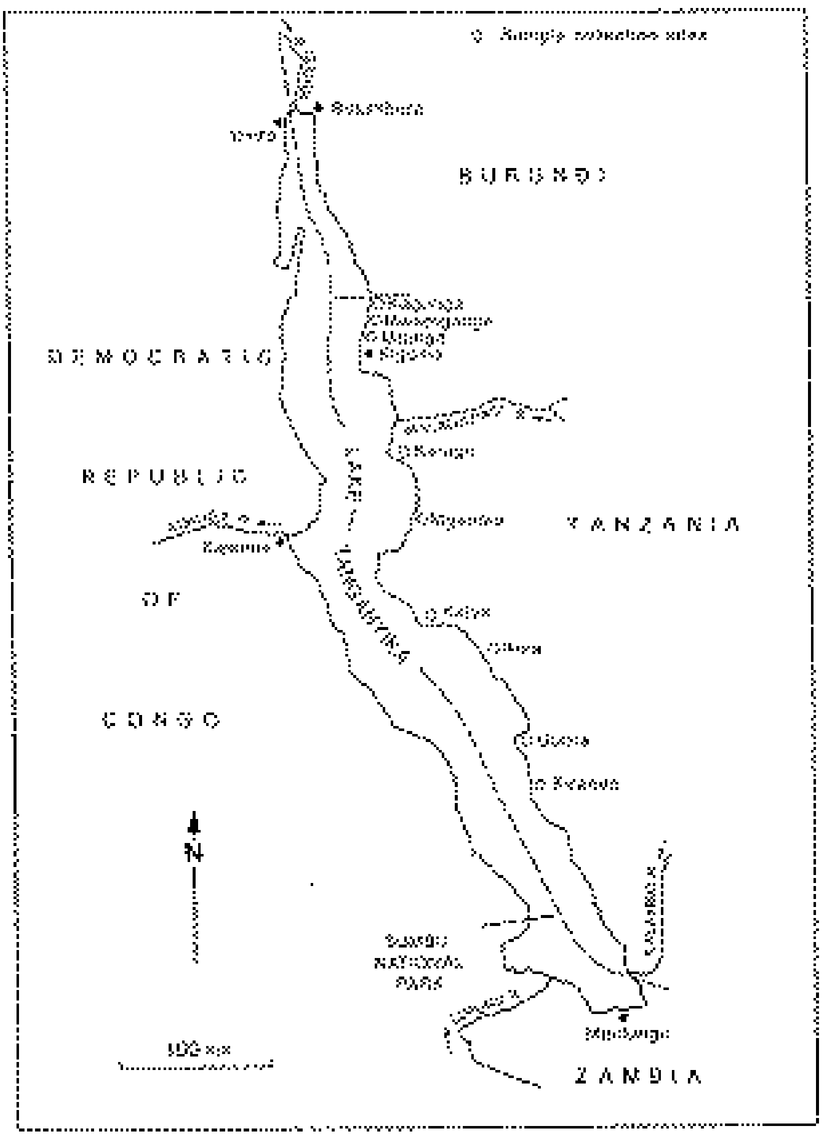
- **heavy metals** from mining and leather tanning industries, etc.; these are often of concern because a number of them accumulate in sediment (Degens and Kulbicki, 1973), fish food organisms, and thus fish tissue (FAO/SIDA, 1983; Maage *et al.*, 1994).

## 2. PESTICIDES

### 2.1 Introduction

This work represents the most wide-ranging survey of pesticides in fish and bivalves in Lake Tanganyika since the work of Deelstra and co-workers in 1976. A total of 24 samples of fish and bivalves were collected from various locations (see Figure 1) on the Tanzanian shoreline and analysed for a range of organochlorine pesticide residues. The fish samples were selected on the basis of their dietary and economic importance. Bivalves were included in the monitoring programme because their more sedentary behaviour can be expected to provide more localised pollution data.

**Figure 1 : Location of sample collection sites**



## 2.2 Assessment

The assessment focuses on the following:

- A comparison of residue concentrations in fish tissues from the present project with literature values from earlier work in Lake Tanganyika

- Pesticide residue levels in Lake Tanganyika compared to water bodies in Africa and elsewhere

- Possible trends within Lake Tanganyika

- Residue concentrations in bivalves from Lake Tanganyika

In assessing and comparing pesticide residue data, the multiplicity of factors controlling the uptake of pesticides into living tissues needs to be constantly borne in mind. Thus, for example, the organochlorine pesticides monitored in this programme are generally very fat-soluble and therefore tend to preferentially bioaccumulate in the parts of the organism with the highest fat content. The fat content and hence the pesticide loadings of an individual fish will in addition to the nature of its diet depend also on its age, sex, stage of sexual maturity etc. The results of such comparisons thus need to be treated with considerable caution, especially when the sample numbers are relatively small.

## 2.3 Comparison with previous work in Lake Tanganyika

Few data on pesticide residues in fish from the lake are available. As mentioned in the PSS baseline review, the principal source of data derives from the work of Deelstra et al in 1976. They analysed a range of fish species collected from various locations in Burundian waters. The results from the present study, which collected samples from Tanzanian waters, are compared with these earlier data in Table 1.

**Table 1: Mean concentrations (ug/kg dry mass) of pesticide residues in fish species from Lake Tanganyika**

| Species | Tissue/organ | Location | DDE | DDT |
|---|---|---|---|---|
| *Limnothrissa miodon*[1] | whole fish | Burundi | 620 | 193 |
| *Limnothrissa miodon*[2] | whole fish | Tanzania | 20 | 7 |
| *Stolothrissa tanganicae*[1] | whole fish | Burundi | 603 | 263 |
| *Stolothrissa tanganicae*[2] | whole fish | Tanzania | - | 3 |

Notes:
[1] Deelstra *et al.* (1976)
[2] present project

An examination of the above data shows that DDE (the breakdown product of DDT) and DDT concentrations recorded in the Burundi samples are substantially higher than the levels recorded in the same species from the present project. To our knowledge, no samples were taken from Tanzanian waters during the 1976 work. Similarly the present sampling programme was confined to Tanzanian waters. No contemporaneous comparisons of these results can therefore be made. It is distinctly possible however that the DDE and DDT concentrations in these species from Burundian waters may now be considerably lower than they were in 1976. Organochlorine pesticides have been used extensively on cotton crops such as those grown along the Burundi lakeshores. It might therefore be expected that DDE and DDT levels in fish tissues might be higher at the northern end of the lake rather than further south.

## 2.4 Comparison with other water bodies

In order to put the results from the current work in context, it is important to compare the residue concentrations with those from water bodies elsewhere. The extent to which this can be achieved are somewhat limited because the type of residues analysed varies widely and the results are often expressed in different units. Nevertheless a comparison of the present data with results from other relevant studies is given in Table 2.

**Table 2: Pesticide residues (ug/kg dry mass) in fish from Lake Tanganyika: a comparison with other studies**

| Species | Tissue | Location | DDE | Endosulphan | Dieldrin |
|---|---|---|---|---|---|
| *Lates stappersi* | muscle | Tanganyika | 6.2 | 90 | 17 |
| *Lates mariae* | muscle | Tanganyika | 6.0 | 7 | 9 |
| *Clarias mossambicus* | muscle | Hola, Kenya | - | 55 | - |
| *Tilapia sp.* | whole | Nyumba reservoir | 14 | - | 10 |
| *Tilapia nilotica* | muscle | L. Victoria | 49 | - | - |
| *Lates niloticus* | muscle | L. Victoria | 17 | - | - |
| *Sathoredon mossambicus* | muscle | L.Turkana | 5.5 | - | - |

Looking first at the DDE data it is clear that the residue concentrations from the fish collected from Lake Tanganyika are comparable to those from other African water bodies. No account is taken of the different species being compared and any consequent differences in diet or position in the food chain so such comparisons must be treated with caution. However the fish species listed are not grossly dissimilar in their behaviour and the similarity in residue concentrations between, for example, the DDE concentrations in Lake Turkana (a very remote lake in Kenya) and Lake Tanganyika suggests that the latter is also relatively free of contamination. The endosulphan and dieldrin concentrations in the samples from Tanganyika are also similar to those found in other studies. There is no evidence from this data to suggest that the fish in Lake Tanganyika have high pesticide residue levels or that concentrations are significantly different from other African water bodies.

## 2.5 Possible trends within Lake Tanganyika

The data reported by Dr Chale (unpublished) of LTBP were scrutinised in order to ascertain whether spatial variations in pesticide concentrations existed. Thus, for example, the DDE, endosulphan, lindane, heptachlor and dieldrin residue data for *Lates stappersi* collected from Karago, Mwamgongo, Mtanga and Utinta were examined. No correlation between location and residue concentrations could be found for this or any other species This is not unexpected, given the mobility of the fish species concerned and the relatively small sample size.

## 2.6 Residue concentrations in bivalves.

Owing to the small sample size and the lack of other comparable data in the literature it is difficult to comment on whether the concentrations in *Mutela spekei* (endosulphan 5.4, heptachlor 80 and dieldrin 4.0) are typical of residues in the bivalves of the lake. The levels found are comparable to the residues in fish tissues. This particular species of bivalve favour rocky shores and is therefore less exposed to the type of river borne sediments likely to contain pesticide residues.

## 2.7 Overall Conclusions - pesticides

The overall results would seem to indicate that Lake Tanganyika is relatively free from pesticide pollution at the present time. However in assessing the potential threat to biodiversity and to public health posed by such contaminants a number of points need to be emphasised.

- The present survey, although it makes a significant contribution to our knowledge of contaminant levels in the lake, is still relatively limited in its scope. No recent data are presently available on pesticide residues in fish from Zambia, Burundi or the DR Congo.

- Although of less commercial significance and dietary significance, few bivalve residue data are available. Bivalves are particularly useful as monitors of local contamination.

- Pesticides can have subtle effects on fish populations, which may not be immediately recognised by monitoring residue levels in adult fish. Thus certain pesticides, even at very low levels, can detrimentally effect breeding success by altering breeding displays and by reducing survival rate of fish fry.

It is therefore strongly recommended that the future management of the lake should include provision for a carefully designed and comprehensive pesticide-monitoring programme involving carefully selected species from the waters of all four countries. The residues analysed should reflect current pesticide use in the lake basin region.

# 3. HEAVY METALS

## 3.1 Introduction

Fish from Lake Tanganyika serve as a major source of protein for the population of the four surrounding countries: Burundi, Tanzania, DR Congo and Zambia. Fish can however accumulate significant amounts of heavy metals from both water and food and can thus be used to monitor the level of pollutants in lake waters. That fish represent an important component of the diet also raises concerns regarding potential health risks. The monitoring programme reviewed here was designed to provide up to date information on the levels of heavy metals in various fish and bivalve species so that that any threats posed to lake biodiversity and human health by these contaminants could be assessed, and so that any control measures deemed necessary could be included in the SAP.

## 3.2 Scope of Programme

The current programme represents the largest survey of heavy metals in fish and bivalves in lake Tanganyika since the work of Sindayigaya and his co-workers in 1994. In all over 1515 fish and 86 bivalve samples were collected from various locations (see Figure 1) on the Tanzanian shoreline. The fish species sampled were selected on the basis of their dietary and economic importance. Bivalves were included in the monitoring programme because their more sedentary nature and feeding habits can be expected to provide more localised data.

## 3.3 Assessment

The assessment focuses on the following:

- A comparison of metal concentrations in fish tissues from the present project with literature values from earlier work
- A comparison of metal concentrations in Lake Tanganyika with those from other African water bodies
- Possible trends in concentrations within Tanzanian waters
- Metal concentrations in bivalves from Tanzanian waters

Before commencing such an assessment, it needs to be stressed that because of the multiplicity of factors controlling metal uptake into living organisms, data comparisons between individual organisms, species, times and geographical areas are fraught with difficulties. The results of such comparisons thus need to be treated with caution.

### 3.4 Comparison with previous work in Lake Tanganyika

The main source of information on metal concentrations in fish from Lake Tanganyika derive from the work of Benemariya *et al.* (1991) and Sindayigaya *et al.* (1994) who analysed a range of fish species collected from the Burundi waters of the lake. The results from these two studies are compared with the data from the present project in Table 3. An examination of the Cu, Fe, Mn, Zn, Pb, and Cd data for *L. Stappersii* shows a very good agreement between the earlier results from Burundi and the more recent results from the present project. Although there is less opportunity for comparisons in the case of *Lates Marie* owing to the restricted range of elements analysed in the samples from Burundi, the results still appear to be in good agreement. Concentrations of Fe and Zn are clearly higher than the other elements measured, but this accords well with the literature and are not necessarily an indication of pollution by these two metals.

**Table 3. Mean concentrations ($\mu gg^{-1}$ dry mass) of heavy metals in fish species for Lake Tanganyika.**

| Species | Tissue/organ | Location | Cu | Fe | Mn | Zn | Pb | Cd |
|---|---|---|---|---|---|---|---|---|
| *Lates stappersi*[1] | Muscle | Tanzania | 3.4 | 33 | 0.6 | 18 | 5.0 | 0.23 |
| *Lates stappersi*[2] | Muscle | Burundi | 1.7 | 35 | 5.0 | 21 | 0.01 | 0.03 |
| *Lates stapersi*[3] | Muscle | Burundi | 1.7 | - | - | 15.5 | - | - |
| *Lates mariae*[1] | Muscle | Tanzania | 4.0 | 34 | 1.2 | 16 | 5.0 | 0.25 |
| *Lates mariae*[2] | Muscle | Burundi | 0.9 | - | - | 17 | - | - |
| *Stolothrissa tanganicae*[1] | Whole body | Tanzania | 5.9 | 169 | 12 | 133 | 5.0 | 0.39 |
| *Stolothrissa tanganicae*[2] | Whole body | Burundi | 3.2 | 134 | 17 | 200 | 0.04 | 0.27 |
| *Stolothrissa tanganicae*[3] | Whole body | Burundi | 5.5 | - | - | 147 | - | - |

[1] present project
[2] Sindayigaya *et al.* (1994)
[3] Benemariya *et al.* (1991)

The higher metal concentrations in *Stolothrissa tanganicae* ('dagaa') are probably due to the fact that the samples for analysis were prepared by grinding the whole fish. Generally speaking, metals tend to preferentially accumulate in liver and kidneys and in some species, the head, rather than in the muscle tissue. Once again, the agreement between the data from the previous work in Burundi and that from the present project is good.

### 3.5 Comparison with data from other water bodies

Metal concentrations in muscle tissue from the present project are compared with data from similar types of samples from other African water bodies in Table 4. An examination of the data indicates that the current results are broadly comparable to the concentrations found in fish samples from other parts of the continent and on the basis of the presently available data there is no evidence that the fish of Lake Tanganyika contain unacceptably high levels of metal contaminants.

**Table 4. Mean concentrations (μgg$^{-1}$ dry mass) of heavy metals in fish species: a comparison of data from Lake Tanganyika with literature values for other African water bodies.**

| Species | Tissue/organ | Location | Cu | Fe | Mn | Zn | Pb | Cd |
|---|---|---|---|---|---|---|---|---|
| *Lates stappersi*[1] | Muscle | L. Tanganyika | 3.4 | 33 | 0.6 | 18 | 5.0 | 0.23 |
| *Composite sample*[2] | Muscle | Hartbeesport Dam, South Africa | 2.9 | - | 12 | 120 | 1.0 | 0.05 |
| *Composite sample*[2] | Muscle | Voëlvlei Dam, South Africa | 3.8 | - | 9.2 | 55 | <0.1 | 0.06 |
| *Tilapia niloticus*[3] | Muscle | River Nile, Egypt | - | - | - | - | 0.42 | 0.02 |

Notes:

[1] present project
[2] Greichus *et al.* (1977). Composite sample of two species: *Leponis machrochirus* and *Micropterus salmoides.*
[3] El Nabauri *et al.* (1987).

## 3.6 Spatial variation within Tanzanian waters

Metal concentrations in fish samples (*Lates stappersi*) from six sampling locations in Tanzanian waters are listed together with data from the same species from Burundi waters are listed in Table 5. As can be seen from Figure 1, the locations are listed in a north to south sequence. No spatial trends in the data are discernible nor is there any evidence that any particular location has higher concentration levels than others. As this particular species is a deep water fish throughout its life and is thought to migrate widely throughout the lake, this result is not unexpected.

**Table 5. Mean concentrations (μgg$^{-1}$ dry mass) of heavy metals in muscle tissue of *Lates stappersi* collected from various locations on Lake Tanganyika.**

| Location | Cu | Fe | Mn | Zn | Pb | Cd |
|---|---|---|---|---|---|---|
| **Burundi waters** | 1.7 | 35 | 5 | 21 | 0.01 | 0.30 |
| **Tanzania waters**[1] | | | | | | |
| *Kagunga* | 4.1 | 38 | 0.8 | - | 0.5 | 0.30 |
| *Mwamgongo* | 4.4 | 32 | 0.5 | 16 | 3.2 | 0.20 |
| *Mtango* | 5.4 | 23 | 0.3 | 18 | 0.8 | 0.20 |
| *Karago* | 2.1 | 38 | 0.7 | 19 | 13.0 | 0.25 |
| *Ikola* | 2.2 | 29 | 0.6 | 16 | 3.8 | 0.30 |
| *Utinta* | 1.8 | 36 | 0.7 | 17 | 4.6 | 0.30 |

Notes:
[1] See Figure 1 for locations listed

### 3.7 Metal concentrations in bivalves

Mean concentrations of metals in the endemic bivalve *Mutela spekei* collected from Kirando and Utinta in the Tanzanian waters of the lake are given in Table 6. This particular species favours rocky shores and is adapted to turbulent water. It is clear from the results obtained that concentrations of iron and manganese are significantly higher than the other metals. That the concentrations of cadmium, lead , copper etc are low in comparison strongly suggests that the source of the iron and manganese concentrations is geochemical in nature. Iron and manganese tend to be closely associated in tropical soils and sediments.

**Table 6. Mean concentrations ($\mu gg^{-1}$ dry mass) of heavy metals in bivalve samples of *Mutela spekei* collected from the Tanzanian waters of Lake Tanganyika.**

| Location | Cu | Fe | Mn | Zn | Pb | Cd |
|---|---|---|---|---|---|---|
| *Tanzania* | | | | | | |
| *Kirando* | 4.5 | 12980 | 7890 | 76 | 8.4 | 0.50 |
| *Utinta* | 2.1 | 9170 | 5200 | 72 | 4.8 | 0.36 |

Notes:
[1] See Figure 1 for locations listed

### 3.8 Overall conclusions - heavy metals

On the basis of the work reported in 1994 by Sindayigaya et al. (1994), the authors concluded that, as far as potential contaminants such as copper, iron, manganese, zinc, lead and cadmium were concerned, Lake Tanganyika could still be considered as a non-polluted area. The present data provides no justification for significantly changing that assessment. There is, at present, no indication that levels are high enough to cause morbidity or mortality amongst the fish themselves or to pose threats to human health following consumption.

However, as has been emphasised earlier in this assessment, the uptake of metals into fish tissues depends on a large number of factors and unless these are adequately taken into account , it is possible that subtle increases in pollutant concentrations may go unnoticed. It is therefore recommended that management plans for the lake include regular monitoring of metals in fish and bivalve tissues. Particular emphasis should continue to be placed on species of commercial and dietary importance and those species such as bivalves that can be used to monitor local contamination in areas of the lake potentially subject to industrial pollution.

## 4. REFERENCES


Benemariya H., Robberecht H. and Deelstra H. 1991. Atomic absorption spectrometric determination of zinc, copper and selenium in fish from Lake Tanganyika, Burundi, Africa. Sci. Total Environ., 105:73-85.

Deelstra H. 1977a. Danger de pollution dans le Lac Tanganyika. *Bulletin de la Société belge des Etudes Géographiques,* 46: 23-35.

Deelstra H. 1977b. Organochlorine insecticide levels in various fish species in Lake Tanganyika. *Med. Fac. Landbouww. Rijksuniv. Gent.,* 42: 869-882.

Deelstra H., Power J. L. and Kenner C. T. 1976. Chlorinated hydrocarbon residues in the fish of Lake Tanganyika. *Bulletin of Environmental Contamination and Toxicology,* 15: 689 698.

Degens E. T. and Kulbicki G. 1973a. Data file on metal distribution in East African rift sediments. *Woods Hole Oceanographic Institution Technical Report,* 73-15: 1-280.

El-Nabawi A., Heinzow B and Kruse H. 1987. As, Cd, Cu, PB, Hg, and Zn in fish from the Alexandria region, Egypt. Bull. Environ. Contam. Toxicol., 889-897.

FAO/SIDA. 1983. Manual of methods in aquatic environmental research. Part 9. Analyses of metals and organochlorines in fish. Rome: *FAO Fish. Tech. Pap.,* 212: 1-33.

Greichus Y. A., Greichus A., Amman B.A., Call D.J., Hamman C.D. and Potts R.M. 1977. Insecticides, polychlorinated biphenyls and metals in African lake ecosystems. I: Haartbeenspoort Dam, Transvaal and Voelvlei Dam, Cape province, Republic of South Africa. Arch. Contam. Toxicol., 6:371-383.

Sindayigaya E., van Cauwenbergh R., Robberecht H. and Deelstra H. 1994. Copper, zinc, manganese, iron, lead, cadmium, mercury and arsenic in fish from Lake Tanganyika, Burundi. Sci. Total. Environ., 144, 103-115.

Thorslund A. E. 1971. Report on survey of inland water pollution in Uganda, Kenya, Zambia and Tanzania. FAO Regular Programme Report, 11. FAO, Rome.

Maage A., Eckhoff K. and Kjellevold M. 1994. Fluorine, iodine, iron, zinc and selected fatty acid profiles in fish and staple food from East Africa. Bergen, Norway: Institute of Nutrition, Directorate of Fisheries; *FAO project GCP/INT/467/NOR, Fish in Nutrition*, l-l0, 4 Tables.

Matthiessen P. 1977. A visit to Tanzania with reference to the problem of pesticide run off into Lake Tanganyika. *London, Centre for Overseas Pest Research,* 9p. (mimeo). *Limnologie,* 22: 2662.