Seasonal and Spatial Variations in Water Quality and Its Ecological Implications on Challawa River, Nigeria

*[1]A.H. Kawo, [1]B.A. Abdullahi, [2] M.Y. Saminu, [2]S.K. AbdulHadi and [2]A.G. Sha'aya'u
[1]Department of Biological Sciences, Bayero University, PMB 3011, Kano, NIGERIA
[2]Pollution Control Laboratory Ministry of Environment, Kano State, NIGERIA
[Corresponding Author: ahkawo@yahoo.com]

ABSTRACT: The water quality of Challawa River, Kano, Nigeria at three sites was investigated for a period of eighteen months (January, 2005 - June, 2006). Results obtained showed some degree of variations along the river course. The pH, colour, temperature, bicarbonate and turbidity values increased from sample site I (upstream), through site III (downstream) of the river. Levels of dissolved oxygen and phosphate decreased down the stream while biochemical oxygen demand, chemical oxygen demand, electrolytic conductivity, nitrate and sulphate fluctuated between sites. Significant differences ($P < 0.05$) between both sites and seasons for colour, pH, temperature, electrolytic conductivity, bicarbonate and sulphate exist while no significant difference ($P > 0.05$) was observed on both sites and seasons for turbidity, nitrate and phosphate. However, dissolved oxygen, biochemical oxygen demand and chemical oxygen demand were significantly different ($P < 0.05$) only between seasons. The implications of the results were discussed.
Keywords: Physico-chemical quality, seasonal, spatial, variation, Challawa River, Kano.

INTRODUCTION

Water quality assessment remains a useful tool for pollution control and assessment, development of fishery resources, planning of water resource control and management as well as control of disease vectors. Increasing industrialization and urbanization has led to a wide-scale contamination of Nigeria's surface waters from industrial effluents, domestic sewage discharges and excessive usage of fertilizers and pesticides (Ajayi and Osibanjo, 1981; Egborge and Benka-Coker, 1986; Victor and Ogbeibu, 1985; 1986; 1991; Benka-Coker and Ojior, 1995; Ademoroti, 1996; 2003; Moussa and Kawo, 2005). The Challawa River, is the second largest river after Kano River in Kano State. It meets the Kano River at Tamburawa, some twenty kilometers from Kano town and flows to the northeast and joined River Hadejia. It serves as the major source of drinking water for the Kano metropolis and its neighbouring communities. It is subjected to effluent discharges from industries sited along its bank. Sewage and municipal waste input, surface runoffs and soil erosion may also contribute to pollution of the river along its course. Along the bank of the river are confectioneries, pharmaceutical industries, rubber, leather and food processing factories as well as small agro-allied industries such as soap manufacturing firms and slaughterhouse. Untreated wastewaters from these industries are often discharged into the river leading to high biochemical oxygen demand, nitrate, phosphate and lowered dissolved oxygen contents (Ahmed and Tanko, 1994; Mukhtar and Deeni, 1995; Bashir *et al*., 2002; Ibrahim, 2003; Bashir and Kawo, 2004). Human settlements, such as Panshekara, Zawachiki, Challawa, Yandanko, Kumbotso and Tamburawa, are found along the river bank, which has encouraged the communities to farm. During heavy rains, the farmlands are flooded, resulting in the washing of plant debris, pesticide and fertilizer residues into the water body. Nutrients, such as phosphates and nitrates, which are constituents of many fertilizers, usually increase algal growth, leading to eutrophication (Alabaster and Lloyd, 1980; Moss, 1980; Welch, 1980). In addition, according to Bashir *et al* (2002), Bashir and Kawo (2004) as well as Kawo *et al*. (2006), industrial and domestic wastes could add large amounts of organic and inorganic substances into aquatic systems, which increase the turbidity. It has been reported that small amounts of suspended matter on spawning sites may affect the life history of fishes (Adikwu and Zaki, 1999; Haruna and Abdullahi, 1999). High concentrations of suspended solids reduce transparency and photosynthesis and may clog the gill of fishes. It also lowers the temperature of surface waters (Egborge, 1981). In addition, physico-chemical factors such as dissolved oxygen, biochemical oxygen demand, salinity, pH and conductivity have been associated with water pollution (Brown *et al.*, 1967; Moss, 1980). Water pollution by industrial and domestic wastes as well as surface runoffs has become a threat to the continued existence of plants and animals, and may ultimately threaten the quality of human life. This is what substantiates the need for the study of the physico-chemical qualities of Challawa river water so as to ascertain its suitability for human and other animal use. The present work reports the physico-chemical quality of the river water and its ecological implications.

MATERIALS AND METHODS

Sample collection and analysis

The samples were collected and handled in accordance with the method of APHA (1998). Raw river water and wastewater effluent samples for the analyses were collected from three different sites fortnightly for a period of eighteen months (January, 2005 - June, 2006). The samples were collected from Yandanko village (representing agricultural and domestic effluents) while the industrial effluents were collected from Challawa Industrial Estate, Phase III and Challawa river at the largest water intake point for the Challawa waterworks. The sample collection sites were designated as follows (Figure 1):

Site I - Agricultural and domestic wastewater effluents

Site II - Challawa river water

Site III - Industrial wastewater effluents

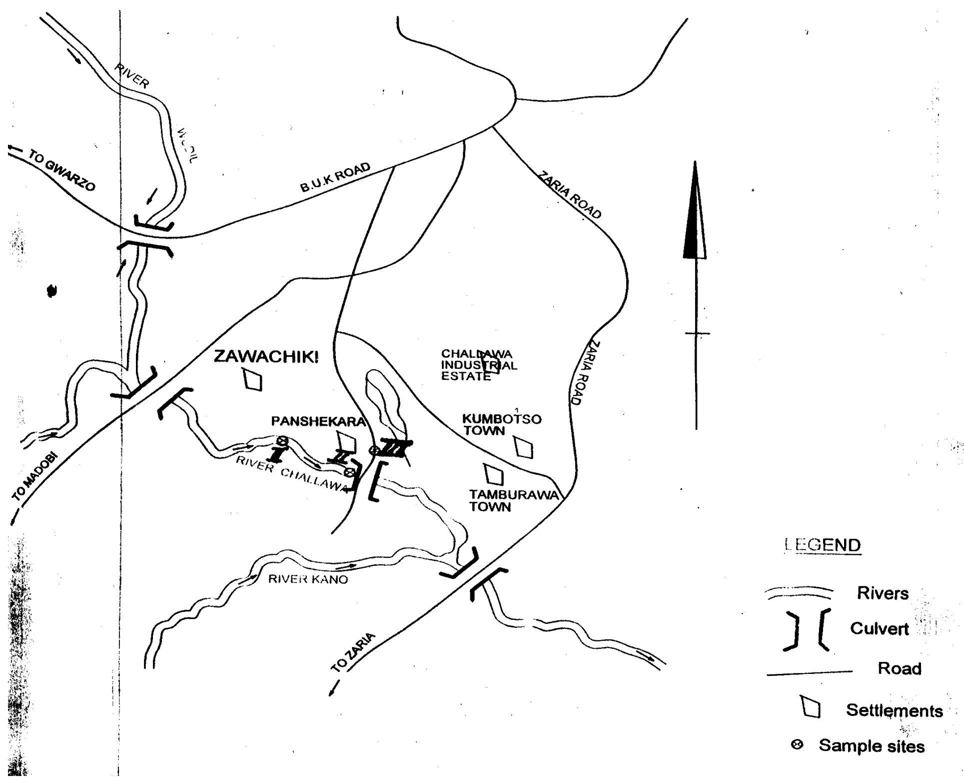

Figure 1: Map of Challawa River showing sample collection sites

Samples were collected from each sampling site twice a month in all-plastic, 5-liter capacity bottles acidified with 1% HNO_3. The samples were collected in the morning (7-8 am) by dipping the bottles sliding over the surface of the running water with mouth against the water current as described by Clymo *et al* (1978). All chemicals used were of analytical grade (BDH

Chemicals Ltd, Poole, England). Analyses of the samples were carried out within four days of collection. De-ionized water was used for control treatments. All analyses were replicated for quality assurance of the data and mean results were recorded and expressed in standard units. All pH and temperature measurements were carried out at the point of sample collection using a portable digital pH-thermometer (Jenway, UK). Dissolved oxygen and biochemical oxygen demand contents were determined using DO_2 meter (model 9071, UK). Electrolytic conductivity was measured using CO150 conductivity meter (model 50150, UK) while colour, COD, bicarbonate, turbidity, nitrate, phosphate and sulphate contents were determined using DR/20-10 model portable spectrophotometer. All analyses were replicated for quality assurance of the data and mean results were recorded and expressed in standard units.

Statistical analysis

Data collected were subjected to statistical analysis (Singha, 2002) using one-way ANOVA to test whether seasonal and spatial fluctuations had any significant effect on the physico-chemical qualities of the river water and wastewater effluents.

RESULTS AND DISCUSSION

Spatial and seasonal variations of some physical and chemical factors in Challawa River water and wastewater effluents are presented in Tables 1 and 2. Upstream-downstream variations were observed in pH, electrolytic conductivity, sulphate and turbidity. The fluctuations observed in turbidity and sulphate levels may be due to increased industrial and human activities, especially laundry, with progress downstream. The mean pH range (7.88 – 8.69) reveals the slightly basic (sites I and III) to near neutrality (site II) nature of the wastewater effluents and river water respectively. The fluctuations in the pH levels with increasing distance downstream may partly be due to dilution effect. On the other hand, the pH generally remained alkaline during the wet season, tending towards neutral during the dry season (Table 2). This could be attributed to the dilution by rain water influent as well as the removal of CO_2 by plants especially phytoplanktons for the purpose of photosynthesis. Ohmain and Benka-Coker (1997) reported that the WHO maximum permissible levels for turbidity and electrolytic conductivity for domestic and industrial waters as 500 mg/l and 1250 µs/cm respectively.

On the average, the values of turbidity within the sampled areas of the river fall within the acceptable limits for domestic and industrial purposes while those of electrolytic conductivity were far below the limits. Statistically, significant differences ($P < 0.05$) existed between both sites and seasons for pH, conductivity and sulphate except that for turbidity ($P > 0.05$). The storm water of Kano city is usually accompanied by refuse, mud and sand, which was diverted to the Challawa River. This could lead to an increased turbidity, conductivity and siltation. The situation could thus reduce transparency and photosynthesis and may clog the gill of fishes (Egborge, 1981; 1986). The fluctuations observed in turbidity levels may be due to increased industrial and human activities, especially laundry, with progress downstream.

Temperature situation remained favourable throughout the two seasons; it was generally low during the dry season and high during the rainy season (Table 2). However, the lowest and highest values recorded both in sites and seasons did not amount to the critical thermal minimum and maximum of 8ºC and 30ºC respectively (Haruna and Abdullahi, 1999). The river biocommunity could be affected interactively depending on the species type, stage of development, acclimation temperature, dissolved oxygen and level of pollution. Although slight differences were observed in temperature values between both sites and seasons, the differences were statistically significant ($P < 0.05$) between both the sites and seasons. The exceptionally high temperature generally recorded in site III (Tables 1 and 2) may be attributed to the chemical and hot water effluents discharged into the river from neighboring industries (William and Shaw, 1982).

Table 1: Physico-chemical parameters of Challawa river water and wastewater effluents

Parameter	Site I	Site II	Site III
Colour (Hazen)	73.2a	76.2b	95.6c
pH	8.31a	7.88b	8.69c
Temperature (°C)	26.6a	27.2b	28.5c
Dissolved oxygen (mg/l)	18.9a	10.2a	9.27a
Biochemical oxygen demand (mg/l)	7.54a	6.68a	7.04a
Chemical oxygen demand (mg/l)	1104.6a	1157.2a	477.1a
Electrolytic conductivity (dsm^{-1})	1.04a	2.40b	1.39c
Bicarbonate (mg/l)	19.1a	19.4b	32.6c
Turbidity (NTU)	490.0a	571.5a	455.6a
Nitrate (mg/l)	10.3a	67.1a	52.4a
Phosphate (mg/l)	67.9a	65.3a	33.5a
Sulphate (mg/l)	218.5a	278.2b	224.2c

Figures followed by different letters are significantly different (P < 0.05).

A gradient in the dissolved oxygen values along the river profile was observed, with a range of 9.27 mg/l at station III to 18.9 mg/l at station I. Such gradients could be attributed to the increased input of industrial effluents from the local industries sited along the banks of the river, leached domestic wastes from several waste dumps, erosional and surface run-offs and other human activities with progress downstream of the river. In addition, Williams and Shaw (1982) reported that local temperature rise as a result of discharge of hot water effluents from factories into a receiving body of water reduces the solubility of oxygen in the water. These reasons could have attributed to the gradient in the dissolved oxygen values observed. Though the dissolved oxygen values decreased downstream, they were still above 5.0 mg/l., with no significant difference between sites (P > 0.05) but season (P < 0.05). According to Alabaster and Lloyd (1980), Moss (1980) and FEPA (1991), when environmental conditions are favorable, a maximum constant level of 5.0 mg/l of dissolved oxygen is satisfactory for aquatic life and domestic purposes. Thus, the dissolved oxygen of the Challawa River water at areas studied falls within the acceptable limits. The 5-day biochemical oxygen demand values ranged from 6.68 to 7.54 mg/l of the water samples. Though there were fluctuations between both stations and seasons, no significant difference observed between sites (P > 0.05) but significantly differed between seasons (P < 0.05).

Pollution of water may take place through leaching of excessive amounts of phosphate from agricultural fertilizer runoffs, water treatment and biological wastes and residues into streams, rivers and lakes (Dix, 1983; Ademoroti, 1996; 2003). In addition, industrial effluents and use of detergents and surfactants can significantly add phosphates to freshwaters. These could have explained the reason for the generally high values of phosphate in this study (Tables 1 and 2). The mean phosphate content through the studied areas of the river profile was generally high (33.5 – 67.9 mg/l) except at station II with a mean value of 65.3 mg/l. The high values might be due to run-off drainage from nearby farmlands. However, there was no any significant difference (P > 0.05) between both sites and seasons. The permissible standard (APHA, 1998) for phosphate in freshwater is 50 mg /l. Therefore, the level of this parameter at the sampled areas is slightly higher than the acceptable limits for domestic and industrial purposes.

Nitrates may come from fertilizers, industrial wastes and biological stabilization. In high concentrations, nitrates may produce in man a condition known as methanoglobinaemia (blue babies), which generally affects infants under six months of age. For this reason, a level of 45 mg/l has been established as the maximum allowable concentration of nitrates in public drinking water supplies. In freshwaters, however, nitrate is found in concentrations from 0 to 10 mg/l (Wetzel, 1983). On the other hand, sulphate may be beneficial or detrimental in water used for manufacturing and domestic supplies. The recommended concentration in freshwaters has been set at 200-250 mg/l (Moss, 1980; APHA, 1998). The fluctuations observed in these nutrients (Table 1) may be due to increased industrial and human activities, especially laundry, with progress downstream. The levels of nitrate and sulphate ions in the present study were generally high during the wet season (Table 2). This could be attributed the rain floods; thus giving increased sewage load from the various sewage points. The concentrations of these nutrients are also affected by time of year (increase in late rainy season owing to agricultural runoffs) and the geology of the area under study (Wetzel, 1983). These could have been the reasons for the observed variations between the seasons (Table 2).

Table 2: Physico-chemical parameters of Challawa river water and wastewater effluents during dry (DS) and wet (WS) seasons

Parameter	Sample site I		Sample site II		Sample site III		Average
	DS	WS	DS	WS	DS	WS	
Colour (Hazen)	66.7a	80.9b	73.6a	78.9b	85.2a	105.9b	81.9
pH	8.15a	8.47b	7.40a	8.26b	8.47a	8.92b	8.28
Temperature (ºC)	24.7a	28.5b	26.7a	27.7b	27.0a	29.9b	27.4
DO_2 (mg/l)	5.63a	15.4b	5.82a	14.5b	5.13a	13.4b	9.98
BOD_5 (mg/l)	4.10a	10.9b	4.01a	9.34b	3.56a	10.5b	7.07
COD (mg/l)	1067.0a	1142.3b	1067.1a	1244.4b	943.7a	1172.3b	1106.1
Conductivity (dsm^{-1})	1.10a	0.98b	3.89a	0.9b1	5.06a	1.46b	2.23
Bicarbonate (mg/l)	16.6a	21.5b	16.6a	22.2b	17.5a	33.1b	21.3
Turbidity (NTU)	444.4a	537.1a	599.4a	543.6a	526.2a	521.2a	528.7
Nitrate (mg/l)	52.7a	59.8a	46.6a	87.7a	71.6a	59.9a	63.1
Phosphate (mg/l)	61.2a	74.7a	70.4a	60.3a	71.6a	60.1a	66.4
Sulphate (mg/l)	200.3a	236.7b	325.0a	231.3b	197.8a	250.6b	240.3

Figures followed by different letters are significantly different ($P < 0.05$).

The salinity of soils and irrigation waters is often given in terms o electrolytic conductivity. According to Ogunrombi (1975) and Okuofu (1992), conductivities below 750 µmhos/cm at 25ºC are considered to be satisfactory for irrigation. However, salt-sensitive crops may be adversely affected at conductivities of 250-750 µmhos/cm. The average conductivities recorded in this study were 1.04 dsm^{-1}, 2.40 dsm^{-1} and 1.39 dsm^{-1} at sites I, II and III respectively. These were recorded at average temperatures of 26.6°C, 27.2ºC and 28.5°C respectively (Table 1). These values are far below the limits given by Ogunrombi (1975) and Okuofu (1992). Thus, it could be suggested that salt-sensitive crops may thrive well if irrigated with these waters. This may partly explain the reasons for the high yields of irrigated farmlands along the course of the river as lamented by the interviewed farmers.

CONCLUSIONS & RECOMMENDATIONS

Challawa River represents a case where pollution influences could not be completely avoided. Areas used as waste dump sites, farmlands, and other domestic activities like laundry, are very close to some of the sampling stations and would therefore influence the spatial variations in water chemistry of the river. Generally, it seems that there is need to consider further treatment of wastewaters draining into the Challawa river in order to reduce the risks to public health likely to arise from the uncontrolled irrigation as is currently the practice, with the river water by the communities along the river bank. It is also recommended that some form of monitoring of the effluents should be instituted in order to detect potential risks to users of the river water as well as the consumers of crops irrigated with such water.

ACKNOWLEDGEMENTS The authors are very grateful to the authorities of Bayero University, Kano for the Research Grant support (Ref. No. URC/2001/012). We are also grateful to the Staff and Management of the Pollution Control Laboratory (Farm Centre, Kano) of the Kano State Ministry of Environment for providing us with the research facilities.

REFERENCES

Ademoroti, C.M.A. (1996). *Standard methods for water and effluents analysis*. 1st edition, Foludex press limited, Ibadan, Nigeria. 182pp.

Ademoroti, C.M.A. (2003). *Environmental chemistry and toxicology*. 1st edition, Foludex press limited, Ibadan, Nigeria. Pp79-184.

Adikwu, I.A. and Zaki, M.G. (1999). Aspects of the biology of the fishes in the Hadejia-Nguru wetlands, north-eastern Nigeria III: Reproduction and fecundity. *African Journal of Material and Natural Sciences* **1(1)**: 95-106.

Ahmed, K. and Tanko, A.I. (1994). Stream water quality and pollution hazards in River Hadejia, Kano, Nigeria. *A Paper Presented at the 2nd National Hydrology Symposium Organized by the National Committee on UNESCO-IHP*. National Institute of Water Resources, Kaduna, Nigeria. November, 1994.

Ajayi, S.O. and Osibanjo, O. (1981). Pollution studies on Nigerian rivers II: Water quality of some Nigerian rivers. *Environmental Pollution Series B* **2**: 87-95.

Alabaster, J.S. and Lloyd, R. (1980). *Water quality for freshwater fish*. 1st edition. Butterworth publishers limited, London. 283pp.

American Public Health Association (APHA, 1998). *Standard methods for the examination of water and wastewaters*. 20th edition American Waterworks Association and Water Environment Federation, USA. Parts 1000-10,000. 10145pp.

Bashir, H., Kawo, A.H., Abdullahi, B.A. and Okuofu, C. (2002). The effects of industrial effluents on the phytoplankton and zooplankton populations in some streams in Kano, Nigeria. *African Journal of Material and Natural Sciences* **2(2):**1-6.

Bashir, H. and Kawo, A.H. (2004). Environmental pollution – A case study of wastewater effluent parameters of some Industries in Kano, Nigeria. *Biological and Environmental Sciences Journal for the Tropics* **1(1)**:1-6.

Benka-Coker, M.O. and Ojior, O.O. (1995). Effect of slaughterhouse wastes on the water quality of Ikpoba River, Nigeria. *Bioscience Technology* **52**:5-12.

Brown, V.M., Jordan, D.H.M. and Tiller, B.A. (1967). The effect of temperature on the acute toxicity of the phenol to rainbow trout in hard water. *Water Research* **1**: 587-594.

Clymo, R.S., Golterman, H.L. and Ohnstad, M.A.M. (1978). *Methods for physical and chemical analysis of freshwater*. 2nd edition, Freshwater Biological Association Scientific Publications, London. 213pp.

Dix, H.M. (1983). *Environmental Pollution*. John Wiley and Sons, New York, USA. 621pp.

Egborge, A.B.M. (1981). The suspended matter content of Lake Asejire: A new impoundment in Nigeria. *Freshwater Biology* **1**: 402-412.

Egborge, A.B.M. and Benka-Coker, J. (1986). Water quality index: Application in the Warri River, Nigeria. *Environmental Pollution Series B* **12**: 27-40.

Federal Environmental Planning and Protection Agency (FEPA, 1991). *Guidelines for the national water quality standards for human consumption*. Federal Republic of Nigeria.

Haruna, A.B. and Abdullahi, B.A. (1999). Observations on the seasonal variations in water quality and some ecological implications of Jakara Lake, Kano, Nigeria. *African Journal of Material and Natural Sciences* **1(1)**: 107-112.

Ibrahim, S. (2003). *Survey of some aspects of biodiversity and physico-chemical characteristics of Challawa river water, Kano, Nigeria*. M.Sc thesis (unpublished). Department of Biological Sciences, Bayero University, Kano, Nigeria. 72pp.

Kawo, A.H., Aliyu, B.S., Bashir, H. and Mukhtar, M.D. (2006). *Ecology at a* *glance*. 1st Edition. Samarib Publishers, Kano, Nigeria. 112pp.

Moss, B. (1980). *Ecology of freshwaters*. Blackwell Scientific Publications Ltd, UK. 332pp.

Moussa, A.D. and Kawo, A.H. (2005). *Clarias gariepinus* as bioindicator of copper, lead and nickel in some ponds around Kano metropolis, Kano, Nigeria. *International Journal of Research in Bioscience* **1(1)**: 1-5.

Mukhtar, M.D. and Deeni, Y.Y. (1995). Microbiological and physico-chemical studies of Salanta River, south-central Kano metropolis, Kano, Nigeria. *Proceedings of the 9th/10th annual conference of the Nigerian Association for Aquatic Sciences (NAAS) held at the University of Agriculture Abeokuta, Ogun State, Nigeria, 30th Nov. – 2nd Dec., 1995*. pp241-250.

Ogunrombi, J.A. (1975). The potential use of sewage treatment plant effluents at Ahmadu Bello University, Zaria. *Savanna* ***4***:173-179.

Ohmain, E.I. and Benka-Coker, M.O. (1997). Spatial variations in water chemistry of Ikpoba River. *Nigerian Journal of Microbiology* ***11***:39-44.

Okuofu, C.A. (1992). Physico-chemical and biological analysis of Ahmadu Bello University waste stabilization pond effluents. *Samaru Journal of Agricultural Research* **9**: 69-75.

Singha, P. (2002). *Introductory text on biostatistics*. 3rd edition. Gadza Publishers Ltd., Kaduna, Nigeria. 261pp.

Victor, R. and Ogbeibu, A.E. (1985). Macro-benthic invertebrates of a stream flowing through farmlands in southern Nigeria. *Environmental Pollution Series A* **39:** 337-349.

Victor, R. and Ogbeibu, A.E. (1986). Re-colonization of macro-benthic invertebrates in a Nigerian stream after pesticide treatment and association disruption. *Environmental Pollution Series A* **41**: 125-137.

Victor, R. and Ogbeibu, A.E. (1991). Macro-invertebrate communities in the erosional biotope of an urban stream in Nigeria. *Tropical Zoology* **4**:1-12.

Welch, E.B. (1980). *Ecological effects of wastewater*. 1st edition. Cambridge University Press, Cambridge. 526pp.

Wetzel, R.G. (1983). *Textbook of Limnology*. Rd edition. W.B. Saunders publishers, Philadelphia.

Williams, J.I. and Shaw, M. (1982). *Microorganisms*. 2nd edition. Mill and Boon Publishers Ltd, London. 176pp.