WATER POLLUTION MODELLING OF THE RIVER BENUE IN THE REACH OF MAKURDI TOWN

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ABSTRACT

A reach of River Benue (in Makurdi), one of the two major rivers in Nigeria was monitored for a period of seven months traversing dry and rainy seasons of the year for pollution modelling. The process of field sampling, laboratory analysis, and regression modelling of flow depth and pollutants concentration revealed the following: (i) pollution in River Benue is influenced by natural regimes such as rainfall and discharges. Physical and chemical pollutants increased with rainfall while microbial pollution is inversely proportional to rainfall; (ii) microbial pollution of the river is more severe than physical and chemical pollution and has more effect on public health; (iii) unlike time, there is no trend in degree of pollution with respect to space; (iv) a positive non-linear relationship exists between water related diseases in Makurdi and coliform organisms in the river; (v) non-linear models for physical and chemical pollutants and; (vi) linear and polynomial models for flow depth and water pollutants. The models yielded values of coefficients of correlation ranging form 0_8537_0.9994 implying good fitting. The regression models are reliable for monitoring and prediction of water quality in this area, with both cost and time saving advantages.

1.0 INTRODUCTION

Water is universally accepted as one of the principal element of life and may also pass the test of a limited renewable resource. A renewable resource as used herein implies a resource that has a means of replenishment as it is being depleted. For instance, rainfall is a means of replenishing river flow and/or ground water reserves after some depletion. In the water flow system, some sort of equilibrium is maintained within a time period it however, more water is taken out of the system than is replaced then a sustained imbalance between outflow and inflow exists; hence the term limited renewable resource (Nwaogazie, 1990). Also, where water is adversely being polluted by man's uncontrolled activities, it may not be considered renewable resources.

Water pollution manifests itself in form of impairment of the quality of the water. Raven and others (1998) divided water pollutants into eight categories viz: sediment pollution, sewage, disease causing agents, organic compounds and inorganic plant and algae nutrients (e.g., Nitrogen and Phosphorus). Others are inorganic chemicals, radioactive substances and thermal pollution. Besides the discharge of specific pollutants in water, the construction of dams, reservoirs and river diversions can also degrade water quality.

The pollution of water directly or indirectly affect public health. Various studies have shown that some chemicals are so harmful that even in trace amounts can cause illness or even death in humans. For instance, nitrates in drinking water can cause methemoglobinemia (Ugada, 1986; Hertzman, 1995). Klein (1969) reported that the consumption of water with excess TDS has laxative effects on humans. Pi and others (2002) linked induction of oxidative stress in humans to chronic exposure to arsenic in drinking water. According to claudio (2002), consumers of fish and crabs from rivers contaminated with poly-chlorinated biphenyls (PCBS) and prone to cardiovascular diseases, endocrine disruptions and cancers such as breast cancer and leukemia. Childhood brain tumours have been shown to be associated with water contaminated with nitrites and nitrates (Mueller and others, 2001).

Most water borne diseases plaguing man are caused by pathogenic microbial organisms. At fact, the relationship between polluted water and diseases was firmly established with the cholera epidemic of 1854 in London, England (Henry, 1989). Viruses, bacteria, parasites and protozoa are among the micro organisms involved in microbial pollution of water.

Over the years a considerable amount of time and effort have been devoted to the improvement of water quality in rivers employing a combination of heuristic and mathematical techniques. The adoption of water quality modelling is essential for prediction or forecasting which is an important ingredient in formulating water pollution control policies.

A review of literature indicates many studies of river water quality modeling to date. Kahlig

(1979), derived a routing procedure for short-term prediction of down stream pollution using an exact solution of Taylor's dispersion equation. Tarrimond and Nelson (1980) presented a method for simulating the gross changes in river water quality which may result from natural variations in flow, systematic changes to flow regime as a whole or major changes in discharge quality. Stefan and Demetracouples (1981) focused on river contamination simulation using linear concepts. Chen and Kuo (1999) developed a two-layer tank model based on linear system theory and use of the gamma assuming a completely mixed system.

In Nigeria, recent attempts have been made to produce base-line information on the quality of some Nigerian rivers. Moses (1979) and Nawa (1982) studied aspects of the physico-chemical characteristics of the Cross River and reported that water quality of the river was mainly influenced by natural regimes such as rainfall and discharges. Odokuma and Okpokwasihi (1997) monitored the organic pollution of the new Calabar River. However, no attempt was made to seek mathematical representation of the quality phenomenon.

Nwaogazie and Ogelle (1997) reported linear and non-linear relationships between pollutants and consistent time-trends in degree of pollution on the Obinna river basin. Ohaji (1999) developed models for predicting biochemical oxygen demand (BOD) and dissolved oxygen (DO) in Okrika stream using New moment method.

Aboiya (2000) investigated the pollution of river Benue in Makurdi but the work was limited in scope. Also, no attempt was made to seek mathematical relationship between the various parameters investigated. The objective of this research is to increase the scope with respect to time and space and then develop mathematical models that can describe the relationships between pollution parameters and the resultant effect on public health.

2.0 MATERIALS & METHODS.

2.1 Area of Study

River Benue is one of the two major rivers in Nigeria. It starts from the Camerounian mountains and flow westwards through Makurdi to meet the River Niger at Lokoja in Kogi State. Its tributaries include but not limited to Rivers Dongo, Katsina-Ala, Bantaji and Taraba (Fig. 1). Along the Makurdi New bridge, the river is 1.194km wide with an average depth and cross-sectional area of 7.82m and 4608.42m^2 respectively.

The valley of the river which is covered with metasediments, consists of land areas below 300m above sea level. The flood plain, which is characterized by extensive swamps, is good for dry season irrigated farming.

Makurdi town, located in the Benue valley experience a typical tropical climate with distinct dry and wet seasons. The wet season, which lasts for seven months, starts from April and ends in October. There is however, usually one or more early heavy rains in January, February or March. The dry season begins in November and ends in March. Within the same period, the area experiences two distinct weather situations: While harmattan, with cool and chilly weather is experienced from December to early February, hot weather and high temperatures are experienced between the later part of February and early April. The average maximum and minimum daily temperature are respectively 35^{O}C and 21^{O}C. The average monthly rainfall distribution is depicted in Fig. 2.

In Makurdi, the study area, the river is subjected to various sources of pollution. Industrial wastes from the Benue Brewery Limited (BBL) and Nigeria Bottling Company (NBC) all located along Gboko road are channelled into the river. Also, wastes from the New Garage market and the abattoir near the new bridge are washed into the river. Other sources of pollution of the river are faeces from humans defaecating directly in the river; washed animal and human wastes from land to the river as well as fertilizers and other chemicals applied to the crops that are usually grown at the river banks.

The contamination of this river has led to incidences of water related diseases in the area. Notable among water related diseases in Makurdi are typhoid fever, amoebic dysentery and cholera. River Benue is the main source of water supply for the inhabitants of Makurdi, both for industrial, agricultural and domestic purposes. These informed the decision to study its pollutional level especially at it affects human health.

2.2 Sampling, laboratory analyses and Data collection

Water sample were taken mouthy at a depth of 0.4m from the surface of the water at a distance of 5m from the right bank at five sampling points marked A, B, C, D & E in fig. 3 along a reach of the River Benue in Makurdi. Point A is upstream of the point where effluents from BBL and NBC enters the river. B is downstream of A at a distance of 2 km. Point C, downstream of B is below the Makurdi New bridge at a distance of 2.5 km from B. D is at the Makurdi water works, 1.5 km downstream of C. E is a point downstream of the New garage market at a distance of 3 km from D. The sampling period covered seven months from march through September, 2002.

On the water samples collected, chemical and microbial laboratory analyses were performed (Akpen, 2002). Total Suspended Solids (TSS), Colour, Total Iron, Copper, Lead, Phosphate and Manganese concentrations were determined using HACH model DR/2000 spectrophotometer according to the procedures outlined in the manual. pH was determined with HACH pH comparator. While HACH model 44600 conductivity/TDS meter was used in determining the concentration of TDS and conductivity according to the methods described in the manual. Chloride, Dissolve Oxygen (DO), calcium and magnesium concentrations were obtained using HACH digital titrator model 16900-1. Microbial test was performed to estimate the concentration of total coliform (TC) and Faecal Colifom (FC) bacteria. The Most Probable Number (MPN) test according to APHA (1994) was used for the analysis.

Beside laboratory analyses, records of flow depth were collected from the Federal Inland Waterways Authority Makurdi (Fig. 4). Also, records of patients suffering from water-related diseases in Makurdi were collected from the Federal Medical Centre Makurdi covering the period under investigation (Table 3.1).

3.0 RESULTS & DISCUSSION.

3.1 Comparison of laboratory results with WHO standards

The maximum and/or minimum values of the various parameters irrespective of which month or sampling point they occur were isolated for comparison with WHO standards as shown in Table 1.2. The purpose of the comparison was to choose the principal pollutant for trend analysis and modelling with a secondary advantage of ease of handling data. It is obvious from Table 1.2 that parameters like colour, iron, manganese, copper, lead, total suspended solids (TSS), Faecal Coliforms (FC) and Total Coliferms (TC) have concentrations above WHO limits indicating pollution and were therefore considered for further analysis. Also, included for modelling were total dissolved solids (TDS) and conductivity because economy and ease of measurement in the laboratory.

3.2 Trend Analysis

The results of TSS concentration measurements as a function of time are presented in Fig. 5 TSS values were high during the rainy months as indicated by the steady rise from April and May to a peak in September. There was however a drop in TSS concentration in July probably because of the short dry period (usually referred to as August break). The TSS concentration at point E was consistently higher than the other sampling points reaching a maximum of 155mg/l in September. The least value of 12mg/l was recorded at point B in March. The relatively low value of TSS in the dry month (March) and high values in the rainy season showed that increased rainfall results in increase surface run-off hence more suspended solids were washed into the river. Also, the high current resulting from an increase in volume of water due to heavy rainfall, leads to resuspension of solid particles originally settled at the bottom of the river. Further more, apart from the larger run-off contributing area of the sampling point E over that of the entire study area, recreational and commercial activities such as fishing and transportation of goods and people across the river are concentrated at this point. Hence, there is greater resuspension of settled sediments at this point. There was however no consistency in the degree of pollution at points A, B, C & D with respect to the area contributing to run-off. This is due to the introduction of surface run-off into the river at different points along the river. The high TSS values, observed during the rainy season is similar to the trend reported by Odokuma and Okpokwasili (1997) in the New Calabar River. However, Okah (1999) observed a reverse trend for the Imo river system.

The time variation of the other physico-chemical parameters are depicted in Figs. 6 - 12 and those of the microbial parameters are presented in Figs. 13 and 14. The following are discernable from the plots: First pollution in River Benue is influenced by natural regimes such as rainfall and discharges. Chemical pollutant concentrations generally decrease in the dry season and increase in the rainy season. This is because less materials are discharged into the river from surface run-off. Also, there is no consistency in the degree of pollution with respect to space due to the introduction of surface wastes at different points along the reach of the river investigated.

The microbial parameters however, should a reverse trend to that of physico-chemical parameters. Their concentrations were higher during the dry than the rainy months similar to Nwaogazie and Ogelle (1997) observation at the Obinna river. The low concentration in the rainy season is due to the effect of dilution as a result of increase in rainfall and hence volume of water in the river. Just as in the case of physico-chemical pollutants, there was no trend in the degree of microbial pollution with respect to space.

From Table 1.1, 62 water-related disease cases each were reported in May and June, the least value of 38 cases were observed in September. The decrease in cases of WD after June is due to the effect of dilution as justified by the reduction in coliform organisms with increase in rainfall (Figs. 13, 14 and 2. The relatively high values recorded from March through June may be due to the residual effect of infections during the preceding dry season (November - March). Higher coliforms were observed during the dry season hence the tendency for greater number of WD cases. Table 1.1 also reveals that microbial pollution has greater effect on public health as most of the reported water-related disease cases are from microbial pathogens. This observation confirms the work of Feachem & others (1978), who reported that hazards from microbial pollution of water to health in the tropics were on a higher scale than from chemical pollution.

3.3 DEVELOPMENT OF REGRESSION MODELS

The parameters chosen in section 3.1 were subjected to regression modelling. Regression models were favoured because of their reliability even with limited data, with a secondary advantage of ease of calibration and application. The parameters concentration at point D (Makurdi water works) were taken to be representative of the entire study area for two reasons: (i) There was no consistency in terms of area of influence (i.e., area contributing flow or run-off) at any point with respect to the entire study area because of the introduction of contaminants at different points along the river (ii) D is the point where water is extracted for treatment and subsequent distribution to the town.

Flow depth, total iron, TDS and WD were respectively chosen as independent variables and regressed with the other parameters as dependent variable. A plot of the dependent variables against the independent variables should either linear or non-linear relationship Mathematically, both the linear and polynomial models as represented as:

$$y = a_0 + a_1x \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

and $$y = A_0 + A_1x + A_2x^2 + \ldots + Anx^n \quad (An \neq 0) \ldots\ldots\ldots\ldots (2)$$

Where a_0, a_1, A_0, A_1, A_2, ... An are the coefficients of the regression models. A computer program Microsoft Excel was then used to calibrate the models.

In the case of a quadratic model: consider the water-related cases (WD) and faecal coliforms for instance, we have the model.

$$WD = 3.9782 + 3.5062(FC) - 0.0516(FC)^2 \quad ...(3)$$

$$r = 0.9318, R^2 = 0.8682$$

Where R^2 = Goodness of fit

r = coefficient of correlation

The summary of the model is shown in Table 1.3. The high coefficient of correlations (r) implies the regression models are representative of the observed field/laboratory data and hence are reliable tools for prediction of water quality in the study area. To verify the models, the models' predictions and the observed data points are presented in Figs. 15 - 22. The observed data point lie either on the regressed model or close to the curves justifying their reliability as prediction tools in the area.

3.4 Measures for abating pollution and its effect on public health

The following measures, will help in minimizing the degree of pollution of the river and/ or its effect on public health:

(i) Proper disposal of animal and human wastes will help in reducing microbial pollution.

(ii) NBC and BBL should implement FEPA (2002) guidelines by treating their wastes to meat the minimum standards before discharging into the river to minimize chemical pollution.

(iii) Public enlightenment campaign should be intensified to educate the people on the dangers inherent in taking water from the river with out any form of treatment.

(iv) As a routine, regular water quality assessment should be carried out and the treatment method modified accordingly to ensure safe water at the tap. Rapid assessment of water quality can done using the models developed in this study.

4.0 CONCLUSION

The processes of data collection, field sampling and laboratory analyses of water samples from River Benue has been presented. The result of the research reveal consistent microbial pollution which is greater during the dry season. Chemical and physical pollution occasionally occurs but is not as severe as microbial pollution and is generally higher in the rainy season.

Water related disease cases reported such as typhoid, fever, cholera, schistosomiasis and bacillary dysentery normally result from infections by pathogenic microbes; which implies the microbial pollution has effect on public health.

There is no trend in degree of pollution with respect to space. As evident in the inconsistency associated with the level of pollution at the various locations relative to the upstream reference point of the reach of the river monitored.

The regression models developed in this study are good tools for motoring and prediction of water quality in the reach of the river investigated, given the high coefficients of correlation they yielded. The models have both cost and time saving advantages.

REFERENCES

1. **Aboiyar, W. (2001),** "Physico-Chemical properties of River Benue at the New Bridge", Unpublished B.Sc. Thesis, Benue State University Makurdi, Nigeria.

2. **Akpen, G. D. (2002)** "Water Pollution Moelling of the River Benue in the Reach of Makurdi Town". Unpublished M. Eng. (Water Resources Engineering) Thesis, University of Port Harcourt, Port-Harcourt, Nigeria.

3. **APHA (1994),** Standard Methods for the Examination of Water and Wastewater. 18th Ed. American Public Health Association.

4. **Chen, S. C. and Kuo, J. T. (1999),** "Two-layer Tank Model for the Treatment of Sorptive Pollutant in Tidal Rivers", In Proceedings of the National Science Council, Republic of China Part A Physical Science and Engineering, National Science Council, Republic of China. Vol. 23, No. 1 pp 143 - 150.

5. **Claudio, L. (2002).** "The Hudson: A River Runs through an Environmental Controversy", Environmental Health Perspectives, Vol. 110, No. 4, pp 184 - 187.

6. **Farrimond, M. S. and Nelson, J. A. R. (1980),** "Flow-Driven Water Quality Simulation Models", Water research, Pergamon press, Great Britain, Vol. 14, No. 8, pp 1157 -1168.

7. **Feachem, R. Chael, M. and Duncan, M. (1978),** Waste waters and Health in hot Climates, John Wiley and Sons, Chichester, 164 p.

8. **Henry, J. G. (1989),** "Water Pollution", In Henry, J. G. and Heinke, G. W. (1989).

Environmental Science and Engineering, Prentice Hall, Inc. Englewood Cliffs New Jersey.

9. **Hertzman, C. (1995),** " Environment and Health in Central and Eastern Europe: A report for Environmental Action Programme for Central and Eastern Europe" World Bank, Washington D. C. USA, pp 41.

10. **Kahlig, P. (1979),** "One-Dimensional Transient Model for Short-term Prediction of Down-Stream Pollution in Rivers". Water Research, Pergamon Press, Great Britain, Vol. 13, No. 12, pp 1311 - 1316.

11. **Klein, L. (1969).** River Pollution III: Control. Buter Worths and Co. Ltd London.

12. **Moses, B. S. (1979),** "The Cross-River, Nigeria. Its Ecology and Fisheries". In proceedings of the International Conference on Kainji Lake and River Basin Development in Africa. Lake Kainji Research Institute, New Bussa, Nigeria. pp 335 - 370.

13. **Mueller, B. A., Newton, C., Holly, E. A. and Martins, S. P. (2001).** "Residential Water Source and the risk of Childhood Brain Tumours". Environmental Health Perspectives, National Institute of Environmental Health Sciences, Vol. 109, No. 6, pp 551 - 556.

14. **Nawa, I. C. (1982),** "An Ecological Study of the Cross-Rivers Estuary" Unpublished Ph. D. Dissertation. University of Keil, Federal Republic of Germany.

15. **Nwaogazie, I.L. (1990)** "Pollution Modelling: A Necessity for provision of Water for all in Nigeria". Nig. J. Tech. Res. Vol. 2, pp 49-55.

16. **Nwaogazie, I. L. and Ogelle, E. (1997),** "Water Quality Modelling of Rice-Irrigated Obina River, Uzo Uwani". J. Water, Air and soil pollution, Kluwer Academic publishers, Netherlands, Vol. 100, pp 197 - 212.

17. **Odokuma, L. O. and Okpokwasili, G. C. (1997),** "Seasonal Influences of the Organic Pollution Monitoring of the New Calabar River, Nigeria". Environmental Monitoring and Assessment, Kluwer Academic publishers, Netherlands. Vol. 45, pp 43 - 56.

18. **Ohaji, E. P. C. (1999),** "Mathematical Modelling of Stream Water Quality by a New Moment Method", Unpublished M. Eng. Environmental Engineering Thesis. University of Port Harcourt, Nigeria.

19. **Okah, I.I. (1999),** "Water Quality Modelling of Imo River System: A Case of Nekede and Obigbo Hydrological Stations". Unpublished M. Eng. Environmental Engineering Thesis, University of Port-Harcourt, Port-Harcourt - Nigeria.

20. **Pi, J., Hirashi, Y., Kumagai, Y. Sun, G. Yoshida, T., Aikawa, H., Rich, C. H. and Shimojo, N. (2002),** "Evidence for Induction of Oxidative stress caused by Chronic Exposure of Chinese Residents to Arsenic Contained Drinking Water". Environmental Health Perspectives, Vol. 110, No. 4 (April 2002), pp 331 - 336.

21. **Raven, P. H., Berg, L. R. and Johnson, G. B. (1998),** Environment,. 2nd Edition. Sanders College publishing, pp 480 - 488.

22. **Stefan, H. G. and Demetracopoules, A. C. (1981),** "Cells in Series Simulation of Riverine Transport." Journal of American Society of Civil Engineers, 107 (H76). pp 675 - 697.

23. **Ugada, C. A. (1986),** "Determination of Iodine, Iron, Nitrate and Biochemical Oxygen Demand in Igala Waters." Unpublished B.Sc. Thesis, Nnamdi Azikiwe University, Awka, Nigeria.

24. **WHO (1993),** Guidelines for Drinking Water Vol. 1 Recommendations, 2nd ed, World Health Organization, Geneva.

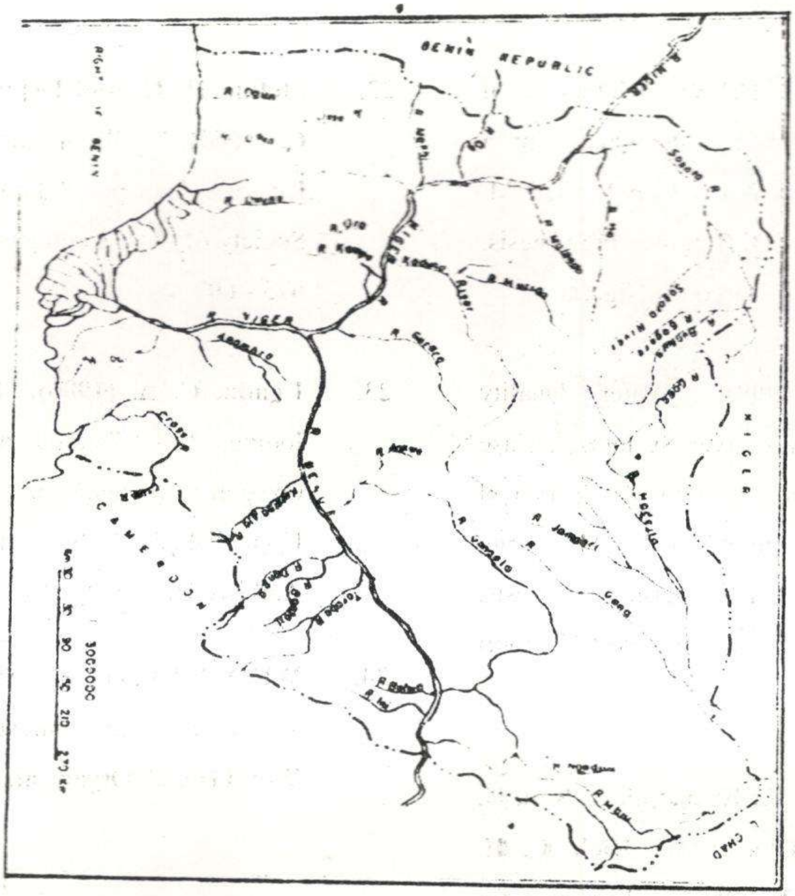

Fig. 1 Drainage Map of Nigeria

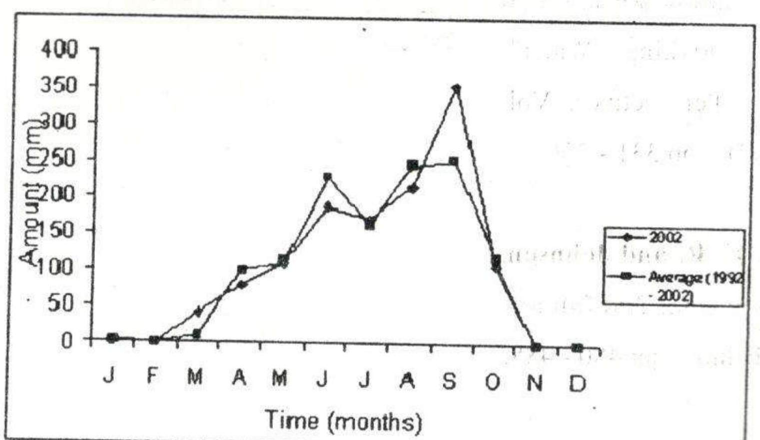

Fig. 2: Average monthly rainfall distribution for Makurdi

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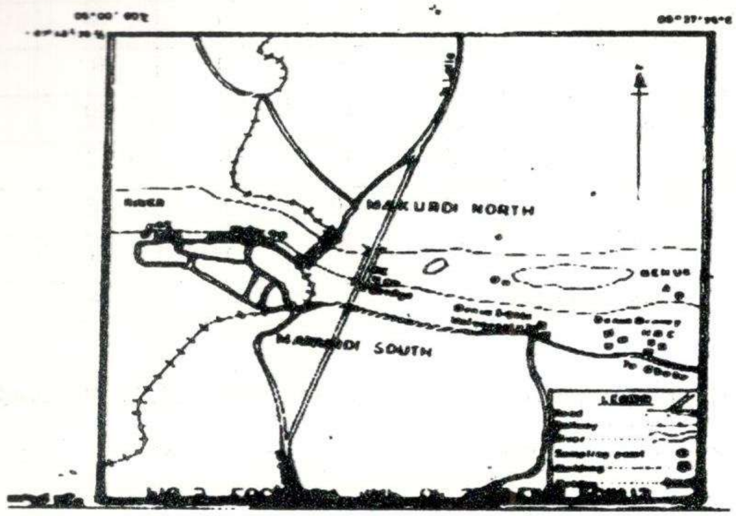

Fig. 3: Sampling points

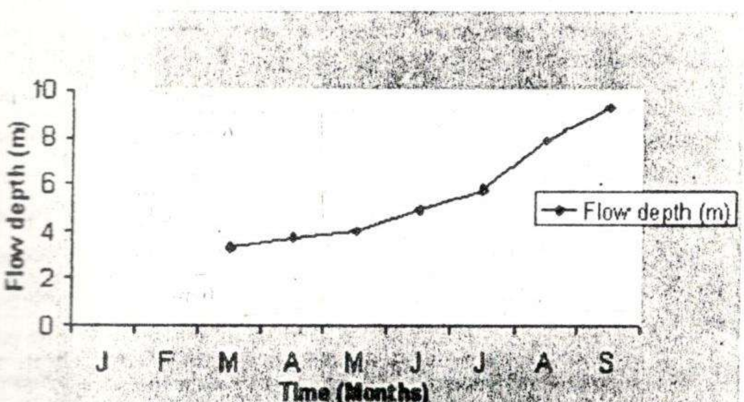

Fig. 4: Flow depth hydrograph

Table 1.1: Water-related disease cases in Makurdi

Diseases	Number of reported cases							Total
	March	April	May	June	July	August	Sept.	
Typhoid fever	9	8	7	11	6	10	5	56
Schistosomiasis	0	0	0	1	0	0	0	1
Gastro enteritis	25	18	26	15	12	10	8	114
Bacillary dysentery	7	22	20	10	16	13	10	98
Diarrhaea	16	13	9	26	20	18	15	117
Total	57	61	62	62	54	51	38	386

Source: Federal Medical Centre Makurdi.

Table 1.2: Comparison of tested water quality indicators with WHO standards.

S/N	Quality Indicator	Concentration	WHO Limit	Remarks
1	Colour	300 pt_co units	15 colour units	Pollution
2	Conductivity	153.6 µs/cm	400 µs/cm	No pollution
3	Calcium	12.01 mg/l	75 mg/l	No pollution
4	Magnesium	7.81	30 mg/l	No pollution
5	TDS	88.3 mg/l	500 mg/l	No pollution
6	PH	6.7 _ 8.5	6.5 - 8.5	No pollution
7	Total Iron	1.59 mg/l	0.1 mg/l	Pollution
8	Manganese	0.5 mg/l	0.05 mg/l	Pollution
9	Copper	0.16 mg/l	0.05 mg/l	Pollution
10	Chloride	27 mg/l	200 mg/l	No pollution
11	Phosphate	0.58 mg/l	5 mg/l	No pollution
12	DO	5.4 mg/l	5 mg/l (min)	No pollution
13	Lead	0.026 mg/l	0.01 mg/l	Pollution
14	TSS	155 mg/l	30 mg/l	Pollution
15	Total coliform	1800 MPN	0	Pollution
16	Faecal coliform	110 MPN	0	Pollution

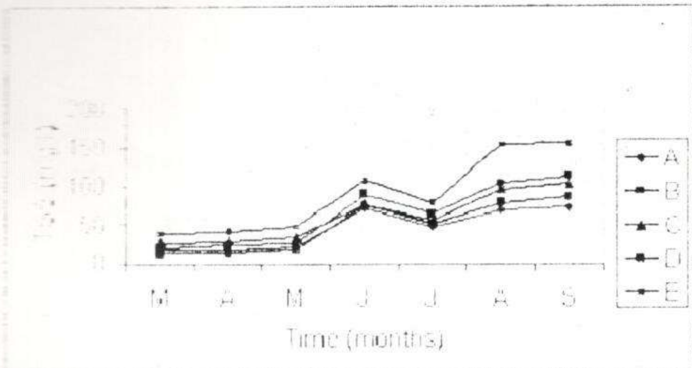

Fig. 5: TSS Concentration of the season

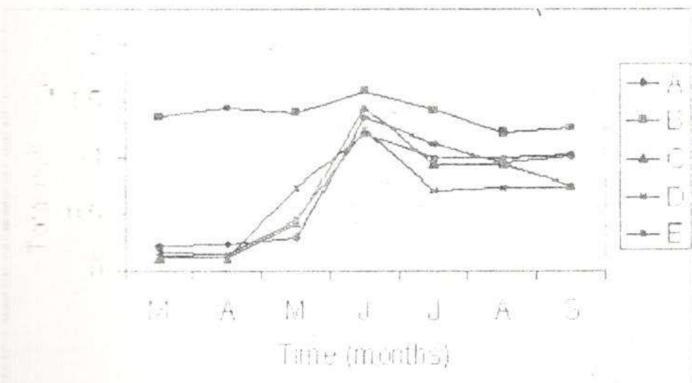

Fig. 6: Total iron concentration as a function of the season

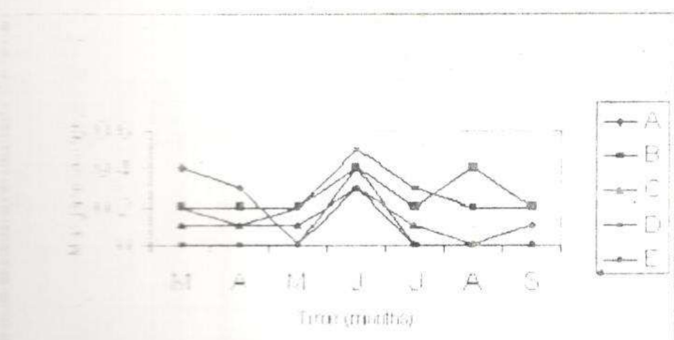

Fig. 7: Manganese concentration as a function of the season

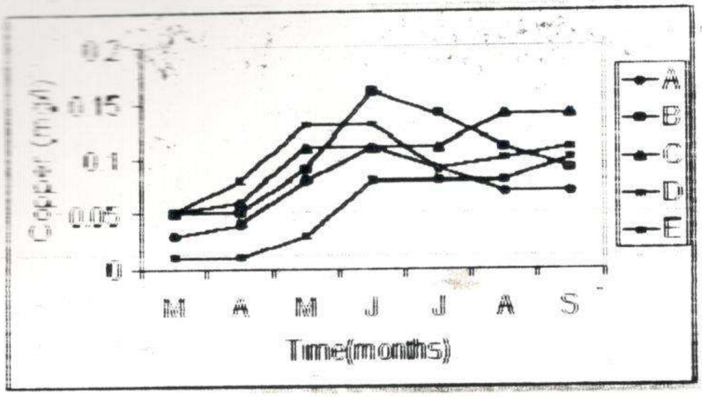

Fig. 8: **Copper concentration as a function of the season**

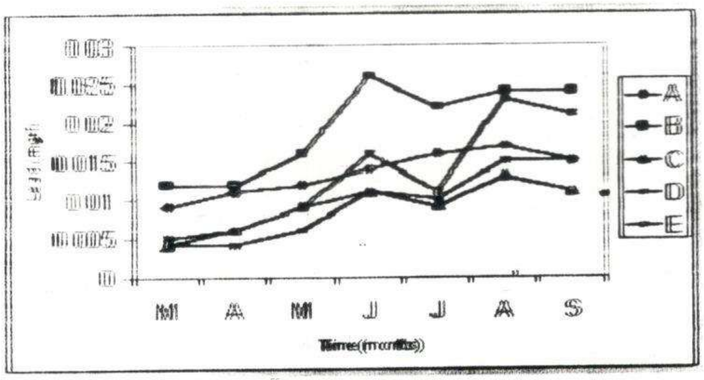

Fig. 9: **Lead concentration as a function of the season**

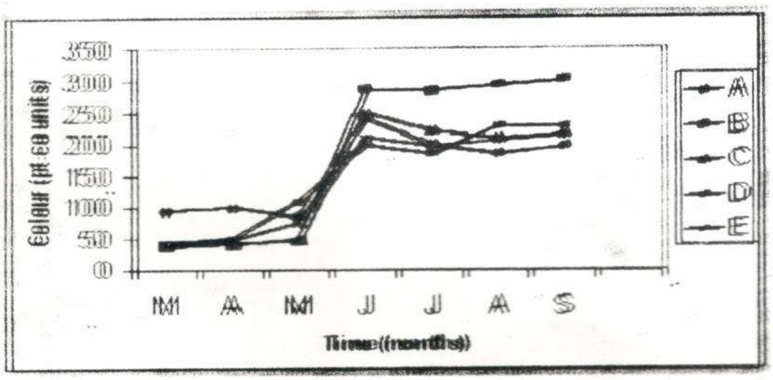

Fig. 10: **Colour concentration as a function of the season**

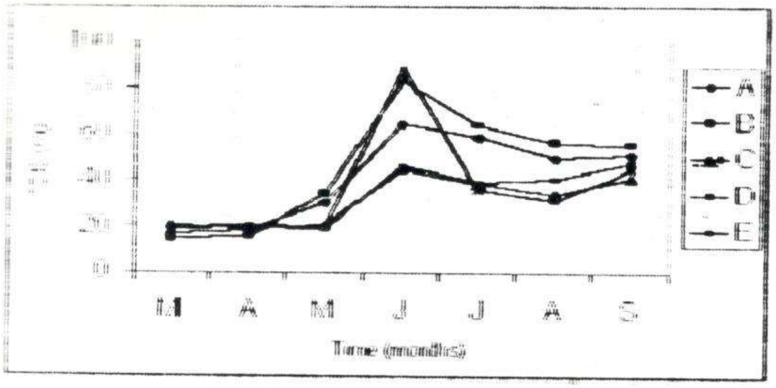

Fig. 11: TDS concentration as a function of the season

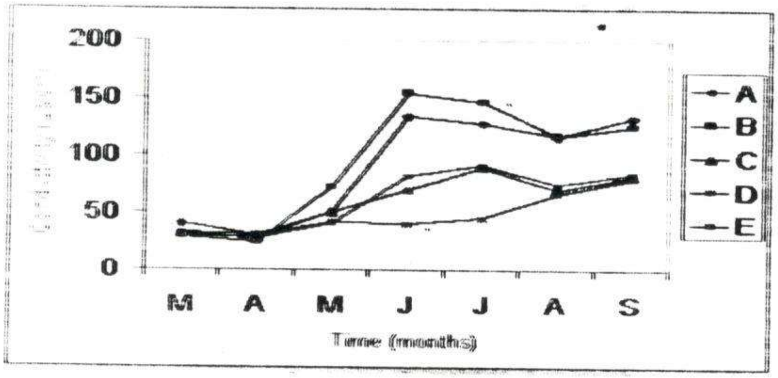

Fig. 12: Conductivity concentration as a function of the season

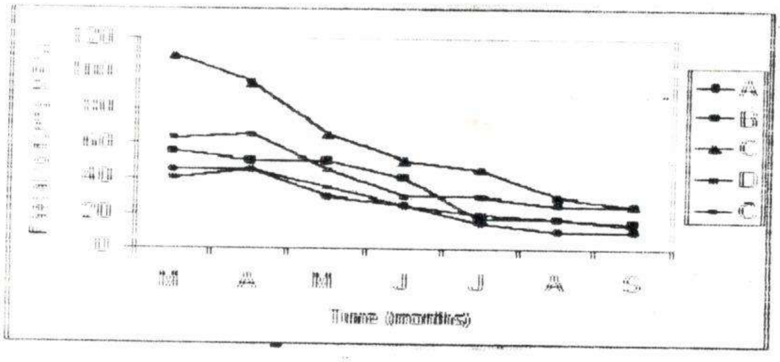

Fig. 13: Faecal coliforms concentration as a function of the season

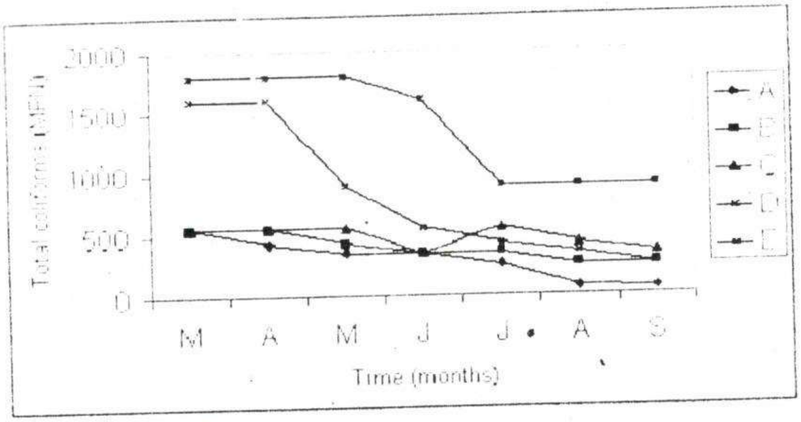

Fig. 14: Total coliforms concentration as a function of the season

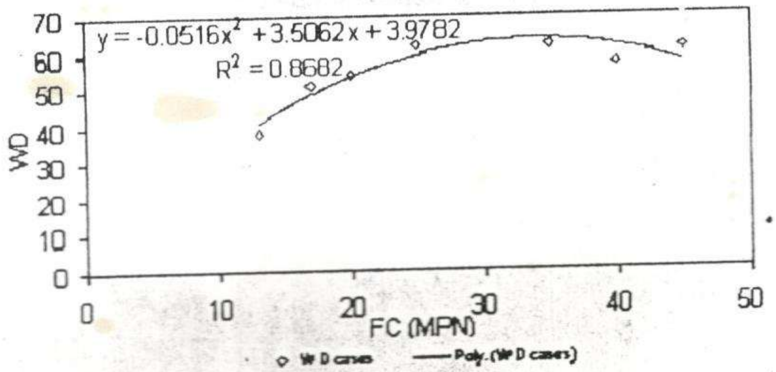

Fig. 15 Regression model of WD against FC

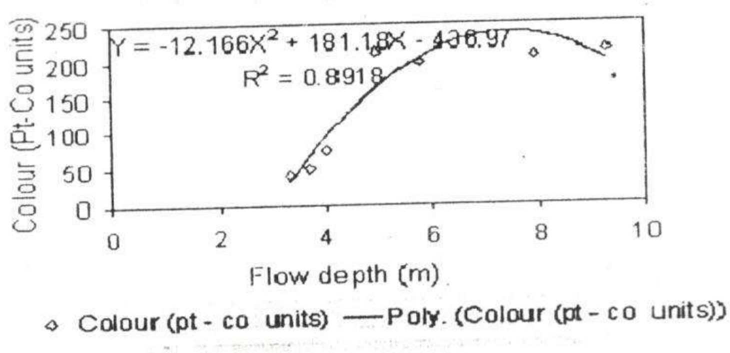

Fig. 16: Regression model of colour against flow depth

Table 1.3 Summary of the Models

S/N	Dependable variable Y	Independent variable X	Regression model	R^2	r
1.	TSS	Flow depth	$Y = -2.8224X^2 + 51.471X - 124.86$	0.8758	0.9358
2.	TDS	Flow depth	$Y = -3.0802X^5 + 93.384X^4 - 1092.8X^3 + 6154.9X^2 - 16664X + 17394$	0.9272	0.9629
3.	Colour	Flow depth	$Y = -12.166X^2 + 181.18X - 436.97$	0.8918	0.9444
4.	Conductivity	Flow depth	$Y = 7.9292X + 3.3307$	0.9534	0.9764
5.	Copper	Flow depth	$Y = -0.0022X^4 + 0.0587X^3 - 0.5679X^2 + 2.3415X - 3.3549$	0.9062	0.9519
6.	Total Iron	Flow depth	$Y = 0.0269X^3 - 0.5667X^2 + 3.8289X - 7.4334$	0.7288	0.8537
7.	Manganese	Flow depth	$Y = -0.0209X^5 + 0.6313X^4 - 7.3528X^3 + 41.215X^2 - 111.09X + 115.38$	0.9289	0.9638
8.	Lead	Flow depth	$Y = 0.002X - 0.0018$	0.8843	0.9404
9.	TSS	TDS	$Y = -0.001X^4 + 0.1875X^3 - 11.713X^2 + 300.97X - 2632.4$	0.9362	0.9676
10.	Colour	TDS	$Y = -0.002X^4 + 0.0402X^3 - 3.0905X^2 + 102.42X - 1034.9$	0.9672	0.9835
11.	Conductivity	TDS	$Y = -1E - 04X^5 + 0.0203X^4 - 1.5462X^3 + 54.782X^2 - 912.56X + 5799.3$	0.9775	0.9887
12.	Copper	Iron	$Y = -34.439X^5 + 104.4X^4 - 114.28X^3 + 55.894X^2 - 11.872X + 0.9219$	0.9994	0.9997
13.	Manganese	Iron	$Y = 0.683X^2 - 0.5969X + 0.0822$	0.9773	0.9886
14.	Lead	Iron	$Y = -0.073X^3 + 0.1362X^2 - 0.0554X + 0.0095$	0.906	0.9518
15.	WD	FC	$Y = -0.0516X^2 + 3.5062X + 3.9782$	0.8682	0.9318
16.	WD	TC	$Y = 8E - 08X^3 - 0.0003X^2 + 0.2437X - 7.5388$	0.9713	0.9855

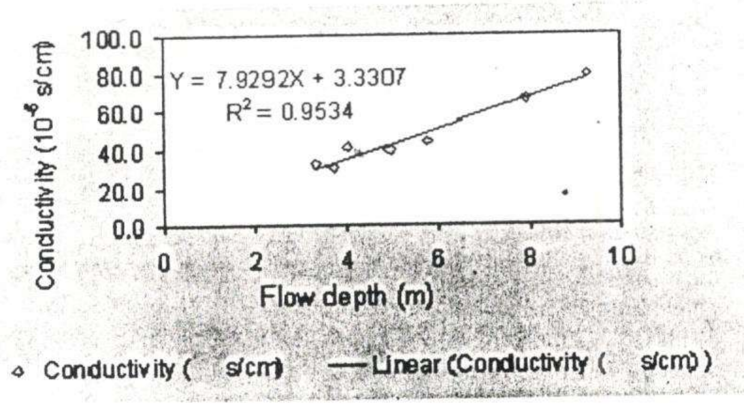

Fig. 17: Regression model of conductivity against flow depth

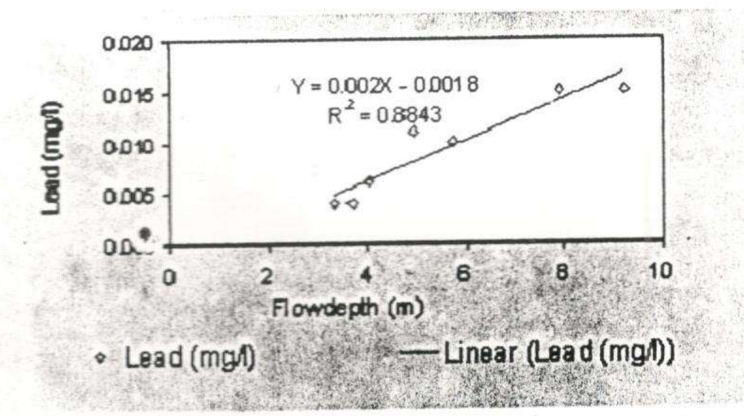

Fig. 18: Regression model of copper against iron

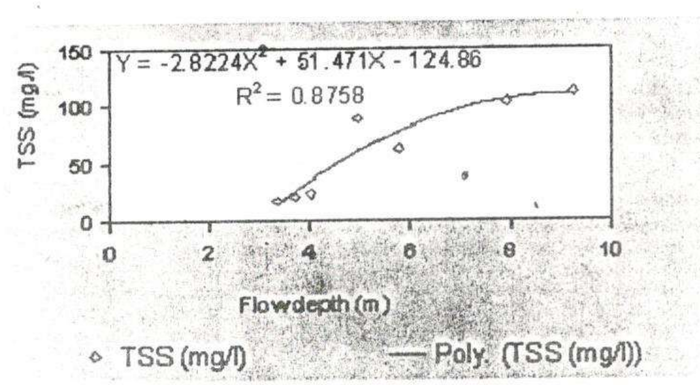

Fig. 19: Regression model of Lead against flow depth

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