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Seasonal Variability of Heavy Metals Concentration in Fish Species Organs from Upper River Benue, Yola- Adamawa State

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Abstract

Seasonal Variability of Heavy metal in Fish species organs in Upper River in Yola Adamawa State was investigated from May 2018 to April 2019. Fish species of commercial importance (*Auchenoglanis occidentalis, Oreochromis niloticus* and *Clarias gariepinus*) were sampled monthly in triplicate for the twelve months. The entire fish samples (*Auchenoglanis occidentalis, Oreochromis niloticus and Clarias gariepinus)* were separated and scales were removed (for those with scales) and washed with running water before dissecting with sterile scissors to remove gills, livers and muscles. Wet digestion technique was used as described by AOAC (2002). Seasonal variability of Heavy metals in fish species Organs were determined by comparing levels obtained in Wet season with the level obtained in Dry season. Data obtained in this study were subjected to descriptive statistics to establish means, standard errors. One way analysis of variance (ANOVA) was used to determine the mean significant seasonal variation (at 0.05) of heavy metals in the fishes from the sampling stations using Statistical Package for Scientists and Engineers (Statistix 9.0). All the heavy metals investigated were present in fish organs except cadmium and chromium which were also below detection level. The mean values of heavy metals obtained in this study revealed that, metals accumulate more in the organs of fish species in dry season than in the wet season. The trend of the accumulation of metal in the study was Zn>Cu>Pb>Ni. The trend of the accumulation of metal in the organs of fish species in this study was liver>liver>flesh>liver of *C.gariepinue>C.gariepinue>O.niloticus> C.gariepinue* Heavy metals Cu, Ni, Pb and Zn recorded their highest values (1.27±0.18mg/kg, 0.31±0.13mg/kg, 0.94±0.05mg/kg and 1.64±0.14mg/kg) in dry season (April, March, December and January) respectively, when compared with wet season in fish of Upper River Benue

Keywords: Heavy metal, Upper Benue, *Auchenoglanis occidentalis, Oreochromis niloticus* and *Clarias gariepinus*

Introduction

Heavy metals belong to the group of elements whose hydro-geochemistry cycles have been greatly accelerated by man. The rapid industrialization, coupled with technological advances in agriculture, has introduced various pollutants (synthetic and organic) into the aquatic ecosystems, which serves as the ultimate sink for most metals (Ogbeibu and Ezeunara, 2002). Fish accumulate toxic chemicals such as heavy metals directly from water and diet, and contaminant residues may ultimately reach concentrations hundreds or thousands of times above those measured in the water, sediment and food (Osman *et al.,* 2007). Adeyeye *et al.* (1996) reported that the concentration of metals is a function of fish species as it accumulates more in some fish species than others. Most heavy metals have no beneficial functions to the body and can be highly toxic. If they enter into the body through inhalation, ingestion and skin they accumulate in the body tissue faster than the body's detoxification pathways can dispose of them (Ekpo *et al*., 2008). High concentration exposure is not necessary to produce a state of toxicity in the body tissue and, overtime, can reach toxic concentration at low levels (Prusty, 1994). Heavy metal toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs of the fish (Edward *et al*. 2016). Long-term exposure may result in slowly progressing physical, muscular, and neurological degenerative processes. The

bioaccumulation of heavy metals in living organisms and biomagnifications describes the processes and pathways of pollutants from one trophic level to another. Various species of fish are mostly used as bio-indicators of heavy metals contamination (Svobodovo *et al., 2004)*.

Upper Benue River receives a wide variety of waste from almost every significant human activity. These include mostly the dumping of domestic wastes, sewage and agricultural wastes. The wastes dumped on land are washed into the river through surface run off. Agricultural activity like farming in both wet and dry season also takes place in this area. Fertilizers, Pesticides and herbicides are extensively used in agricultural production to increase yield and also to control pests, diseases, weeds and other plant pathogens in an effort to reduce or eliminate yield losses and preserve high quality product. These wastes generated flows into the river and may contaminate the water with a variety of contaminants especially heavy metals. Such contaminations might accumulate in various organs of fishes; and such accumulation may affect humans and other species that depend on such fish as food. The presence of heavy metals in aquatic animals like fish is becoming a threat, thereby making them unfit for human consumption. In order to effectively control and manage these, it is imperative to have a clear variability of heavy metal concentration in fishes from Upper Benue River*;* hence the need for this research.

Materials and Methods

Study Area

Adamawa State is located at the North Eastern part of Nigeria. It lies between latitude 7° and 11° N of the equator and between longitude 11° and 14° E of the Greenwich meridian.

Duration of Sampling

The study was conducted for the period of twelve months (12). May 2018 to April 2019. The months of May to October constituted the wet season while the months of November to April constituted the dry season (Adebayo and Tukur 1999, UBRDA, 1985). Fish samples were collected monthly in triplicate for the twelve months.

Fish Sampling Protocol

Fish species of commercial importance (*Auchenoglanis occidentalis, Oreochromis niloticus* and *Clarias gariepinus*) were bought from fish mongers at the study sites. A random composite sampling technique was used without discrepancies for sexes in species. Fish sample was collected in triplicate. The fish samples were transported to the laboratory for Identification, measurement and dissection.

Fish Samples Digestion

The entire fish samples (*Auchenoglanis occidentalis, Oreochromis niloticus and Clarias gariepinus)* were separated. Scales were removed (for those with scales) and washed with running water before dissecting with sterile scissors to remove gills, livers and muscles. Wet digestion technique was used as described by AOAC (2002). The procedure of wet digestion was carried out by transferring 5.0g of gills, liver and muscles of the fish species into Kjeldah flask each and 25ml digestion acid (60% Perchloric acid and 71% nitric acid in the ratio 1:4) was added. The mixture were swirled and heated gently at first until frothing stopped. Thereafter the mixtures were heated until a clear light green solution was obtained. This was allowed to cool and filtered into a 100ml volumetric flask. All the digested liquors were filtered through Whatman 541 filter paper. Distilled water was then added to make up to the mark and ready for metal analysis.

Determination of Heavy Metal in Fish Species

Determination of Heavy metal like Cu, Cd, Cr, Ni, Pb and Zn were made directly on each final solution using a Buck Scientific 200A model, Atomic Absorption Spectrophotometer (AAS) and the values obtained were expressed in milligram per kilogram (kg). Procedural blanks were prepared and aspirated along with the analytical samples in order to correct for background absorption. The levels of heavy metals in muscles, gills and liver were evaluated by comparing the statistical mean levels of the metals in the flesh, gills and liver samples.

Data Analysis

Data obtained in this study were subjected to descriptive statistics to establish means, standard errors, one way analysis of variance (ANOVA) was used to determine the mean significant seasonal variation (at 0.05) of heavy metals in the fishes from the sampling stations using Statistical Package for Scientists and Engineers (Statistix 9.0).

Results

Heavy metal present in the different organs of the different fish species is presented on Tables 1-4. All the heavy metals investigated were present in fish organs except cadmium and chromium which were below detection level.

Table 1 shows the mean standard error and range of Copper present in the organs of *A. occidentalis, O. niloticus and C. gariepinus.* Copper recorded its highest value of 1.28±0.18mg/kg in the liver of *C. gariepinus* in April (dry season) while the lowest value 0.34±0.17mg/kg was recorded in the gills of *O. niloticus* in Julty (Wet season). There was significant difference in variability between season and fish species ($P<0.05$).

Table 2 shows the mean standard error and range of Nickel (Ni) present in the organs of *A. occidentalis, O. niloticus and C. gariepinus.* The highest Nickel(Ni) value of 0.31±0.18mg/kg was recorded in the flesh of *C. gariepinus* in the month of March (dry season) while the lowest value 0.03±0.04mg/kg was recorded in the liver of *O. niloticus* in July (Wet season). There was significant difference in variability between season and fish species ($P<0.05$).

Table 3 shows the mean standard error and range of Lead (Pb) present in the organs of *A. occidentalis, O niloticus and C. gariepinus.* Lead (Pb) recorded its highest value of 0.94±0.05mg/kg in the liver of *O. niloticus* in December (dry season) while the lowest value 0.01±0.12 was recorded in the gills of *A. occidentalis,* gills and flesh of *C. gariepinus* in July,June (Wet season). There was significant difference in variability between season and fish species ($P<0.05$).

Table 4 shows the mean standard error and range of Zinc (Zn) present in the organs of *A. occidentalis, O. niloticus and C. gariepinus.* The highest Zinc (Zn) value of 1.64±0.14mg/kg was recorded in the liver of *C. gariepinus* in the month of January (dry season) while the lowest Zinc(Zn) value 0.21±0.13 was recorded in the gills and flesh of *A. occidentalis* ,and flesh of *C. gariepinus* in the month of July,June (Wet season). There was significant difference in variability between season and fish species ($P<0.05$).

Table 1: Mean Seasonal Variation of Copper in the Organs of Fish from Upper Benue River

fish species	*A. occidentalis*			*C. gariepinus*			*O. niloticus*		
Wet Season									
Months	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
May	0.46±0.10	0.42±0.81	0.80±0.19	0.54±1.63	0.81±0.18	0.51±0.19	0.50±0.15	0.68±0.17	0.41±0.91
Jun	0.50±0.15	0.59±0.61	0.81±0.14	0.56±1.73	0.44±0.10	0.53±0.12	0.36±0.13	0.62±0.13	0.48±0.14
Jul	0.53±0.19	0.58±0.10	0.73±0.13	0.65±1.63	0.73±0.14	0.54±0.70	0.34±0.17	0.50±0.44	0.44±0.71
Aug	0.39±0.23	0.47±0.14	0.73±0.19	0.53±1.73	0.70±0.17	0.57±0.90	0.56±0.18	0.44±0.15	0.43±0.18
Sep	0.51±0.13	0.61±0.81	0.85±0.05	0.62±1.63	0.75±0.15	0.60±0.15	0.53±0.14	0.57±0.19	0.57±0.81
Oct	0.56±0.5	0.63±0.17	0.76±0.17	0.50±1.93	0.60±0.18	0.40±0.12	0.54±0.12	0.73±0.10	0.58±0.18
Dry Season									
Nov	0.41±0.83	0.44±0.91	0.68±0.18	0.61±1.69	0.72±0.18	0.75±0.19	0.39±0.17	0.60±0.19	0.34±0.10
Dec	0.55±0.03	0.52±0.16	0.94±0.10	0.55±1.64	0.59±0.13	0.78±0.14	0.49±0.15	0.67±0.11	0.56±0.12
Jan	0.44±0.17	0.37±0.13	1.24±0.14	0.50±1.62	0.94±0.18	0.75±0.12	0.49±0.19	0.68±0.18	0.37±0.15
Feb	0.62±0.14	0.51±0.12	0.66±0.12	0.52±1.65	0.58±0.19	0.40±0.16	0.46±0.13	0.48±0.14	0.58±0.16
Mar	0.67±0.11	0.42±0.16	0.37±0.11	0.64±1.63	1.27±0.10	0.46±0.12	0.68±0.11	0.60±0.15	0.43±0.19
Apr	0.58±0.13	0.57±0.11	0.66±0.19	0.72±1.63	1.28±0.18	0.40±0.10	0.56±0.12	0.65±0.14	0.55±0.11
Mean	0.55	0.47	0.76	0.59	0.89	0.59	0.51	0.61	0.46

P<0.05=There was significant difference, P>0.05= There was no significant difference

Table 2: Mean Seasonal Variation of Nickel in the Organs of fish from Upper Benue River.

fish species	*A. occidentalis*			*C.gariepinus*			*O. niloticus*		
Wet Season									
Months	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
May	0.07±0.82	0.06±0.51	0.06±0.03	0.06±0.02	0.08±0.09	0.16±0.17	0.12±0.08	0.05±0.03	0.27±2.22
Jun	0.06±0.06	0.05±0.08	0.05±0.09	0.06±0.06	0.05±0.03	0.19±0.11	0.07±0.09	0.09±0.02	0.22±2.48
Jul	0.07±0.04	0.06±0.44	0.06±0.09	0.07±0.07	0.06±0.07	0.25±0.19	0.09±0.02	0.03±0.04	0.20±2.12
Aug	0.06±0.62	0.06±0.03	0.05±0.02	0.06±0.02	0.08±0.09	0.21±0.17	0.08±0.08	0.07±0.09	0.24±2.82
Sep	0.05±0.72	0.05±0.73	0.05±0.08	0.06±0.01	0.06±0.05	0.19±0.13	0.09±0.09	0.07±0.08	0.20±2.32
Oct	0.05±0.09	0.07±0.71	0.05±0.06	0.08±0.09	0.05±0.03	0.18±0.16	0.09±0.03	0.04±0.04	0.24 ±2.42
Dry Season									
Nov	0.03±0.27	0.06±0.01	0.01±0.72	0.09±0.08	0.05±0.83	0.09±0.63	0.08±0.33	0.04±0.09	0.26±2.22
Dec	0.03±0.22	0.05±0.21	0.04±0.06	0.08±0.04	0.06±0.09	0.13±0.33	0.07±0.13	0.03±0.08	0.26±2.432
Jan	0.04±0.08	0.04±0.31	0.03±0.09	0.07±0.07	0.08±0.01	0.13±0.16	0.08±0.08	0.06±0.04	0.27±2.46
Feb	0.02±0.09	0.09±0.40	0.06±0.02	0.07±0.04	0.09±0.09	0.30±0.12	0.07±0.07	0.07±0.02	0.13±2.47
Mar	0.07±0.12	0.07±0.09	0.07±0.04	0.08±0.05	0.07±0.01	0.31±0.13	0.07±0.02	0.08±0.03	0.20±2.42
Apr	0.08±0.05	0.07±0.07	0.08±0.02	0.06±0.02	0.07±0.03	0.30±0.19	0.03±0.03	0.09±0.09	0.29±2.45
Mean	0.05	0.06	0.05	0.08	0.08	0.21	0.07	0.06	0.24

P<0.05=There was significant difference, P>0.05= There was no significant difference

Table 3: Mean Seasonal Variation of Lead in the Organs of fish from Upper Benue River.

fish species	*A. occidentalis*			*C.gariepinus*			*O. niloticus*		
Wet Season									
Months	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
May	0.07±0.13	0.01±0.19	0.11±0.17	0.01±1.74	0.06±0.04	0.02±0.02	0.07±0.26	0.24±0.09	0.03±0.10
Jun	0.13±0.16	0.34±0.16	0.14±0.12	0.01±1.28	0.16±0.02	0.07±0.01	0.05±0.26	0.74±0.05	0.16±0.14
Jul	0.07±0.17	0.01±0.12	0.04±0.13	0.07±1.12	0.10±0.02	0.01±0.02	0.08±0.26	0.30±0.01	0.06±0.12
Aug	0.06±0.12	0.07±0.14	0.02±0.14	0.05±1.95	0.04±0.11	0.06±0.07	0.11±0.26	0.26±0.04	0.11±0.14
Sep	0.05±0.10	0.04±0.11	0.02±0.15	0.06±1.32	0.03±0.17	0.06±0.03	0.12±0.26	0.18±0.06	0.08±0.16
Oct	0.06±0.17	0.03±0.10	0.03±0.12	0.11±1.89	0.04±0.02	0.08±0.04	0.11±0.26	0.16±0.08	0.17±0.13
Dry Season									
Nov	0.07±0.13	0.01±0.19	0.11±0.17	0.01±1.74	0.06±0.04	0.02±0.02	0.07±0.26	0.24±0.09	0.03±0.10
Dec	0.13±0.16	0.34±0.16	0.14±0.12	0.01±1.28	0.16±0.02	0.07±0.01	0.05±0.26	0.94±0.05	0.16±0.14
Jan	0.07±0.17	0.01±0.12	0.04±0.13	0.07±1.12	0.10±0.02	0.01±0.02	0.08±0.26	0.94±0.01	0.06±0.12
Feb	0.06±0.12	0.07±0.14	0.02±0.14	0.05±1.95	0.04±0.11	0.06±0.07	0.11±0.26	0.26±0.04	0.11±0.14
Mar	0.05±0.10	0.04±0.11	0.02±0.15	0.06±1.32	0.03±0.17	0.06±0.03	0.12±0.26	0.18±0.06	0.08±0.16
Apr	0.06±0.17	0.03±0.10	0.03±0.12	0.11±1.89	0.04±0.02	0.08±0.04	0.11±0.26	0.16±0.08	0.17±0.13
Mean	0.07	0.08	0.06	0.05	0.07	0.05	0.09	0.25	0.10

P<0.05=There was significant difference, P>0.05= There was no significant difference

Table 4: Seasonal Variability of Zinc in the Organs of Fish from Upper Benue River

fish species	*A.occidentalis*			*C.gariepinus*			*O. niloticus*		
Wet Season									
Months	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
May	0.27±0.19	0.23±0.12	0.31±0.08	0.41±0.15	0.76±0.12	0.35±0.13	0.61±0.13	0.71±3.52	0.34±0.17
Jun	0.21±0.13	0.24±0.17	0.23±0.03	0.56±0.19	0.38±0.17	0.21±0.12	0.25±0.16	0.68±3.59	0.27±0.13
Jul	0.27±0.15	0.25±0.14	0.21±0.02	0.52±0.12	0.43±0.19	0.23±0.18	0.33±0.12	0.67±3.51	0.33±0.18
Aug	0.31±0.14	0.29±0.19	0.24±0.09	0.52±0.19	0.44±0.12	0.33±0.17	0.45±0.13	0.64±3.59	0.34±0.19
Sep	0.48±0.19	0.45±0.12	0.43±0.01	0.66±0.14	0.62±0.15	0.52±0.15	0.52±0.16	0.69±3.53	0.50±0.14
Oct	0.42±0.16	0.47±0.10	0.46±0.09	0.61±0.11	0.52±0.19	0.56±0.16	0.66±0.12	0.54±3.57	0.49±0.10
Dry Season									
Nov	0.40±0.12	0.30±0.16	0.40±0.07	0.99±0.13	0.99±0.17	0.44±0.14	0.68±0.15	0.68±3.54	0.34±0.12
Dec	0.57±0.16	0.73±0.17	0.30±0.03	0.71±0.18	0.85±0.12	0.43±0.21	0.45±0.18	0.48±3.52	0.27±0.18
Jan	0.31±0.19	0.34±0.13	0.40±0.02	0.58±0.19	1.64±0.14	0.31±0.15	0.52±0.13	0.40±3.58	0.33±0.15
Feb	0.41±0.13	0.40±0.12	0.53±0.09	0.24±0.14	0.74±0.16	0.51±0.12	0.73±0.12	0.67±3.53	0.34±0.13
Mar	0.44±0.12	0.51±0.18	0.44±0.04	0.18±0.12	1.27±0.12	0.38±0.16	0.74±0.18	0.76±3.59	0.50±0.12
Apr	0.52±0.16	0.48±0.10	0.52±0.02	0.23±0.13	0.69±0.11	0.49±0.15	0.56±0.12	0.63±3.27	0.49±0.11
Mean	0.44	0.46	0.43	0.49	1.03	0.43	0.61	0.60	0.44

P<0.05=There was significant difference, P>0.05= There was no significant difference

Discussion

The result of this study showed a significant variability in the accumulation of heavy metals in the different organs of fish species. The mean values of heavy metals obtained in this study revealed that, metals accumulate more in the organs of fish species in dry season than in the wet season (Edward *et al* 2016). The trend of the accumulation of metal in the study was Zn>Cu>Pb>Ni. The trend of the accumulation of metal in the organs of fish species in this study was liver>liver>flesh>liver of *C.gariepinue* > *C.gariepinue*>*O. niloticus*> *C.gariepinue*. The variation in metal concentration in the fish organs was due to different sources of metal pollution, intensive human activities and discharge of municipal waste. Generally, heavy metal concentrations in the tissue of freshwater fish vary considerably among different studies (Chattopadhyay *et al*., 2002, Papagiannis *et al*., 2004), possibly due to differences in metal concentrations and chemical characteristics of water from which fish were sampled, ecological needs, metabolism and feeding patterns of fish and also the season in which studies were carried out. In the present study, cadmium and chromium were below detection level in fish organs. This is true according to the report of some researchers who reported that, multiple factors including season, physical and chemical properties of water can play a significant role in metal accumulation in different fish organs (Hayat *et al.,* 2007). Obasohan and Eguavoen (2008) also stated that dry season affects the accumulation of heavy metals in water, sediments and its reared fish. All the mean values obtained in wet and dry seasons in this study were within the allowable limits for fish food except lead.

Conclusion

The values obtained in this study revealed that, metals accumulate more in the tissues of fish organs in dry season than in the wet season. Generally, the dry season recorded higher heavy metals than the wet season. The values obtained in this study revealed that, metals accumulate more in the tissues of fish organs in dry season than in the wet season. Generally, the dry season recorded higher heavy metals than the wet season. From the above findings therefore, Upper Benue River fish species investigated are said to be moderately polluted with these heavy metals especially in the dry season. Lead is the common heavy metal in fish which was present and above recommended permissible limits.

References

Adebayo A.A. and Tukur, A.L. (1999). *Adamawa in Maps*. First edition Paraclete publishers, Yola-Nigeria.Pp10-30.

Adeyeye, E.I., Akinyugha, R.J., Febosi, M.E., and Tenabe, V.O. (1996). Determination of some metals in *Clariasgariepinus* (Cuvier and Valenciemes), *Cyprinuscarpio* (L) and *Oreochromisniloticus* (L) fishes in a polyculture fresh water pond and their environment. *Aqua cut*. 47, 205-214.

AOAC (2002). *Official Methods of Analysis*: Association of Official Analytical Chemist. 17th Edition: Washington D C. Pp 43-51.

Chattopadhyay, B., Chatterjee, A. and Mukhopadhyay, S.K. (2002). Bioaccumulation of metals in the East Calcutta wetland ecosystem. *Aquatic Ecosystem and Health management.*5:191-203.

Edward, A., Abubakar, A. K., Ladu, B.M. B. (2016). Evaluation of heavy metals concentrations in water and sediment from Upper River Benue, Yola, Adamawa State, Nigeria. *Proceedings of the 31st Annual Conference of Fisheries Society of Nigeria* (FISON) held on 30th Oct-4th Nov at Umar Musa Yar'adua University, Katsina, Nigeria.Pp 109-110

Ekpo, K.E., Asia, I.O., Amayo, K.O. and Jegede, D.A. (2008). Determination of Cadmium, Lead and Mercury in surrounding waters and organs of some species of fishes Kpoba River in Benin City, Nigeria. *Inernational. Jounal. Physical Science* 3:289-292.

Hayat, S., Javed, M. and Razzhaq, S. (2007): "Growth performance of metal stressed Major carps Viz. *Catla Catla, Labeo Rohita* and *Cirrhina mrigala* Reared under semi-intensive culture system," *Pakistan Veterinary Journal*. Vol. 27, No. 1, pp. 8-12.

Obasohan EE, Eguaveon OI (2008) Seasonal Variations of Bioaccumulation of heavy metals in a freshwater fish (Erpetoichthys calabaricus) from Ogba River,Benin City,

Nigeria African Journal General Agric 4: 153- 163.

Ogbeibu, A.E. &P.U. Ezeunara. 2002. Ecological Impact of brewery Effluent on Ikpoda River using the fish communities as bio indicators. *Journal of Aguaculture Research 17: 35-44.*

Osman, A., Wuertz, S., Mekkawy, I., Exner, H, And Kirschbaum, F. (2007).“Lead Induced Malformations in Embryos of the African Catfish *Clarias Gariepinus* (Burchell, 1822), *Environmental Toxicology*, Vol. 22, No. 4, Pp. 375-389.

Papagiannis, I., Kagalou, J.Leonardos, D. Petridis and V. Kalfokaou. (2004). Copper and Zinc in four Freshwater Fish Species from Lake Pamvotis (Greece). *Environmental Int*. 30: 357-362.

Prusty, A.W. (1994). *The use of fish in monitoring water pollution*, Tour Biotech. P. 4-7.

Svobodova, Z. Celechovska, O.Kolara. J. Randak, T. and V. Zlabek, (2004) “Assessment of Metal Contamination in the Upper Reaches of the TichaOrlice River,” *Czech Journal of Animal Science*, Vol. 49, No. 4, 2004, Pp.458-641.

Upper Benue River Basin Development Authority (UBRBDA) (1985). Pp 123-154.